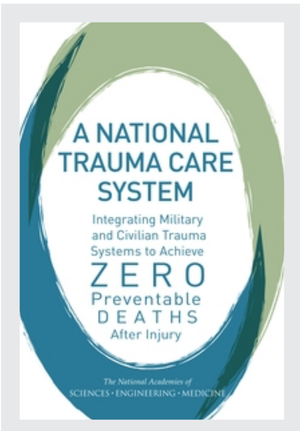

A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury

DETAILS

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A NATIONAL TRAUMA CARE SYSTEM

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Board on Health Sciences Policy

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Dedication

Dr. Norman McSwain (1937-2015) was an extraordinarily valued member of this committee. In honor of his immeasurable contribution to countless military and civilian injured, we humbly dedicate this effort to him. His legacy of training and translating and a laser focus on improving the outcomes of all injured persons permeates every page of this report. We hope he would approve of our efforts.

Norman's leadership in all things trauma is legendary. He was a leader who helped establish emergency medical services (EMS) systems around the world. His focus was on rapid, expert treatment at the scene and speedy transport to qualified trauma centers. There is absolutely no question that his efforts saved an untold number of lives around the world. Very few, if any, physicians have had the impact that Norman had on care of the injured. He was always busy and held many jobs. He was trauma director of the Spirit of Charity Trauma Center, medical director and founder of PreHospital Trauma Life Support, chairman of the Tulane Medical Center Emergency Medicine Section and section chief of Trauma/Critical Care at Tulane, police surgeon for the New Orleans Police Department, and medical director for the New Orleans Jazz and Heritage

Festival for the past 30 years. Despite all of these many responsibilities, Norman famously made time for everyone who wanted to speak with him and learn from him.

Norman moved to New Orleans and Tulane University School of Medicine and Charity Hospital in 1977, where he remained until his death. Norman was the drive behind Charity's response during Hurricane Katrina and, not surprisingly, was one of the last to leave. Typical of Norman, he never asked for recognition, he downplayed his role. His work as a trauma surgeon within Charity is best captured by the many residents and medical students he trained. They absolutely loved the man and are devastated by his death. Norman's legacy lives on not only in New Orleans, where he is an icon, but also in his worldwide impact on emergency trauma care. Working with the National Association of Emergency Medical Technicians and the American College of Surgeons Committee on Trauma, he founded PreHospital Trauma Life Support (PHTLS), whose approach to prehospital care is the worldwide standard. PHTLS has trained more than 1 million providers in 64 countries since offering its first course in New Orleans in 1983. Over the past 14 years, Norman helped guide the Committee on Tactical Combat Casualty Care, revolutionizing prehospital care for military medics around the world. Within the last year, he was also a key member of the Hartford Consensus Working Group and this National Academies of Sciences, Engineering, and Medicine committee, devoted to helping to translate military advances in prehospital trauma care to the civilian sector to enable the nation to be better able to care for the millions of injured civilians. His message rings clearly through these important efforts. He was a passionate supporter of effective trauma systems: early hemorrhage control by immediate bystanders, integrated into timely, expert EMS and police response, and rapid transfer to a center where expert trauma care can be delivered.

Norman was also a huge personality. He lit up the room when he walked in. People felt his presence before they even saw him. Norman was famous for his humor and ready smile. He hosted wonderful parties, was always ready for a great dinner, and served as a shining example of what we can and should be. Norman inspired everyone. He had unlimited energy and passion and his enthusiasm was infectious. Once captured, you never left. He lived at 100 miles per hour every day. He battled his head and neck cancer publicly with grace and style so typical of Norman McSwain. He was a gentleman, a tireless advocate for what was right, a leader, a mentor, a superb team member, and friend to all of us.

Norman is survived by the many members of his biological family, his huge trauma family, and more important, all the trauma survivors who benefited from his extraordinary drive to improve prehospital trauma care around the world. His greeting to everyone will live on: "What have you done for the good of mankind today?"

Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

John Armstrong, Florida Department of Health
Neal Dickert, Emory University School of Medicine
Brian J. Eastridge, The University of Texas Health Science Center at San Antonio
T. Bruce Ferguson, Jr., East Carolina Heart Institute and East Carolina Diabetes and Obesity Institute
Michael Lesk, Rutgers, The State University of New Jersey
Eve Marder, Brandeis University
Kathleen D. Martin, Lankenau Medical Center
Ricardo Martinez, North Highland
J. Wayne Meredith, Wake Forest Baptist Medical Center
Michael M. Merzenich, Posit Science Corporation
James B. Peake, CGI Federal
Peter J. Pronovost, Johns Hopkins Medicine

Kathleen Sebelius, Sebelius Resources, LLC
Peter Taillac, Utah Department of Health

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by **Lewis R. Goldfrank,** New York University School of Medicine and Bellevue Hospital Center, and **Mark R. Cullen,** Stanford University. They were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

War is to be avoided. But if it comes, and history says it will, morality and pragmatism converge on an imperative: to protect those sent into harm's way. Those who serve in the military need and deserve a promise that, should they sustain a traumatic injury, the best care known will come to their assistance to offer them the best chance possible for survival and recovery and, further, that over time, learning and innovation will steadily increase that chance. Under the terms of the Geneva Convention, that same obligation extends to the care of civilian noncombatants who themselves are swept into conflict and injury.

Trauma, of course, is by no means confined to military conflict. In the United States, traumatic injury is a major threat to the health of the public, causing in the aggregate the loss of more years of life than any other source of illness or disability. For every war-related casualty, there are hundreds of trauma patients in civilian life.

The good news is that both the military and civilian sectors have made impressive—arguably remarkable—progress in the care of trauma over the past few decades, with concomitant gains in outcomes. For example, much has been learned and done about timely stabilization and rapid transfer to definitive care, approaches to resuscitation and management of hemorrhage, training and equipage of first responders, and protocols and guidelines for best practices. In military health care, major declines in trauma death rates among injured warriors testify to these advances. The best civilian emergency care systems show similar gains.

This progress has not occurred by chance. Much of the progress in military trauma care is associated with learning processes—lessons gained, captured, and built upon pragmatically—just as contemplated in the description of a "learning health system" in the Institute of Medicine (IOM) report *Best Care at Lower Cost*.

This committee was convened to study and evaluate progress toward better trauma care and outcomes, especially in the military sector; to understand how that progress relates to elements of a learning health system; to recommend how learning and improvement could be even better; and to understand how both trauma care and learning can best be translated between the military and civilian trauma care systems.

As this report documents, the committee's efforts revealed both good news and bad: on the one hand, superb trauma care characterized by important innovations with documented better outcomes, but on the other hand, serious limitations in the thoroughness of the diffusion of those gains over time and space, both within the military and between the military and civilian sectors. Even as the successes have saved many lives, the gaps have cost many lives. An especially significant challenge is to maintain readiness for expert trauma care in the military in the periods between wars. The committee found meeting this need to be one of the several reasons to view the military and civilian trauma care systems as, in many ways, the same system—not two systems, or at least much more closely interconnected than has been the case to date.

As the IOM's learning health system concept emphasizes, progress toward such a system depends strongly on leadership, and this report contains a number of key recommendations for clearer and more consolidated leadership on a national scale to achieve better trauma care. The committee recommends that the United States adopt an overall aim for trauma care of "zero preventable deaths after injury," and sets forth elements of system redesign that would be needed to achieve that aim.

This committee had the great privilege of extensive cooperation and advice from highly experienced military and civilian trauma care experts, many from the front lines of care. Committee members included such experienced caregivers, as well. For those members, such as me, whose careers have not included providing direct trauma care or serving in the military, this exploration has been a truly humbling experience. The committee read about and saw graphic images of some of the horrific forms of injury that today's military combatants incur, and became more fully aware of the grave risks that the nation asks its soldiers, sailors, airmen, and marines to face. We heard compelling cases of heroic rescue in which advanced knowledge, teamwork, and modern technology were used to save lives that only a few years ago would surely have been lost. And we heard testimony from clinicians and care system managers whose courage, initiative, imagination, and unwillingness to concede led directly to crucial innovations, sometimes in the face of significant barriers of habit and bureaucracy. These are heroes—both the injured and those who simply will not quit when trying to help them.

This report documents a number of important and badly needed changes in trauma care beginning with leadership toward a common, bold, shared aim. Accomplishing these changes will not be easy. Indeed, this committee is by no means the first group to suggest a number of these changes. Yet too many of the prior calls for consolidated leadership, strong systemic designs, and clear lines of responsibility have not been heeded. It is our hope that, in honor of the military and civilian trauma patients whose lives and function can be saved in the future, this time will be different. As one committee member put it, when it comes to trauma care, where you live ought not to determine if you live. It is time for a national goal owned by the nation's leaders: zero preventable deaths after injury.

Donald Berwick, *Chair*
Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector

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Acronyms and Abbreviations

ACEP	American College of Emergency Physicians
ACS	American College of Surgeons
ACS COT	American College of Surgeons Committee on Trauma
AEMT	advanced emergency medical technician
AFMES	Armed Forces Medical Examiner System
ASD(HA)	Assistant Secretary of Defense for Health Affairs
ATLS	advanced trauma life support
ATTC	Army Trauma Training Center
CCCRP	Combat Casualty Care Research Program
CCFP	critical care flight paramedics
CDC	Centers for Disease Control and Prevention
CENTCOM	U.S. Central Command
CFR	case fatality rate
CFR	Code of Federal Regulations
CMS	Centers for Medicare & Medicaid Services
CoCOM	combatant command
CONUS	continental United States
CoTCCC	Committee on Tactical Combat Casualty Care
CPG	clinical practice guideline
CSI	Congressional Special Interest
C-STARS	Center for the Sustainment of Trauma & Readiness Skills
C-TECC	Committee for Tactical Emergency Casualty Care
DALY	disability-adjusted life year

DCAS	Defense Casualty Analysis System
DCBI	dismounted complex blast injury
DCR	damage control resuscitation
DHA	Defense Health Agency
DHS	U.S. Department of Homeland Security
DMRTI	Defense Medical Readiness Training Institute
DoD	U.S. Department of Defense
DoDTR	Department of Defense Trauma Registry
DOT	U.S. Department of Transportation
DOW	died of wounds
EAST	Eastern Association for the Surgery of Trauma
ECCC	Emergency Care Coordination Center
ECHO	Extension for Community Healthcare Outcomes
EMR	electronic medical record
EMR	emergency medical responder
EMS	emergency medical services
EMT	emergency medical technician
ENA	Emergency Nurses Association
FBI	Federal Bureau of Investigation
FDA	U.S. Food and Drug Administration
FHP&R	Force Health Protection and Readiness
FICEMS	Federal Interagency Committee on EMS
FITBIR	Federal Interagency Traumatic Brain Injury Research
GAO	U.S. Government Accountability Office
HHS	U.S. Department of Health and Human Services
HIPAA	Health Insurance Portability and Accountability Act
HPSP	Health Professionals Scholarship Program
HRSA	Health Resources and Services Administration
IDF	Israel Defense Forces
IED	improvised explosive device
IOM	Institute of Medicine
IRB	institutional review board
JCIDS	Joint Capabilities Integration and Development System
JTAPIC	Joint Trauma Analysis and Prevention of Injury in Combat
JTS	Joint Trauma System
JTTS	Joint Theater Trauma System

KIA	killed in action
MASH	mobile army surgical hospital
MEDEVAC	medical evacuation
MERcURY	Military En Route Care Registry
METRC	Major Extremity Trauma Research Consortium
MHS	Military Health System
MRMC	U.S. Army Medical Research and Materiel Command
MTF	military treatment facility
NAEMSP	National Association of EMS Physicians
NAEMT	National Association of Emergency Medical Technicians
NASEMSO	National Association of State EMS Officials
NEMSIS	National EMS Information System
NHTSA	National Highway Traffic Safety Administration
NIH	National Institutes of Health
NQF	National Quality Forum
NRAP	National Research Action Plan
NREMT	National Registry of Emergency Medical Technicians
NSCOT	National Study on the Costs and Outcomes of Trauma
NTDB	National Trauma Data Bank
NTDS	National Trauma Data Standard
NTI	National Trauma Institute
NTTC	Navy Trauma Training Center
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PACOM	U.S. Pacific Command
PCORI	Patient-Centered Outcomes Research Institute
PHTR	Pre-Hospital Trauma Registry
PTSD	posttraumatic stress disorder
ROTC	Reserve Officer Training Corps
RTD	returned to duty
SAMMC	San Antonio Military Medical Center
TACEVAC	tactical evacuation
TBI	traumatic brain injury
TCAA	Trauma Center Association of America
TCCC	tactical combat casualty care
TNC	trauma nurse coordinator

TOPIC-M	Trauma Outcomes and Performance Improvement Course-Military
TQIP	Trauma Quality Improvement Program
TXA	tranexamic acid
USAISR	U.S. Army Institute of Surgical Research
USD(P&R)	Under Secretary of Defense for Personnel and Readiness
USUHS	Uniformed Services University of the Health Sciences
VA	U.S. Department of Veterans Affairs
WIA	wounded in action
YPLL	years of potential life lost

Glossary

Allied health professionals: "The segment of the workforce that delivers services involving the identification, evaluation and prevention of diseases and disorders; dietary and nutrition services; and rehabilitation and health systems management" (ASAHP, 2014).

Benchmarking: "A systematic comparison of structure, process, or outcomes of similar organizations, used to identify the best practices for the purposes of continuous quality improvement" (Nathens et al., 2012, p. 443).

Case fatality rate: The percentage of fatalities among all wounded (Holcomb et al., 2006).

Clinical decision support: Tools and systems that provide "timely information, usually at the point of care, to help inform decisions about a patient's care. [Clinical decision support] tools and systems help clinical teams by taking over some routine tasks, warning of potential problems, or providing suggestions for the clinical team and patient to consider" (AHRQ, 2015).

Combat support agency: An organizational body charged to provide department-level and tactical support to the joint operating forces of the U.S. military during combat and other military operations (e.g., Defense Health Agency, Defense Logistics Agency, Defense Intelligence Agency).

Combatant Command: "A unified or specified command with a broad continuing mission under a single commander established and so designated by the President, through the Secretary of Defense and with the advice and assistance of the Chairman of the Joint Chiefs of Staff" (DoD, 2016). There are nine combatant commands, covering both regional (e.g., Central Command, Pacific Command) and functional (e.g., Special Operations Command) areas.

Defense Health Agency: A combat support agency for health and medical operations within the U.S. Department of Defense, the Defense Health Agency is charged with developing strategies to contain costs, improve efficiency, and encourage collaboration and opportunities for joint operations between the three armed services.

Expert trauma care workforce: Each interdisciplinary trauma team at all roles of care includes an expert for every discipline represented. These expert-level providers oversee the care provided by their team members, all of whom must be minimally proficient in trauma care (i.e., appropriately credentialed with current experience caring for trauma patients).

Focused empiricism: An approach to process improvement under circumstances in which: (1) high-quality data are not available to inform clinical practice changes, (2) there is extreme urgency to improve outcomes because of high morbidity and mortality rates, and (3) data collection is possible. A key principle of focused empiricism is using the best data available in combination with experience to develop clinical practice guidelines that, through an iterative process, continue to be refined until high-quality data can be generated to further inform clinical practice and standards of care.

Inclusive trauma care system: "A trauma care system that incorporates every health care facility in a community in a system in order to provide a continuum of services for all injured persons who require care in an acute care facility; in such a system, the injured patient's needs are matched to the appropriate hospital resources" (NHTSA, 2004).

Injury: "The result of an act that damages, harms, or hurts; unintentional or intentional damage to the body resulting from acute exposure to thermal, mechanical, electrical or chemical energy or from the absence of such essentials as heat or oxygen" (NHTSA, 2004).

Joint Theater Trauma System (JTTS): "A systematic and integrated approach to better organize and coordinate battlefield care to minimize morbidity and mortality and optimize the ability to provide essential care required for casualty injuries. . . . The components of the JTTS system include prevention, pre-hospital integration, education, leadership and communication, quality improvement/performance improvement, research, and information systems" (Eastridge et al., 2009, p. 853).

Learning health system: "A system in which science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience" (IOM, 2013, p. 136).

National EMS Information System (NEMSIS): NEMSIS seeks to improve prehospital care through the standardization, aggregation, and utilization of point-of-care EMS data at a local, state, and national levels. It is funded and led by the National Highway Traffic Safety Administration and includes several components, among them the National EMS Database.

National EMS Database: A component of NEMSIS, the National EMS Database is the national repository of standardized EMS event records entered at a local level. EMS event information is aggregated at a state level and then transmitted to the National EMS Database to facilitate research and assessment of the nation's EMS systems.

Operation Enduring Freedom: The official U.S. government name for the War in Afghanistan (October 2001 to December 2014).

Operation Iraqi Freedom: The official U.S. government name for the Iraq War (March 2003 to September 2010).

Patient-centered care: "The experience (to the extent the informed, individual patient desires it) of transparency, individualization, recognition, respect, dignity, and choice in all matters, without exception, related to one's person, circumstances, and relationships in health care" (Berwick, 2009, p. 560).

Performance improvement/quality improvement[1]: "Method for evaluating and improving processes that uses a multidisciplinary approach and that focuses on data, benchmarks, and components of the system being evaluated" (ACS, 2008, p. 45).

Preventable deaths after injury: Those casualties whose lives could have

[1] These terms will be used interchangeably throughout the report.

been saved by appropriate and timely medical care, irrespective of tactical, logistical, or environmental issues.

Readiness: The total military workforce is medically ready to deploy and the military medical force is ready to deliver health care (including combat casualty care) in support of the full range of military operations, domestically and abroad.

Tacit knowledge: Knowledge that is contextual and guided by personal experience, including insights and intuitions that may be difficult to formalize and communicate to others.

Tactical combat casualty care: A framework and set of continuously updated trauma management guidelines that focus on treating life-threatening injuries in the prehospital setting, while taking into account the tactical situation.

Transparency: "Ensuring that complete, timely, and understandable information is available to support wise decisions" (IOM, 2013, p. 142).

Trauma center: "A specialized hospital or facility with the immediate availability of specially trained health care personnel who provide emergency care on a 24-hour–7-day/week basis for injured people" (ACS, 2008).

Trauma patient: A patient who has suffered a serious and potentially disabling or life-threatening injury to one or more parts of the body as a result of an event such as a motor vehicle crash, gun violence, or fall. For the purposes of this report, the term trauma refers only to physical trauma.

Trauma system: "An organized, inclusive approach to facilitating and coordinating a multidisciplinary system response to severely injured patients. A trauma system encompasses a continuum of care provision and is inclusive of injury prevention and control, public health, EMS [emergency medical services] field intervention, ED [emergency department] care, surgical interventions, intensive and general surgical in-hospital care, and rehabilitative services, along with the social services and the support groups that assist injured people and their significant others with their return to society at the most productive level possible." (ACS, 2008).

Trauma workforce: The multidisciplinary group of professionals responsible for the care of injured patients (e.g., surgeons, emergency physicians, nurses, medics, technicians, anesthesiologists, intensivists, radiologists, rehabilitation specialists) as well as the wide range of professionals who directly support the clinical mission (e.g., supply, operations, information technology, management, administration, research, education) and those who collect and analyze data for performance improvement and research purposes.

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Abstract

Trauma care in the military and civilian sectors is a portrait of contradiction—lethal contradiction. On one hand, the nation has never seen better systems of care for those wounded on the battlefield or severely injured within the United States. On the other hand, many trauma patients, depending on when or where they are injured, do not receive the benefit of those gains. Far too many needlessly die or sustain lifelong disabilities as a result. Between 2001 and 2011, approximately 1,000 American service members who perished on the battlefield (roughly 25 percent of all battlefield deaths) died of wounds they could potentially have survived. In the civilian sector, where injury is the leading cause of death for Americans under age 46, as many as 1 in 5 deaths from traumatic injuries may be preventable with optimal trauma care, equating to 200,000-300,000 lives that could be saved over the same 10-year period.

The paradox arises from the laudable successes, pockets of excellence, and numerous examples of innovation in both military and civilian trauma care that can be observed even in the face of such sobering statistics. Battlefield fatality rates have declined substantially since the Vietnam War, particularly in the prehospital setting, and in one special operations unit—the 75th Ranger Regiment—preventable trauma deaths among wounded soldiers were all but eliminated. Wartime innovations in trauma care have included, among others, new paradigms for management of hemorrhage (e.g., early tourniquet use, damage control resuscitation) and prehospital casualty care. Many of these military innovations have emerged in the civilian trauma care setting, but with variable degrees of penetration.

Much of the progress achieved in military trauma care over more than a decade of war was driven by learning processes that align with the cultural and systemic attributes of a "learning health system" as described by the Institute of Medicine. In such systems, data from each care experience is captured and care practices evolve incrementally and pragmatically based on best available evidence. The sense of urgency stemming from deaths on the battlefield drove trauma care practices to evolve to a new level of excellence, and the resulting military medical force represents an enormous store of knowledge and experience. The reality, however, is that the window of opportunity to tap into this pool of knowledge is brief. The threat of system degradation and institutional memory loss looms as many of the leaders who enabled this military medical transformation and who serve as advocates for its perpetuation retire or transition to the civilian sector. Recognizing the magnitude and the immediacy of the need, a group of sponsors, representing both the military and civilian sectors, asked the National Academies of Sciences, Engineering, and Medicine to convene a committee charged with defining the components of a learning health system necessary to enable continued improvement in military and civilian trauma care, and with providing recommendations to ensure that lessons learned from the military's experiences in Afghanistan and Iraq are sustained and built upon for future combat operations and translated into the civilian system (the full statement of task is included in Box 1-6 in Chapter 1).

In its examination of military and civilian trauma systems, the committee observed striking similarities in gaps that lead to preventable death and disability after injury including inconsistency in trauma care capabilities and utilization of best practices across time and geography, as well as diffusion of leadership responsibility. With regard to learning capacity, although many of the individual components of a learning system are in place, the full potential of such a system is not being realized in either sector. Hundreds or more lives could likely be saved in future wars if military trauma care were optimal, and that potential gain soars into the tens of thousands of lives if past and future improvements could be systematically translated into civilian trauma care.

Some significant improvements in military trauma care and learning can be achieved within the military sector alone including, for example, the standardization of best practices and training requirements across the U.S. Department of Defense. However, it is neither feasible nor, in the face of the evidence, rational to address the deficiencies in military trauma care and learning more broadly without extending change efforts to encompass the civilian trauma system, which must serve as a training platform for military trauma care providers, particularly during the interwar period. The low clinical volume of trauma cases outside of the combat setting does not allow military trauma teams to acquire and maintain the expertise neces-

sary to deliver combat casualty care at the level of excellence that is both deserved and needed by the men and women who serve in the U.S. Armed Forces. Military and civilian trauma care and learning will be optimized together, or not at all.

Currently, a national strategy and joint military–civilian approach for improving trauma care are lacking, placing lives unnecessarily at risk. The committee concludes that a unified effort is needed to address this gap and ensure the delivery of optimal trauma care to save the lives of Americans injured within the United States and on the battlefield.

In this report, the committee presents a vision for a national trauma care system driven by a clear and bold aim: zero preventable deaths after injury and minimal disability, for those the nation sends into harm's way in combat, and for every American. It offers 11 recommendations that, if implemented, would help the nation realize this vision through stronger and more consolidated leadership; comprehensive and more accessible trauma data and information management systems; robust research programs and supportive regulatory systems that promote innovation; incentives that drive quality improvement processes; and a network of civilian and military trauma centers to serve as an integrated trauma training platform. This will require an unprecedented partnership across military and civilian sectors and a sustained commitment from trauma system leaders at all levels, but the benefits are clear: the first casualties of the next war would experience better outcomes than the casualties of the last war, and all Americans would benefit from the hard-won lessons learned on the battlefield.

Summary

The sacrifices made by the men and women of the U.S. Armed Forces deserve the profound gratitude of our Nation. For all those who served and gave so much, we thank you. Medical history has been made with the delivery of clinical care under conditions and in environments that few of us can imagine. We must now honor the sacrifices of a generation by ensuring that the lessons learned over the longest period of armed conflict in the history of the United States are not lost.

Trauma care in the military and civilian sectors is a portrait of contradiction—lethal contradiction. On one hand, the nation has never seen better systems of care for those wounded on the battlefield or severely injured within the United States. On the other hand, many trauma patients,[1] depending on when or where they are injured, do not receive the benefit of those gains. Far too many needlessly die or sustain lifelong disabilities as a result.

Since the Civil War, and even more dramatically between the Vietnam War and the present day, rates of survival from battlefield injuries have improved remarkably, even as advances in the kinetic energy and accuracy of weapons have increased their deadliness. In the Vietnam War, the case fatality rate—the percentage of fatalities among all wounded individuals—was 23 percent; in Afghanistan and Iraq, it was 9.3 percent (Rasmussen,

[1] A trauma patient is someone who has suffered a serious and potentially disabling or life-threatening injury to one or more parts of the body as a result of an event such as a motor vehicle crash, gun violence, or fall. For the purposes of this report, the committee uses the term trauma only in reference to physical trauma.

2015; Rasmussen et al., 2015). These impressive gains have not occurred by chance. They are the result of the systematic design and redesign of clinical care processes, systems of battlefield injury management, and support systems, all based on rapid learning from field experiences, the fostering of innovation, and carefully managed reflection involving all levels of care. This evolution was set in motion by a cadre of military medical leaders, many of whom exercised strong initiative acting as internal change agents and, determined to save lives by avoiding the mistakes of the past, championed the design of a better system for casualty care on the battlefield, built on a foundation of military medical history and more recent advances from civilian trauma systems.

Military trauma care system designs include balletic orchestration of evacuation sequences and handoffs using a tiered configuration of five "roles"—from immediate care at the site of injury, through stabilization in field hospitals, and eventually to definitive care in the United States. Points of emphasis in this battlefield system of care include projecting life-saving care far into the field and minimizing delays in patient transfer. Notable advances in military trauma management include, for example, the aggressive use of tourniquets, revised transfusion principles for hemorrhagic shock, and the overall doctrine of tactical combat casualty care, defining the optimal delivery of trauma care under demanding conditions of austerity and danger.

Support system redesigns have included the creation of the U.S. Department of Defense's (DoD's) Joint Trauma System (JTS), as well as an associated trauma registry to foster continual reflection and learning. Using an approach referred to as "focused empiricism,"[2] the JTS works to support continuous real-time performance improvement through the capture and ongoing evaluation of patient care and outcome data in the DoD Trauma Registry (DoDTR), and through the dissemination of evidence-based clinical practice guidelines designed to reduce variations in practice. DoDTR data also support the creation of new knowledge through research, identifying clinical needs and providing direction to the military's combat casualty care research program, which in turn generates new evidence and improves capabilities.

Although the Military Health System's capacity to improve trauma care developed long before the Institute of Medicine (IOM) articulated the

[2] Focused empiricism is a concept embraced by U.S. military medical leadership to capture its approach to process improvement under circumstances in which (1) high-quality data are not available to inform clinical practice changes, (2) there is extreme urgency to improve outcomes because of high morbidity and mortality rates, and (3) data collection is possible (Elster et al., 2013). A key principle of focused empiricism is using the best data available in combination with experience to develop clinical practice guidelines that, through an iterative process, continue to be refined until high-quality data can be generated to further inform clinical practice and standards of care.

principles of a "learning health system,"[3] military trauma care is, at its best, an archetype of those principles in action. Despite that progress, however, military trauma care is by no means always "at its best"—not, at least, if that phrase implies consistency and the promise of the highest achievable quality over time and space. In the face of the common idealized image of the U.S. military—one involving a strong and professional command structure, absolute clarity of roles, consistent adherence to high technical standards, and continual curiosity and learning—the committee sees a paradox. Military trauma care, despite its laudable successes, is

- *inconsistent over time*, with significant loss during interwar periods of clinical competence and hard-won lessons learned on the battlefield;
- *inconsistent over space*, with many of the key, successful innovations in clinical care, systems of care, and support systems being confined to specific geographic commands or even regimental units, rather than becoming the universal norm;
- *inconsistent in the thoroughness of organizational commitment* to total excellence in care, with, for example, ongoing existential threats to the highly successful JTS and highly variable ownership of trauma care quality and performance among line commanders;
- *inconsistent in its management of interfaces* between prehospital and hospital-based care and again between acute trauma care and later phases, such as rehabilitation and long-term follow-up. These defects are especially evident when wounded warriors transition to the veterans health care system and to other components of civilian care and when long-term needs encompass, as they often do, dimensions of psychiatric care, social support, and reentry into civilian life;
- *inconsistent in the deployment of true trauma expertise*, as medical personnel are too often assigned inappropriately on the basis of general medical skills rather than a needs-based requirement according to the particular skills of the provider; and
- *unclear in its leadership structures*, with no single locus of combined responsibility and authority for maintaining the readiness and ensuring the performance of military trauma care teams and of the system as a whole. No one appears to be responsible for setting goals for the readiness of the medical force or for its performance,

[3] In a learning health system, "science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience" (IOM, 2013, p. 136).

> nor do those line commanders who ultimately control resources in the field uniformly claim or reliably accept responsibility for monitoring and ensuring that standards of trauma care are being met on the battlefield.

These gaps lead to a military trauma care system that functions without the stability, standardization, leadership commitment, and resources that would allow it to fulfill the promise the nation owes to its men and women in combat: that the trauma care they will receive will be the best possible in the world, no matter when and where they are injured. The ultimate effect of these gaps is that approximately 1,000 American service members who perished on the battlefield between 2001 and 2011 (roughly 25 percent of all battlefield deaths) died of wounds they could potentially have survived (Eastridge et al., 2012).

The committee found that similar gaps—inconsistency in trauma care quality over time and geographic location, suboptimal transitions between phases of care, diffusion of responsibility—impede the process of continuous improvement and consistent adoption of military lessons learned in the civilian sector, where the burden of traumatic injury is staggering. Surprisingly, the public appears generally to be unaware that trauma is the leading cause of death for Americans under the age of 46 (Rhee et al., 2014). It accounts for approximately half of all deaths in this age group and was associated with an economic cost of approximately $670 billion in medical care expenses and lost productivity in 2013 alone (Florence et al., 2015). Further, because of its disproportionate effects on young people, trauma is the number one cause of years of potential life lost before age 75—greater than either cancer or heart disease (NCIPC, 2015b). Yet despite these sobering statistics, trauma remains a neglected epidemic in the United States. The expectation of survival after severe injury, which has helped drive the continuous improvement seen in military trauma care, has not yet permeated the American public's expectations for civilian trauma care. Of the 147,790 U.S. deaths from trauma in 2014[4] (NCIPC, 2015a), as many as 20 percent may have been preventable with optimal trauma care (Kwon et al., 2014). This figure equates to nearly 30,000 preventable trauma deaths after injury[5] in a single year—about 10 times the number of deaths from the terrorist attacks on September 11, 2001.[6]

[4] This figure excludes deaths due to poisoning (51,966), which are classified by the Centers for Disease Control and Prevention as injury-related deaths.

[5] The committee defines preventable deaths after inury as those casualties whose lives could have been saved by appropriate and timely medical care, irrespective of tactical, logistical, or environmental issues.

[6] During the terrorist attacks on September 11, 2001, 2,977 people perished (McCoy, 2015).

Since 2001, approximately 2 million U.S. civilians have died from trauma[7] (NCIPC, 2015a). In this same period, approximately 6,850 U.S. service members died in theater[8] (DCAS, 2016). Thus, the vast majority of the burden of trauma is borne by the civilian population. Dramatic action is needed to reduce these staggering statistics. Recognizing that the best strategy is to prevent the injury from occurring in the first place, when injuries do occur, the delivery of optimal trauma care represents a critical secondary prevention strategy to avert unnecessary death and disability. Given the military's success in reducing trauma deaths, the civilian sector stands to reap tremendous benefits if best practices can be reliably adapted from the military, and if the same learning system properties that have been highly effective in portions of military trauma care can become manifest in its civilian counterpart. The increasing incidence of multiple-casualty incidents such as those in Sandy Hook, Boston, Paris, and San Bernardino lends additional urgency to the translation of wartime lessons to the civilian sector.

The end of the wars in Afghanistan and Iraq represents a unique moment in history in that there now exists a military trauma system built on a learning system framework and an organized civilian trauma system that is well positioned to assimilate and distribute the recent wartime trauma lessons learned and to serve as a repository and incubator for innovation in trauma care during the interwar period. Together, these two developments present an opportunity to integrate military and civilian trauma systems, thereby ensuring continuous bidirectional learning, but this will require unprecedented partnership across military and civilian sectors, along with a sustained commitment from trauma system leaders at all levels, to ensure that the necessary knowledge and tools are not lost. Recognizing the importance of this window of opportunity, a group of sponsors,[9] representing both the military and civilian sectors, asked the National Academies of Sciences, Engineering, and Medicine to convene a committee charged with defining the components of a learning health system necessary to enable continued improvement in military and civilian trauma care, and with providing recommendations to ensure that lessons learned over the past

[7] This figure excludes deaths due to poisoning, which are classified by the Centers for Disease Control and Prevention as injury-related deaths, over the same time period (536,018).

[8] The term "theater" refers to the theater of war, which is the area of air, land, and water that is, or may become, directly involved in the conduct of a war (DoD, 2016).

[9] The Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector was established with funding from three federal agencies (DoD's U.S. Army Medical Research and Materiel Command, the U.S. Department of Transportation's National Highway Traffic Safety Administration, and the U.S. Department of Homeland Security's Office of Health Affairs) and five professional organizations (the American College of Emergency Physicians, American College of Surgeons, National Association of Emergency Medical Services Physicians, National Association of Emergency Medical Technicians, and Trauma Center Association of America).

decade from the military's experiences in Afghanistan and Iraq are both sustained and built upon for future combat operations and translated into the U.S. civilian system (the full statement of task is included in Box 1-6 in Chapter 1).

A LEARNING SYSTEM FRAMEWORK FOR CONTINUOUS IMPROVEMENT IN TRAUMA CARE

The committee was asked to identify and describe the key components of a learning health system necessary to optimize care of individuals who have sustained traumatic injuries in military and civilian settings. To that end, the committee turned to the IOM's framework for a learning health system (IOM, 2013), adapting it for systems of trauma care and using it to "interrogate" the status quo. The committee found that although many of the individual components are in place, the full potential of a learning system is not being realized in either sector (as summarized in Table S-1).

The committee takes as its beacon the accomplishments of the 75th Ranger Regiment, a U.S. Army special operations force that, driven by the vision and action of its commanding officer, closed those gaps. For the 75th Rangers, the ability to deliver combat casualty care to their wounded comrades became as important as the more traditional military proficiencies of marksmanship, mobility, and communication. Constant reflection, data-driven performance improvement, and ambitious innovation, along with total support from the top and total involvement of the workforce, became their doctrine. The results set a new benchmark: virtually eliminating preventable trauma deaths under the most trying of conditions. Crucially, the line commanders, starting with the commanding officer, took full responsibility for the achievement of this goal (Kotwal et al., 2011).

By extrapolating from the outcomes of best-in-class trauma care delivery systems that exemplify the characteristics of a high-functioning learning system, one can estimate the societal benefit that could be achieved through the uniform provision of high-quality trauma care. Had the level of care achieved by the 75th Ranger Regiment been provided throughout the military during the wars in Afghanistan and Iraq, hundreds of service members who perished in the line of duty over a decade of war might have survived (Eastridge et al., 2012).[10] In the civilian sector, as many as 200,000 American lives—a population the size of the city of San Bernardino, California—could have been saved in the same period of time if all trauma centers in the United States had achieved outcomes similar to those at the highest-

[10] Survivability determinations were based on medical information only and did not take into account resource restrictions or operational conditions that may have prevented timely access to appropriate medical care (Eastridge et al., 2012).

TABLE S-1 Learning Trauma Care System Components in Military and Civilian Settings

Digital Capture of the Trauma Patient Care Experience

Patient care experiences across the continuum of care are digitally captured and linked in information systems, including trauma registries, such that each patient experience yields information on the effectiveness, quality, and value of the trauma care delivered. Bottom-up design of data systems, where care generates the data, ensures that data capture is seamlessly integrated into the provider workflow and is available in real time for performance improvement primarily and research secondarily.

MILITARY SECTOR FINDINGS	CIVILIAN SECTOR FINDINGS
Prehospital care is not consistently digitally captured and the prehospital registry does not link to data from hospital-based care. Separate registries are maintained for en route care and other specialty areas, such as orthopedics and infectious disease. DoD registry data are not linked to long-term outcomes in VA information systems.	Prehospital care is unpredictably captured (particularly digitally) and does not link to the outpatient (emergency department) or inpatient experience at a national level. Long-term care and outcomes are not digitally captured and linked to acute care for performance improvement. Patient-level linkages are not possible between national registries for prehospital and hospital-based care.

Coordinated Performance Improvement and Research to Generate Evidence-Based Best Trauma Care Practices

The supply of knowledge is continuously and reliably expanded and improved through the systematic capture and translation of information generated by coordinated performance improvement and research activities.

MILITARY SECTOR FINDINGS	CIVILIAN SECTOR FINDINGS
The Joint Trauma System's use of registry-driven rapid-cycle performance improvement has enabled evidence-based improvements to patient care processes. Increased research investment is needed to address fundamental knowledge gaps in best trauma care practices. Current federal regulations concerning privacy and human subjects protections and their interpretations expressed as "guidance documents" pose barriers to learning and continuous improvement in trauma care.	The American College of Surgeons National Trauma Data Bank and Trauma Quality Improvement Program have enabled evidence-based improvement to patient care processes. Increased research investment is needed to address fundamental knowledge gaps in best trauma practices. Current federal regulations concerning privacy and human subjects protections and their interpretations expressed as "guidance documents" pose barriers to learning and continuous improvement in trauma care.

continued

TABLE S-1 Continued

Processes and Tools for Timely Dissemination of Trauma Knowledge

Trauma care providers have access to tools such as continuously updated clinical practice guidelines and clinical decision support tools to capture, organize, and disseminate the best available information to guide decision making and reduce variation in care and outcomes. Clinical decision support tools and telemedicine make knowledge of best trauma care practices available at the point of care.

MILITARY SECTOR FINDINGS	CIVILIAN SECTOR FINDINGS
Guideline development and dissemination processes are agile but focused largely on surgical care (e.g., versus nursing care). Telemedicine capabilities have been key in performance improvement efforts but are not optimally utilized.	Processes for guideline development exist but are fragmented and do not consistently capture and deliver the best and most up-to-date evidence available to guide, support, tailor, and improve clinical decision making and care, safety, and quality. No national-level entity or leader has been designated responsible for guideline development and dissemination.

Systems for Ensuring an Expert Trauma Care Workforce

Continuous learning and improvement are designed into trauma system processes. Ongoing individual skill building and team training, as well as feedback loops, build and sustain an expert trauma care workforce.

MILITARY SECTOR FINDINGS	CIVILIAN SECTOR FINDINGS
Ensuring the appropriate expertise of the trauma care workforce is impeded by reduced caseloads during interwar periods, competition for resources with the beneficiary care mission, reliance on just-in-time training, and a lack of standardized training informed by best practices in military trauma care (e.g., clinical practice guidelines).	Sharing of new civilian best trauma care practices/experiences with the military community is not occurring systematically (and vice versa), and no national framework has been defined for integrating military best practices into skill building, team building, and certification processes.

continued

TABLE S-1 Continued

Patient-Centered Trauma Care

The trauma care process is managed around the patient experience, feedback is sought from trauma patients when the process is evaluated for improvement, and patients are involved in redesign of the trauma system and have a voice in trauma research. Patient-centered care features timely access to high-quality prehospital, definitive, and rehabilitative care, with seamless transitions between each of these echelons to ensure that physical and psychological health care needs are met.

MILITARY SECTOR FINDINGS	CIVILIAN SECTOR FINDINGS
Patient care is fragmented across the trauma care continuum, and trauma systems do not optimally address the holistic needs of the patient. Given the nature of trauma, decisions may be made with little to no patient input. Consequently, greater efforts are needed to engage patients and their families in decision making and in the design and evaluation of care processes.	Patient care is fragmented across the trauma care continuum, and trauma systems do not optimally address the holistic needs of the patient. Given the nature of trauma, decisions may be made with little to no patient input. Consequently, greater efforts are needed to engage patients and their families in decision making and in the design and evaluation of care processes.

Leadership-Instilled Culture of Learning

Leadership will influence the extent to which a culture of learning and improvement permeates a trauma system. Leadership instills a culture of learning by defining learning as a central priority of a trauma system, removing barriers to improving care systems and, most notably at the point of care, setting quantifiable aims against which progress can continually be measured and promoting a nonpunitive environment.

MILITARY SECTOR FINDINGS	CIVILIAN SECTOR FINDINGS
Commitment to creating an environment that promotes learning and continuous improvement is variable across DoD and over time. Service parochialisms and an inconsistent level of understanding by senior medical and line leadership of the value of a learning trauma care system impede continuous learning and improvement.	A pervasive cultural barrier impedes learning from mistakes, as liability concerns and fear of disciplinary action or loss of reputation (at the individual and organizational levels) trump patient safety and performance improvement goals.

continued

TABLE S-1 Continued

Transparency and Aligned Incentives for Quality Trauma Care	
Drawing on data from trauma registries and other information systems, performance improvement programs support the evolution and improvement of trauma systems by benchmarking systems' performance against that of other similar organizations and by making performance information available at the provider, team, center, and system levels. Multiple complementary incentives are aligned to encourage continuous improvement and reward high-quality care.	
MILITARY SECTOR FINDINGS	**CIVILIAN SECTOR FINDINGS**
Military trauma care providers lack real-time access to their own performance data, although a weekly video teleconference is a means of obtaining feedback in a timely manner. Few military treatment facilities submit data to a trauma quality improvement program for benchmarking purposes, limiting transparency and performance improvement across DoD military treatment facilities. Financial incentives cannot easily be used to drive improvement in trauma care quality given current military processes for budgeting and accountability for health care spending. Other levers (e.g., promotion) are not adequately employed.	Trauma quality improvement programs exist for trauma centers but there is no common process in place for benchmarking safety, quality, processes, prices, costs, and outcomes of prehospital care or whole trauma systems, and for making that information available for care improvement and informed decision making by clinicians, patients, and their families. There are no national metrics (such as those promulgated by the National Quality Forum) to drive national trauma quality initiatives. Emergency medical services is not a provider type under the Social Security Act, so prehospital trauma care is not linked to national health care reform efforts to improve quality and reduce preventable deaths after injury.

Aligned Authority and Accountability for Trauma System Leadership	
Responsibility, authority, and resources are aligned to enable leadership to steward the system. Defined leadership is accountable for trauma capabilities and system performance, with the authority to create and enforce policy and ensure that the many stakeholders involved work together to provide seamless, quality care.	
MILITARY SECTOR FINDINGS	**CIVILIAN SECTOR FINDINGS**
Responsibility, authority, and accountability for battlefield care are diffused across central and service-specific medical leadership, as well as line leadership, resulting in variability in care processes and outcomes across time, facilities, and geography.	At a national level, there is no governmental civilian health lead for trauma care (including prehospital, in-hospital, and post-acute care) to support a learning health system for trauma care, despite past recommendations that such a lead agency be established.

performing centers (Hashmi et al., 2016). Yet no person, group, or institution in the United States bears responsibility for the aim for both military and civilian trauma care that informed this study: to eliminate preventable deaths after injury and minimize trauma-related disability. Concerted efforts aimed at establishing the type of "learning trauma care systems" the committee observed in the 75th Ranger Regiment and top-performing civilian trauma systems can save tens of thousands of lives on an annual basis and mitigate suffering for many times that number of trauma patients.

A VISION FOR A NATIONAL TRAUMA CARE SYSTEM

History has demonstrated that military and civilian trauma care are inextricably linked. In many ways, the successes of the military's trauma system parallel the significant progress made over the past 50 years with the development and refinement of a regionalized, systems-based approach to trauma care across the civilian sector. Sophisticated civilian trauma care systems in the United States emerged from the successes and lessons of military trauma care during the wars in Korea and Vietnam, and, subsequently, DoD adopted and adapted the principles of civilian trauma care systems for application in the military and the development of the JTS over the course of the wars in Afghanistan and Iraq, demonstrating a continual ebb and flow between the two sectors.

Moreover, sustaining needed expertise and capacity in the military trauma care system is simply impossible absent integration with civilian trauma care systems, given the essential role of the civilian sector in facilitating combat-relevant research and maintaining the expertise of the military trauma care workforce. This linkage also is critical to (1) ensuring adequate preparedness for disasters and other mass casualty incidents, (2) ensuring full transfer of lessons learned between the two sectors, and (3) improving the civilian emergency and trauma care delivery system. Thus, it is neither feasible nor, in the face of the evidence, rational, to attempt to resolve the military's trauma care capability challenges or to enhance its learning capacity without broadening those changes to encompass the civilian trauma care system and the relationships between the two. Military and civilian trauma care and learning will be optimized together, or not at all.

> ***Conclusion:*** *A national strategy and joint military and civilian approach for improving trauma care is lacking, placing lives unnecessarily at risk. A unified effort is needed to address this gap and ensure the delivery of optimal trauma care to save the lives of Americans injured within the United States and on the battlefield.*

The committee envisions a national trauma care system grounded in sound learning health system principles applied across the delivery of care—from point of injury to hospitalization, rehabilitation, and beyond. Achieving this vision will require a systems approach that synergizes military and civilian efforts, committed leadership from both sectors, as well as a strategy that defines common standards, interoperable frameworks, and points of accountability to reduce variation in care and outcomes while supporting continuous learning and innovation at the point of care delivery.

RECOMMENDATIONS FOR LEADERSHIP

The success of the 75th Ranger Regiment demonstrates that eliminating preventable deaths after injury—the 20,000-30,000 that occur on a yearly basis in the United States and those on the battlefield—is an achievable goal (Hashmi et al., 2016; Kwon et al., 2014). However, accomplishing the necessary consistency, reliability, and constancy of uniformly superb trauma care—on a day-to-day basis as well as during mass casualty incidents—will require significant changes in leadership structures within DoD, in civilian trauma care, and in the combined efforts of the two sectors. The current absence of any higher authority to encourage coordination, collaboration, standardization, and alignment in trauma care across and within the military and civilian sectors has resulted in variation in practice, suboptimal outcomes for injured patients, and a lack of national attention and funding directed at trauma care at a level commensurate with its enormous societal burden. Leadership from the White House will be required to optimize U.S. trauma care delivery within and across the military and civilian sectors; to catalyze further development of the necessary public-private partnerships between governmental and civil society leaders; and to ensure accountability across the many federal agencies (e.g., DoD, the U.S. Department of Veterans Affairs [VA], the U.S. Department of Health and Human Services [HHS], the U.S. Department of Homeland Security [DHS], the U.S. Department of Transportation [DOT]) involved in trauma care. No level of government below the White House has the leverage to achieve this level of collaboration, and thereby to avert needless deaths and disability due to suboptimal trauma care.

Recommendation 1: The White House should set a national aim of achieving zero preventable deaths after injury and minimizing trauma-related disability.

Recommendation 2: The White House should lead the integration of military and civilian trauma care to establish a national trauma care system. This initiative would include assigning a locus of accountability

and responsibility that would ensure the development of common best practices, data standards, research, and workflow across the continuum of trauma care.

To achieve the national aim (Recommendation 1), the White House should take responsibility for

- creating a national trauma system comprising all characteristics of a learning organization as described by the Institute of Medicine;
- convening federal agencies (including HHS, DOT, VA, DHS, and DoD) and other governmental, academic, and private-sector stakeholders to agree on the aims, design, and governance of a national trauma care system capable of continuous learning and improvement;
- establishing accountability for the system;
- ensuring appropriate funding to develop and support the system;
- ensuring the development of a data-driven research agenda and its execution;
- ensuring the reduction of regulatory and legal barriers to system implementation and success;
- ensuring that the system is capable of responding domestically to any (intentional or unintentional) mass casualty incident; and
- strategically communicating the value of a national trauma care system.

While national leadership for better coordination, learning, and improvement of trauma care is important, progress also is possible within DoD given some significant changes in leadership actions and accountability.

Through the JTS, DoD's education and training enterprise, and its research investment over the course of the wars in Afghanistan and Iraq, the military has established an ad hoc system that has many of the components needed to support learning for improved trauma care. However, DoD has yet to achieve the full potential of a learning trauma care system, and improved linking of individual components into a unified system is needed. Additionally, this system has not been embraced across all combatant commands,[11] nor is it guaranteed to be sustained over time. Several different groups have made recommendations to DoD leaders for sustaining and

[11] A combatant command is "a unified or specified command with a broad continuing mission under a single commander established and so designated by the President, through the Secretary of Defense and with the advice and assistance of the Chairman of the Joint Chiefs of Staff" (DoD, 2016). There are nine combatant commands, covering both regional (e.g., Central Command, Pacific Command) and functional (e.g., Special Operations Command) areas.

improving upon trauma care advances realized over the last decade, but these recommendations have not as yet been translated into action.

The military has no unified medical command, no single senior military medical leader, directorate, or division solely responsible for combat casualty care. The Defense Health Agency (DHA) was created to serve as the Military Health System's joint combat support agency, but leadership responsibility for developing the structure and content of a robust learning trauma care system appears to be diffused across DHA, the Office of the Assistant Secretary of Defense for Health Affairs, and the military service medical commands. DHA has not yet established a single point of accountability responsible for driving requirements for trauma care across DoD. Oddly for a military system known for its command and control, with respect to battlefield trauma care and its continuous improvement, no one is in charge. Further, final authority and responsibility for the delivery of combat casualty care in the deployed setting is assigned to line commanders who have little education in or exposure to the principles of combat casualty care and trauma systems.

Overall, DoD's current trauma care system and resources (1) are not aligned with or accountable to a specific DHA leader in support of its combat support agency mission, (2) lack consistency in training and practice across the services and combatant commands, and (3) fail to hold medical and line leadership accountable for the standards of trauma care provided and for combat casualty care outcomes.

Recommendation 3: The Secretary of Defense should ensure combatant commanders and the Defense Health Agency (DHA) Director are responsible and held accountable for the integrity and quality of the execution of the trauma care system in support of the aim of zero preventable deaths after injury and minimizing disability. To this end

- **The Secretary of Defense also should ensure the DHA Director has the responsibility and authority and is held accountable for defining the capabilities necessary to meet the requirements specified by the combatant commanders with regard to expert combat casualty care personnel and system support infrastructure.**
- **The Secretary of Defense should hold the Secretaries of the military departments accountable for fully supporting DHA in that mission.**
- **The Secretary of Defense should direct the DHA Director to expand and stabilize long-term support for the Joint Trauma System so its functionality can be improved and utilized across all combatant commands, giving actors in the system access to timely evidence, data, educational opportunities, research, and performance improvement activities.**

To meet the needs of the combatant commanders, the accountable DHA leader should sustain and fund elements of a learning trauma care system that are performing well within DoD, and better align efforts that today are fragmented or insufficiently supported. Steps to take to these ends include

- developing policies to support and foster effective engagement in the national learning trauma care system;
- integrating existing elements of a learning system into a national trauma care system;
- maintaining and monitoring trauma care readiness for combat and, when needed, for domestic response to mass casualty incidents;
- continuously surveying, adopting, improving and, as needed, creating novel best trauma care practices, and ensuring their consistent implementation across combatant commands;
- supporting systems-based and patient-centered trauma care research;
- ensuring integration across DoD and, where appropriate, with the VA, for joint approaches to trauma care and development of a unified learning trauma care system;
- arranging for the development of performance metrics for trauma care, including metrics for variation in care, patient engagement/satisfaction, preventable deaths, morbidity, and mortality; and
- demonstrating the effectiveness of the learning trauma care system by each year diffusing across the entire system one or two deeply evidence-based interventions (such as tourniquets) known to improve the quality of trauma care.

As difficult as clarifying responsibility and authority for trauma care may be in the military, it is even more challenging in the civilian sector, where leadership in this area has been left mainly to states, counties, and municipalities, with little federal oversight to ensure the achievement of national goals or consistent practices. No single federal entity is accountable for trauma care capabilities in the United States. At the national level, coordinating bodies and processes are fragmented and severely under-resourced for the magnitude of the task:

- The Emergency Care Coordination Center (ECCC) was created by presidential directive in response to an IOM (2007) recommendation for the creation of a lead federal agency that would consolidate the many government programs involved in trauma care. The ECCC, however, is an unfunded office housed within the Office of the Assistant Secretary for Preparedness and Response, with little influence to link trauma care to broader health care reform efforts.

- In 2005, the Federal Interagency Committee on EMS (FICEMS) was created to foster partnership and collaboration among federal agencies involved in emergency medical services. However, FICEMS lacks the authority and funding to fully execute this mission.
- The National Highway Traffic Safety Administration staffs an Office for Emergency Medical Services, which has led several critical initiatives to improve prehospital care. However, this office is underresourced, and these efforts have been largely disconnected from HHS's health care delivery reform efforts.
- Current health care delivery reform efforts within the Centers for Medicare & Medicaid Services do not include the improvement of trauma care systems.
- The American College of Surgeons imposes requirements for trauma center verification but has no influence over prehospital care organizations.

The lack of formal, funded mechanisms for coordination, communication, and translation in trauma care has contributed to inefficiency and variation across the civilian sector in clinical care practices, education and training, research efforts, and continuous performance improvement—all of which have contributed in turn to suboptimal outcomes for injured patients in the United States.

Recommendation 4: The Secretary of Health and Human Services (HHS) should designate and fully support a locus of responsibility and authority within HHS for leading a sustained effort to achieve the national aim of zero preventable deaths after injury and minimizing disability. This leadership role should include coordination with governmental (federal, state, and local), academic, and private-sector partners and should address care from the point of injury to rehabilitation and post-acute care.

The designated locus of responsibility and authority within HHS should be empowered and held accountable for

- convening a consortium of federal (including HHS, DOT, VA, DHS, and DoD) and other governmental, academic, and private-sector stakeholders, including trauma patient representatives (survivors and family members), to jointly define a framework for the recommended national trauma care system, including the designation of stakeholder roles and responsibilities, authorities, and accountabilities;

- developing a national approach to improving care for trauma patients, to include standards of care and competencies for prehospital and hospital-based care;
- ensuring that trauma care is included in health care delivery reform efforts;
- developing policies and incentives, defining and addressing gaps, resourcing solutions, and creating regulatory and information technology frameworks as necessary to support a national trauma care system of systems committed to continuous learning and improvement;
- developing and implementing guidelines for establishment of the appropriate number, level, and location of trauma care centers within a region based on the needs of the population;
- improving and maintaining trauma care readiness for any (intentional or unintentional) mass casualty incident, using associated readiness metrics;
- ensuring appropriate levels of systems-based and patient-centered trauma care research;
- developing trauma care outcome metrics, including metrics for variation in care, patient engagement/satisfaction, preventable deaths, morbidity, and mortality; and
- demonstrating the effectiveness of the learning trauma care system by each year diffusing across the entire system one or two deeply evidence-based interventions (such as tourniquets) known to improve the quality of trauma care.

The measure of a learning system's effectiveness is whether it is capable of supporting broad, rapid, meaningful change in practice. Accordingly, as directed in Recommendations 3 and 4, military and civilian stakeholders should commit to diffusing specific improvements in trauma care (e.g., broad availability of tourniquets or reliable application of a key trauma response protocol) every year throughout the system, and setting explicit, numeric aims for their adoption within aggressive time frames (e.g., within 6 months or 1 year). Diffusing straightforward, evidence-based practices—or attempting to do so—would test whether the learning trauma care system actually has value and impact, serve to highlight its deficiencies, and support its improvement. If successful, such efforts also could build confidence in the system among key actors (e.g., clinicians, medics) and increase its use.

While significant improvements to the learning system for trauma care are required, a complete redesign of the entire system (with all the consensus building and resource mobilization entailed) will not be accomplished overnight. Yet the urgent need to avoid preventable deaths after injury demands concomitantly urgent action. It is by no means wise or necessary to wait for a full redesign of the system before taking action. Setting aims for the near term would be an efficient way to drive broad and needed improvement now. A beneficial by-product would be immediate continuous innovation in the learning system generated in pursuit of such aims.

RECOMMENDATIONS FOR AN INTEGRATED MILITARY–CIVILIAN FRAMEWORK FOR LEARNING TO ADVANCE TRAUMA CARE

Learning and improvement are difficult, if not impossible, without a continuous supply of data and narrative information. Learning systems are avid for such information, digest it rapidly, and maintain "memory" over time so that the information accumulates and lessons are retained. Such an information environment has strong cultural characteristics, nurturing curiosity, disclosure, trust, and shared learning, as well as, crucially, minimizing fear. Fear poisons learning. The emphasis on data use is for purposes of learning, not judgment.

In the world of trauma care, this bias toward information and data in the service of learning would take several forms, including robust and continuous registry-driven analyses, systems for communication and exchange of ideas, access to scientific insights, and total workforce engagement.

Ensuring Access to and Use of Rich and Timely Data and Information

In both the military and civilian sectors, patient data are fragmented across independent data systems and registries, limiting the extent to which patient care and systems of care can be evaluated and improved. Linkages are incomplete or entirely missing among prehospital care, hospital-based acute care, rehabilitation and post-acute care, and medical examiner data. Further, current systems are not optimally designed or used to afford providers real-time access to their (individual or team) performance data. The failure to collect, integrate, and share trauma care data across the continuum of care limits the ability to analyze long-term patient outcomes and use that information to improve performance at the front lines of care. The collection and integration of the full spectrum of patient care and long-term outcome data using patient-centric, integrated registry systems need to be a priority in both sectors if the full potential of a learning trauma care system is to be realized, deaths from survivable injuries are to be reduced, and functional outcomes for the injured are to be maximized.

Recommendation 5: The Secretary of Health and Human Services and the Secretary of Defense, together with their governmental, private,

and academic partners, should work jointly to ensure that military and civilian trauma systems collect and share common data spanning the entire continuum of care. Within that integrated data network, measures related to prevention, mortality, disability, mental health, patient experience, and other intermediate and final clinical and cost outcomes should be made readily accessible and useful to all relevant providers and agencies.

To implement this recommendation, the following specific actions should be taken:

- Congress and the White House should hold DoD and the VA accountable for enabling the linking of patient data stored in their respective systems, providing a full longitudinal view of trauma care delivery and related outcomes for each patient.
- The Office of the National Coordinator for Health Information Technology should work to improve the integration of prehospital and in-hospital trauma care data into electronic health records for all patient populations, including children.
- The American College of Surgeons, the National Highway Traffic Safety Administration, and the National Association of State EMS Officials should work jointly to enable patient-level linkages across the National EMS Information System project's National EMS Database and the National Trauma Data Bank.
- Existing trauma registries should develop mechanisms for incorporating long-term outcomes (e.g., patient-centered functional outcomes, mortality data at 1 year, cost data).
- Efforts should be made to link existing rehabilitation data maintained by such systems as the Uniform Data System for Medical Rehabilitation to trauma registry data.
- HHS, DoD, and their professional society partners should jointly engage the National Quality Forum in the development of measures of the overall quality of trauma care. These measures should include those that reflect process, structure, outcomes, access, and patient experience across the continuum of trauma care, from the point of injury, to emergency and in-patient care, to rehabilitation. These measures should be used in trauma quality improvement programs, including the American College of Surgeons Trauma Quality Improvement Program (TQIP).

Elements that promote the adoption of innovations and best practices include support from leadership, conduits for sharing knowledge, and mechanisms for identifying potentially beneficial practices of other organizations and sectors (IOM, 2013). Each is critical to the realization of a national system for trauma care that ensures the diffusion of best practices within and across the military and civilian sectors. Conduits for sharing knowledge could include clinical guidelines that enable the diffusion and uptake of knowledge within and across sectors, as well as person-to-person connections that enable the sharing of tacit knowledge—the kind of practical know-how that comes from experience at the front lines of care delivery.

The military utilizes a flexible and agile approach to guideline development, distinct from that found in the civilian sector. While this enables rapid and continuous improvement in the military sector, more formal processes also are needed to encourage joint military–civilian discussion of guidelines so as to enhance bidirectional translation. Telemedicine has significantly advanced opportunities to disseminate best practices by facilitating real-time access to trauma experts, but this potential remains underrealized in both military and civilian trauma care settings.

Recommendation 6: To support the development, continuous refinement, and dissemination of best practices, the designated leaders of the recommended national trauma care system should establish processes for real-time access to patient-level data from across the continuum of care and just-in-time access to high-quality knowledge for trauma care teams and those who support them.

The following specific actions should be taken to implement this recommendation:

- DoD and HHS should prioritize the development and support of programs that provide health service support and trauma care teams with ready access to practical, expert knowledge (i.e., tacit knowledge) on best trauma care practices, benchmarking effective programs from within and outside of the medical field and applying multiple educational approaches and technologies (e.g., telemedicine).
- Military and civilian trauma management information systems should be designed, first and foremost, for the purpose of improving the real-time front-line delivery of care. These systems should follow the principles of bottom-up design, built around key clinical processes and supporting actors at all levels through clinical transparency, performance tracking, and systematic improvement within a learning trauma care system. Therefore, the greater trauma community, with representation from all clinical and allied disciplines, as well as electronic medical record and trauma registry vendors,

should, through a consensus process, lead the development of a bottom-up data system design around focused processes for trauma care.

- HHS and DoD should work jointly to ensure the development, review, curation, maintenance, and validation of evidence-based guidelines for prehospital, hospital, and rehabilitation trauma care through existing processes and professional organizations.
- Military and civilian trauma system leaders should employ a multipronged approach to ensure the adoption of guidelines and best practices by trauma care providers. This approach should encompass clinical decision support tools, performance improvement programs, mandatory predeployment training, and continuing education. Information from guidelines should be included in national certification testing at all levels (e.g., administrators, physicians, nurses, physician assistants, technicians, emergency medical services).

The committee found that the research investment in trauma care is not commensurate with the importance of injury, which accounts for nearly 10 percent of total disability-adjusted life years (DALYs) lost in the United States each year (U.S. Burden of Disease Collaborators, 2013) but receives only about 1 percent of the National Institutes of Health's (NIH's) biomedical research budget. Despite being the leading cause of death for Americans under the age of 46, in 2015, injury research accounted for only $399 million of NIH's approximately $30 billion budget (HHS, 2015; NIH, 2016). Although proportionality to disease burden is an overly simplistic method by which to set research budgets, this disparity indicates a lack of patient advocacy and public understanding of trauma and the role of research in addressing gaps in optimal trauma care.

Ultimately, to close critical gaps in knowledge of optimal trauma care practices and delivery systems, the United States needs a coordinated military–civilian trauma care research effort with defined objectives, a focus on high-priority needs, and adequate resourcing from both sectors. It is clear that current funding levels fall far short of the mark. In 2012, President Obama issued an executive order directing federal agencies to create a National Research Action Plan (NRAP) on posttraumatic stress disorder (PTSD), other mental health conditions, and traumatic brain injury. This presidential directive has been successful in drawing attention to the issue of traumatic brain injury, generating additional research investment, and requiring government agencies to coordinate their efforts. The success of the NRAP demonstrates how executive action from the White House can draw attention to overlooked areas of research such as trauma and induce federal agencies to coordinate their efforts in the absence of a funded congressional mandate.

Recommendation 7: To strengthen trauma research and ensure that the resources available for this research are commensurate with the importance of injury and the potential for improvement in patient outcomes, the White House should issue an executive order mandating the establishment of a National Trauma Research Action Plan requiring a resourced, coordinated, joint approach to trauma care research across the U.S. Department of Defense, the U.S. Department of Health and Human Services (National Institutes of Health, Agency for Healthcare Research and Quality, Centers for Disease Control and Prevention, U.S. Food and Drug Administration, Patient-Centered Outcomes Research Institute), the U.S. Department of Transportation, the U.S. Department of Veterans Affairs, and others (academic institutions, professional societies, foundations).

This National Trauma Research Action Plan should build upon experience with the successful model of the NRAP and should

- direct the performance of a gap analysis in the military and civilian sectors that builds on previous analyses, looking at both treatment (clinical outcome studies) and systems research to identify gaps across the full continuum of care (prehospital and hospital-based care and rehabilitation) and considering needs specific to mass casualty incidents (e.g., natural disasters, terrorist attacks) and special patient populations (e.g., pediatric and geriatric patient populations);
- develop the appropriate requirements-driven and patient-centered research strategy and priorities for addressing the gaps with input from armed forces service members and civilian trauma patients;
- specify an integrated military–civilian strategy with short-, intermediate-, and long-term steps for ensuring that appropriate military and civilian resources are directed toward efforts to fill the identified gaps (particularly during interwar periods), designating federal and industry stakeholder responsibilities and milestones for implementing this strategy; and
- promote military–civilian research partnerships to ensure that knowledge is transferred to and from the military and that lessons learned from combat can be refined during interwar periods.

The execution of a National Trauma Research Action Plan would certainly require a significant infusion of trauma research funding. This funding should be based on a determination of need stemming from the gap analysis recommended above and a review of current investments.

Beyond resources and infrastructure, research in a learning system for trauma care necessitates a regulatory environment that consciously fosters learning and exchange, or at least is not inimical to them, while protecting the interests of human subjects and addressing privacy concerns. The committee found that military and civilian trauma systems share barriers to the effective functioning of a learning trauma care system as a result of the current federal regulatory landscape, which impedes quality improvement and research activities.

Recommendation 8: To accelerate progress toward the aim of zero preventable deaths after injury and minimizing disability, regulatory agencies should revise research regulations and reduce misinterpretation of the regulations through policy statements (i.e., guidance documents).

In the process of implementing this recommendation, the following issues are points to consider:

- Prior national committees and legislative efforts have recommended that Congress, in instances of minimal-risk research where requiring informed consent would make the research impracticable, amend the U.S. Food and Drug Administration's (FDA's) authority so as to allow the FDA to develop criteria for waiver or modification of the requirement of informed consent for minimal-risk research. The present committee supports these recommendations, which would address current impediments to the conduct of certain types of minimal-risk research in the trauma setting (e.g., diagnostic device results that would not be used to affect patient care).
- For nonexempt human subjects research that falls under either HHS or FDA human subjects protections as applicable, DoD should consider eliminating the need to also apply 10 U.S.C. § 980, "Limitation on Use of Humans as Experimental Subjects" to the research.
- HHS's Office for Civil Rights should consider providing guidance on the scope and applicability of the Health Insurance Portability and Accountability Act (HIPAA) with respect to trauma care and trauma research such that barriers to the use and disclosure (sharing) of protected health information across the spectrum of care (from the prehospital or field setting, to trauma centers and hospitals, to rehabilitation centers and long-term care facilities) will be minimized.

- The FDA, in consultation with DoD, should consider establishing an internal Military Use Panel, including clinicians with deployment experience and patient representative(s) (i.e., one or more injured soldiers), that can serve as an interagency communication and collaboration mechanism to facilitate more timely fielding of urgently needed medical therapeutic and diagnostic products for trauma care.
- In trauma settings in which there are unproven or inadequate therapeutic alternatives for life-threatening injuries, the FDA should explore the appropriate scientific and ethical balance between premarket and postmarket data collection such that potentially lifesaving products are made available more quickly (after sufficient testing). At the same time, the FDA should consider developing innovative methods for addressing data gaps in the postmarket setting that adhere to regulatory and statutory constraints.
- Consistent with its approach to applications for rare diseases, the FDA should consider exercising flexibility in evidentiary standards for effectiveness within the constraints of applicable law when a large body of clinical evidence (albeit uncontrolled) supports a new indication for an FDA-approved product for the diagnosis or treatment of traumatic injury, and pragmatic, scientific, or ethical issues constrain the conduct of a randomized controlled trial (e.g., on the battlefield or in the prehospital setting).
- A learning trauma care system involves continuous learning through pragmatic methods (e.g., focused empiricism) and activities that have elements of both quality improvement and research. HHS, when considering revisions to the Common Rule, should consider whether the distinction it makes between quality improvement and research permits active use of these pragmatic methods within a continuous learning process. Whatever distinction is ultimately made by HHS, the committee believes that it needs to support a learning health system. Additionally, HHS, working with DoD, should consider providing detailed guidance for stakeholders on the distinctions between quality improvement and research, including discussion of appropriate governance and oversight specific to trauma care (e.g., the continuum of combat casualty care, and prehospital and mass casualty settings).

Reporting on performance data and practice variation can drive the adoption of evidence-based trauma care practices by enabling comparison across centers and systems and identifying practices and design elements that are associated with superior performance. Although mechanisms currently exist that allow comparison across trauma centers, there are no mechanisms in place to enable comparison across systems for prehospital care or regional trauma systems.

Recommendation 9: All military and civilian trauma systems should participate in a structured trauma quality improvement process.

The following steps should be taken to enable learning and improvement in trauma care within and across systems:

- The Secretary of HHS, the Secretary of Defense, and the Secretary of the VA, along with their private-sector and professional society partners, should apply appropriate incentives to ensure that all military and civilian trauma centers and VA hospitals participate in a risk-adjusted, evidence-based quality improvement program (e.g., ACS TQIP, Vizient).
- To address the full continuum of trauma care, the American College of Surgeons should expand TQIP to encompass measures from point-of-injury/prehospital care through long-term outcomes, for its adult as well as pediatric programs.
- The Center for Medicare & Medicaid Innovation should pilot, fund, and evaluate regional, system-level models of trauma care delivery from point of injury through rehabilitation.

Learning from the military experience, the greatest opportunity to save lives is in the prehospital setting, and the integration of prehospital care into the broader trauma care system is needed to ensure the delivery of optimal trauma care across the health care continuum, best understand the impact of trauma care, and recognize and address gaps and requirements to prevent deaths after injury. Because emergency medical services (EMS) is not currently a provider type designated under the Social Security Act, HHS does not link the emergent medical care delivered out of hospital to value-based payment or other current health care reform efforts. As a result, EMS continues to be a patchwork of systems across the nation with differing standards of care, few universal protocols, and perverse payment standards, yielding inconstant quality of care and variable patient outcomes. Such a system is not optimally designed to serve as a training platform for the military during interwar periods.

Recommendation 10: Congress, in consultation with the U.S. Department of Health and Human Services, should identify, evaluate, and implement mechanisms that ensure the inclusion of prehospital care (e.g., emergency medical services) as a seamless component of health care delivery rather than merely a transport mechanism.

Possible mechanisms that might be considered in this process include, but are not limited to:

- Amendment of the Social Security Act such that emergency medical services is identified as a provider type, enabling the establishment of conditions of participation and health and safety standards.
- Modification of CMS's ambulance fee schedule to better link the quality of prehospital care to reimbursement and health care delivery reform efforts.
- Establishing responsibility, authority, and resources within HHS to ensure that prehospital care is an integral component of health care delivery, not merely a provider of patient transport. The existing Emergency Care Coordination Center could be leveraged as a locus of responsibility and authority (see Recommendation 4) but would need to be appropriately resourced and better positioned within an operational division of HHS to ensure alignment of trauma and emergency care with health delivery improvement and reform efforts.
- Supporting and appropriately resourcing an EMS needs assessment to determine the necessary EMS workforce size, location, competencies, training, and equipping needed for optimal prehospital medical care.

Building Training Platforms to Ensure a Ready and Expert Trauma Care Workforce

Under current circumstances, it is impossible to maintain the readiness of an expert military trauma care workforce, especially during periods between wars. The Military Health System simply does not experience the clinical volume of trauma cases during interwar periods to allow trauma teams to acquire and maintain expertise in trauma care. There appears to be no credible plan in place for remedying this situation, which virtually ensures that wounded service members in a future war will, at least for a time, have worse outcomes than would have been achieved with full readiness. The committee was struck by a statement made by General Peter Chiarelli, former Vice Chief of Staff for the U.S. Army, during its July 2015 meeting:

> We are going to repeat the same mistakes we have made before. We are going to think our doctors are trained. They are not going to be trained. You have just got to pray your son or daughter or granddaughter is not the first casualty of the next war. Pray they come in at about the year five mark. (Chiarelli, 2015)

The best clinical outcomes are achieved by trauma teams that care for trauma patients on a daily basis. In much the same way that military line leadership trains for combat constantly, military trauma teams need to regularly take care of actual trauma patients to ensure the highest quality of care for combat casualties. An expert military trauma workforce needs to be built and sustained to achieve trauma care capabilities defined by DoD—specifically, the Joint Capabilities and Integration Development System—as necessary to the success of its wartime mission. To this end, it will be necessary to establish trauma-specific career paths with defined standards for competency, and to achieve increased integration of the military and civilian trauma systems.

Recommendation 11: To ensure readiness and to save lives through the delivery of optimal combat casualty care, the Secretary of Defense should direct the development of career paths for trauma care (e.g., foster leadership development, create joint clinical and senior leadership positions, remove any relevant career barriers, and attract and retain a cadre of military trauma experts with financial incentives for trauma-relevant specialties). Furthermore, the Secretary of Defense should direct the Military Health System to pursue the development of integrated, permanent joint civilian and military trauma system training platforms to create and sustain an expert trauma workforce.

Specifically, within 1 year, the Secretary of Defense should direct the following actions:

- Ensure the verification of a subset of military treatment facilities (MTFs) by the American College of Surgeons as Level I, II, or III trauma centers where permanently assigned military medical personnel deliver trauma care and accumulate relevant administrative experience every day, achieving expert-level performance. The results of a needs assessment should inform the selection of these military treatment facilities, and these new centers should participate fully in the existing civilian trauma system and in the American College of Surgeons' TQIP and National Trauma Data Bank.
- Establish and direct permanent manpower allocations for the assignment of military trauma teams representing the full spectrum of providers of prehospital, hospital, and rehabilitation-based care to civilian trauma centers. Provision should be made for these teams to obtain experience in prehospital care, burn care, pediatric trauma, emergency general surgery, and other aspects of trauma care across the system.

- Identify the optimum placement of these teams based on criteria determined by the DHA including but not limited to volume, severity, diversity, and quality-of-care outcomes of trauma patients at the civilian trauma centers, as well as the required number of teams as determined by a comprehensive DoD assessment.
- Develop and sustain a research portfolio focused on optimizing mechanisms by which all (active duty, Reserve, and National Guard) military medical personnel acquire and sustain expert-level performance in combat casualty care, to include research on evolving training modalities and technologies (e.g., simulation, telemedicine).
- Hold the DHA accountable for standardizing the curricula, skill sets, and competencies for all physicians, nurses, and allied health professionals (e.g., medics, technicians, administrators). The development of these curricula, skill sets, and competencies should be informed by data from the DoD Trauma Registry and DoD-developed clinical practice guidelines (including tactical combat casualty care and JTS guidelines); best civilian trauma care practices, outcomes, and data; and professional organizations representing the full spectrum of the military trauma care workforce. The JTS should validate these curricula, skill sets, and competencies.

CONCLUSION

In studying the performance of the military trauma care system and its learning capacity, the committee found a cup far more than half full. Indeed, other sectors of care, military and civilian alike, would do well to take lessons from the extraordinary history of progress in combat casualty care—but also its failures. It is time for the nation to improve its approach to trauma care. If the current course of trauma care continues, the consequences will be dire for tens of thousands of trauma patients who deserve, and could have, better outcomes (Hashmi et al., 2016; Kwon et al., 2014).

In its work on learning health systems (IOM, 2013), the IOM has provided a useful template for redesign that can enable a much better trauma care system. In its albeit-isolated examples of success in the field, the Military Health System has shown not only what is possible, but also how it can be accomplished. The next steps recommended by the committee would replace these isolated examples with a comprehensive learning system. The key requirements for doing so are known: stronger and more consolidated leadership; clearer, bolder aims; much more comprehensive and more usable data and information systems; support for innovation through increased research investment; continuing emphasis on local knowledge and capacity; and much higher and more consistent levels of cooperation within the military, between the military and civilian sectors, and across the nation. Of key importance to the military's readiness mission, progress will require a paradigm shift that entails seeing military and civilian trauma care as tightly interconnected—not two systems, but one.

The problem is of such magnitude and the current systems are so fragmented that the committee believes action and leadership are needed at the highest levels of the White House, as well as across HHS, DoD, the VA, DOT, and DHS. History has shown that anything less will fail to realize the goal—ambitious but achievable—articulated by the committee during the course of this study: zero preventable deaths after injury and minimal trauma-related disability for those the nation sends into harm's way in combat and indeed, for every American.

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Part I

Introduction, Overview, and Framework

1 Introduction

"Those who cannot remember the past are condemned to repeat it."
—George Santayana (1905)

On January 29, 2016, Bob Woodruff celebrated his 10th Alive Day—marking the day he should have died, but didn't. Ten years earlier, the reporter and recently appointed co-anchor for ABC's World News Tonight *was embedded with the Army's 4th Infantry Division in Taji, Iraq, covering the handover of the U.S. military's security mission to the native Iraqi forces. On January 29, 2006, Bob and his cameraman were filming from the top of an Iraqi armored vehicle when the convoy came under attack. The detonation of a roadside improvised explosive device (IED) sent shrapnel ripping through the air. More than 100 rocks were blasted into the left side of Bob's head and upper body. A rock the size of a half dollar entered the left side of his neck, traveling across to lodge in the right side, just adjacent to his carotid artery. Other rocks shot through the armhole of his flak jacket, producing a fist-sized hole in his back and shattering his scapula. Incredibly, the rocks stopped a millimeter short of his chest wall. The force of the IED blast shattered Bob's skull over the left temporal lobe—the region of the brain responsible for speech and language—sending bone shards into the outer surface of his brain and slightly displacing his left eye from the socket.*

Bob might have died within minutes if not for the quick actions of his colleague and producer, who was instructed by the Iraqi interpreter in the vehicle to put pressure on the gaping neck wound, which had been pumping out blood. Amid active gunfire, an Army helicopter landed to evacuate the *injured. Bob was flown to a military hospital in Baghdad, where he was assessed and stabilized before being flown to a field hospital in Balad, Iraq, capable of dealing with his severe injuries. An Army neurosurgeon operated on Bob's head injury as insurgents shelled the hospital with mortars. The military surgical team removed a piece of his skull 16 cm across to relieve the rapid swelling in his brain and prevent further injury from rising pressure within the skull. He would live without that piece of his skull for almost 4 months.*

The next day, Bob was flown to Landstuhl Regional Medical Center in Germany, where he underwent further surgeries to remove rocks and other debris, remaining there for approximately 60 hours before being transferred to Bethesda Naval Hospital in Washington, DC. For both flights, Bob was transported on a U.S. Air Force plane specially outfitted to transport patients with all of their medical equipment and a dedicated medical team. The unique capability of the Critical Care Air Transport Teams has substantially shortened the time required to move combat casualties out of the Middle East theater of operations to trauma centers in both Germany and the United States. During the Vietnam War, the full evacuation sequence could have taken more than 45 days.

Bob was unconscious for 36 days. During that time, there was no way to know the extent of the impact of his injuries on his physical abilities—speech and hearing—or cognitive function. Would he be prone to sudden angry outbursts or inappropriate behavior, depression, or posttraumatic stress disorder? All are telltale signs of traumatic brain injury—a haunting legacy of the wars in the Middle East.

On March 6, 2006, Bob woke up. Despite his uncertain prognosis, the degree and speed of his recovery were remarkable. In those early days, listening, speaking, and even thinking were challenging, and it seemed to Bob as though his brain had been shifted into a lower gear, a sensation likened to trying to swim through Jello. He had difficulty retrieving certain words, a condition known as aphasia. For Bob and his family, the recovery process would feel painstaking and unending, but with their support, the fog lifted little by little each day. In October 2006, just 9 months after his injury, he returned to work at ABC News.

Bob received the same standard of quality trauma care afforded to every military service member. He was treated by world-class surgeons, nurses, and other military medical professionals whose knowledge of best treatment practices for traumatic brain injury had been greatly advanced through years of experience during the war—experience and knowledge that today, 10 years later, has yet to be fully and systematically passed on to their civilian counterparts. As doctors would later confide to his wife, *Lee, had this kind of traumatic brain injury occurred in the United States instead of that Iraqi desert, Bob likely would not have survived.*[1]

BACKGROUND AND RATIONALE FOR THIS STUDY

More than any other events in history, the exigencies of war have advanced the care of the injured. American surgeons returning from the battlefields of every national conflict since the Civil War have brought home to civilian care the advances of military medicine (Pruitt, 2008; Trunkey, 2000). One fundamental lesson learned over the years is that surviving a major injury depends on optimal prehospital care and the minimizing of time to definitive care, made possible today by highly organized trauma systems that support the timely identification and triage of patients to a level of care commensurate with the extent and severity of their injuries. Although an organized structure for evacuation of battlefield casualties to a system of hospitals with waiting surgeons was first developed by the U.S. military during the Civil War (Manring et al., 2009), advances made during the conflicts in Korea and Vietnam have had the most notable role in shaping this modern systems approach to trauma care (see Box 1-1).

Unfortunately, however, the military has faced throughout history the recurring problem that wartime advances in trauma care are neither sustained during the interwar period nor fully translated to the civilian sector. Haphazard collection of medical histories and inadequate archiving of lessons learned have contributed to the loss of knowledge as military physicians, nurses, and other care providers have returned to their civilian lives (Churchill, 1952, 1972). The price of the resultant decline in readiness to deliver battlefield care is paid in the lives of the men and women first to deploy at the start of the next conflict, as the military health system is forced to relearn those lessons lost (DeBakey, 1996; Gross, 2015) (see Box 1-2). Because the military has historically relied on the voluntary and obligatory recruitment of medical professionals from the civilian sector during wartime, further integration of the military and civilian trauma communities is critically important to ensure that military readiness is maintained between conflicts and that trauma care improves in both settings (Eastman, 2010; Schwab, 2015).

The 1966 National Academy of Sciences report *Accidental Death and Disability: The Neglected Disease of Modern Society* (NRC, 1966) first brought to light the little-known fact that injury is a leading cause of death

[1] This account of Bob Woodruff's injury in Iraq and the trauma care he subsequently received through the military's trauma care system was drawn from that published in the Woodruffs' book, *In an Instant: A Family's Journey of Love and Healing*. The use of his story in this report was approved by Mr. Woodruff.

Box 1-1 ADVANCES IN TRAUMA SYSTEM ORGANIZATION DURING THE KOREAN AND VIETNAM ERAS

During and between the conflicts in Korea and Vietnam, the U.S. military refined the components of an enhanced system for clearing the battlefield and responding to combat casualties, aiming to minimize the time to definitive care. In World War II, the time lag between injury and surgery was 6 to 12 hours (Trunkey, 1983). During the Korean War, this delay was dramatically reduced through the decision to bypass battalion aid stations and transport injured soldiers directly to a mobile army surgical hospital (MASH). These units were capable of providing resuscitative surgical care within 10 miles of the battlefield and were supported by helicopter ambulances, allowing treatment of injured patients within 2 to 4 hours (Manring et al., 2009; Trunkey, 1983). Such tactics, particularly the use of helicopters, were further refined during the Vietnam War and translated to the civilian sector as deployed medical providers returned home.

Box 1-2 TOURNIQUETS: MILITARY LESSONS LOST

Prior to combat operations in Afghanistan and Iraq, tourniquet use had been the subject of debate for decades. This debate persisted despite data from World War II, the Korean War, and the Vietnam War showing that hemorrhage from extremity wounds was the leading cause of medically preventable deaths on the battlefield—such deaths from extremity wounds could be averted by simple first-aid measures, including the application of tourniquets (Bellamy, 1984; Lindsey, 1957). Fear regarding possible limb loss, ineffective designs, and misuse all contributed to the controversy surrounding the use of tourniquets (Richey, 2007).

Tourniquet use was reinvigorated within the U.S. Special Operations Forces community following the 1993 conflict in Mogadishu, Somalia (Butler et al., 2000), and subsequently incorporated into guidelines for tactical combat casualty care. Research on new tourniquet designs was initiated to overcome known deficiencies in the World War II-era tourniquets that were still in use at the start of the wars in Iraq (Operation Iraqi Freedom) and Afghanistan (Operation Enduring Freedom) (Kragh et al., 2013). In February 2003, before the invasion of Iraq, the Committee on Tactical Combat Casualty Care called for every American deployed to war to carry and know how to use a modern tourniquet to treat battlefield casualties, with an increasing emphasis on stopping bleeding faster (Walters et al., 2005). For conventional U.S. military forces, however, tourniquets were considered an intervention of last resort until well into Operation Enduring Freedom and Operation Iraqi Freedom, and many units were neither equipped with them nor trained in their use until after a series of congressional inquiries in 2005 instigated a military-wide effort to field tourniquets (Kragh et al., 2013). From 2005 to 2011, an estimated 1,000 to 2,000 lives were saved by widespread tourniquet distribution to deploying U.S. military service members (Andersen et al., 2012; Butler and Blackbourne, 2012).

and disability among Americans (Rhee et al., 2014) and issued a call to action to translate the lessons learned from war to the civilian sector. The report identified advancing care of the injured as a moral imperative, reflecting on how poorly the average citizen might fare if struck by a motor vehicle in a large U.S. city compared with a soldier wounded in a rice paddy in Southeast Asia. The report called for efforts to blanket the United States with overlapping, regional trauma systems to ensure that wherever an injury might occur, a coordinated system of care would be in place to provide the best care possible.

In the 50 years since that report was published, both the military and civilian sectors have made significant progress toward achieving this goal. In both settings, this progress has been due in large measure to the commitment of key champions, the development of uniform (albeit disconnected) data collection systems, and the use of these data for continuous quality improvement. In the civilian sector, an early federal government investment in the development of infrastructure at the state and regional levels,[2] combined with political will in some pioneering states to enact trauma system legislation, also played an important role (Bailey et al., 2012a,b; Eastman et al., 2013). Now statewide and regional trauma systems and trauma centers are ubiquitous across the country, albeit of varying capabilities and coverage. Encouraging is the fact that more than 80 percent of Americans now have access to a Level I or Level II trauma center within 1 hour by land or by air (Branas et al., 2005).

Building on this progress in the civilian sector, the military invested in the development of the U.S. Department of Defense's (DoD's) formal trauma system, the Joint Trauma System (JTS), and its associated trauma registry (discussed in more detail in Chapter 4) to meet combat casualty care needs during the wars in Iraq (Operation Iraqi Freedom) and Afghanistan (Operation Enduring Freedom). Since its inception, the JTS has served as the military's coordinating entity for trauma care. The DoD Trauma Registry (DoDTR) is the largest repository of combat injury and trauma care data. The collection of DoDTR data and its integration with the military's requirements-driven research program represents a novel approach to trauma care in the military, as does the prompt and practical translation of evidence stemming from those registry data and research into JTS performance improvement processes, such as the development of clinical practice guidelines and the use of telemedicine conferencing (Blackbourne et al., 2012). Through its efforts to enhance outcomes using evidence-based performance improvement processes, the military has worked toward establishing what the Institute of Medicine refers to as a "continuously learning

[2] The committee uses the term "regional" here to indicate trauma systems organized at the substate level and those that cross neighboring state boundaries.

health system" (IOM, 2013), in which its trauma care experience is captured, integrated with its research program, and systematically translated into more reliable care (described in more detail in Chapter 3).

Between 2005 and 2013, the case fatality rate (CFR)[3] for U.S. service members injured in Afghanistan decreased by nearly 50 percent, despite an increase in the severity of injury among U.S. troops during that same period (Bailey et al., 2013; Rasmussen et al., 2013). This improvement in combat survival has been attributed in part to the development of the JTS and the military's dedicated investment in trauma research and care (Bailey et al., 2013; Elster et al., 2013a; Rasmussen et al., 2013).

Despite these efforts, however, nearly 1,000 soldiers, sailors, airmen, and marines died of potentially survivable injuries[4] during Operation Iraqi Freedom and Operation Enduring Freedom (Eastridge et al., 2012). A review of U.S. service member deaths occurring in theater[5] using data from the Armed Forces Medical Examiner System showed that approximately 25 percent of prehospital deaths (2001-2011) and 50 percent of in-hospital deaths (2001-2009) were potentially medically preventable. The vast majority of these fatalities (80.0 and 90.9 percent for in-hospital and prehospital deaths, respectively) were associated with hemorrhage (Eastridge et al., 2011, 2012). Acknowledging this information is painful to military leadership and, especially, to the families of those who died. However, those leaders and families surely would agree that to honor and learn from the sacrifice of these service members, it is necessary to talk openly about this issue and work as hard as possible to improve the military trauma care system so that there are zero preventable deaths after injury (defined in Box 1-3) in the next war.

The extent to which preventable deaths permeate civilian trauma systems is equally alarming. A recent meta-analysis of hospital trauma deaths found that approximately 20 percent were survivable (Kwon et al., 2014).[6] Thus, despite progress in both the civilian and military sectors, significant gaps in trauma care remain. Across both sectors, the quality of trauma care

[3] Case fatality rate (CFR) is the percentage of fatalities among all wounded individuals (Holcomb et al., 2006).

[4] Survivability determinations were based on medical information only and did not take into account resource restrictions or operational conditions that may have prevented timely access to medical care (Eastridge et al., 2012).

[5] The term "theater" refers to the theater of war, which is the area of air, land, and water that is, or may become, directly involved in the conduct of the war (DoD, 2016).

[6] The meta-analysis by Kwon and colleagues (2014) yielded the most robust estimate of preventable death after injury identified by the committee. It should be noted, however, that the studies included in that analysis were largely from outside the United States and focused on in-hospital deaths. At this time, data on prehospital trauma deaths in the civilian sector are lacking. Therefore, the overall incidence of preventable death after injury is likely higher than that found by Kwon and colleagues (2014).

Box 1-3 DEFINING PREVENTABLE DEATHS AFTER INJURY

For the purposes of this report, the committee defines preventable deaths after injury as:

Those casualties whose lives could have been saved by appropriate and timely medical care, irrespective of tactical, logistical, or environmental issues.

Preventable deaths after injury should be determined by thorough review of medical examiner reports and all available prehospital and hospital medical records. A multidisciplinary panel of experts, using a consensus rule format, should review the compiled data for each fatality and determine if the primary anatomic cause of death was potentially preventable through the delivery of appropriate and timely medical care. Variables of interest during such reviews include mechanism of injury, injury descriptions (including severity), and medical interventions performed. Using the existing trauma system, this information should be communicated to the appropriate leadership, so that corrective actions can be taken. Furthermore, these data should help focus injury research, especially where appropriate interventions are lacking.

SOURCES: Davis et al., 2014; Eastridge et al., 2012; Holcomb et al., 2007; Kelly et al., 2008.

and outcomes for injured patients vary greatly; briefly put—where one is injured may determine whether one survives. From these findings, it is clear that swift and decisive action is warranted to address the state of trauma care and the significant burden of injury in military and civilian systems.

With the drawdown of U.S. troops from Afghanistan and Iraq, the nation once again has an opportunity to benefit from the lessons learned about trauma care from the past 15 years of war and ensure that they are not forgotten. Failure to do so will have deadly consequences. Unfortunately, however, as the wars end and service members continue to leave the military, the experience, knowledge, and advances in trauma care gained over the past decade are being lost. This loss has implications for the quality of trauma care both in the military and in the civilian sector, where the adoption of military advances can improve the delivery of everyday trauma care and the response to multiple-casualty incidents. Recent events in Sandy Hook, Boston, Paris, and San Bernardino highlight the unfortunate reality that active shooter and mass casualty incidents have become increasingly common in everyday American life and lend urgency to the translation of wartime lessons in trauma care to the civilian sector. During an interwar period, however, degradation of the military's integrated education and training, research, and trauma care programs can impede cross-sector pollination.

The Societal Burden of Traumatic Injury

The societal burden of traumatic injury is staggering, resulting from wounds sustained not just on the battlefield but also in everyday civilian life. Trauma, comprising both unintentional and intentional injuries,[7] is the third leading cause of death overall in the United States (NCIPC, 2015c). Unlike other leading causes of death, moreover, which typically affect individuals later in life, trauma disproportionately affects the young, killing those who might otherwise have lived long and productive lives[8] (NRC, 1966). As noted earlier, injury remains the leading cause of death among children and adults under the age of 46, accounting for nearly half of all deaths in this age group (Rhee et al., 2014) (see Figure 1-1). Together, unintentional and intentional injuries account for more years of potential life lost before age 75 than any other cause, including cancer or heart disease (NCIPC, 2015d) (see Figure 1-2). In 2014, there were 147,790 civilian deaths from trauma[9] (NCIPC, 2015b), more than 10,000 of which were among children[10] (NCIPC, 2015a). Assuming that as many as 20 percent of civilian trauma deaths are the result of survivable injuries (Kwon et al., 2014), had they received optimal trauma care, the lives of nearly 30,000 Americans might have been saved in 2014 alone.

Globally, the trends are even more disconcerting. In 2010, trauma accounted for 5.1 million deaths, almost 1 in 10 deaths, worldwide. Trauma deaths disproportionately affect low- and middle-income countries. Whereas trauma caused 6 percent of deaths in high-income countries in 2010, it accounted for 11 percent of deaths in low-income countries in Southeast Asia and 12 percent of deaths in low-income countries in the Americas (Norton and Kobusingye, 2013). In developing nations, children are especially vulnerable to death from injury (Brown, 2015). Across the world, more than 2,000 children die daily from unintentional injury alone (Peden et al., 2008). As in the United States, the burden of injury is expected to rise globally over the coming decades (Rhee et al., 2014). The World Health Organization predicts that the three leading causes of death from injury worldwide—road traffic crashes, homicide, and suicide—will rise in rank compared to other leading causes of death. By 2030, road traffic crashes are predicted to rise from the ninth to the fifth leading cause of death (WHO, 2010).

Of course, the full burden of trauma is not confined to premature death; trauma also has enormous consequences in terms of disability and

[7] Intentional injuries include suicide and homicide.

[8] It should be noted, however, that the age of trauma patients is rising, a trend associated with falls among older adults.

[9] This figure excludes deaths due to poisoning (51,966).

[10] "Children" is defined here as anyone 18 years old or younger.

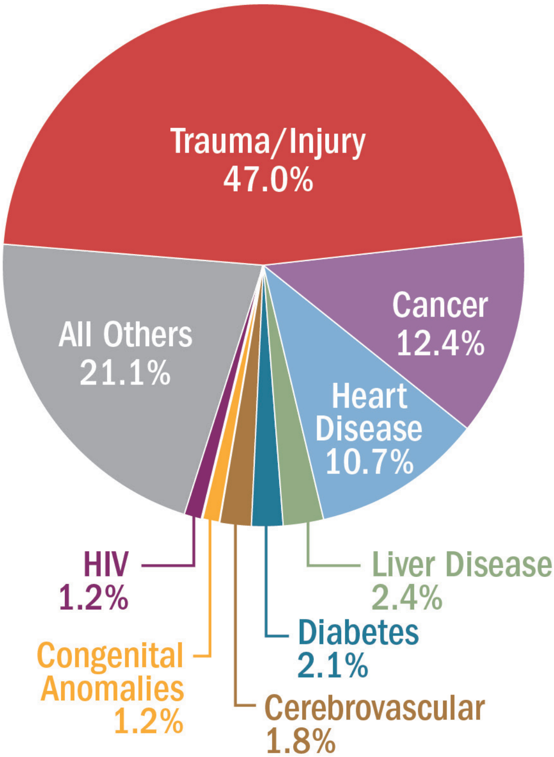


FIGURE 1-1 Leading causes of death, United States: 2014, ages 1-46 years.
SOURCE: Data retrieved from NCIPC, 2015b.

future quality of life. In the military, injured patients are sustaining and surviving greater injuries than ever before, creating increased needs for acute, chronic, and rehabilitative care. Musculoskeletal injuries cause the majority of long-term disability associated with battlefield injuries, accounting for an estimated 69 percent of conditions resulting in unfit for duty determinations during the conflicts in Afghanistan and Iraq (as determined by the U.S. Army Physical Evaluation Board during reviews of service members injured between 2001 and 2005) (Cross et al., 2011). Amputations contribute significantly to this burden. For example, while the rate of single amputation has remained constant, the percentage of amputees who have sustained multiple amputations during the wars in Afghanistan and Iraq (30 percent) is much higher than in previous conflicts (Krueger et al., 2012). Moreover, traumatic brain injury (TBI) has been diagnosed in over 23,000 combat casualties from 2000 to 2013 (DVBIC, 2015). Although the major-

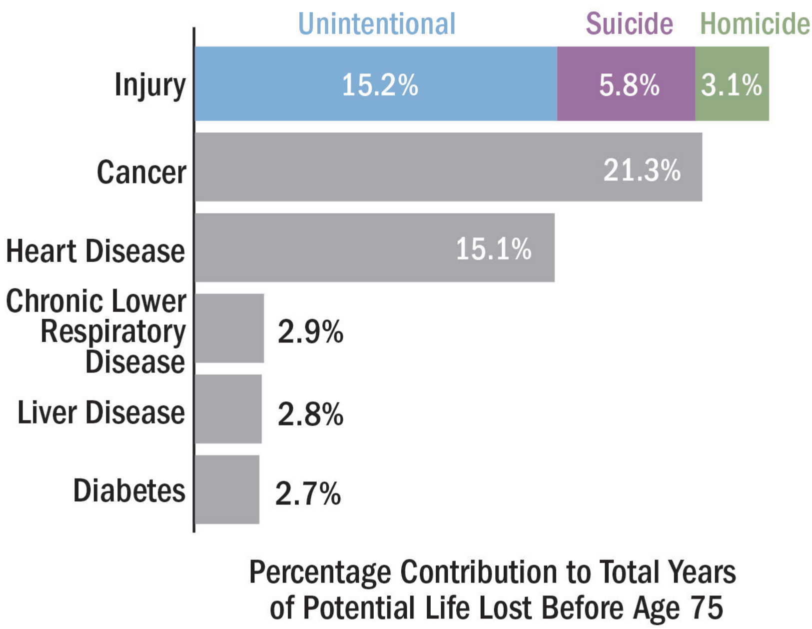


FIGURE 1-2 Leading causes of years of potential life lost before age 75, United States, 2014.

SOURCE: Data retrieved from NCIPC, 2015d.

ity of these injuries are typically classified as "mild TBI," they have been associated with symptoms of posttraumatic stress disorder (PTSD), depression, and other psychological conditions, and have significant implications for the quality of life of those injured and for their loved ones. Hoge and colleagues (2008) determined that PTSD was strongly associated with mild TBI: 43.9 percent of service members who reported loss of consciousness and 27.3 percent of those with altered mental status screened positive for PTSD 3-4 months following a year-long deployment to Iraq, compared with 16.2 percent of injured soldiers without mild TBI (Hoge et al., 2008). Improvised explosive devices (IEDs) designed to maim in Afghanistan and Iraq also have increased the occurrence of genitourinary trauma; it has been estimated that more than 12 percent of war injuries involve this type of trauma (Woodward and Eggertson, 2010).

The burden of injury-related disability in the civilian sector is equally striking. Although outcomes vary, decrements in physical and psychosocial functioning are common following injury and can have significant lifelong consequences for the injured person and his or her family. The National Study on the Costs and Outcomes of Trauma (NSCOT), for example, found that of more than 2,700 injured adults evaluated 1 year postinjury, 20.7 percent screened positive for PTSD, and 6.6 percent showed signs of depression. Nearly one-half (44.9 percent) of those working before incurring their injury had not yet returned to work at 1 year (Zatzick et al., 2008). As is true in the military, extremity trauma and TBI make the greatest contribution to the overall burden associated with nonfatal injuries.

Looking at financial costs, in 2013 injuries and violence cost $671 billion in medical care and lost productivity (Florence et al., 2015). Trauma affects the entire health care system, contributing significantly to the rising cost of health care in America. Each year, it accounts for 41 million emergency department visits and 2.3 million hospital admissions (NTI, 2014). In 2012, trauma-related conditions were the most costly for adults ages 18-64, accounting for $56.7 billion in health care expenditures; across all ages, trauma-related conditions consistently rank among the top four most costly conditions (Soni, 2015). Thus, despite the characterization of trauma as the "neglected epidemic of modern society" in a 1966 National Research Council report (NRC, 1966, p. 5) and numerous calls to action since that time, the economic and societal burden of trauma throughout the world represents an ongoing and increasing public health crisis.

Trauma morbidity and mortality statistics convey clearly that the vast majority of the burden of trauma is borne by the civilian population. Since 2001, there have been approximately 2 million U.S. civilian deaths from trauma[11] (NCIPC, 2015b). In the same period, approximately 6,850 U.S. service members have died in theater (DCAS, 2016). Given this burden, as well as the military's success in reducing trauma deaths and advancing rehabilitative care, the civilian sector has much to gain from the translation of military best practices in trauma care. Critical among these lessons learned is that, in many cases, even severe traumatic injuries are survivable with optimal delivery of trauma care in the context of a proper support system. The expectation of survivability after traumatic injury seen in the military, however, has not permeated the American public at large.

The Importance of Readiness to Deliver High-Quality Trauma Care

The impressive results in advancing trauma care achieved by the military since the start of the wars in Afghanistan and Iraq include unprecedented survival rates for casualties arriving at a military treatment facility, reaching as high as 98 percent (Kotwal et al., 2013). As shown in Figure 1-3, the CFR in combat operations of the 21st century has been reduced by more than half compared with that during the Vietnam War (Lenhart et al., 2012). The percent killed in action (KIA) has been reduced to one-third

[11] This figure excludes deaths due to poisoning, which are classified by the Centers for Disease Control and Prevention as injury-related deaths, over the same time period (536,018).

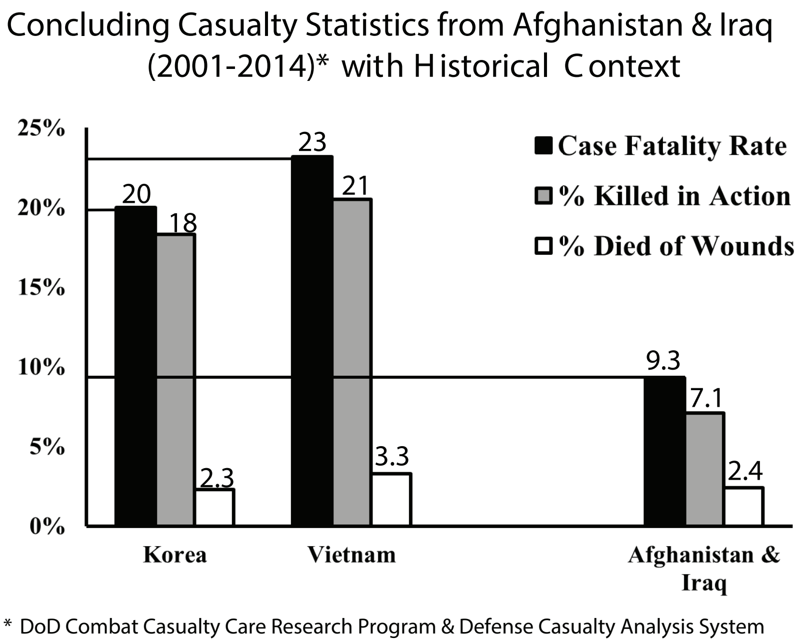


FIGURE 1-3 Case fatality rates during the Korean War, the Vietnam War, Operation Enduring Freedom, and Operation Iraqi Freedom.

NOTES: The statistics presented in this figure were calculated using data collected from the Defense Casualty Analysis System (DCAS), not from the DoD Trauma Registry. In calculating percent killed in action and percent died of wounds, the number of wounded individuals returned to duty (RTD) was not subtracted from the total number of wounded service members because RTD data are not collected in DCAS.

SOURCE: Proceedings of 2014 Military Health System Research Symposium, 2015.

of Vietnam levels, while the percent who died of their wounds (DOW) after reaching a military treatment facility has remained level, indicating that gains have been achieved primarily in the prehospital environment (see Box 1-4 for definitions of combat casualty care statistics). Factors influencing this improved survivability relative to previous conflicts likely include advances in personal protective equipment (e.g., body armor), differences in enemy tactics, the development of a mature deployed trauma system, and improved training based on the concepts of tactical combat casualty care. Congruent with these observations are data from Eastridge and colleagues (2012) showing that deaths due to peripheral extremity hemorrhage decreased from 23.3 deaths per year prior to 2006 to 3.5 deaths per year by 2011, which the authors associate with the military-wide fielding of tourniquets over the course of the wars in Afghanistan and Iraq.

Box 1-4 COMBAT CASUALTY CARE STATISTICS

Wounded in action (WIA): The number of combat-injured casualties who survived their injuries or died after reaching a military treatment facility (battalion aid station, forward surgical facility, combat support hospital, and higher levels of hospital care). Note that WIA does not include those casualties designated as killed in action (KIA) (see below), so the total number of combat-wounded service members is calculated as WIA + KIA.

Killed in action (KIA): The number of combat deaths that occur before the wounded reach a military treatment facility, expressed as a percent of those wounded in action minus those returned to duty within 72 hours (RTD), who are assumed to have sustained minor injuries.

$$\%KIA = \{[KIA/(KIA + [WIA - RTD)]\} * 100$$

%KIA reflects (1) the lethality of the weapons that caused the injuries, (2) the effectiveness of point-of-injury and medic care, and (3) the availability of evacuation from the tactical setting. KIA also is influenced by the use of protective equipment, such as body armor.

Died of wounds (DOW): The number of all deaths that occur after the wounded reach a military treatment facility, expressed as a percentage of total wounded minus those returned to duty within 72 hours (RTD).

$$\%DOW = [DOW/(WIA - RTD)] * 100$$

%DOW reflects the effectiveness of care provided at military treatment facilities and perhaps also the appropriateness of field triage and initial care, the use of optimal evacuation routes, and the application of a coordinated trauma systems approach in a mature theater of war. To some extent %DOW is influenced by the severity of the injuries of admitted patients (rapid evacuation mechanisms may result in higher numbers of unsalvageable patients arriving at military treatment facilities, which will reduce KIA rates and inflate DOW rates.

Case fatality rate (CFR): The percentage of fatalities among all wounded.

$$CFR = [(KIA + DOW)/(KIA + WIA)] * 100$$

CFR is a measure of the overall lethality of the battlefield among those who receive combat wounds. Because the denominator is limited to the wounded, CFR is not a total mortality rate that would denote all deaths relative to the entire deployed population at risk.

SOURCE: Holcomb et al., 2006.

Despite these accomplishments, however, gaps in capabilities and opportunities to improve care remain, particularly in the prehospital setting. Between 2001 and 2011, 87.3 percent of military battlefield fatalities occurred before those wounded reached a combat hospital. As noted above, although the vast majority of these deaths were caused by nonsurvivable injuries, hundreds of these service members might have survived[12] if optimal trauma care had been delivered (Eastridge et al., 2012) (see Figure 1-4). Although the number of casualties who died of their wounds after reaching the hospital was much smaller, more than 50 percent of those deaths occurred from injuries that were potentially survivable (Eastridge et al., 2011).

The CFR data shown in Figure 1-5 for Afghanistan (A) and Iraq (B) demonstrate variability in the military's ability to care for an injured soldier over time and across the two theaters of war. CFR data from Operation Enduring Freedom, which closely follow the trends of the KIA data while the percent DOW remains relatively level, suggest the earlier-noted improvements in prehospital care and evacuation capabilities in the period between 2005 and 2015. This finding is consistent with a recent report by Kotwal and colleagues (2016) noting a statistically significant reduction in percent KIA and CFR following a 2009 mandate from the Secretary of Defense that prehospital helicopter transport of critically injured combat casualties occur within 60 minutes of injury or less. Median transport times (from call to arrival at the treatment facility) decreased from 90 to 43 minutes following that mandate. The reasons for the relatively flat DOW, KIA, and CFR rates over time in Iraq are not clear, but differences in timing between the two engagements are a likely partial explanation. The vast majority of combat-related injuries occurred in Iraq between 2003 and 2008 (see Figure 1-6), a period when DoD's trauma system was still maturing. Making comparisons across the two theaters also is difficult as the terrain, enemy tactics, and distribution of medical assets differed considerably. Notably, the number of casualties increased significantly in Afghanistan starting in 2009, but the CFR and percent KIA continued to decrease.

An important emphasis of this report is that sustaining and building upon the advances in military trauma care achieved over the past decade are essential to ensuring medical readiness so that the military has the capability to provide optimal care for the very first injured soldier in the next conflict, whenever and wherever it may occur. It is not clear, however, that the military's broader health system can support the continued level of excellence in trauma care delivered at the peak of the wars in Afghanistan and Iraq without substantial commitment from leadership and change in

[12] Survivability determinations were based on medical information only and did not take into account resource restrictions or operational conditions that may have prevented timely access to medical care (Eastridge et al., 2012).

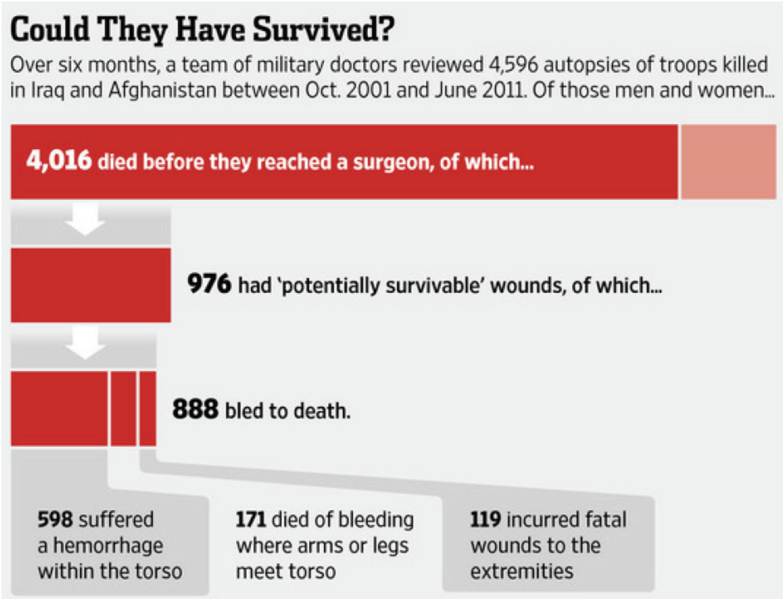


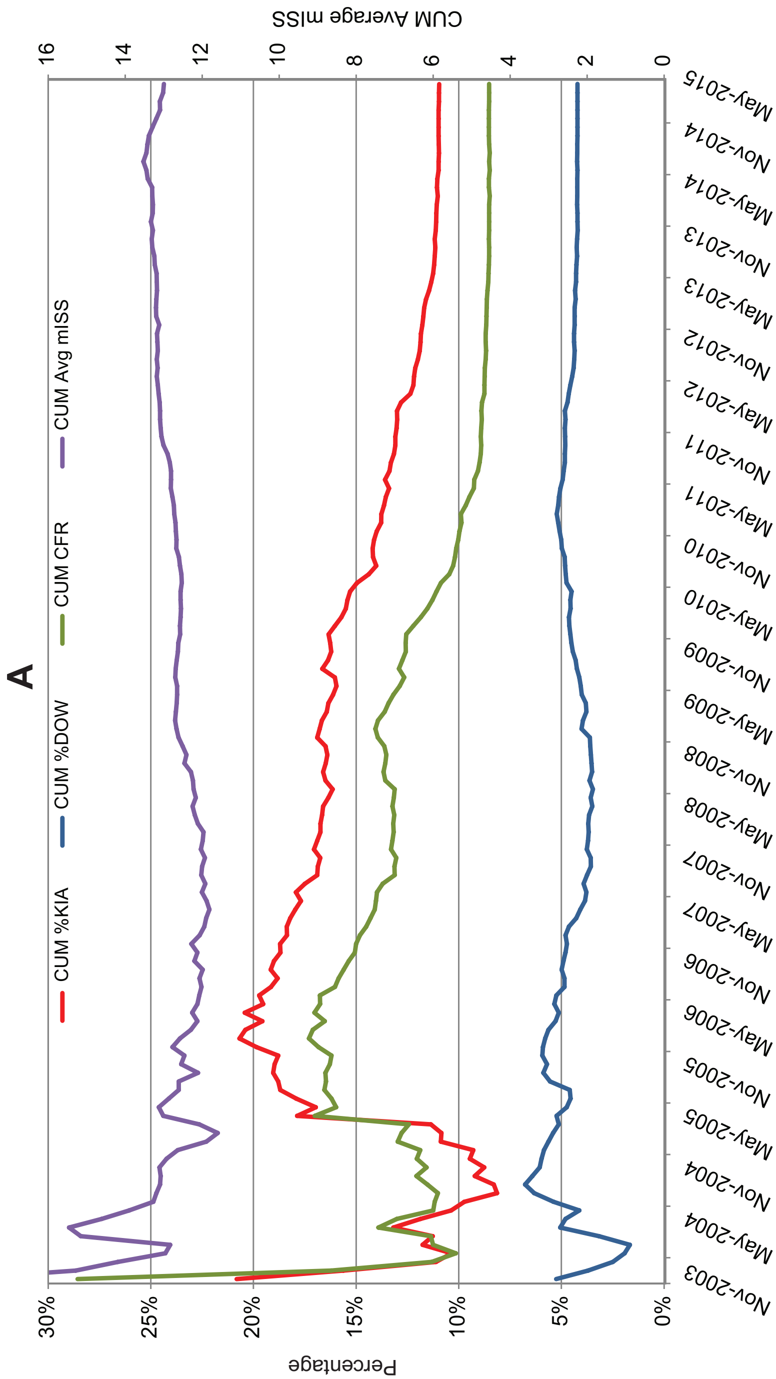
FIGURE 1-4 Military preventable deaths in the prehospital setting.

SOURCE: Reprinted with permission of Dow Jones Company, from Are U.S. soldiers dying from survivable wounds? Phillips, M. M., *Wall Street Journal*, 2014; permission conveyed through Copyright Clearance Center, Inc.

the processes by which a ready medical force is delivered. As the committee heard from General Peter Chiarelli, former Vice Chief of Staff for the U.S. Army, during its July 2015 meeting:

> We are going to repeat the same mistakes we have made before. We are going to think our doctors are trained. They are not going to be trained. You have just got to pray your son or daughter or granddaughter is not the first casualty of the next war. Pray they come in at about the year five mark. (Chiarelli, 2015)

Beyond their benefits to the military sector, the rapid advances in trauma care capability achieved in wartime can yield crucial benefits in civilian settings. The effective translation of advances in care—for example, in hemorrhage control, damage control resuscitation, and the development of cutting-edge prosthetic and orthotic devices—from the military to the civilian sector can benefit not only trauma care provided on a daily basis but also that provided during and after mass casualty incidents. The increasing incidence of civilian trauma resembling that seen on the battlefield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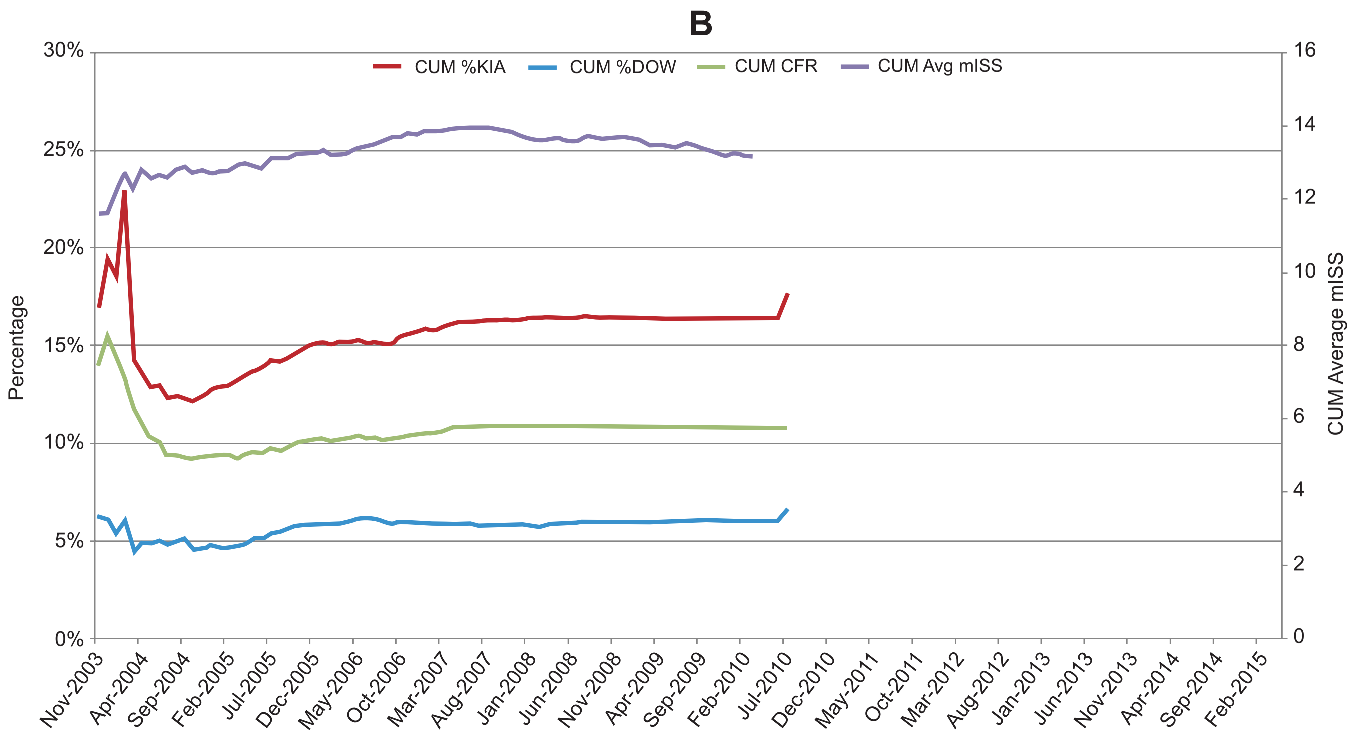

FIGURE 1-5 Cumulative percent killed in action (KIA), percent died of wounds (DOW), case fatality rate (CFR), and average military injury severity score (mISS), Operation Enduring Freedom (A) and Operation Iraqi Freedom (B).

SOURCE: Joint Trauma System. Data retrieved from the DoD Trauma Registry.

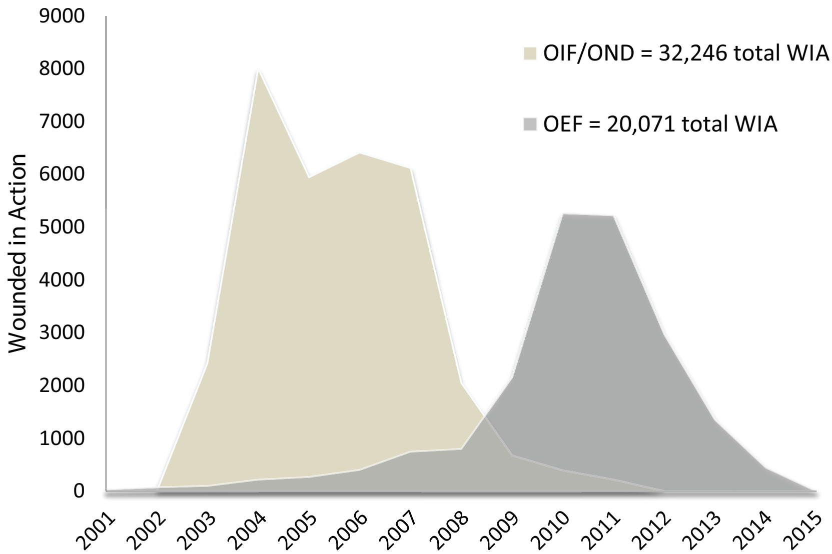

FIGURE 1-6 Wounded in action between 2001 and 2015, Operation Enduring Freedom and Operation Iraqi Freedom/Operation New Dawn.

NOTES: Data were retrieved from the Defense Casualty Analysis System (DCAS). OEF = Operation Enduring Freedom; OIF = Operation Iraqi Freedom; OND = Operation New Dawn; WIA = wounded in action.

attests to the importance of this translation and demonstrates the extent to which lessons learned by the military can be applied in responding to mass casualty incidents in civilian settings (Elster et al., 2013b). The Federal Bureau of Investigation (FBI) reports that between 2000 and 2013, there were 1,043 casualties from mass shootings in the United States (Blair and Schweit, 2014). According to a December 2, 2015, *New York Times* article, there were more days with than without a mass shooting[13] in the United States in 2015 (LaFraniere et al., 2015). The value of military trauma care practices applied to domestic mass casualty incidents is highlighted by the success of the medical response following the Boston Marathon bombing (see Box 1-5).

At the same time, however, it should be emphasized that the most substantial benefit of military lessons learned in trauma care to the civilian sector is the prevention of deaths that occur every day from injuries that, given state-of-the-art trauma care capabilities, should not be fatal. Although mass casualty incidents are horrifying and tragic, a verified Level I

[13] Mass shooting was defined as wounding or killing four or more people.

Box 1-5

THE BOSTON MARATHON BOMBING: APPLICATION OF MILITARY TRAUMA CARE PRACTICES TO A CIVILIAN MASS CASUALTY INCIDENT

On April 15, 2013, two improvised explosive devices (IEDs) detonated during the 117th Boston Marathon resulted in more than 260 casualties, many of whom had injury patterns similar to blast injuries seen in Afghanistan and Iraq. Immediate medical care for the injured was available from a nearby temporary medical tent staffed with paramedics, physicians, nurses, and other providers who had been prepared to provide care for the runners (Gates et al., 2014; Kotz, 2013). Three fatalities occurred on scene, but there were no additional deaths among the injured individuals who were seen at a hospital (Biddinger et al., 2013). Sixty-six of the injured patients sustained at least one extremity injury, many had serious vascular injuries, and there were 17 cases of lower extremity traumatic amputation. In all, 27 tourniquets were applied at the scene. While small sample sizes and other factors, such as short transport times (average transport time to an emergency department was less than 30 minutes) make it impossible to associate tourniquet use with mortality outcomes in this event, the trauma care provided during the Boston bombing demonstrates a paradigm shift regarding civilian-sector use of prehospital tourniquets based on the military's recent wartime experience (King et al., 2015). Had the bombing occurred a decade earlier, it is unlikely that tourniquets would have been applied to prevent deaths from extremity hemorrhage. Notably, however, all of the tourniquets applied on scene were improvised, despite military data showing inconsistency in the effectiveness of improvised tourniquets and recommendations that commercial, purpose-designed tourniquets be used (King et al., 2015; Kragh et al., 2013). Thus, this mass casualty incident also showed that some aspects of the military's posture on prehospital tourniquet use have been lost in translation (King et al., 2015).

trauma center in the United States will see on average two to three times that many trauma patients in a single year (ACS, 2015) (equating to approximately 27,000 to 40,000 trauma patients in the same 13-year period that saw the 1,043 casualties from mass shootings reported by the FBI). Yet despite the clear importance of a domestic trauma response capability, no systematic processes have been instituted to ensure that the lessons learned from military experience are translated comprehensively to the civilian sector (Hunt, 2015).

A Brief But Critical Window of Opportunity

The military medical force of the wars in Afghanistan and Iraq is the most experienced and successful medical force the military has produced in its long history (Mullen, 2015). Over the course of these two wars, military medicine was transformed. The sense of urgency stemming from deaths on the battlefield drove trauma care practices to evolve to a new level of excellence, and the resulting military medical force represents an enormous store of knowledge and experience. The unfortunate reality facing the military, however, is that the window of opportunity to tap into this pool of knowledge is brief. Already, many of the leaders who enabled this military medical transformation and who serve as advocates for its perpetuation are retiring or transitioning to the civilian sector. In 5-10 years, a substantial number will be gone (Mullen, 2015). Wars and domestic mass casualty incidents will surely occur in the future, but with this loss of institutional memory, the question is how the sense of urgency to continuously improve trauma care and save lives can be sustained. Several recent reports and articles (discussed further in Chapter 7) offer recommendations for achieving the systematic preservation and transferal of military lessons learned, at both the systems and clinical care levels, so they can be leveraged and built upon to advance trauma care capabilities (Butler et al., 2015; DHB, 2015; Kotwal et al., 2013; Maldon et al., 2015; Rotondo et al., 2011; Sauer et al., 2014). In developing this report, the committee built on the insightful analyses and recommendations of these previously convened expert groups.

A Vision for Optimal Trauma Care

Maximum survivability and optimal quality of life and health after trauma depend on efficient and effective health care delivery from the point of injury to rehabilitation and beyond, supported by an overarching system that encompasses performance improvement, continual learning, research, education, and training. For the United States, this vision for trauma care can best be achieved when the military and civilian trauma systems coordinate, continually learning from each other and striving to improve. Capitalizing on lessons learned at the patient level, in capability development, and in system design and quality improvement within both sectors makes sense; would help appropriately address the burden of disease; would leverage economies of scale to save lives through trauma care; and would prepare the nation to provide optimal care for daily trauma events, as well as those occurring on the battlefield and during mass casualty incidents.

The 75th Ranger Regiment, an element of U.S. Army Special Operations Command, exemplifies how a commitment to the principles of a learning system can significantly reduce and even eliminate deaths from potentially survivable wounds. From 2001 to 2010, DoD-wide KIA and DOW statistics were 16.4 and 5.8 percent, respectively. In this same period, the 75th Ranger Regiment achieved markedly better outcomes—10.7 percent KIA and 1.7 percent DOW. Most impressively, while the greater U.S. military population faced a preventable death rate of up to 25 percent, the 75th Ranger Regiment documented only one potentially survivable fatality in the hospital setting and no preventable deaths in the prehospital setting (Kotwal et al., 2011).

These remarkable accomplishments are attributable largely to the regiment's casualty care system, a program characterized by command ownership, comprehensive tactical combat casualty care (TCCC) training, data collection, and continual process improvement (Kotwal et al., 2011, 2013; Mabry, 2015). The regiment's line commander at the time, then Colonel Stanley McChrystal,[14] took complete ownership of the unit's casualty care system, issuing a directive that all Rangers focus on medical training as one of the regiment's four major training priorities (placing combat casualty care on a par, for example, with marksmanship) (Kotwal et al., 2011; Mabry, 2015). Colonel McChrystal's leadership was a driving force in ensuring that tactical leaders assumed responsibility for the casualty response system and that all unit personnel were thoroughly trained in TCCC—a framework and set of continuously updated guidelines focused on treating life-threatening injuries in the prehospital setting while taking the tactical (nonmedical) situation into account (Kotwal et al., 2013; Mabry, 2015). This integration of TCCC into line command responsibilities was unique within DoD, which traditionally has left medical care to medical providers, with little input from tactical leaders (Kotwal et al., 2011). The regiment also independently established and utilized a unique Ranger Casualty Card and prehospital trauma registry to capture data historically challenging to collect, providing the continuous feedback necessary for performance improvement throughout the unit (Blackbourne et al., 2012; Kotwal et al., 2011). The critical decision of commanders to provide Rangers with the knowledge, training, and equipment to render immediate care, when linked to an effective joint theater trauma system featuring coordinated evacuation sequences and patient handoffs across the trauma care continuum, led to an unprecedented reduction in preventable deaths and the greatest survival record in the history of war.

A central message of this report is the importance of significantly greater integration of the U.S. military and civilian trauma systems to achieve the goal of zero preventable trauma deaths, regardless of where (e.g., urban or rural) and when (e.g., at the start or the end of a war) an injury occurs. In the pursuit of this goal, the 75th Ranger Regiment serves as an exemplar for all, demonstrating how an integrated trauma system with strong leadership and continuous feedback and improvement (i.e., a learning trauma care system) can dramatically improve trauma outcomes. Others have already taken up this cause. In response to the demonstrated success of the 75th Ranger Regiment, the Israel Defense Forces (IDF) Medical Corps set a goal of eliminating preventable deaths across all branches and services of the IDF and developed a plan for achieving this goal (Glassberg et al., 2014). Execution of this plan—called "My Brother's Keeper"—began with

[14] McChrystal later achieved the rank of General.

engaging line commanders in a commitment to this goal, incorporating the concept into all command training and education programs, and reinforcing collaborations with Israeli civilian health system and international partners. Progress toward the goal will be monitored through continuous analysis of casualty data in the IDF Trauma Registry, use of which will help in refining equipment, doctrine, and training over time.

By extrapolating from the outcomes of best-in-class trauma care systems, it is possible to estimate the societal benefit that could be achieved through the uniform provision of high-quality trauma care. Had care at the level achieved by the 75th Ranger Regiment been provided throughout the military during the wars in Afghanistan and Iraq instead of being confined to one regiment, hundreds of service members who perished in the line of duty over the course of a decade might have survived. In the civilian sector, one estimate is that nearly 20,000 Americans could be saved each year if all trauma centers achieved outcomes similar to those at the highest-performing centers (Hashmi et al., 2016), a figure that equates to 200,000 trauma deaths prevented in that same 10-year period.[15] Concerted efforts aimed at establishing the type of learning trauma care system developed by the 75th Ranger Regiment and other best-in-class trauma systems will be essential to improving trauma care in both the military and civilian contexts. A framework for such a learning trauma care system is described in Chapter 3.

In light of trauma's profound burden and the increasing threats to homeland security, improving the nation's military and domestic trauma response capability is a national imperative. Deliberate steps to codify and harvest the lessons learned within the military's trauma care system are needed to ensure a ready military medical force for future combat and to eliminate preventable trauma deaths and disability after injury in both the military and civilian sectors. The end of the wars in Afghanistan and Iraq represents a unique moment in history in that there now exists a nascent military trauma system built on a learning system framework and an organized civilian trauma system that is well positioned to assimilate and distribute the recent wartime trauma lessons learned and to serve as a repository and an incubator for innovation in trauma care during the interwar period. Together, these two developments present an opportunity to integrate military and civilian trauma systems, thereby ensuring continuous bidirectional learning. To this end, unprecedented partnership across mili-

[15] This estimate takes into account only improvements in in-hospital care. There is no equivalent estimate for the number of lives that could potentially be saved from simultaneous improvements in prehospital care. In one metropolitan jurisdiction, analysis of medical examiner reports indicated that nearly 30 percent of prehospital trauma deaths resulted from potentially survivable injuries, and of these, 64.4 percent were at least in part attributable to hemorrhage (Davis et al., 2014).

tary and civilian sectors and a sustained commitment from trauma system leaders at all levels will be required to ensure that this knowledge and these tools are not lost. Lives hang in the balance.

CHARGE TO THE COMMITTEE AND STUDY SCOPE

Study Origin and Charge to the Committee

Concerned that the lessons learned from military wartime experience have not been translated to the civilian sector in a comprehensive or systematic fashion, Richard Hunt, then director for medical preparedness policy for the White House National Security Council, engaged in discussions with the National Academies of Sciences, Engineering, and Medicine in 2014, indicating that a study on this topic would be "of interest and of benefit to the nation" (Hunt, 2015), as well as complementary to a concurrent White House effort on bystander interventions for life-threatening traumatic hemorrhage.[16] In 2015, the Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector was established with funding from three federal agencies (DoD's Medical Research and Materiel Command, the U.S. Department of Homeland Security's Office of Health Affairs, and the U.S. Department of Transportation's (DOT's) National Highway Traffic Safety Administration) and five professional organizations (the American College of Emergency Physicians, American College of Surgeons, National Association of Emergency Medical Services Physicians, National Association of Emergency Medical Technicians, and Trauma Center Association of America). This group of sponsors, representing both the military and civilian sectors, asked the National Academies of Sciences, Engineering, and Medicine to conduct a consensus study to define the components of a learning health system necessary to enable continued improvement in trauma care in both the civilian and military sectors, and to provide recommendations for ensuring that lessons learned over the past decade from the military's experiences in Afghanistan and Iraq will be sustained and built upon for future combat operations, as well as translated to the U.S. civilian system. The full charge to the committee is presented in Box 1-6.

To respond to this charge, the National Academies of Sciences, Engineering, and Medicine convened a committee comprising experts in each element of the spectrum of trauma care, as well as military medicine and combat casualty care, pediatrics, bioethics, competency-based medicine,

[16] On October 6, 2015, the White House launched the "Stop the Bleed" campaign to provide people with the knowledge and tools to save lives by stopping life-threatening hemorrhage during an emergency prior to the arrival of emergency medical personnel (White House, 2015).

Box 1-6

STATEMENT OF TASK FOR THE COMMITTEE ON MILITARY TRAUMA CARE'S LEARNING HEALTH SYSTEM AND ITS TRANSLATION TO THE CIVILIAN SECTOR

An ad hoc committee will define the components of a learning health system necessary to enable continued improvement in trauma care in both the civilian and the military sectors (improving survival and reducing morbidity). Trauma care, for the purposes of this report, is defined as encompassing: integrated and coordinating emergency medical services and trauma care systems; point of injury or tactical care; en-route care or care during transport; initial resuscitation including care at small facilities prior to trauma center; care at the trauma center including emergency medicine, trauma surgery and specialty surgical care, anesthesia, and critical care; and transition to but not inclusive of rehabilitation and recovery. In this endeavor, the committee will characterize the military's Joint Trauma System (JTS) and Defense Health Program research investment and their integrated role as a continuous learning and evidence-based process improvement model. The committee will examine opportunities to ensure that the advances in trauma care developed by the U.S. Department of Defense (DoD) over the past decade from experiences in Afghanistan (Operation Enduring Freedom) and Iraq (Operation Iraqi Freedom) are sustained and built upon for future combat operations. Finally, the committee will consider the strategies necessary to more effectively translate, sustain and build upon elements of knowledge and practice from the military's learning health system into the civilian health sector and lessons learned from the civilian sector into the military sector.

Specifically, the committee will address the following three tasks:

1. Drawing from existing models, identify and describe the key components of a learning health system necessary to optimize care of individuals in military and civilian settings who have sustained traumatic injuries.
2. Characterize the components of the military's JTS and the trauma research investment of the Defense Health Program that together have enabled real-time, evidence-based or evidence-guided process improvement in trauma care consistent with the principles of a learning health system. Consider how these components can or should be expanded and, where appropriate, standardized across DoD, and how they should align with other learning health systems, including those in the civilian sector such as regional or statewide trauma systems. In doing so:
   a. Characterize the relative uniqueness of the military's Defense Health Program and its investment in trauma and injury research compared to other private or federal investments in trauma research. Discuss the benefits, limitations and relative effectiveness of its capabilities- and gaps-driven research approach.
   b. Characterize how civilian education systems for medical, allied health, and other relevant professions, as well as the military-specific medical education at the nation's Uniformed Services University of the Health Sciences and across the Military Health System, prepare individuals to be leaders in this trauma-specific learning health system.
3. Define how such a learning health system can ensure lessons learned from the military's knowledge-generating research investment are sustained and built upon for future combat operations, and translated into the U.S. civilian health system. Consider the importance of relevant civilian and military trauma-related education and training systems, the need for military and civilian-sector trauma-focused research investment, systematic processes for changing system-wide protocols, and/or performance improvement processes for providers.
   a. Identify mechanisms to enable implementation of knowledge, interventions and/or trauma care processes from the military into practice by the civilian sector (civilian

trauma systems, trauma centers, and relevant emergency medical services including first responders), and vice versa.

b. Identify factors that promote or limit that translation, considering ethical considerations in defining evidence standards necessary for changes in clinical care or guidelines and the value of a "focused empiricism" approach.

To address the above tasks, the committee will draw on 3-4 case studies centered around common combat-related injuries that are also relevant to civilian sector trauma cases and highlight the opportunities and challenges to establishing and sustaining a trauma care learning health system. The case studies may be based upon the following traumatic injuries, or other relevant examples, and should feature real life medical cases. One case study should include pediatric trauma care.

- Complex dismounted secondary blast injury with extremity amputation, face injuries, a compromised airway and hemorrhagic shock
- Secondary blast injury with penetrating fragment wounds to the head and extremities with an extremity vascular injury and shock
- 35 percent total body surface area burn with early renal and pulmonary failure
- Explosive injury resulting in tension pneumothorax, blunt solid organ injury with intraperitoneal hemorrhage and shock
- High velocity gunshot wound to the thigh with soft tissue injury, open femur fracture, vascular injury and limb ischemia
- Closed complex pelvic and femur fractures with hemorrhagic shock

The case studies will highlight to the extent possible:

- Levels of evidence used to develop military and civilian (as applicable) clinical guidelines for the spectrum of trauma care in each case.
- Pertinent innovative changes (devices, medications, equipment, methods) that have been incorporated into the spectrum of trauma care for each case as a result of the DoD's evidence-based improvement process.
- Processes by which patient and injury information was collected, stored, reviewed and analyzed by the JTS, including how this information was used for the JTS's evidence-based improvement process and made available for clinical and epidemiologic research.
- How collection, storage, review and analysis of patient injury and management information differed for those killed in action versus those wounded in action (i.e., different system for those who die prior to arrival at a medical center thus eliminating ability to study ways to improve survival).
- Impact that evidence-supported changes in military trauma care and the JTS's evidence-supported process improvement may have had on survivability.
- How the results of the military's DHP research investment and elements of focused empiricism have been integrated into the JTS, its clinical practice guidelines and usual military practice.
- Evidence of how these changes may be effectively integrated into military training and doctrine (e.g., special units such as the Army Rangers) and how these lessons learned can be applied in the civilian sector.
- Time elapsed between the compilation/publication of evidence and development and implementation of clinical guidelines.

learning health care systems, information systems, comparative effectiveness research, health services research, delivery and financing of health care, clinical guideline development, and medical education and training. Biographies of the committee members are presented in Appendix F.

Study Scope

As specified in its statement of task, the committee was charged with evaluating trauma care in its acute phase only, starting at the point of injury and ending at the transition to rehabilitation. Although the committee recognizes and acknowledges that prevention and rehabilitation both play critically important roles in reducing the burden of traumatic injury and improving later quality of life, these components were intentionally excluded from the committee's scope of work. Still, the committee believes it is important to emphasize that the full continuum of trauma care extends from prevention to rehabilitation and reintegration into society. Indeed, the best strategy to eliminate deaths from trauma is to prevent injuries from occurring in the first place. Although primary prevention strategies are not discussed in any depth in the present report, the committee notes that previous reports have addressed this important topic (see Box 1-7) and many resources are available through the Centers for Disease Control and Prevention National Center for Injury Prevention and Control (http://www.cdc.gov/injury). Similarly, the committee did not conduct an evaluation of systems and best practices for rehabilitation in military and civilian settings but instead refers readers to a number of previous reports that have addressed this topic (see Box 1-7). That said, it is important to recognize that care delivered in the acute phase has significant implications for later rehabilitation; improved acute care and reduced mortality will certainly increase the need for robust rehabilitation support to ensure quality of life. Further, long-term outcome data captured during rehabilitation and post-acute care (e.g., quality of life, level of function, and other patient-centered outcomes) are of critical importance to acute-phase providers in a learning system to inform continuous quality improvement activities (as discussed in more detail in Chapter 4). With this in mind, elements related to rehabilitation are mentioned where appropriate throughout this report.

While not explicitly excluded from the scope of work for this study, an examination of methods to diagnose, prevent, and treat PTSD and other mental health disorders associated with physical trauma was considered by the committee as an expansion of scope that could not have been addressed in a comprehensive way given the committee's limited time and resources. However, recognizing the importance of early screening and intervention during the acute-care phase to prevent or mitigate downstream mental health sequelae of physical trauma, these issues are addressed in the con-

Box 1-7 PREVIOUS REPORTS ON PREVENTION, REHABILITATION, AND MENTAL HEALTH

Primary injury prevention, rehabilitation, and mental health have been a focus of multiple reports released by the Institute of Medicine, including the following reports that are available for free download from the National Academies Press (www.nap.edu):

Prevention
- Institute of Medicine and National Research Council. 1985. *Injury in America: A continuing public health problem*. Washington, DC: National Academy Press.
- Institute of Medicine. 1999. *Reducing the burden of injury: Advancing prevention and treatment*. Washington, DC: National Academy Press.

Rehabilitation
- Institute of Medicine. 2005. *Enabling America: Assessing the role of rehabilitation science and engineering*. Washington, DC: The National Academies Press.
- Institute of Medicine. 2007. *The future of disability in America*. Washington, DC: The National Academies Press.
- Institute of Medicine. 2011. *Cognitive rehabilitation therapy for traumatic brain injury: Evaluating the evidence*. Washington, DC: The National Academies Press.
- Institute of Medicine. 2011. *Nutrition and traumatic brain injury: Improving acute and subacute health outcomes in military personnel*. Washington, DC: The National Academies Press.
- Institute of Medicine. 2013. *Returning home from Iraq and Afghanistan: Readjustment needs of veterans, service members, and their families*. Washington, DC: The National Academies Press.

Mental Health
- Institute of Medicine. 2010. *Provision of mental health counseling services under TRICARE*. Washington, DC: The National Academies Press.
- Institute of Medicine. 2013. *Substance use disorders in the U.S. Armed Forces*. Washington, DC: The National Academies Press.
- Institute of Medicine. 2014. *Treatment for posttraumatic stress disorder in military and veteran populations: Final assessment*. Washington, DC: The National Academies Press.

text of holistic trauma patient care in Chapter 6. Relevant reports are also noted in Box 1-7.

The committee also acknowledges that trauma care is just one aspect of a far larger emergency care system, and although an analysis of that broader system is beyond the scope of this report,[17] the committee included in its deliberations the impacts of its recommendations on the overall emer-

[17] The emergency care system was the focus of the Future of Emergency Care series of Institute of Medicine reports released in 2007. The committee looked to these resources in developing its recommendations with respect to trauma care.

gency care system in hopes that steps taken to improve trauma care will have the added value of reducing preventable deaths and disability associated with other acute, time-sensitive conditions.

The primary charge to the committee was to focus on the military's trauma system and research investment, as well as the bidirectional translation of lessons learned and best trauma care practices between the military and civilian sectors. Although the committee was not tasked with evaluating the civilian sector independently, it did learn about civilian trauma systems in the course of its information gathering and comments on the civilian sector in this report as it relates to the sustainment of military advances in trauma care and opportunities for improved translation between the military and civilian sectors.

STUDY APPROACH

Study Process

During the course of its deliberations, the committee sought information through a variety of mechanisms. These mechanisms included a series of information-gathering meetings that were open to the public, including a public workshop held to obtain background information on leadership and accountability, trauma data and information systems, clinical guideline development, and military education and training for readiness. A second meeting, held in September 2015, included two additional information-gathering sessions, the first of which focused on ethics and regulatory issues that influence a learning system, and the second of which addressed the burden of injury and trauma research investment in the military and civilian sectors. During the course of the September 2015 meeting, the committee also participated in the military's JTS Video Teleconference, a weekly worldwide trauma conference held to discuss the previous week's military trauma cases. In addition, the committee held a series of Web-based meetings in which it heard from experts in civilian emergency medical services, trauma nursing, and military leadership. Agendas for these meetings can be found in Appendix E.

The committee gathered additional information by reviewing the peer-reviewed and gray literature. The committee also requested documents and information from DoD, DOT, HHS, and other trauma stakeholder organizations to better inform its deliberations, and received materials submitted by members of the public for its consideration throughout the course of the study.[18] Finally, the committee commissioned papers on (1) cur-

[18] A list of materials submitted to the committee's public access file can be requested from the National Academies of Sciences, Engineering, and Medicine's Public Access Records Office.

rent military–civilian exchange practices, and (2) the collection and use of trauma data. Key excerpts from these papers are included in Appendixes C and D, respectively, and the papers are available in their entirety on the study's website.[19]

Case Studies

In accordance with its statement of task, the committee's conclusions and recommendations were informed by case studies focused on combat-related injuries, many of which are commonly encountered in the civilian setting as well. These case studies include the following traumatic injuries: extremity hemorrhage, blunt trauma with vascular injury, pediatric burn, dismounted complex blast injury, and severe TBI. Because the committee lacked direct access to medical case histories for U.S. service members wounded on the battlefield, the case studies were initially authored by DoD personnel and submitted to the committee for review. The committee invited input from all of the study sponsors on the cases' format and content and requested additional information from DoD using a standardized template created for this purpose. The case studies were then further developed through an iterative process of revision and review (see Appendix A). Each case study offers insight into the military's learning process for trauma care, illustrating specifically, for example, the levels of evidence used to develop clinical guidelines and the processes by which patient and injury information was collected, stored, reviewed, and analyzed by the JTS. In doing so, these cases reveal gaps that remain in the military trauma system and facilitate consideration of how best to translate advances in trauma care to the civilian sector. A committee-generated collective analysis of the case studies is presented in Appendix B. Throughout this report, the committee uses boxes drawing from these case studies to demonstrate the opportunities and challenges of establishing a learning trauma care system.

ORGANIZATION OF THE REPORT

This report is organized into three parts that collectively define a learning trauma care system necessary to sustain and build on the recent advances in military trauma care and to facilitate continuous bidirectional translation of trauma care advances between the military and civilian sectors. Part I of the report includes Chapters 1 through 3. Chapter 2 provides an overview of the essential elements of a trauma system and their application in the military and civilian trauma systems. That chapter also outlines the existing mechanisms by which the military and civilian systems interface

[19] See nationalacademies.org/TraumaCare.

for bidirectional translation. Chapter 3 presents a framework for a learning trauma care system, drawing on the components of a learning health system as articulated by the Institute of Medicine (2013) report *Best Care at Lower Cost* and applying those components to a trauma care system. Using this framework, Part II assesses the strengths and gaps in the military and, at the national level, civilian trauma systems, focusing specifically on generating and applying knowledge to improve trauma outcomes (Chapter 4), creating and sustaining an expert trauma care workforce (Chapter 5), delivering patient-centered trauma care (Chapter 6), and leveraging leadership and fostering a culture of learning (Chapter 7). Each of these four chapters ends with a summary of key findings and the committee's conclusions in the respective topics. While focusing on the military sector, these chapters do provide a general overview of civilian-sector differences to highlight areas in which the structure and processes of the civilian sector impact military sustainment of trauma care advances and bidirectional translation of lessons learned and best practices between the two sectors. The final part of this report, Chapter 8, highlights the committee's key messages—particularly the need for an integrated national approach to trauma care—and concludes with recommendations on advancing a national learning trauma care system.

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2

Overview of Contemporary Civilian and Military Trauma Systems

As discussed in Chapter 1, lessons learned from United States involvement in armed conflicts have played an important role in advancing the care of injured patients in the civilian sector. One defining lesson that contributed to the development of today's regionalized civilian trauma systems is that surviving traumatic injury depends on reaching definitive care—a hospital capable of providing optimal care—as soon as possible. This principle is captured in the commonly used phrase "right patient to the right place at the right time" (ACS, 2014; Eastman et al., 2013). In 1966, the National Research Council laid the foundation for translating this principle to the civilian center, calling for the development of regionalized trauma systems to support the timely identification and triage of patients to a level of care commensurate with the extent and severity of their injuries (NRC, 1966). Over the past 50 years, significant progress has been made to this end, with a regionalized systems-based approach to trauma care being implemented in most states around the nation. More recently, the U.S. Department of Defense (DoD) adopted the principles of a trauma system for application in the military, developing the Joint Trauma System (JTS) over the course of the wars in Afghanistan and Iraq (ACS, 2014; Bailey et al., 2012a). Despite these laudable achievements, however, the full potential of a national trauma system featuring seamless sharing of data, best practices, and lessons learned within and across the military and state-based civilian systems has not yet been realized.

This chapter provides an overview of civilian and military trauma systems in the United States, focusing on structure, process, and variability in patient outcomes. As the structure, organization of services, and capabilities of trauma systems affect the delivery of care, the chapter begins with an overview of essential elements of a trauma care system and the inclusive approach that has emerged in the civilian sector as an optimal model for trauma system development. The chapter then describes the variability in the essential elements of a trauma care system that characterizes civilian systems across the nation, which has resulted in concomitant variability in patient outcomes. Subsequently, the chapter focuses on the development of the contemporary military trauma system and highlights the organizational structure and processes (e.g., the chain of command) that impact the delivery of trauma care on the battlefield. Lastly, this chapter describes how the military and civilian systems currently interface for bidirectional translation of trauma care advances and lessons learned.

ESSENTIAL ELEMENTS OF A HIGH-PERFORMING TRAUMA CARE SYSTEM

The overall purpose of a trauma system is to address the needs of all injured patients "wherever they are injured and wherever they receive care" (ACS, 2014, p. 1). In many ways, the organization and delivery of trauma care in the United States serve as a paradigm for health care in the 21st century adopted by the Institute of Medicine's (IOM's) Committee on the Quality of Health Care in America, which concluded that above all else, "a framework for a new health system should be based on systems that can organize themselves to achieve a shared purpose by adhering to a few well-thought-out general rules, adapting to local circumstances, and then examining their own performance" (IOM, 2001, p. 34). In keeping with the vision set forth by that committee, the aims of trauma systems are to provide care that is safe, effective, timely, patient-centered, efficient, equitable, and sustainable over time (ACS, 2014; IOM, 2001).

Every civilian regional trauma system is unique—a reflection of stakeholders' tailoring the system to meet local needs based on regional population, economic, and geographic characteristics. Furthermore, each system is a dynamic entity, evolving in response to lessons learned, critical review, and changes in the population. As a result, trauma care delivery in the civilian sector occurs in the context of a "system of systems."

Although every regional trauma system is unique, certain essential elements should be in place in any civilian or military trauma system to optimize efficiency and effectiveness. These elements, described in the sections below, are

- system leadership and statutory authority, with adequate funding to maintain an enduring system infrastructure;

- a trauma system plan developed and maintained by a multidisciplinary group of stakeholders and based on the needs of the population served by the system;
- creation, verification, and assurance of a sustainable trauma care workforce across the continuum of care;
- coordinated injury prevention efforts;
- prehospital care that includes effective communication systems and timely triage, transport of the injured to the appropriate level of hospital facility, and point of injury and en route care;
- regional categorization of hospital capabilities and designation/verification of trauma centers, with established criteria for interhospital transfers to ensure that patients receive the appropriate level of care;
- seamless transfer of patients to rehabilitation services, with attention paid to both their physical and psychosocial needs;
- system-wide trauma registries and information systems to support continuous quality improvement activities;
- research to develop the evidence needed to establish treatment guidelines for optimal care and outcomes (at both the individual patient and system levels); and
- integration with disaster preparedness programs.

While not exhaustive, these elements describe the fundamental features of a regionalized approach to the delivery of trauma care. In *Model Trauma System Planning and Evaluation* (HRSA, 2006), the Health Resources and Services Administration (HRSA) provides further detail on these elements and has served as a guide to modern trauma system development across the states. Critical to the effective integration of the various elements is a trauma system plan that is rooted in a public health approach to injury control, incorporating the core functions of assessment, policy development, and assurance (ACS, 2014; Bailey et al., 2012a; HRSA, 2006). The public health approach ensures that a regional trauma system is not merely a cluster of emergency services, but a comprehensive, organized structure for care of all injured patients within a defined geographic region. It emphasizes a three-pronged approach to improving health by

1. identifying the problem, based on data (assessment);
2. developing and implementing an intervention (policy development); and
3. evaluating the outcome of the intervention (assurance) (HRSA, 2006).

The public health approach allows for the systematic collection of trauma-related data; the use of these data to develop comprehensive policies; and verification that services and facilities are adhering to triage, transport, and clinical care guidelines (ACS, 2014). Using data, policy, and evaluation, a trauma system can provide optimal care along the continuum from initial injury to transfer to rehabilitation. Most important, the public health approach emphasizes a population-based approach that ensures that the needs of a defined population are met in a manner that is effective, efficient, and patient-centered. As discussed later in this chapter, this means that prehospital and hospital resources must be configured in such a way that the most severely injured patients have timely access to a limited number of specialty referral centers with sufficient patient volumes to maintain quality, while the majority of less severe injuries are adequately cared for in a larger number of lower-level facilities.

System Leadership and Statutory Authority

If a trauma system is to be successful, a lead agency must have the legal and doctrinal authority necessary to ensure a high level of care for the injured. Following from the public health approach to injury control, this lead agency must be able to (1) continually assess trauma system structure, function, and outcomes; (2) create policy and guidelines responsive to such analyses; and (3) through a verification process, ensure the system's optimal functioning. "Statutory authority and administrative rules support trauma system leaders and maintain trauma system infrastructure, planning, oversight, and future development," throughout the continuum of care (ACS, 2008, p. 5). Further, the lead agency ensures the integrity of the trauma system and supports integration, collaboration, and coordination with other engaged entities. This approach ensures that all system components meet or exceed predescribed standards of care and adhere to evidence-based clinical practice guidelines. Absent statutory authority or rules, there would be nothing to prevent a hospital—any hospital—from calling itself a trauma center, nor would there be any means of ensuring that an ambulance can bypass a closer hospital in favor of direct transport to a center with all the resources needed to provide a patient with immediate and effective trauma care (Eastman et al., 2013).

For the most part, authority and accountability for trauma capabilities in the civilian system are regionalized, and, as discussed later in this chapter, vary from location to location (Hoyt, 2015b). States establish the authority and oversight for trauma system development, promulgating statutes and regulations for trauma center and trauma system participation and integration. State leadership also defines funding streams for system development and processes for trauma center designation/verification (HRSA, 2006). Each state has a lead agency. While these agencies most commonly reside within health departments, some operate on a stand-alone basis. The lead agency is responsible for integrating the trauma system with a range of other health care and community-based groups, including emergency management, social service agencies, public health, law enforcement, and disaster preparedness, among others (Eastman et al., 2013). Testimony provided to the committee emphasized the extent to which leadership and advocates at the state and local levels (e.g., local responders, local government, hospital corporations, medical directors) are critical to the optimal functioning of a trauma system (Patrick, 2015). Many states have adopted the concept of a regional trauma council to oversee the development of their trauma system infrastructure.

Box 2-1 highlights one state where a strong lead agency and enabling state legislation have been critical to achieving coordination, regionalization, and accountability. Underscored in this case study is the important role played by the public in advocating for and supporting the system. Continuously engaging the public through membership on key committees can make a difference in the system's long-term sustainability.

In addition to state authorities, a range of federal stakeholders provide further trauma system leadership. However, no single federal entity is accountable for trauma capabilities and coordination across state boundaries in the United States, despite previous recommendations that a lead agency for emergency and trauma care be established (IOM, 2007a,b,c). Rather, multiple agencies share responsibility for ensuring that gaps in access to quality trauma care are addressed and best practices are developed and promulgated within the broader context of the civilian health care delivery system (see Box 2-2).

Professional societies, which exist for the full spectrum of the trauma care workforce, are another important source of trauma system leadership. These societies engage in a range of activities, including trauma system consultation and verification (e.g., the American College of Surgeons), education and training (e.g., National Association of Emergency Medical Technicians, Society of Trauma Nurses), and advocacy (e.g., American Trauma Society, Trauma Center Association of America).[1]

Trauma System Plan

The trauma system, as defined in statute, is best outlined in a trauma system plan that is developed in accordance with the needs of the popula-

[1] The societies named here are offered as examples and are not intended as a comprehensive list. Space does not permit listing the many specialists, disciplines, and societies of health professionals focused on ensuring quality trauma care.

Box 2-1

STRONG STATE LEGISLATION ENABLES A COORDINATED, REGIONALIZED APPROACH TO TRAUMA CARE IN MARYLAND

Emergency medical services (EMS) and trauma care in Maryland are coordinated through a unique statewide system that features a central communications center, statewide EMS protocols, and a state-operated air medical transport service. An independent, executive-level agency, the Maryland Institute for Emergency Medical Services Systems (MIEMSS), is responsible for the coordination of all EMS. MIEMSS has an executive director and is governed by an 11-member governor-appointed state EMS Board. The responsibilities of the executive director and the EMS Board are defined by law. The EMS Board is advised by a 31-member Statewide Emergency Medical Services Advisory Council, whose membership is defined by statute.

Maryland's EMS system has enjoyed stable funding as a result of a registration fee surcharge that is used to support the Maryland Emergency Medical System Operations Fund, which funds, among other things, MIEMSS, the Aviation Division of the Maryland State Police, the Maryland Fire and Rescue Institute, and the R. Adams Cowley Shock Trauma Center.

The authority of MIEMSS and the EMS Board to coordinate an effective EMS system has been strengthened by several pieces of state legislation. As laid out in statute, MIEMSS and the EMS Board are responsible for licensing and regulating commercial ambulance and aeromedical transport services, and also hold authority for licensing and certifying all levels of prehospital providers. Legislation enacted in 1998 established a 13-member Provider Review Panel to review problems related to the quality of patient care and to investigate allegations of provider misconduct. The panel recommended corrective actions to the EMS Board. Subsequently, an Office of Compliance was created within MIEMSS, and an Incident Review Committee was established.

The Maryland system was founded on the strength of a single personality, R. Adams Cowley. Yet 50 years later, the unity and strength of the system remain unchanged. The trauma centers are closely knit, and each center fully supports the system. The sense of system is strong. A tight bond also exists between prehospital personnel and those who work in the trauma centers. Individual center needs are not as important as the integrity of the system. The centers meet quarterly. TraumaNet, comprising representatives from each trauma center, is responsible for system-wide performance improvement and advocates in the legislature for a wide variety of trauma-related topics. The various centers cooperate on virtually all issues, and transfer of patients between the various levels of trauma care is smooth. The sense of system permeates both prehospital and in-hospital care.

SOURCES: MIEMSS, 2016; TraumaNet, 2013.

tion, an inventory of services and their geographic distribution, and any gaps identified in the planning process. The plan should be developed and maintained by a multidisciplinary group of stakeholders that includes, among others, trauma surgeons, emergency physicians, nurses, trauma program managers, prehospital personnel, rehabilitation providers, information system personnel, hospital administrators, and prevention experts.

Box 2-2 CIVILIAN TRAUMA SYSTEM STAKEHOLDERS AT THE FEDERAL LEVEL

In the civilian sector, a range of federal agencies engage in emergency and trauma care, including the U.S. Department of Health and Human Services (HHS), the U.S. Department of Transportation's (DOT's) National Highway Traffic Safety Administration (NHTSA), the U.S. Department of Homeland Security (DHS), and the U.S. Department of Veterans Affairs (VA).

HHS: Within HHS, multiple entities influence and direct the nation's trauma care capabilities. The Office of the Assistant Secretary for Preparedness and Response houses the Emergency Care Coordination Center, which was created in 2009 by presidential directive (Carr, 2015; HHS, 2014) to "support the [U.S. government's] coordination of in-hospital emergency medical care activities and to promote programs and resources that improve the delivery of our nation's daily emergency medical care and emergency behavioral health care" (HHS, 2009). Other HHS agencies with prominent roles supporting trauma-related research and care delivery include the Centers for Medicare & Medicaid Services, the Agency for Healthcare Research and Quality, the National Institutes of Health, the Centers for Disease Control and Prevention, and the Health Resources and Services Administration.

NHTSA: NHTSA was created in 1966 following passage of the Highway Safety Act and was given the authority to fund improvements to emergency medical services (EMS). In the ensuing decades, NHTSA's Office of EMS has provided leadership in advancing the overall EMS system (IOM, 2007b), as evidenced by the agency's significant number of publications and programs in this area (NHTSA, 1996, 2000, 2004, 2011). NHTSA also supports the National EMS Information System and has initiated EMS Compass (see Chapter 4) as part of its systems approach to improving patient outcomes and monitoring system performance (Dawson, 2015).

DHS: The effective delivery of trauma care is directly tied to DHS's core mission to prepare for, respond to, and recover from all threats, including natural disasters and other mass casualty events in the civilian setting (e.g., mass shootings, detonation of improvised explosive devices). The Medical First Responder Coordination Branch within DHS's Office of Health Affairs aims to enhance national medical first responder capabilities, including EMS. Activities include the identification of gaps in medical first responder preparedness planning, resources, and education/training, as well as the development of guidance such as the recently released *First Responder Guidance for Improving Survivability in Improvised Explosive Device and/or Active Shooter Incidents* (DHS, 2015).

VA: The role of the VA as it relates to the delivery of trauma care is tied most significantly to the rehabilitation of military veterans. The aim is seamless and timely transfer to post-acute rehabilitation services, which limits the degree of disability and allows patients to return to the highest possible level of function (Bailey et al., 2012a).

Also critical to the development and maintenance of a trauma system plan is involvement of the general public, as well as trauma patients and their families who can speak firsthand about perceived gaps in the delivery of care. The plan should clearly outline how the needs of special populations are addressed. Typically, these populations include patients with specific types of injuries (e.g., burns, spinal cord injury), pediatric patients, and populations with unique barriers to access (rural, individuals with disabilities). Finally, the plan should undergo ongoing and regular assessment and be updated to meet the changing environment of the system.

Creation, Verification, and Assurance of a Sustainable Trauma Care Workforce

Critical to the success and sustainability of any trauma system is a workforce that is adequately trained and credentialed, and whose expertise is maintained. Leadership and policy need to ensure that members of the interdisciplinary workforce (nurses, EMS providers, emergency and EMS physicians, surgeons, advanced practice providers, other medical specialists, administrators, and information specialists) are trained, educated, and resourced to provide optimal care. Moreover, results from ongoing research and advances in care need to feed into continuous improvement of training curricula and skill set competencies. Periodic evaluation and adjustment of the size and scope of practice of the workforce need to be part of the system-level performance improvement and verification process.

Coordinated Injury Prevention Efforts

Approximately half of all trauma deaths occur at the scene of the injury or during transport to a hospital (Demetriades et al., 2005). As the majority of these deaths can be avoided only by preventing the injury from occurring (i.e., through primary prevention), an effective trauma system has an injury prevention strategy as one of its key components, with local epidemiologic data being used to target prevention initiatives. The Haddon matrix,[2] represents a commonly used conceptual framework for injury prevention and control efforts that can help inform such initiatives by identifying primary prevention strategies that reduce the risk of an injury-producing event (e.g., speed limits and laws that limit driving under the influence), secondary

[2] The Haddon matrix was developed by William Haddon, the first director of the National Highway Traffic Safety Administration, and is configured as a grid where rows represent the injury phases (before, during, and after) and columns represent influencing factors (e.g., human factors, injury agents or vehicles, and environmental conditions). Interventions can be listed within each cell of the grid, thus generating a diverse mix of primary, secondary, and tertiary prevention strategies (Haddon, 1970, 1980).

interventions that minimize the severity of an injury once an event takes place (e.g., restraint use, vehicle design), and tertiary prevention strategies that mitigate the health impact when injuries do occur (e.g., prompt access to emergency medical services) (Haddon, 1970, 1980).

The lead agency and providers within the system need to engage the public, community-based groups, prevention experts, and business entities to enact well-defined and evidence-based prevention programs that are responsive to local needs. Trauma survivors and families who have lost a loved one as a result of trauma can play a particularly effective role in helping to identify and advocate for injury prevention programs and policies. Their involvement also can enable them to make a contribution that can be an important component of their recovery. Interaction with public service agencies, such as the state department of health, is essential to successful implementation of prevention programs, and collaborations with multiple agencies, hospitals, and professional associations can broaden the impact of prevention initiatives. It is well accepted that a multipronged approach to injury prevention is necessary, one that emphasizes the three Es:

- Education (about the risks of injury and safe behavior)
- Engineering, ergonomics, and product design (to modify the built environment)
- Enforcement (of safety legislation and regulations) (Baker, 1973)

Where relevant and/or necessary, however, legislative efforts may yield the greatest impact on injury prevention, as has been demonstrated for laws related to seat belts, driving under the influence, and bicycle helmets (Anderson et al., 2009; Mock et al., 2004; Thompson et al., 1999). It is important to emphasize that, to be effective, prevention initiatives must have equal priority with other aspects of the trauma system and thus require dedicated human and physical resources.

Prehospital and En Route Care

Trauma centers are at the core of any trauma system, but have limited value in the absence of a strategy for ensuring timely access to the appropriate level of care. Emergency medical services (EMS), including access to these services through enhanced communications and 911 call systems, provide the critical link between an injury event and definitive care. However, in the initial moments after injury, bystanders and first responders (e.g., law enforcement) can occupy a crucial role, initiating lifesaving care before EMS personnel arrive (discussed further in Box 7-8).

The focus of the EMS response is on stabilizing the injured patients and transporting them to the appropriate level of care for further intervention

(Eastman et al., 2013). Although the provision of EMS is inherently local (Patrick, 2015), local systems are configured differently across the United States. Nationwide, there are an estimated 21,283 credentialed EMS agencies (FICEMS, 2011), comprising a mixture of private, public, and volunteer systems that often operate independently and sometimes at odds with each other. There is no one-size-fits-all configuration for EMS. Therefore, a fully integrated system at the regional level will have mechanisms in place to hold local EMS providers accountable for compliance with standardized (preferably evidence-based) protocols and active participation in system-wide quality improvement activities (Kupas et al., 2015).

Prehospital care providers also play an important role in ensuring that communication systems are utilized to limit death and disability either at the single patient level or at the population level in the case of mass casualty incidents. Ongoing communication between prehospital care providers and receiving facilities is essential to ensure seamless handoff of patients to a prepared hospital-based trauma team. The EMS communication to the trauma center initiates a trauma team activation. This trauma team includes the emergency physician, nurses, trauma surgeons, a surgical specialist, radiology, interventional radiology, respiratory therapy, the laboratory, the blood bank, the operating suite, critical care, and specialty care areas. Psychologists, child life specialists, social workers, and chaplains also are needed to support families and provide psychological first aid. Ideally, real-time information on available resources within the system helps with triage and transport decisions. An effective communication system also connects the EMS system with other public safety providers, including police, fire, emergency management, and public health personnel. These linkages are particularly important in coordinating the medical response system with the incident command system in the case of disasters or mass casualty incidents.

Definitive Care Facilities

At the heart of the trauma system is a network of hospitals or trauma centers that are equipped and staffed to provide definitive care for injuries across the spectrum of severity. As discussed in greater depth in the following sections, these facilities submit data to registries, participate in performance improvement activities, and have agreements with other centers in place to address interfacility transfer, educational support, and outreach (ACS, 2014; Bailey et al., 2012a). High-quality, patient-centered care should be the standard in all trauma centers. While this is not yet the reality in most centers, efforts increasingly are being made to embrace a more collaborative care approach.

Across the United States, hospitals are recognized as trauma centers by two means: designation and verification. Trauma center designation occurs at the state or local level. In this process, which may vary from location to location, a state or local municipality identifies criteria to categorize trauma centers (ATS, 2016). Trauma center verification on the other hand is a voluntary, evaluative process offered by the American College of Surgeons (ACS) in which the ACS verifies the presence of specific resources outlined in *Resources for Optimal Care of the Injured Patient* (ACS, 2014). While some states designate five levels of hospital trauma centers, ACS only verifies Level I, II, and III trauma centers (ACS, 2014). The different levels of a trauma center indicate differences in resource availability, which translate to different roles and responsibilities (see Table 2-1). Level I and Level II centers provide the highest, most sophisticated level of care for the most severely injured. Level I centers, which are often university-based teaching hospitals, provide care for every aspect of injury and have responsibility for leading trauma education, research, and system planning. Level II centers offer many of the same clinical services as Level I centers, but may not provide the same level of comprehensive care or care for the most complex injuries. Level III, IV, and V centers serve patients in communities that lack immediate access to Level I or II centers, and provide emergency assessment, resuscitation, and stabilization before possible transfer to a higher-level trauma center (ACS, 2014; Eastman et al., 2013). The readiness of these lower-level centers to resuscitate and initiate treatment for major injuries and then expedite patient transfer to a higher level of care is a fundamental characteristic of a regional trauma system, one that plays a particularly critical role in rural areas of the United States where transport times to high-level facilities are long. Well-defined transfer guidelines are an essential element of the trauma system plan. The use of telemedicine within the context of an integrated system of care also can enhance the capabilities of Level III, IV, and V centers.

The number and distribution of trauma centers within a region should be based on need and known geographic barriers to access (ACS, 2015b). Guidelines for establishing the appropriate number, level, and location of trauma centers should be included in the trauma plan, and the lead agency should have the authority to designate trauma centers according to the plan. The guidelines should be based on a locally driven consensus process that engages all the appropriate stakeholders and above all else, focuses primarily on the needs of the injured (ACS, 2015b). Operationalizing a needs-based allocation of trauma centers has been difficult, however, as a result of long-standing traditions, local politics, and the changing landscape of health care delivery and payment policies. In the 1990s, many hospitals closed their trauma centers or reduced the level of care they were able to provide (e.g., from a Level II to a Level III facility) because of financial pressures (Shen et al., 2009). As some of these pressures have dissipated, trauma center designation has become more desirable, which has led to a possible

TABLE 2-1 Description of Trauma Center Levels

Trauma Center Level	Characteristics
Level I	• Tertiary care center that functions as a regional resource through the provision of comprehensive trauma care • All specialties represented • Can provide definitive trauma care to all patients • Provides leadership in prevention, education, and research • Has a minimum annual volume of severely injured patients
Level II	• Tertiary care center with most specialties represented • Can provide definitive trauma care to most patients • Functions as a regional resource center in the absence of a Level I center; plays a supportive role if a Level I center is in close proximity
Level III	• Responsible for initial evaluation and management of critically injured patients • Provides general and orthopedic surgical interventions as required • Provides definitive care to less severely injured patients • Has transfer agreements with Level I or II centers for severely injured patients
Level IV	• Can provide initial care to severely injured patients prior to transfer to a higher level of care • Basic emergency department facilities with physicians and nurses available upon patient arrival • Surgical specialties necessarily available • Has transfer agreements with higher-level centers
Level V	• Might be a nursing station or clinic (e.g., ski resort medical clinic) • Provides initial evaluation and stabilization with limited diagnostic capabilities • Prepares patients for transfer to a higher level of care • Has transfer agreements with higher-level centers

SOURCE: Adapted from Eastman et al., 2013.

oversupply of trauma centers in some areas of the country (Eastman et al., 2013). The committee's discussions with several experts suggested that developing strategies for ensuring the appropriate number and configuration of trauma centers based on population needs may be one of the most important challenges facing trauma systems in the next 5 years. Addressing this challenge will require developing evidence-based methods for determining the appropriate number and location of trauma centers within a region and ensuring that statutes are in place that give the lead agency the authority to designate trauma centers according to these methods. ACS is leading efforts to develop a needs-based assessment tool that can be used by those regions struggling with this issue.[3]

Transfer to Rehabilitation

Since most patients who sustain severe injuries will survive, it is critical to ensure that they have every opportunity to return home and integrate back into everyday life. The process of rehabilitation should start in the acute care facility and should address both physical and psychosocial needs of patients and their families (psychosocial considerations and the transition to rehabilitation are discussed further in Chapter 6). It is important to note that care provided in the acute phase is directly linked to the rehabilitation required later on. For example, the level and type of limb amputation can affect the fitting of a prosthesis (Krajbich et al., 2016; Robb, 2015), and effective pain management during acute care has been associated with reduced psychological sequaelae (Bryant et al., 2009; Holbrook et al., 2010). Equally important is early and ongoing screening for psychosocial distress and referral to the appropriate services to avoid the development of diagnosable conditions of posttraumatic stress and depression and their impact on long-term disability. When a patient screens positive for a mood disorder, referral to a mental health specialist is important. Timely transfer to post-acute rehabilitation services (both inpatient and outpatient) can further limit the degree of permanent impairment and allow the patient to return to the highest possible level of function. Despite the importance of rehabilitation, however, its integration with other phases of care is perhaps the weakest link in the trauma care continuum (Eastman et al., 2013). Thus, it is important for each trauma system to conduct a rehabilitation needs assessment to determine the number, type, and quality of such services required and available in the geographic region. Rehabilitation specialists should play a leadership role to ensure that rehabilitation issues are integrated into the overall trauma system plan.

Trauma Management Information Systems and Quality Improvement Activities

Data on the processes and outcomes of care within a system are critical to ensuring that the system evolves and improves over time. Trauma

[3] A preliminary draft of this tool was released in September 2015 and is available at https://www.facs.org/quality-programs/trauma/tscp/nbats#nbatstool (accessed May 17, 2016).

registries have been a standard part of civilian trauma system development, research, and quality improvement activities for decades. The trauma performance improvement process and the trauma registry are the hallmark functions of the trauma center, second only to patient care. These functions entail monitoring compliance with evidence-based practice, care delivered, and system performance to ensure that opportunities for improvement are quickly identified and addressed, optimizing patient outcomes. Performance measures vary based on geographic location, size, environmental conditions, population, and economic investments. Targeted performance measures evaluate system performance such as time from call to EMS on scene, scene response times by ground and air medical services, trauma transfers within the region, and trauma patients transferred more than twice.

Trauma registries exist at the hospital, regional, state, and national levels, with data flowing along this continuum from the local to the national level, although some regions rely on the state trauma registry to provide data for performance improvement and system advancement. Information such as injury patterns, geographic locations of injury, and frequency of injuries identified by a state trauma registry can help target resources for regional and statewide injury prevention programs and special populations, identifying, for example, the need for pediatric trauma centers or burn centers.

The National Trauma Data Bank (NTDB) is the largest aggregation of U.S. trauma registry data, containing more than 6 million patient records (ACS, 2015a). Submission to the NTDB is a required structural element of ACS's trauma center verification process,[4] but all trauma centers, including those that are state-designated, are eligible to submit data to the NTDB. The NTDB also is a critical part of the ACS Trauma Quality Improvement Program (TQIP), used increasingly by ACS-verified and state-designated trauma centers to compare their outcomes against national mortality benchmarks in support of quality improvement efforts (Nathens et al., 2012).[5,6] States can create state TQIP collaborative programs that benchmark outcomes and performance relative to other state TQIP collaboratives. Doing so allows the state to define high performance and highlights opportunities for improvement. NTDB data also have been used at the national level to examine variations in processes of care across levels of trauma care and the impact of these variations on outcomes (Shafi et al., 2009a). One important limitation of NTDB data is that they do not include information

[4] ACS verifies Level I, II, and III trauma centers.

[5] Starting in January 2017, all Level I, II, and III trauma centers seeking ACS verification or reverification must participate in TQIP.

[6] Personal communication, M. Neal, American College of Surgeons, to E. Cornett, the National Academies of Sciences, Engineering, and Medicine, regarding the National Trauma Data Bank and Trauma Quality Improvement Program, April 12, 2016.

from facilities other than trauma centers and therefore cannot be used for assessing important system-level outcomes such as access to trauma center care (Olson and Bowman, 2012).

More recently, prehospital data have been aggregated into the National EMS Database, which is a component of the National Highway Traffic Safety Administration's (NHTSA's) National EMS Information System (NEMSIS) (Dawson, 2006). Submission of data to NEMSIS is voluntary, however, and there is as yet no program equivalent to TQIP by which EMS agencies can benchmark their institutional performance, although, as discussed further in Chapter 7, some states, including North Carolina, have established their own EMS performance improvement systems (Mears et al., 2010). Linking state-level EMS data with the state trauma registry can assist in performance reviews, such as determining time from 911 calls to arrival at appropriate trauma centers, transfer times, and tracking of patients who are transferred more than once or are transferred out of the region or state because of limited resources.

Research

Research is the empirical feedback loop that validates and sustains continuous improvement in trauma care. Research findings help define best practices and thereby alter the course of system development. To be most effective, research data in all their forms must be made available to investigators and other stakeholders, allowing for the introspection necessary for the system to evolve to meet the needs of the population being served.

Research activity is a required capability of high-level trauma centers. As noted, most Level I trauma centers reside within academic medical centers, encouraging and facilitating the development of a structured research program (ACS, 2014). In addition, researchers need to increase efforts to understand the perspectives of patients and their families and consider those perspectives in defining gaps in the knowledge base, incorporating in their research outcome measures that are meaningful to patients and their families, and identifying ethically acceptable approaches to research in the acute phases of injury.

Integration with Disaster Preparedness Programs

The trauma system is an essential resource for state, regional, and local responses to mass casualty incidents and needs to be tightly integrated into disaster and crisis response plans. This need highlights the value of integrating the trauma system with public health and emergency management systems. Working relationships and cooperation between the trauma system and these agencies enable a more rapid and organized response in the event of a disaster. Hurricanes Katrina and Rita in 2005 and the fertilizer explosion in West, Texas, in 2013 are examples of such coordination with trauma systems at the regional and state levels, respectively (Epley et al., 2006; Walker, 2013).

It also is important for the trauma system and its centers to conduct periodic resource assessments to evaluate their surge capacity for responding to mass casualty incidents (Gomez et al., 2011; Klima et al., 2012). These resource assessments should be complemented by simulated incident or tabletop drills requiring a multiagency system-wide response. Such drills provide an opportunity to test the emergency preparedness and mass casualty response plans for the trauma system and to train the teams that will respond should such an event occur. These simulated scenarios are likely to identify gaps (e.g., in preparation, triage, and team interactions) that could threaten the integrity of a response (King et al., 2006; Rivara et al., 2006). For example, not all EMS agencies or emergency rooms are equipped with the supplies (e.g., tourniquets) necessary to respond to public health disasters or massive trauma (King et al., 2015). Performance improvement and after-action review of disaster responses help identify additional opportunities for stakeholder integration, education, and system improvement, as well as lessons learned to share with other trauma systems (Campion et al., 2016).

THE IMPORTANCE OF INCLUSIVE CIVILIAN TRAUMA SYSTEMS

Early trauma system development efforts of NHTSA were focused on state regulations, EMS education, communication systems, medical direction, and trauma center development (Mullins, 1999). The Trauma Systems Development Act of 1990 was designed to provide planning support for such system development. Preparation of the original *Model Trauma Care System Plan* of 1992, revised in 2006, was a product of this planning and was led by HRSA. However, limited funding to support the process impeded further development and implementation of this plan in most states.

Early efforts in trauma system development in the United States focused on establishing exclusive networks of highly specialized trauma centers, primarily in urban environments, for treatment of the most severely injured patients. Less attention was paid to integrating into the system other acute care facilities that could care adequately for the majority of less severe injuries. While this approach worked well for those injured in close proximity to a trauma center, it failed to address the broader public health challenge of how to provide optimal care to any injured patient, regardless of location (ACS, 2014). In the latter part of the 1990s, a more inclusive and population-based approach to trauma system development was embraced, in which all acute health care facilities with a round-the-clock emergency department play a role in the system by undergoing verification of their capabilities, providing care at a level allowed by their resources, and transferring patients to a higher level of care when necessary.

An inclusive and integrated approach to regional trauma systems is designed to provide care across the full spectrum of injury severity within a defined geographic region and ensure that every injured person is triaged to a level of care commensurate with his or her injury (IOM, 2007c). To this end, the committed efforts of all medical facilities in the region are required. The goal of such a system is to serve the population by matching the needs of the injured to the appropriate levels of care, ensuring that the most severely injured are treated in a limited number of specialty centers with sufficient patient volume to maintain quality while minimizing duplication of expensive resources across the system.

The American College of Surgeons Committee on Trauma has played a key role in catalyzing the development of inclusive trauma systems, developing a series of documents—*Resources for Optimal Care of the Injured Patient*—that set forth the characteristics and resources that represent the minimal expectations for verification of hospitals as trauma centers at varying levels of care (ACS, 2014). ACS also offers a trauma system consultation program that provides regions and states with a multidisciplinary analysis of their system, with the goal of system improvement that is tailored to local needs (ACS, 2014).

When fully operational, inclusive systems ensure a continuum of care, from public access to services through 911 call centers to effective communication systems, out-of-hospital EMS, timely triage and transport to definitive acute care facilities, and transfer to rehabilitation services as appropriate (see Figure 2-1). The trauma care continuum thus represents a chain of survival, with communication and coordinated efforts across all providers and levels of care being essential to maximize outcomes for injured patients. Breaks in the continuum "almost certainly contribute to excess morbidity and mortality" (Bailey et al., 2012a, p. 34).

Substantial evidence now supports the benefits of such an inclusive, regionalized approach to the delivery of trauma care. Studies have shown that treating the most severely injured in a designated Level I or Level II trauma center is associated with a significant survival benefit, is cost-effective, and leads to improved quality of life among survivors (Bailey et al., 2012b; MacKenzie et al., 2006, 2010; Mann et al., 1999; Nathens et al., 2000). MacKenzie and colleagues (2006) found that the risk of dying for a patient with moderate to severe injury was significantly lower for patients treated at a trauma center as compared to those treated at a non-trauma center facility. Likewise, Haas and colleagues (2010) found that severely injured patients who were first transferred to a facility other than a trauma center were nearly 25 percent more likely to die than those who were transferred to a trauma center immediately after injury. Similarly, Sampalis and col-

FIGURE 2-1 The trauma care chain of survival.

leagues (1997) found that immediate transport to a Level I trauma center reduced morbidity and mortality for severely injured patients. A greater degree of integration and involvement of all acute care facilities also benefits patients, being associated with a significantly lower injury-related mortality (Utter et al., 2006).

REGIONAL VARIABILITY IN TRAUMA SYSTEMS ACROSS THE UNITED STATES

The development of a national system of regional trauma systems is an ongoing effort, shepherded by leaders at the federal, state, regional, and local levels. Some states and local jurisdictions have achieved great success with the coordinated implementation of the critical trauma system components described in this chapter, observing concomitant improvements in mortality rates and serving as exemplars for others (one model statewide system is described in Box 2-3). Despite the demonstrated benefit of inclusive, regionalized trauma systems, however, variability in implementation of the essential elements of a trauma system remains across the nation (Eastman et al., 2013; Utter et al., 2006). This failure to conform to best practices in trauma system design and trauma care has resulted in variable patient outcomes such that following a traumatic injury, where one lives may determine whether one lives.

This variability in system design and performance is at odds with the American public's expectations for high-functioning trauma systems. According to a 2004 Harris Interactive poll, the vast majority of Americans recognize the value of trauma systems: 90 percent believe it is extremely or very important for their state to have a trauma system, and the majority view having a trauma center nearby as equally or more important than having a fire department (83 percent), police department (83 percent), or library (89 percent) (Champion et al., 2006). And despite evidence that outcomes for injured patients vary across the country (discussed in the sections below), two-thirds of Americans are extremely or very confident that they would receive the best medical care should they sustain a serious or life-threatening injury (Champion et al., 2006). It is evident, therefore, that the public's expectations are not being met and, more alarming, that the public is relatively unaware of the disparities in trauma system development and quality nationwide.

Variability in Trauma System Access

Nearly 2,000 trauma centers exist nationwide; 2013 estimates from the American Trauma Society suggest there are 213 Level I, 313 Level II, 470 Level III, and 916 Level IV or V centers (Eastman et al., 2013). However, these centers are not distributed evenly across the country (see Figure 2-2). Although several factors influence geographic variability in trauma mortality, the association between the lack of access to an appropriate level of trauma care and higher mortality rates among trauma patients is compelling (Eastman, 2010) (see Figure 2-3). Studies have shown that 69.2 percent and 84.1 percent of Americans have access to a

Box 2-3 **IMPLEMENTATION OF BEST TRAUMA SYSTEM PRACTICES IN PENNSYLVANIA**

In 1985, a comprehensive Emergency Medical Service Act (Act 45) was signed into law, recognizing the Pennsylvania Trauma Systems Foundation (PTSF) as the accrediting body for trauma centers in Pennsylvania. The PTSF is governed by a multidisciplinary board of stakeholders from state government, hospitals, and emergency medical services (EMS) within the Commonwealth. In 1991 and 1992, further legislation linked insurance reimbursement for care for automobile-related injuries and workmen's compensation to accredited Pennsylvania trauma centers.

The PTSF, as dictated by statute, oversees a voluntary system of hospitals that wish to participate as trauma centers within the Commonwealth. It has the responsibility and authority to create standards; establish policy; and collect, analyze, and disseminate data on the quality, timeliness, and documentation of care provided by the trauma centers. The PTSF has the authority to accredit hospitals as trauma centers and remove the accreditation if standards are not met or outcomes are poor (PTSF, 2016a). The PTSF does not have authority or responsibility for prehospital care; however, it does have strong representation of EMS and prehospital organizations on its board.

Through its Standards Committee, the PTSF sets standards for trauma centers that meet or exceed those outlined in the American College of Surgeons Committee on Trauma's *Resources for Optimal Care of the Injured Patient* (ACS, 2014). The PTSF recognizes and accredits Level I through IV trauma centers and Level I and II pediatric trauma centers (PTSF, 2016b). Its Registry Committee oversees a statewide trauma registry, which has been in existence since 1986. Data have been a powerful tool for elevating trauma care across the state. Each trauma center must submit to the PTSF a comprehensive data set on each trauma patient within 45 days of patient discharge. These data are used to monitor outcomes, direct performance improvement, and drive educational needs and programs.

The trauma registry is also an important tool during the site survey process, used to measure the timeliness and quality of care. It contains more than 750,000 records and has been instrumental in driving performance improvement efforts unprecedented in other states. Rigorous interrater reliability testing is conducted through personal visits

Level I or Level II trauma center, respectively, within 1 hour by land or by air, but the availability of trauma center care at any level is still severely limited in some areas of the country (Branas et al., 2005). Most dramatic is the disparity between rural and urban/suburban regions; only 24 percent of rural residents have access to a Level I or Level II trauma center within 1 hour, compared with 86 percent and 95 percent of suburban and urban residents, respectively. In other areas, however, the number of Level I and II trauma centers alone far exceeds the number needed to concentrate the patient volumes that have been shown to correlate with improved quality and outcome (Branas et al., 2005; Eastman et al., 2013). In such areas, each center has a lower patient volume, which may reduce to each trauma center, where a sample of medical records is abstracted. The PTSF also provides ongoing education and training for trauma centers and hospitals pursuing accreditation. In addition, it gives quarterly reports to each trauma center, benchmarking their data against the state average for complications and process measures.

The PTSF Outcomes Committee, comprising staff from Pennsylvania's trauma centers, has served to optimize performance improvement activities in trauma centers and throughout the entire trauma system since 1996 and has launched multiple initiatives. Pennsylvania is the only state in the country in which all trauma centers use the same performance improvement software as a tool for reviewing patient care, trending outcomes, and providing evidence of rigorous performance improvement during accreditation surveys. Three years ago, a central performance improvement database housed at the PTSF was launched, with trauma centers submitting analyses on every mortality case. That database is analyzed to identify high- and low-performing trauma centers and showcase practice patterns that lead to optimal outcomes in injured patients. In 2014, the PTSF started using contemporary risk-adjusted analyses of mortality data. A study of mortality in Pennsylvania over a 10-year period revealed that the state's mortality rate among patients presenting with moderate or severe injury decreased by 40-50 percent from 2000 to 2009 (Glance et al., 2012).

The PTSF has invested extensively in cutting-edge technology, stakeholder-driven systems development, and powerful peer review performance improvement processes. These three elements have guided the PTSF in optimizing care of injured patients throughout Pennsylvania in partnership with trauma centers and other organizations. The PTSF has been successful in ensuring that trauma care is a constant focus of those responsible for delivering health and emergency care in Pennsylvania. It has created an expectation that all seriously injured patients will be taken to and cared for within an accredited trauma center. Currently the state has 34 trauma centers that provide timely access to trauma care for well over 95 percent of Pennsylvania residents and those working or traveling in the Commonwealth (see http://www.traumamaps.org/Trauma.aspx [accessed May 19, 2016]).

the quality of care. Thus there is an argument to be made for limiting the number of Level I or II centers within a region (Eastman et al., 2013; Haas et al., 2009; Nathens and Maier, 2001).

Variability in Adoption of Best Trauma Care Practices

Even when patients have timely access to trauma centers, these centers must be properly utilized to make an impact. Guidelines and recommendations for best practices in field triage and in trauma care exist, but compliance with these guidelines varies widely. The American College of Surgeons and the U.S. Centers for Disease Control and Prevention (CDC) have devel-

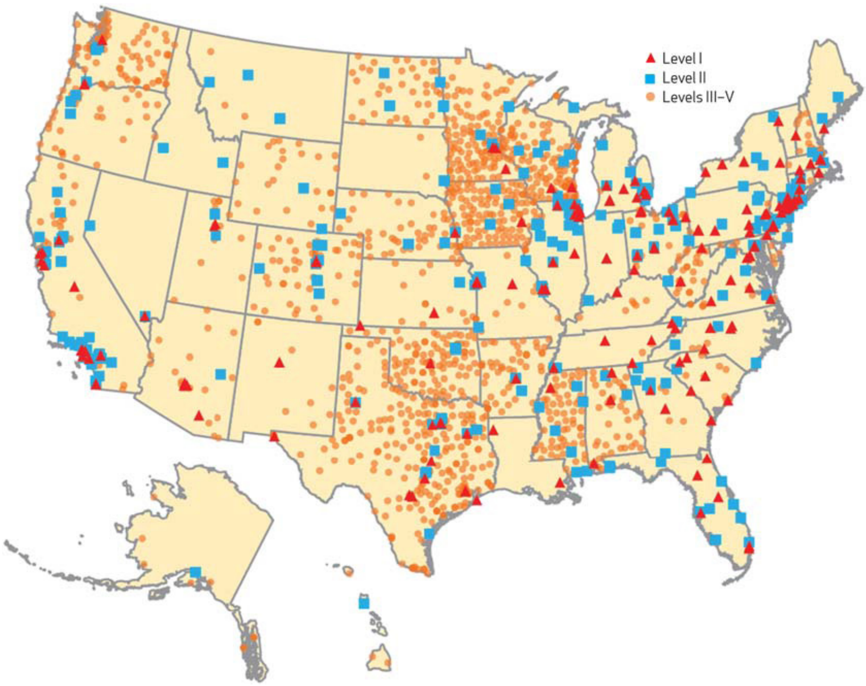

FIGURE 2-2 Trauma centers in the United States, 2012.

NOTE: Because of limited resolution when trauma centers are depicted on a national scale, the presence of multiple trauma centers within a single city may not be apparent in this figure.

SOURCE: Copyrighted and published by Project HOPE/*Health Affairs* as Eastman et al., Sustaining a coordinated, regional approach to trauma and emergency care is critical to patient health care needs. Health Aff (Millwood). 2013; 32(12):2091-2098. The published article is archived and available online at www.healthaffairs.org.

oped and promulgated evidence-based criteria for field trauma triage (ACS, 2014; CDC, 2012; Sasser et al., 2009). These criteria represent an attempt to balance both under- and overtriage, so that patients are taken to an appropriate trauma center, while higher-level trauma centers are not overwhelmed with minimally injured patients (Barnett et al., 2013; Newgard et al., 2013). The use of these criteria has been shown to be cost-effective (Faul et al., 2012), but inappropriate triage of patients remains a problem. In some regions, one-third of severely injured patients are not transferred to a Level I or II center (Nathens et al., 2004), with elderly patients at the greatest risk of being undertriaged (Gage et al., 2012; Nakamura et al., 2012). State EMS protocols vary in their incorporation of these triage criteria: as of 2011, 16 states indicated that they had fully or partially implemented the CDC's 2006 guidelines (CDC, 2012).

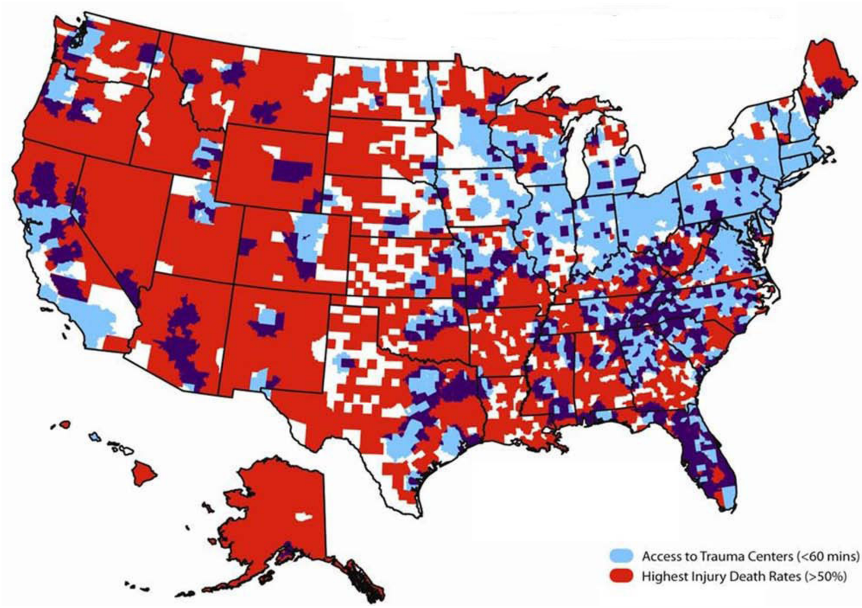

FIGURE 2-3 Lack of access to an appropriate level of trauma care is associated with higher trauma patient mortality.

SOURCE: Map provided by Charles Branas, Ph.D., Professor of Epidemiology, University of Pennsylvania, 2016.

Once a patient has been transferred to the appropriate trauma center, his or her care may vary depending on the center. As with triage, evidence-based best practice guidelines for trauma care exist and have been shown to improve outcomes, yet compliance with these guidelines is variable (Sobrino et al., 2013). A study of 55 trauma centers found that only 1 was compliant with all 32 practice protocols, while half were compliant with 14 of the 32. Patient outcomes likewise vary at different trauma centers, and Shafi and colleagues (2014) suggest that this inconsistency may be due to the level of compliance with commonly recommended clinical practices. The five trauma centers they studied varied dramatically in the level of compliance, from a low of 12 percent to a high of 94 percent.

Interhospital variation in risk-adjusted outcomes among trauma patients indicates that the quality of care provided across trauma centers varies as well (Shafi et al., 2009b, 2010) (see Figure 2-4). While trauma centers with the highest patient volumes have been shown to have better patient outcomes, including lower mortality, fewer days on ventilator, and less severe organ failure (Minei et al., 2014), better patient outcomes

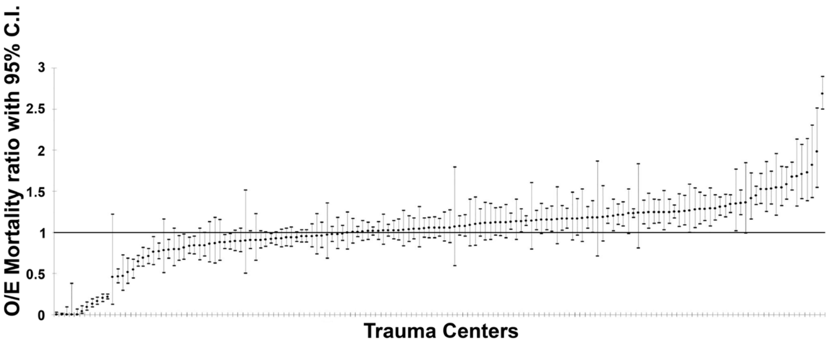

FIGURE 2-4 Variation in risk-adjusted mortality rates across trauma centers.

NOTES: Ratios compare observed mortality rate in a trauma center with the expected mortality rate based on the center's patient mix, i.e., a rate that is risk adjusted for such factors as age, injury severity, and comorbidities. The figure shows three distinct groups of trauma centers: high-performing (O/E mortality ratio < 1), moderate-performing (O/E mortality ratio = 1), and low-performing (O/E mortality ratio > 1). All trauma centers with confidence intervals that cross 1 perform at the same level (moderate).
C.I. = confidence interval; O/E = observed-to-expected.

SOURCE: Reprinted, with permission, from Shafi et al., 2010, Health care reform at trauma centers—mortality, complications, and length of stay. *The Journal of Trauma and Acute Care Surgery* 69(6):1367-1371.

also are associated with higher levels of compliance with recommended clinical practices. Shafi and colleagues (2014) found that at Level I trauma centers, every 10 percent increase in compliance with recommended practices resulted in a 14 percent reduction in in-hospital mortality. When an individual patient received all of the recommended care, he or she was 58 percent less likely to die than a patient who did not.

Variability in Emergency Medical Services Systems

Like access to and care provided at trauma centers in the United States, the organization and outcomes of the estimated 21,283 EMS systems nationwide vary significantly (FICEMS, 2011). EMS systems range from individual ambulance services that operate by "home rule"[7] to coordinated regional or county-based systems. The latter comprise multiple individual ambulance services working together to achieve cohesive systems of dispatch, preparedness for mass casualties, uniform medical protocols and quality oversight, and integration with the hospitals and health care

[7] "Home rule is a delegation of power from the state to its sub-units of governments (including counties, municipalities, towns or townships or villages). That power is limited to specific fields, and subject to constant judicial interpretation, but home rule creates local autonomy and limits the degree of state interference in local affairs" (National League of Cities, 2013).

systems within the region. Additionally, the ambulance services that make up EMS systems vary from fire agency based, to municipal "third service" agencies (separate from the municipal police and fire agencies), to private agencies (FICEMS, 2011). These various types of EMS systems are staffed by volunteer or paid EMS providers that are trained and equipped to offer varying levels of medical care.

The challenges inherent in such variability and the importance of unifying the many EMS stakeholders have long been recognized. In 1996, NHTSA assembled these stakeholders to craft a unifying vision for EMS. The resulting document, the *EMS Agenda for the Future,* has led to advances in training, education standards, and scope of practice, among others (NHTSA, 1996). Although levels of providers and scopes of practice continue to vary from state to state, NHTSA has published a national EMS scope of practice model that offers standard definitions for levels of training and interventions performed by different levels of EMS providers (NHTSA, 2007). This national scope of practice model encompasses (1) emergency medical responders (EMRs), who have minimum training to provide the most basic care as a first response to life-threatening medical emergencies; (2) emergency medical technicians (EMTs), the basic level of ambulance provider, who provide comprehensive basic life support care and expertise in extrication, patient lifting and handling, and transportation; (3) advanced EMTs (AEMTs), who are able to administer several medications and advanced life support care; and (4) paramedics, who provide a broad spectrum of advanced life support care including administration of advanced prehospital procedures and multiple medications. Although these national scopes of practice represent an attempt to standardize these levels of providers, the scope of practice for each level can differ significantly among the states (IOM, 2007b).

Beyond these variations in the types of EMS systems and the providers that staff them, wide variation exists in the acceptance of best practices and the outcomes of patients with various medical conditions. EMS providers generally follow medical protocols that may be local (applying only to a single agency), countywide, regional, or statewide (Kupas et al., 2015) (see Figure 2-5). Although there are few evidence-based guidelines that pertain to EMS, they are growing in number, and the National Association of State EMS Officials recently completed a project that produced model clinical guidelines for EMS care (NASEMSO, 2014). Data that can be used to associate outcomes of trauma patients with prehospital care provided by different types of EMS agencies or providers are scant. However, research has shown significant differences in survival—as great as twofold—among severe trauma patients treated by EMS in various communities across North America (Minei et al., 2010; Newgard et al., 2008).

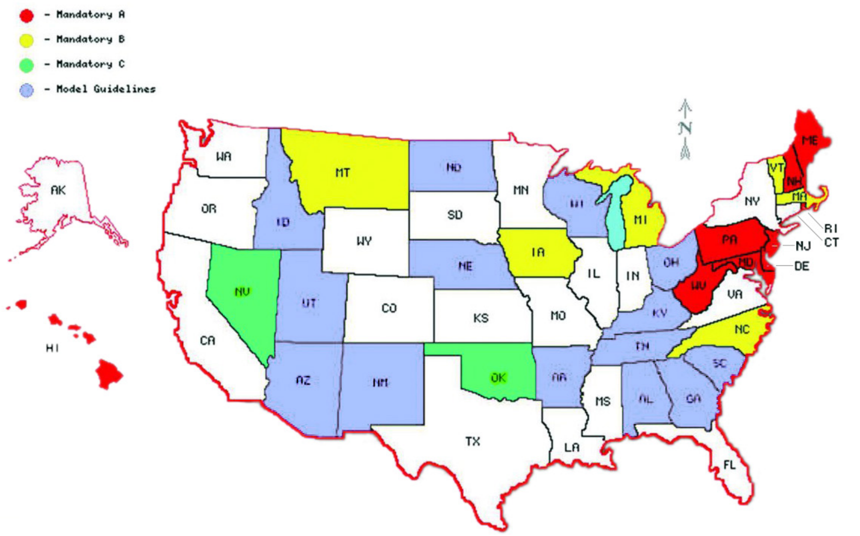

FIGURE 2-5 States with mandatory or model statewide advanced life support protocols, 2013.

NOTES: States colored red, yellow, or green have mandatory statewide protocols (yellow and green indicate the existence of a state process by which EMS can petition to alter those protocols or develop their own). States colored blue have model protocols that local or regional EMS can choose to use. In states that are white, no statewide protocols or model guidelines exist.

SOURCE: Kupas et al., 2015, reprinted by permission of Taylor & Francis Ltd.

OVERVIEW OF THE MILITARY'S TRAUMA CARE SYSTEM

Just as the sophisticated civilian trauma systems in the United States emerged from the successes and lessons of military trauma care during the wars in Korea and Vietnam, the military has contemporized, expanded, and improved upon principles of civilian trauma system design that evolved over more than 25 years in the period between the end of the Vietnam War and the wars in Afghanistan and Iraq. This section describes the development and features of the military's contemporary system for trauma care delivery—the Joint Trauma System (JTS)—and its relation to the broader Military Health System (MHS). Also described below is the distribution of responsibility for trauma care in the military, and the variability in trauma systems across the military.

The Development of the Military's Joint Trauma System

At the start of the U.S. engagement in Afghanistan in 2001, there was no joint plan or system for delivering trauma care in theater. Service-specific (i.e., Army, Navy, Air Force) medical personnel and other assets were embedded in deploying military forces, consistent with the organization of trauma care employed in previous conflicts (DHB, 2015). Following U.S. entry into combat operations in Afghanistan and Iraq, a group of military clinicians identified the need for a more systematic approach to trauma care in U.S. Central Command[8] (CENTCOM) for soldiers wounded on the battlefield (Bailey et al., 2012a). This inclusive system—the Joint Theater Trauma System—was implemented in 2004 and modeled after the successful regionalized trauma systems in the civilian sector. Its stated vision was "to ensure that every soldier, marine, sailor, or airman injured on the battlefield has the optimal chance for survival and maximal potential for functional recovery" (Eastridge et al., 2006).

The critical elements and capabilities of military and civilian trauma systems are largely the same. While varying slightly in the application of these trauma system principles, both share the goal of meeting the needs of patients wherever they are injured and wherever they receive care. As in the civilian sector, the military's inclusive trauma system is designed to integrate care across the continuum, beginning at the point of the injury, and to minimize the time to definitive care.

There are, however, some basic operational and environmental differences between military and civilian trauma care that impact the way that care is delivered. In the context of military trauma, for example, it is frequently necessary for a patient to receive care at multiple facilities after being wounded, with "life- and limb-preserving care" being provided far forward on the battlefield and at military treatment facilities (MTFs) (Bailey et al., 2012a, p. 34). Thus the military must ensure the capability to deliver trauma care interventions separated in space and time that in the civilian world often would take place within a single trauma center. Further, compared with civilian practice, the military must manage a high volume of severe multisystem injuries in an environment in which resources (supplies such as diagnostic and surgical equipment, as well as staff) are limited, and transport times are unpredictable. The military also is frequently overwhelmed by multiple or mass casualties, and point-of-injury care and evacuation may be impeded by an active firefight or other dangerous circumstances (Lenhart et al., 2012), a situation not as commonly encountered in the civilian sector. Finally, the military's trauma system in theater must continuously and rapidly adapt to an evolving combat environment. For

[8] There are nine unified (joint) combatant commands (CoCOMs) in the U.S. military, covering both regional (e.g., Central Command, Pacific Command) and functional (e.g., Special Operations Command) areas. Located between the European and Pacific CoCOMs, Central Command (CENTCOM) covers the "central" area of the globe, including Afghanistan and Iraq.

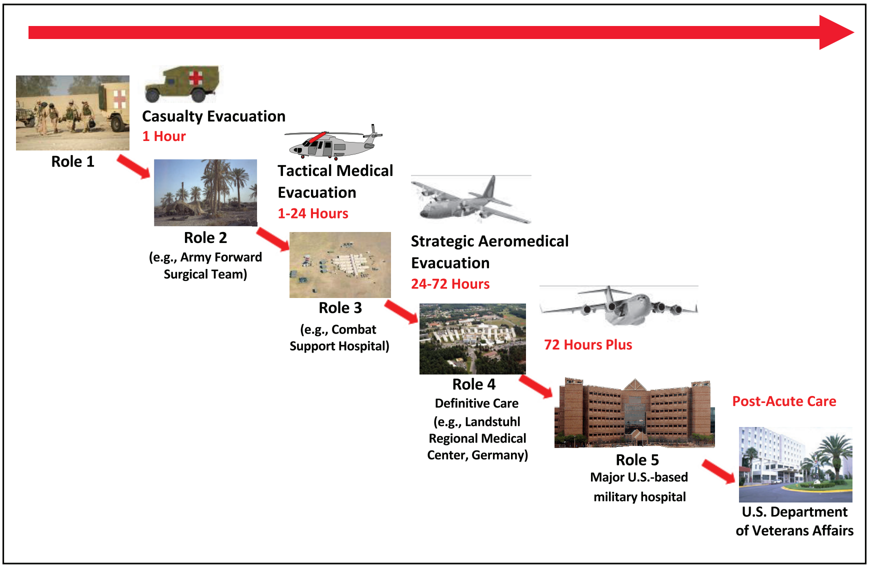

FIGURE 2-6 Military trauma care continuum.
SOURCE: Adapted from Bailey et al., 2012a.

example, security situations can change rapidly in a given area and logistical support evolves as the theater matures. In contrast, civilian trauma care systems are more stable and predictable.

The military organizes its trauma care continuum and MTFs into five levels or "roles" of care[9] (see Figure 2-6). Each role corresponds to the level of care provided. Role 1 first responders (self, buddy, or medic) in the prehospital setting assess the injury, provide emergency care (e.g., apply tourniquets for hemorrhage control), and arrange for evacuation to a higher-level facility. Role 2 provides limited hospital capability for forward resuscitative care (emergency resuscitation, damage control surgery, blood transfusion) through small treatment facilities and mobile forward surgical teams consisting of surgeons, anesthetists, nurses, and technicians. Role 3 facilities are large, semipermanent facilities (combat support hospitals) that provide surgery, intensive care, postoperative care, and specialty care. Patients requiring longer-term care are evacuated to Role 4 or 5 definitive care facilities. Transport between these echelons may include a medical team and management of the patient, although some evacuations emphasize speed over medical care (Lenhart et al., 2012). Depending on the nature of

[9] While the American College of Surgeons uses Level I as the highest level of definitive care in the civilian sector, the military uses Role 5 as its highest level of care.

the injury and the distance to a higher-level medical facility, casualties may be transported directly from the point of injury to a Role 3 MTF.

In 2005, the Joint Theater Trauma Registry was established—modeled after the NTDB and now called the Department of Defense Trauma Registry (DoDTR)—to systematically collect information on injuries, including demographic, mechanistic, physiologic, diagnostic, therapeutic, and outcome data (Eastridge et al., 2009; Pruitt and Rasmussen, 2014). While prehospital data were integrated into the DoDTR in 2013, documentation of prehospital trauma care has and continues to be suboptimal (Haut et al., 2016). The analysis of data maintained in the DoDTR allows for near-real-time improvement in trauma care delivery and patient outcomes across the trauma care continuum. Additionally, the DoDTR has served as a key source of data for retrospective research and facilitated programmed, requirements-driven research performed by the military's Combat Casualty Care Research Program. As discussed in more detail in Chapter 4, the development and maturation of the military's registry-driven performance improvement processes and medical research program have played a key role in decreasing mortality and morbidity over the course of the wars in Afghanistan and Iraq (Pruitt and Rasmussen, 2014).

In 2010, the JTS[10] became a formal program of record under the U.S. Army Institute for Surgical Research (Bailey et al., 2012a), where it provides for ongoing development and maintenance of the military trauma system's support infrastructure, including the DoDTR and performance improvement processes (see Figure 2-7). Although the JTS serves as the military's de facto lead agency for trauma, recognized as a DoD Center of Excellence in 2013, the military has not formalized this role (Robb, 2015). A lack of doctrinal authority limits its capacity to function as a lead agency for the military trauma system. For example, the JTS does not have the authority to set policy or ensure that standards are met through a verification process (Rotondo et al., 2011).

As shown in Figure 2-7, the JTS interfaces with two programs that both represent critical elements of a model trauma system as described earlier in this chapter—prevention and research. The DoD's Joint Trauma Analysis and Prevention of Injuries in Combat (JTAPIC) program has the responsibility to collect, integrate, analyze, and store operations, intelligence, materiel, and medical data to inform solutions that prevent or mitigate injury in the deployed setting (i.e., primary and secondary prevention strategies) (JTAPIC, 2016). For example, data gathered about injury patterns during the conflicts in Afghanistan and Iraq have informed the design and field-

[10] Whereas the functional domain of the Joint Theater Trauma System is limited to the U.S. CENTCOM theater of operations, the JTS supports a military trauma system capability across all combatant commands (Rotondo et al., 2011).

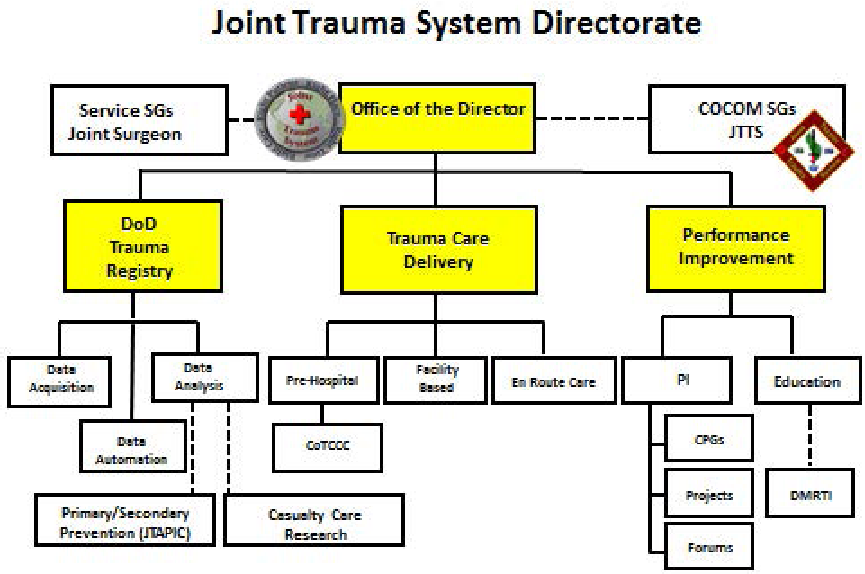

FIGURE 2-7 Organizational structure of the Joint Trauma System Directorate, showing linkages to the DoD's Joint Trauma Analysis and Prevention of Injuries in Combat (JTAPIC) program, the DoD's Combat Casualty Care Research program, and the Defense Medical Readiness Training Institute (DMRTI).

NOTE: CoCOM = combatant command; CPG = clinical practice guideline; CoTCCC = Committee on Tactical Combat Casualty Care; DoD = U.S. Department of Defense; JTTS = Joint Theater Trauma System; PI = performance improvement; SG = surgeon general.

SOURCE: Adapted from Bailey et al., 2012a.

ing of body armor and other personal protective equipment (DCBI Task Force, 2011; Eastridge et al., 2006). Similar observations regarding the increase in multiple fragment injuries resulting from the use of improvised explosive devices by insurgents (GAO, 2009) led to "up armoring" of military vehicles to reduce penetration and occupant injury (Zoroya, 2013). Protective equipment, along with the emphasis on predeployment training (discussed further in Chapter 5), have likely contributed to the significantly lower case fatality rate associated with the recent wars in Afghanistan and Iraq as compared to the Vietnam War (Eastridge et al., 2006) (see Figure 1-3). Given the value of DoDTR to support the epidemiological analysis of injury patterns and the identification of prevention strategies (e.g., uniform redesign, seat-belt education initiatives), continued coordination between the JTS and JTAPIC is essential. The JTS is also closely linked to the DoD's combat casualty care research program, informing research priorities based on registry-driven performance improvement data and, on the back end, integrating research-generated knowledge into evolving clinical practice guidelines (this interface is discussed in more detail in Chapter 4).

Distribution of Responsibility for Trauma Care in the Military

Mirroring the distribution of leadership across numerous local, state, and federal agencies in the civilian sector, responsibility for the delivery of military trauma care is spread across multiple entities and actors within the DoD (see Figure 2-8).[11] As in the civilian sector, there is no single point of accountability for the military's medical readiness mission.

Within the MHS, the Assistant Secretary of Defense for Health Affairs (ASD(HA)) serves as principal advisor for health issues for DoD and is responsible for policy development and oversight of all MHS programs and activities. As the Defense Health Program appropriation holder, the ASD(HA) is responsible for administering the MHS budget, which includes management of the resources that fund the service medical departments (DoD, 2014). While the ASD(HA) directs policy, the health missions of the MHS are administered through each service's surgeon general, along the organizational lines of the Army, Navy, and Air Force. In addition, execution of policy within the MHS is facilitated by a joint combat support agency[12]—the Defense Health Agency (DHA) (DoD, 2014; Schwab, 2015).

Established in 2013, the DHA is charged with developing strategies to contain costs, improve efficiency, and encourage collaboration and opportunities for joint operations among the three services. As a combat support agency, the DHA's mission is to enable the Army, Navy, and Air Force medical departments to "provide a medically ready force and ready medical force" to all combatant commands during peacetime and wartime (DHA, 2014, p. 3). To provide advice on tactical management of the MHS, the DHA works collaboratively with the service surgeons general[13] and members of Joint Staff.[14]

The DHA consists of a number of directorates. Under its Education and Training Directorate, the DHA leads standardized education and training across the MHS and coordinates professional development and sustainment

[11] The roles and responsibilities of these entities and actors are discussed in greater detail in Box 7-5.

[12] Combat support agencies provide department-level and tactical support to the joint operating forces of the U.S. military during combat and other military operations (DoD Directive 3000.06). Other examples of DoD combat support agencies include the Defense Logistics Agency and the Defense Intelligence Agency.

[13] The director of the DHA, a lieutenant general, holds the same rank (3-star general) as the service surgeons general.

[14] The Joint Staff assists the chairman of the Joint Chiefs of Staff, who is the principal military adviser to the President, the Secretary of Defense, and the National Security Council.

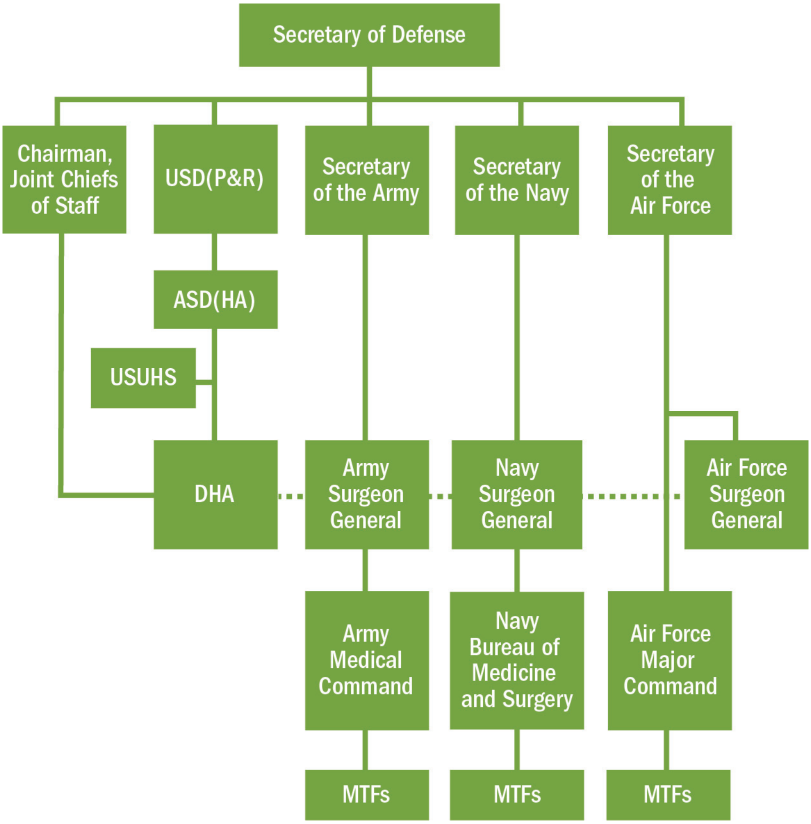

FIGURE 2-8 Organization chart for the U.S. Department of Defense's Military Health System.

NOTE: ASD(HA) = Assistant Secretary of Defense for Health Affairs; DHA = Defense Health Agency; MTF = military treatment facility; USD(P&R) = Under Secretary of Defense for Personnel and Readiness; USUHS = Uniformed Services University of the Health Sciences.

SOURCES: Adapted from DHA, 2014; DoD, 2014.

programs. The DHA's Research, Development, and Acquisition Directorate coordinates medical research taking place across the services and the MHS, prioritizing important research and minimizing redundant work. Within its Healthcare Operations Readiness Division, the DHA has centralized management over service-support functions, including theater information systems, logistics, and facilities. In this capacity, the DHA aims to ensure force health protection and implements deployment-related health policy (DHA, 2014; DoD, 2014).

At this time, however, the DHA remains in an immature state of transition to full operational capacity. The DHA's roles and responsibilities, particularly in relation to those of the military departments, are still evolving.

Two distinct branches of the military chain of command affect the delivery of combat casualty care on the battlefield. The first encompasses the unified combatant commands (e.g., CENTCOM). Each unified combatant command has its own commander who reports directly to the Secretary of Defense. Combatant commanders are responsible for the operational direction of the forces assigned to the combatant command and the performance of any assigned missions. As a result, it is line—i.e., nonmedical leadership that maintains control over the budget, personnel, and equipment assigned by the military departments to support combat casualty care in theater.

The second chain of command runs from the Secretary of Defense to the Secretaries of the military departments. Through their respective service chiefs, the Secretaries of the Army, Navy, and Air Force exercise control, authority, and direction over those personnel not specifically assigned to combatant commanders or the National Capital Region.[15] Each individual service medical command is responsible for and has control over its military treatment facilities (DoD, 2014). This complex hierarchical structure creates challenges to ensuring the consistent application of best trauma care practices and achieving standardization across DoD. Differences among the services in approaches to readiness and medical care capabilities in theater (particularly at Role 2 and Role 3 facilities) have been noted (DHB, 2015). The resultant deficits in interoperability impede system cohesion.

Although the DHA has been designated a combat support agency for health and medical operations, the complex overlapping and conflicting authorities among the combatant commands, the Joint Staff, the Secretary of Defense, and the military departments make it extremely difficult to establish reliable joint combat casualty care processes and systems; set and allocate funding for readiness, research, and staffing priorities; and establish a single point of accountability for delivering quality medical services across all combatant commands.

Variability in Trauma Systems Across the Military

As mentioned previously, the Joint Theater Trauma System is limited to the CENTCOM theater of operations. In contrast, the JTS is designed "to support a continuous deployable global trauma systems capability" for the entire military, ready to facilitate and guide the implementation of a theater trauma system in each combatant command (DHB, 2015). At

[15] The DHA exercises control over military treatment facilities and personnel not specifically assigned to combatant commanders within the National Capital Region.

this time, however, the JTS operates largely in CENTCOM alone. The JTS is working with Pacific Command to assist that combatant command in proactively establishing its own theater trauma system (DHA, 2014; Gross, 2015). While the JTS has reached out to other combatant commands, it has received limited response (Gross, 2015). Although the JTS is a formal DoD entity with a global mission, it was established as a noncommand and tenant organization of the U.S. Army Institute of Surgical Research, which is a subordinate organization under the U.S. Army Medical Research and Materiel Command. It lacks the organizational and leadership authority to effect doctrinal change in regional combatant commands.

CENTCOM itself displays great variability in the extent to which line leaders and their units have committed to the principles of an inclusive trauma system and adhered to the best practices (e.g., clinical practice guidelines) emerging out of the JTS. This variability is reflected in patient outcomes. As discussed in Chapter 1, the 75th Ranger Regiment—characterized by complete line ownership of medical care—achieved dramatically better outcomes compared with the greater military population (Kotwal et al., 2011).

HOW MILITARY AND CIVILIAN SYSTEMS INTERFACE FOR BIDIRECTIONAL TRANSLATION

As evidenced in the preceding sections, the delivery of trauma care in the military and civilian sectors forms a diverse landscape. Partnership across the military and civilian systems can facilitate the transfer of lessons learned and encourage the continued advancement of trauma care in both sectors. While interface between the military and civilian sectors is hardly a new phenomenon, a number of collaborative platforms have recently been developed to encourage the bidirectional translation of best practices.

Training Pipeline and Practice at Military Trauma Centers

The vast majority of military surgeons, nurses, and medics receive their medical training in the civilian sector. Following graduation, the surgeons undertake residencies in the military or continue their postgraduate training in the civilian sector. For those who complete their medical education and training in the civilian sector, interface with the military is limited. Those who complete their education in the military sector are similarly isolated from the civilian world.

After residency or fellowship training, military surgeons are assigned either to an MTF or to a civilian trauma center with an embedded military cadre that oversees predeployment training. These service-specific trauma training centers, discussed in more detail in Chapter 5, have provided valuable opportunities for bidirectional sharing of knowledge, as well as the generation of new knowledge through joint military–civilian research initiatives. In addition to surgeons, other military medical specialists assigned to civilian trauma training sites include anesthesiologists, emergency physicians, nurse anesthetists, nurses, and technicians, offering opportunities for cross-sector learning at all provider levels (Cannon, 2016).

Currently, three MTFs are verified as trauma centers by the American College of Surgeons: San Antonio Military Medical Center (SAMMC) (Level I), Walter Reed National Medical Center (Level II), and Landstuhl Regional Medical Center (Level III) (Cannon, 2016). Verification gives the physicians, nurses, and medics assigned to these facilities numerous opportunities to engage with civilian trauma leaders. Experienced civilians frequently maintain the trauma infrastructures of these MTFs, an interface that imparts to military physicians the knowledge and administrative skills necessary to provide organizational leadership for trauma care in combat zones. SAMMC also hosts civilian trauma experts as visiting professors, and SAMMC physicians are invited to attend events with visiting professors at the University of Texas Health Sciences Center at San Antonio (see Box 2-4). These interactions enable military personnel to learn about advances in civilian trauma care and expose the visiting professors to lessons learned in military trauma care (Cannon, 2016). Most military physicians, nurses, and allied health providers, however, provide beneficiary care at non-trauma center MTFs, where they have few opportunities to exchange ideas and lessons learned with civilian trauma professionals and little opportunity to put their lessons learned into practice. During the wars in Afghanistan and Iraq, military personnel deployed to Landstuhl Regional Medical Center or facilities in those two countries had the opportunity to interact with visiting civilian surgeons through the Senior Visiting Surgeon Program. Between 2005 and 2012, 192 civilian surgeons participated in this program. Participants reported that they gave lectures, conducted research, established mentorship relationships with military surgeons, and were exposed to military practices that were relevant to their civilian trauma care (Blackbourne et al., 2012; Moore et al., 2007).

In the combat context, physicians, nurses, and medics deployed through the Reserves and National Guard are an important force in encouraging bidirectional translation of best practices and lessons learned. These individuals are immersed in the civilian sector, bringing that expertise to their deployed team. Following deployment, they return to the civilian sector, where they can apply lessons learned during their military experience (Cannon, 2016).

Box 2-4 SAN ANTONIO AS A REGIONAL LEARNING COLLABORATIVE

San Antonio Military Medical Center (SAMMC) is the only military treatment facility (MTF) that is verified as a Level I trauma center. SAMMC is a high-volume trauma center, evaluating nearly 3,500 acutely injured trauma patients each year and admitting more than 2,600 patients. The high volume necessary to achieve Level I trauma center verification is attained in part by treating civilian patients from the local area. The patients treated at SAMMC often have injuries similar to those seen in combat, thus giving military personnel the opportunity to gain competency that is applicable to combat casualty care. In addition to the ongoing evaluation and treatment of patients, SAMMC works to test and promote advances in trauma care, especially lessons learned from combat, such as the use of balloon aortic occlusion for trauma resuscitation (Knuth, 1996; Ross, 2010), the prehospital use of purposed tourniquets (Eastridge et al., 2006), and advanced extracorporeal care for patients with severe acute respiratory distress syndrome (Bailey et al., 2012b, 2013; Holcomb et al., 2013). The complex also hosts the Center for the Intrepid, which offers military casualties state-of-the-art rehabilitation services.

While SAMMC has the capacity to train only a small percentage of military medical personnel, the training it provides has clear benefits over training in civilian trauma centers or in non-trauma center MTFs. SAMMC's verification as a Level I trauma center and its integration into the regional civilian trauma system enables military physicians, nurses, and medics to attain and sustain expertise in trauma care and to interact, conduct research, and collaborate with civilian trauma care providers—for example, through the Southwest Texas Regional Advisory Council and the South Texas Research Organizational Network Studies on Trauma and Resilience (STRONG STAR) research consortium (Gerhardt et al., 2013). In addition, it allows for the exchange of knowledge and practices between the civilian and military sectors so that advances in care can be shared to improve care for all patients. The regional learning collaborative established at San Antonio offers a template for the rest of the nation to emulate, demonstrating in practice how the integration of military and civilian systems betters trauma care for the nation as a whole (Cannon, 2016).

Societies and National Meetings

Professional societies have provided support for military medical providers throughout the recent conflicts. Civilian societies, such as the American Academy of Orthopaedic Surgeons, American Association for the Surgery of Trauma, American College of Surgeons, Orthopaedic Trauma Association, and Society of Vascular Surgeons facilitate the exchange of information and collaboration between military and civilian surgeons (Cancio et al., 2015), and they give military surgeons a platform for peer review of their research, as well as an opportunity to lead and participate in academic medical activities. Nursing (e.g., Society of Trauma Nurses) and prehospital care societies (e.g., National Association of Emergency Medical Technicians) serve similar roles for those disciplines.

National meetings provide another venue for exchange and collaboration between military and civilian providers. Participation at such meetings can accelerate the translation of advances from one sector to another. For example, Cancio and colleagues (2015) found that the migration of the concept of "damage control resuscitation" from its origins in the military to civilian publications was due in part to presentations at meetings and publications in journals, suggesting successful translation of lessons learned in the military to the broader civilian context. Military personnel have participated in civilian meetings throughout the recent conflicts, with a peak in participation during 2005 to 2007 (Cancio et al., 2015). Civilian participation in military societies is less common, although civilian attendance at the Military Health Service Research Symposium has increased in recent years.

Beginning in 2006, the American Academy of Orthopaedic Surgeons, together with the Orthopaedic Trauma Association, the Society of Military Orthopaedic Surgeons, and the Orthopaedic Research Society, has sponsored an annual 2-day symposium that brings the military and civilian orthopaedic trauma communities together to share best practices and define research priorities for the future. Publications resulting from each symposium have helped define current knowledge gaps regarding management of major limb trauma for Congress, DoD, the National Institutes of Health, and industry (AAOS, 2016). The first symposium defined the current state of practice, focusing on challenges related to combat casualty care (Bosse et al., 2012). Subsequent topics included challenges in definitive reconstruction, barriers to return of function and to duty, maintaining force readiness during an era of military transition, and disaster preparedness (Andersen et al., 2015).

Unfortunately, a 2012 DoD policy change (due to sequestration) limits the number of military personnel participating in civilian meetings and the frequency of that participation despite the clear benefits to both sectors. As a cost-cutting measure, the Office of the Secretary and Deputy Secretary of Defense must now approve all conference attendance by military personnel (Carter, 2012). This change has resulted not only in fewer military personnel attending meetings, but also far fewer military papers being presented (Cancio et al., 2015).

Military–Civilian Leadership-Level Partnerships

Given the variety of stakeholders engaged in the delivery of trauma care, the transfer of best practices and lessons learned between the military and civilian systems depends on an integrated and collaborative systems approach. Recognizing this fact, military and civilian leaders in trauma care have developed two collaborative platforms—the Federal Interagency Committee on Emergency Medical Services (FICEMS) and the Military Health System American College of Surgeons (MHS/ACS) Strategic Partnership.

FICEMS

The delivery of EMS across the nation involves the work of and interaction between numerous federal agencies. To complement these activities, FICEMS was established in 2005 to institutionalize these relationships and ensure coordination among the federal agencies involved with emergency medical services. FICEMS's membership includes DHS, DoD, DOT, the Federal Communications Commission, HHS, and a State EMS Director appointed by the Secretary of Transportation (Dawson, 2015).

Building on a number of successes, FICEMS is gradually focusing its efforts on greater specificity and accountability through a formal strategic planning process. Included within FICEMS's *Strategic Plan* are objectives related to applying lessons from military and civilian incidents to the EMS community and transitioning military EMS providers to civilian practice (Dawson, 2015; FICEMS, 2013). In uniting the efforts of the military and civilian sectors and making the translation of lessons learned a priority, FICEMS serves as a meaningful platform for working toward improved care in the prehospital setting throughout the United States.

MHS/ACS Strategic Partnership

The concept behind this partnership, launched in December 2014, emerged from the shared recognition by DoD and the American College of Surgeons of the need for a synergistic and collaborative relationship between the military and civilian sectors to ensure that the next generation of surgeons would be adequately prepared to deliver optimal trauma care to patients (Hoyt, 2015a,c). Through this partnership, the civilian sector, represented by the American College of Surgeons, can partner with DoD in four areas:

- creation of a quality, learning collaborative
- education and readiness
- formal assessment of the JTS
- consideration of how to create an infrastructure for clinical trials using clinical registries and trauma hospital networks (Hoyt, 2015b)

Box 2-5 lists specific agreements outlined in the partnership charter.

CONCLUSION

When the critical elements of a trauma system are in place and integrated across the continuum of care, optimal care can be delivered. The experiences

Box 2-5 **AGREEMENTS FORMALIZED IN THE CHARTER OF THE MHS/ACS STRATEGIC PARTNERSHIP**

- Share information related to the curriculum used to teach military surgical skills through expansion of the ACS Advanced Surgical Skills for Exposure in Trauma course and other programs
- Share information related to existing education offerings of importance to military and surgical communities that are interested in humanitarian and disaster response
- Share information related to validation of the military's Optimal Resources handbook
- Share information related to potentially increasing the involvement of military surgeons in the ACS senior leadership program
- Share information related to review of the DoD Combat Casualty Care Research Program
- Share information on relevant research portfolios, including research conducted through the ACS National Trauma Data Bank® and Trauma Quality Improvement Program®
- Plan a presentation of an ACS military surgeon symposium at the 2015 ACS Clinical Congress
- Share information related to systems-based practice, including dissemination of surgical clinical practice guidelines and development of an optimal resources manual for surgical care

SOURCE: Excerpted from Hoyt, 2015c.

of the 75th Ranger Regiment and the Pennsylvania and Maryland trauma systems attest to the value of such integration. As highlighted in this chapter, however, there is room for improvement in both the military and civilian trauma systems. The implementation of inclusive systems and patient outcomes vary dramatically across both sectors. Similarly, the interface between the military and civilian systems is neither structured nor systematic, limiting the exchange of best practices and lessons learned between the two systems.

Outcomes would be improved in both settings if learning processes were in place to encourage continuous bidirectional translation and diffusion of best practices. To this end, it is important to evaluate how well the trauma systems of both sectors function as learning systems. Chapter 3 outlines a framework for such an evaluation, and Chapters 4 through 7 analyze the strengths and gaps of the military and civilian trauma care systems according to this framework.

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3

A Framework for a Learning Trauma Care System

The committee was asked to identify and describe the key components of a learning health system necessary to optimize care of individuals who have sustained traumatic injuries in military and civilian settings. In this chapter, the committee describes the characteristics of high-performing learning health systems and, by applying a learning system lens to trauma system components, develops a framework for an optimal learning trauma care system.

CHARACTERISTICS OF A LEARNING HEALTH SYSTEM

The Institute of Medicine (IOM) defines a continuously learning health system as one "in which science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience" (IOM, 2013, p. 136). In this inherently iterative process, innovation is introduced and continuously refined in response to evolving care needs and circumstances (see Figure 3-1). In the absence of a learning system approach, the diffusion of new evidence, innovation, and knowledge can take considerable time (Rogers, 2010). A learning health system holds great promise, offering a path by which the many stakeholders involved can manage health care's rapidly increasing complexity; achieve greater value; and capture opportunities from emerging technology, industry, and policy (IOM, 2013). In short, a continuously learning health system aims to deliver the best care, optimizing outcomes for patients across the system at greater value.

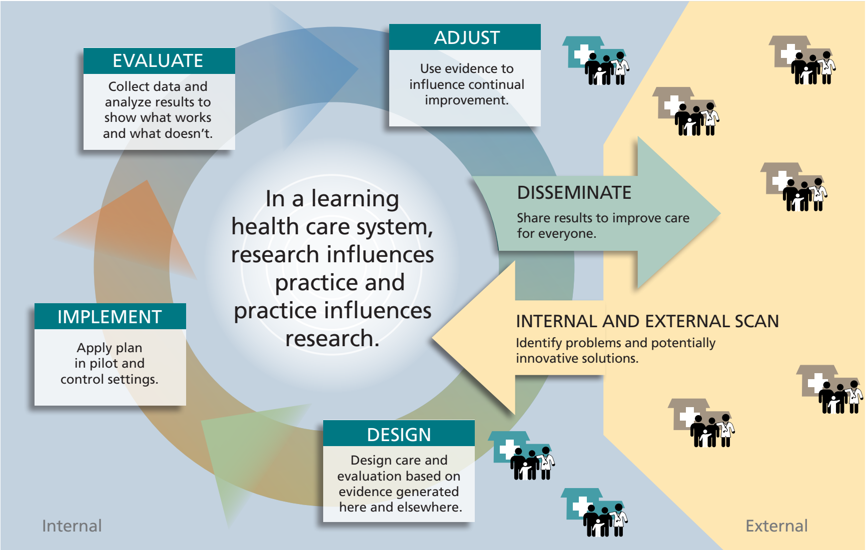

FIGURE 3-1 How a continuously learning health system works.
SOURCE: From Greene et al., 2012. Copyright © 2012 American College of Physicians. All Rights Reserved. Reprinted with the permission of American College of Physicians, Inc.

In developing a framework for a learning trauma care system (described later in this chapter), the committee built upon the components of a continuously learning health system characterized in the 2013 IOM report *Best Care at Lower Cost* (see Table 3-1). These elements capture not only the technical and practical components required to improve care but also the system-level characteristics necessary to encourage continuous learning and improvement. These seven components, falling under the categories of science and informatics, patient–clinician partnerships, incentives, and continuous learning culture, are requisite in designing a health system characterized by continuous learning and innovation.

Although necessary, these seven structural components are by themselves insufficient to ensure the success of a learning health system; a sound strategy and system architecture are not a guarantee of effective implementation. Success depends also on the way in which these components align and work together to facilitate continuous learning and improvement. Inertia, conflicting values, oversaturation of ideas, and fear are all potential barriers that can stall and even dismantle the efforts of a system striving toward rapid continuous learning.

Across multiple sectors, there are exceptional examples of learning systems characterized by large-scale learning and exchange around a shared

TABLE 3-1 Components of a Continuously Learning Health System

Science and Informatics	
Real-time access to knowledge	A learning health system continuously and reliably captures, curates, and delivers the best available evidence to guide, support, tailor, and improve clinical decision making and care safety and quality.
Digital capture of the care experience	A learning health system captures the care experience on digital platforms for real-time generation and application of knowledge for care improvement.
Patient–Clinician Partnerships	
Engaged, empowered patients	A learning health system is anchored on patient needs and perspectives and promotes the inclusion of patients, families, and other caregivers as vital members of the continuously learning care team.
Incentives	
Incentives aligned for value	A learning health system has incentives actively aligned to encourage continuous improvement, identify and reduce waste, and reward high-value care.
Full transparency	A learning health system systematically monitors the safety, quality, processes, prices, costs, and outcomes of care, and makes information available for care improvement and informed choices and decision making by clinicians, patients, and their families.
Continuous Learning Culture	
Leadership-instilled culture of learning	A learning health system is stewarded by leadership committed to a culture of teamwork, collaboration, and adaptability in support of continuous learning as a core aim.
Supportive system competencies	A learning health system constantly refines complex care operations and processes through ongoing team training and skill building, systems analysis and information development, and creation of the feedback loops for continuous learning and system improvement.

SOURCE: Adapted from IOM, 2013, p. 138.

goal (see Boxes 3-1, 3-2, and 3-3). In drawing on these and other models, the committee identified attributes that distinguish exceptional, high-performing learning systems from typical systems (summarized in Table 3-2). These attributes described in the sections below, can be envisioned as animating the IOM report's structural framework, highlighting various management approaches that will encourage a learning system to truly thrive.

TABLE 3-2 Characteristics That Distinguish Exceptional, High-Performing Learning Systems

TYPICAL LEARNING SYSTEMS	EXCEPTIONAL LEARNING SYSTEMS
The aim of the network is to facilitate general learning.	The aim of the network is crisp and quantifiable.
The system is oriented to focus upward in the hierarchy; leadership receives data and reports.	The system is oriented to focus on the needs of the customer; leadership removes barriers to progress in the field.
The system catalogues explicit knowledge (libraries).	The system facilitates the exchange of tacit knowledge (just-in-time).
The system furnishes aggregate information.	The system measures team performance.
The system has "theory lock".	The system applies many stimulants to effect change.
A large investment is made in teaching and training.	Experimentation and improvisation are encouraged; there are high expectations for testing and adjustment.
Consensus is regarded as a value.	Agility is regarded as a value.
New networks are created.	Existing networks are harnessed.
The system is centrally managed.	System management is distributed; losing control is viewed as success.

SOURCE: This table draws on McCannon and Perla (2009).

Setting Crisp, Quantifiable Aims

In a typical learning system, there exists a vague notion that the aim for the system is to facilitate learning. This aim, however, does not create a sense of urgency around improving performance. Exceptional learning systems mobilize people to action by setting crisp, quantifiable aims that are oriented toward specific improved outcomes—for example, reducing clinically preventable mortality to zero.

Focusing on the Needs of the Customer

When a system is focused upward in the hierarchy and stakeholders are concerned primarily with using data and reports to placate leadership, the capacity of the system to learn is limited. Exceptional learning systems are oriented to focus on the needs of the customer (in a health care system, these would be the front-line providers of care), and leadership is focused on removing barriers to progress in the field. Project Extension for Community Healthcare Outcomes (ECHO) is an example of a learning system that has excelled because it is driven by a strong customer focus (see Box 3-1).

Facilitating the Exchange of Tacit Knowledge

Knowledge can be categorized as either explicit or tacit (Polanyi, 1966). *Explicit knowledge* can be collected and transmitted in a formal and systematic way (Nonaka, 1994; Polanyi, 1966). Although didactic methods (lectures, reading textbooks) are predominant as an educational model, a preponderance of evidence shows that optimal learning in adults does

Box 3-1 LEARNING SYSTEM MODEL: PROJECT ECHO

Project Extension for Community Healthcare Outcomes (ECHO), a program that began at the University of New Mexico School of Medicine in 2003, connects primary care clinicians practicing in local communities with specially care teams to better manage patients with chronic conditions that require complex care (Arora et al., 2014). Initially focused on the treatment of hepatitis C virus, Project ECHO has since been expanded to nearly 30 diseases and conditions in which there is a need to improve capacity to delivery complex health care (e.g., HIV, chronic pain), particularly in locations where specialists are in short supply. Today, Project ECHO operates in 22 states and 5 countries outside of the United States, including military treatment facilities within the U.S. Department of Defense's Military Health System (Project ECHO, 2016).

Using basic videoconferencing technology, primary care providers present cases to specialist teams and each other during weekly virtual "teleECHO clinics" (Arora et al., 2014). Project ECHO enables participating providers to deliver high-quality care for patients through three "learning loops": (1) longitudinal patient co-management with specialists, (2) collaboration with other primary care providers through shared case-management decision making, and (3) presentations on topics relevant to the management of the disease. Engagement in such a learning community helps providers develop expertise and overcome a number of difficulties common among those who treat medically underserved populations: isolation, excessive workload, inability to consult with colleagues, and lack of access to new scientific knowledge (Arora et al., 2007, 2010).

Project ECHO has been highly successful. A 2011 prospective study demonstrated that treatment for hepatitis C virus provided by primary care clinicians at ECHO sites was equal to that provided by university-based specialists (Arora et al., 2011). In a separate analysis, more than 90 percent of providers in the hepatitis C virus program reported that the project helped them achieve competence in the management and treatment of hepatitis C virus patients (Arora et al., 2007). More broadly, this model offers health care providers an invaluable opportunity to expand their knowledge and expertise. By offering education, training, and mentoring to clinicians and community health workers, comprehensive and high-quality care is available to many patients who might not otherwise have such access (Arora et al., 2014).

not occur through such methods; rather, knowledge is more efficiently absorbed and transmitted through practice and application. *Tacit knowledge* is contextual and draws on personal experience to include insights and intuitions that may be difficult to formalize and communicate to others (Becerra-Fernandez and Sabherwal, 2001). The classic example that conveys the difference between explicit and tacit knowledge is learning to ride a bike. Anyone who has ever ridden a bike can testify that one cannot learn to ride a bike from a set of directions, but must get on and learn through experience how to calibrate one's balance.

A common tendency in a typical learning system is to catalog or make libraries of knowledge and information so as to capture everything that is known in one central location. However, vast databases of such explicit knowledge do not necessarily translate to improved performance at the periphery. An exceptional system is characterized by an understanding that much more useful to those responsible for delivering care in the field is access to expertise that yields practical or tacit knowledge of how care is best delivered, often thought of as "tricks of the trade."

Measuring Team Performance

Continuous tracking and measurement of progress is requisite to accomplishing any goal. In high-performing learning systems, however, the generation of performance data extends down to the level of the team or individual practitioner. Like having clear and quantifiable aims, performance data that show progress at the provider level can generate excitement and inspire corrective action far better than aggregate data showing only system performance. Illustrating this point, a commitment to monthly reporting and measurement of each individual community's progress against carefully determined benchmarks was crucial to the success of the 100,000 Homes Campaign, a learning network that housed more than 100,000 chronically homeless people over a 4-year period (see Box 3-2).

Applying Multiple Stimulants to Effect Change

Changing behavior is a complex and challenging undertaking requiring a multifaceted approach that encompasses both positive and negative stimulants (carrots and sticks). Too often, the full array of available incentives is neglected in favor of a single mechanism for driving engagement, a concept known as "theory lock." In health care, for example, there is a strong focus on using payment as an incentive for changing the way care is delivered (IOM, 2013). Although certainly important, payment alone does not provide sufficient incentive to drive behavior change systematically. A more sophisticated approach is to apply multiple stimulants, focusing heav-

Box 3-2 LEARNING SYSTEM MODEL: 100,000 HOMES CAMPAIGN

The 100,000 Homes Campaign was a national initiative, led by the nonprofit Community Solutions, that ran from 2010 to 2014. Its aim was to mobilize cities and communities across the United States to house 100,000 chronically homeless people. The initiative encompassed 186 cities and communities that jointly housed more than 105,000 people in that 4-year period (100,000 Homes, 2014a). They worked together in a closely knit learning community, coming together regularly online, through webinars, and in person to share common challenges, breakthroughs, and tools. A particularly important tactic in the campaign was to get each participating community to commit to housing 2.5 percent of its chronically homeless population each month. The campaign calculated that if every community met this goal, it would exceed its overall objective. The provision of monthly data for each participant (and limiting the monthly deliverable to a manageable 2.5 percent) gave the initiative the direction and focus it needed to succeed (100,000 Homes, 2014b). The regular drumbeat of data on progress from each community also helped the campaign's management team identify where to focus its support (i.e., on lagging communities or on high performers that others could emulate).

ily on positive reinforcement such as recognition and collaboration, but also including regulation and transparency, and in cases of negligence or serious underperformance, even disciplinary action.

Encouraging Experimentation and Improvisation

Strict adherence to what one has been taught leads to system stagnation. Continuous learning and associated improvements in care occur through experimentation in the field, and exceptional learning systems encourage (and even require) this kind of behavior. Although such tools as clinical practice guidelines are useful for disseminating best practices in health care and reducing unwarranted variations in practice, rote compliance with such protocols may also lead to harm since no guideline can perfectly fit the needs of every patient. However, empowering health care providers to deviate from protocol based on the best information at hand requires an environment free of fear.

Regarding Agility as a Value

Consensus, while an important value that has its place in a learning system, can have the undesirable effect of bogging the system down and impeding progress. The superior values are agility and speed. As long as there is consensus on aims, allowing stakeholders to explore different approaches toward those shared aims can rapidly advance knowledge and learning.

Harnessing Existing Networks

All human systems are encoded in networks. People use a myriad of different structures and processes to connect with each other. Consequently, building new networks from scratch to solve any particular problem is inefficient. Exceptional learning networks harness and build on those that already exist.

Instituting Distributed System Management

The typical system is centrally managed; guidance and rules are dictated by a central organization. However, tight central management of the system can impede the rapid learning that can occur when front-line providers are encouraged to improvise and experiment (as discussed above). When peripheral participating organizations are empowered to run ahead of the center and function as laboratories for learning, not only are specific practices and knowledge being spread, but a culture of change management evolves within those organizations.

A FRAMEWORK FOR A LEARNING TRAUMA CARE SYSTEM

Systems for trauma care, like all other facets of health care delivery, face challenges in distilling an ever-expanding knowledge base from research and other scientific inquiry into meaningful clinical evidence and rapidly translating that evidence into wide-scale improvements in patient care. Too rarely is available knowledge used to improve the care experience. Equally inadequate is the extent to which information on the care experience is captured and applied to improving the knowledge base (IOM, 2013). The consequences include missed opportunities, waste, and preventable morbidity and mortality, as is evident in the variation in practice and outcomes observed in the field of trauma care (summarized in Chapter 2). This variation represents a failure in knowledge management and indicates that systems are not designed and managed to support optimal care and learning. A rapidly learning health system leverages recent advances in health information technology to access and apply evidence in real time, drawing knowledge from both traditional clinical research and patient care experiences. The combination of these forms of knowledge generation works to advance the rapid adoption of best care practices. In short, "evidence informs practice and practice informs evidence" (Greene et al., 2012, p. 207).

By applying a learning health system lens to the critical elements of a trauma system, the committee identified the following components of a continuously learning trauma care system optimally designed for continuous learning and improvement. These components are characterized in Table 3-3, which follows Figure 3-2, and detailed further in the following sections.

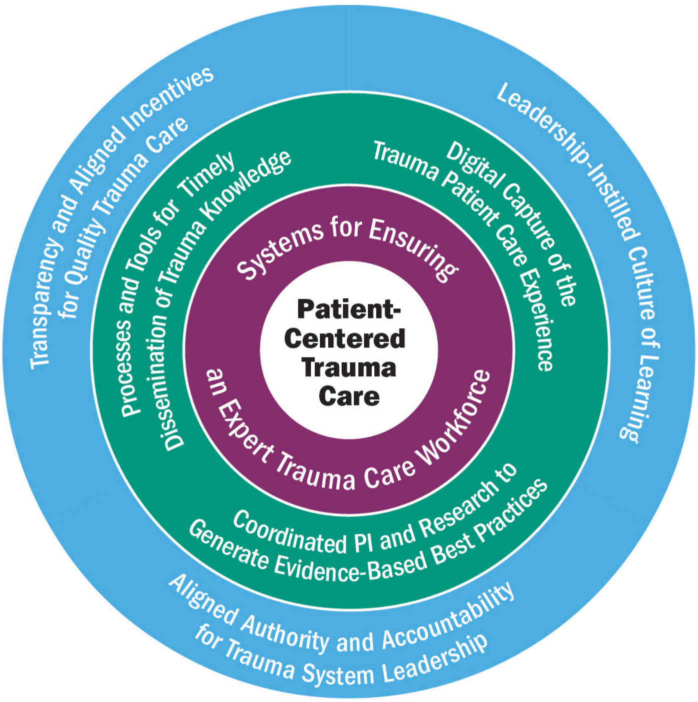

FIGURE 3-2 Components of a learning trauma care system.
NOTE: PI = performance improvement.

Digital Capture of the Trauma Patient Care Experience

In a learning trauma care system, knowledge develops as a natural by-product of care processes such that each patient experience yields information on the effectiveness, quality, and value of the trauma care delivered. To this end, patient care experiences across the continuum of care are digitally

TABLE 3-3 Components of a Continuously Learning Trauma Care System

Digital Capture of the Trauma Patient Care Experience	Patient care experiences across the continuum of care are digitally captured and linked in information systems, including trauma registries, such that each patient experience yields information on the effectiveness, quality, and value of the trauma care delivered. Bottom-up design of data systems, where care generates the data, ensures that data capture is seamlessly integrated into the provider workflow and is available in real time for performance improvement primarily and research secondarily.
Coordinated Performance Improvement and Research to Generate Evidence-Based Best Trauma Care Practices	The supply of knowledge is continuously and reliably expanded and improved through the systematic capture and translation of information generated by coordinated performance improvement and research activities.
Processes and Tools for Timely Dissemination of Trauma Knowledge	Trauma care providers have access to tools such as continuously updated clinical practice guidelines and clinical decision support tools to capture, organize, and disseminate the best available information to guide decision making and reduce variation in care and outcomes. Clinical decision support tools and telemedicine make knowledge of best trauma care practices available at the point of care.
Systems for Ensuring an Expert Trauma Care Workforce[a]	Continuous learning and improvement are designed into trauma system processes. Ongoing individual skill building and team training, as well as feedback loops, build and sustain an expert trauma care workforce.
Patient-Centered Trauma Care	The trauma care process is managed around the patient experience, feedback is sought from trauma patients when the process is evaluated for improvement, and patients are involved in redesign of the trauma system and have a voice in trauma research. Patient-centered care features timely access to high-quality prehospital, definitive, and rehabilitative care, with seamless transitions between each of these echelons to ensure that physical and psychological health care needs are met.
Leadership-Instilled Culture of Learning	Leadership will influence the extent to which a culture of learning and improvement permeates a trauma system. Leadership instills a culture of learning by defining learning as a central priority of a trauma system, removing barriers to improving care systems and, most notably at the point of care, setting quantifiable aims against which progress can continually be measured and promoting a nonpunitive environment.

TABLE 3-3 Continued

Transparency and Aligned Incentives for Quality Trauma Care	Drawing on data from trauma registries and other information systems, performance improvement programs support the evolution and improvement of trauma systems by benchmarking systems' performance against that of other similar organizations and by making performance information available at the provider, team, center, and system levels. Multiple complementary incentives are aligned to encourage continuous improvement and reward high-quality care.
Aligned Authority and Accountability for Trauma System Leadership	Responsibility, authority, and resources are aligned to enable leadership to steward the system. Defined leadership is accountable for trauma capabilities and system performance, with the authority to create and enforce policy and ensure that the many stakeholders involved work together to provide seamless, quality care.

[a] In an expert trauma care workforce, as defined by the committee, each interdisciplinary trauma team at all roles of care includes an expert for every discipline represented. These expert-level providers oversee the care provided by their team members, all of whom must be minimally proficient in trauma care (i.e., appropriately credentialed with current experience caring for trauma patients).

captured and linked in information systems, including trauma registries, to enable the generation, exchange, and application of information for the following purposes:

- **Surveillance—**Surveying the data in a registry can lead to the identification of trends in injury patterns, mortality, and long-term outcomes.
- **Performance improvement—**Registry data can be used to generate performance data at the individual provider, team, and system levels and inform changes in clinical practice or system design.
- **Research—**Significant challenges impede the conduct of prospective randomized controlled trials on trauma care in civilian and military settings. Registry data offer the opportunity to perform retrospective, hypothesis-driven, outcomes-based analyses to identify best practices or gaps in care.

If aim defines the system, the primary aim of a trauma management information system needs to be clinical improvement, with support for research serving as a secondary aim.

Trauma registries, which collect disease-specific clinical data in a uniform format, are an important tool for knowledge generation in a learning trauma care system. In such a system, data from hospital-based registries are collated into a regional registry that includes data from all hospitals in the system and linked such that data generated across the continuum of care are available in a single data set. When possible, these data are further linked to law enforcement, crash incident reports, emergency department records, administrative discharge data, medical examiner records, vital statistics data, and cost data to provide epidemiologic and outcome information, as well as information related to cost-effectiveness. These data are made accessible by the lead agency to support injury surveillance, performance improvement efforts, and trauma care research. Data have the greatest impact if they conform to national standards[1] related to case acquisition and registry coding conventions. Adhering to such standards increases the value of state trauma management information systems by providing national benchmarks and allows the lead agency to evaluate the performance of the entire system.

To support optimal learning, clinical quality of care, and continuous improvement, data systems (which capture the trauma data included in registries) are designed using a bottom-up approach so that data capture is seamlessly integrated into the provider workflow. Measurement for improvement purposes focuses on care delivery processes, as opposed to individual provider performance (Berwick et al., 2003). Bottom-up design captures data at the level of small, individual decisions, including both process steps and outcomes. Clinicians' access to their own short- and long-term clinical results encourages individual improvement. Bottom-up design further supports the consolidation of these data across all clinicians to support assessment of care processes at the level of a clinic, hospital unit, hospital, health care system, state, or country (James and Savitz, 2011).

Through the collection of clinical, cost, and patient satisfaction data, bottom-up data systems improve care while reducing costs. This approach is more timely, efficient, and accurate than that used by top-down data systems, which measure for selection rather than improvement. Top-down systems focus on a number of readily available intermediate or final outcome measures, ranking individual providers with the intent that public reporting and consumers' desire to select high-value care will incentivize providers to improve their own performance. Such system design, however, fails to capture the granular data necessary for improvement. Furthermore, selection measures are expensive to collect and frequently are inaccurate, incomplete, and untimely, given the necessity of relying on data abstraction (Berwick et al., 2003).

[1] Two such national civilian standards are the National Highway Traffic Safety Administration's National EMS Information System, which standardizes the collection of data on emergency medical services (Dawson, 2006; Mann et al., 2015), and the American College of Surgeons' National Trauma Data Standard, which addresses the standardization of hospital registry data collection (ACS, 2015).

The granular data elements captured in bottom-up systems are a critical part of regular care delivery. With proper design, these elements can be integrated into routine care so that front-line providers see them as essential to their daily work rather than as an external burden. The following steps are entailed in the design of a bottom-up data system and its integration into clinical workflow to create an outcomes tracking system[2]:

1. Identify a high-priority clinical process. Select processes at the decision level (i.e., the individual steps used by clinical teams to actually deliver care).
2. Build an evidence-based clinical practice guideline for the target process,[3,4] using formal evidence review, expert opinion, and existing acceptable practice. Represent the guideline as a flow chart that tracks at the level of clinical workflow—again at the decision level, where clinicians make choices and execute actual care. Usually, the best way to do this is to track a typical patient sequentially through the process.
3. Lay out how the guideline might blend into the clinical workflow, using such tools as standing order sets, clinical flow sheets, action lists, and patient worksheets. Often these tools are integrated into an electronic medical record.
4. Build a bottom-up data system[5] into the same clinical workflow. This data system will track all variations from the guideline, as well as intermediate and final clinical, cost, and satisfaction outcomes

[2] The outlined process adapts the formal methods used for designing data systems that support large, multicenter randomized controlled trials (Pocock, 1983).

[3] This guideline does not need to be perfect; it just needs to come close enough to be integrated into clinical work.

[4] Military and civilian trauma systems have developed and use numerous clinical practice guidelines. For these clinical processes, steps 1 and 2 are already complete.

[5] Generally, the same team that developed the guideline also builds the data system.

- For each step in the guideline, identify reports and analyses useful for understanding and managing the care of individual patients and the process as a whole.
- Build a trial example of actual reports that the final outcomes tracking system should routinely produce.
- Identify all data elements necessary to build each report and build a formal coding manual.
- Reduce the coding manual to a self-coding data sheet.
- Test the self-data coding sheet against the final report packet and in actual clinical practice.
- Cross-walk the final coding manual against existing automated data, identifying missing data elements.
- Data architects design data storage structures within a data warehouse. Analysts prepare and program standard analytic reports for automated production (James, 2003).

(James, 2003; Nelson et al., 1996). These point-of-contact data can then be captured in a longitudinal registry.

5. Establish a formal organizational structure (e.g., a clinical development and review team) that regularly reviews guideline variations and clinical outcomes, with the aim of systematically improving the guideline to better serve and support front-line teams. This group keeps track of salient new research findings in the peer-reviewed literature and incorporates proven innovations into the guideline. This same group usually leads internal "drill down" improvement efforts[6] (James, 2003).

By incorporating a clinical practice guideline into providers' routine workflow, bottom-up systems ensure that providers need not rely on their own memory. Furthermore, this process validates the guideline against actual practice; supports regular updating of the guideline to keep it aligned with best current practice; and provides transparency data to clinical teams, patients, and health care overseers. With rare exceptions, it is impossible to build a guideline that perfectly fits any patient. It is the professional duty of the physicians, nurses, pharmacists, therapists, and technicians who care for the patient to vary from protocol based on individual patient needs. In the event that variation is necessary, clinicians explain this as part of the clinical record. The ability of bottom-up data systems to identify and track outlier cases to their root causes also allows data system designers to identify and correct any errors within the data system itself (as opposed to variances in care decisions) that may be producing these outliers. This feature supports the continuous improvement of the data system, encouraging broad support and trust from front-line provisions. The result is a reduction in practice variation and continued improvement in care through the existence and operation of a continuous learning loop. An example of a civilian health system that has successfully utilized this bottom-up approach is described in Box 3-3.

Coordinated Performance Improvement and Research to Generate Evidence-Based Best Trauma Care Practices

A core aim of a learning health system is to expand and improve the supply of knowledge available to address health care questions. "The capacity for learning increases exponentially when the system can draw knowledge from multiple sources" (IOM, 2013, p. 164). Thus, a learning trauma care system derives evidence for best care practices from a combi-

[6] "Drill down" performance efforts support investigation and improvement. Knowledgeable experts propose and test data elements that might be interesting. If suggested data elements demonstrate utility, they are then merged into the larger outcomes tracking system.

Box 3-3

LEARNING SYSTEM MODEL: INTERMOUNTAIN HEALTHCARE'S BOTTOM-UP APPROACH TO CLINICAL MANAGEMENT

Intermountain Healthcare is a not-for-profit health system based in Salt Lake City. It serves Utah and southeastern Idaho with 22 hospitals and 185 clinics (IOM, 2011; James and Savitz, 2011). Through the development of bottom-up data systems and measurement for improvement, Intermountain has achieved impressive improvements in clinical quality that reduce the cost of care delivery.

A crucial component of this success was Intermountain's recognition that its existing administrative data systems were insufficient to support a bottom-up approach to clinical management. Existing systems failed to track as much as 50 percent of the data critical to managing clinical processes (James and Savitz, 2011). Using the measurement for improvement approach, Intermountain designed a data set to capture adherence to guidelines, as well as short- and long-term clinical, cost, and service outcomes. New data systems created for the purpose of clinical management were built around these data.

The development of these bottom-up data systems during the late 1990s has supported Intermountain's "shared baselines" approach to clinical management. This process begins with the identification of high-priority conditions and procedures, based on patient numbers and health risk. For each priority thus identified, Intermountain organizes a team of professionals, including physicians, nurses, technicians, therapists, pharmacists, and administrators. This group then develops an evidence-based clinical practice guideline, which is incorporated into all aspects of clinical work, including clinical workflows, information systems, training, supplies, and educational materials. Practitioners are required to use these baseline guidelines, but also are expected to adapt them to each patient's individual needs and medical history. Intermountain tracks compliance with the baseline with the goal of reducing or eliminating unwarranted variance among providers while encouraging variance based on patient needs. These standardized yet flexible standards of care allow providers to follow a default path for a clinical process while focusing on a few critical factors that may require customization of the protocol (IOM, 2011; James and Savitz, 2011).

Since the inception and expansion of this shared-baselines approach, Intermountain has documented improvements in clinical outcomes and reductions in care delivery costs. Because clinical processes are standardized, variance is measured, and clinical outcomes are monitored, routine patient care can result in new evidence about best practices. With nearly 100 percent of patients contributing to the knowledge base, Intermountain can quickly adjust the practice guidelines to reduce errors and costs while improving patient outcomes (IOM, 2011). In one of Intermountain's earliest successes—involving the management of settings on mechanical ventilators used to treat acute respiratory distress syndrome—the rate of guideline variance was reduced from 59 to 6 percent within 4 months. For the most seriously ill patients, survival increased from 9.5 to 44 percent, and the cost of care decreased by 25 percent (Morris et al., 1994). Further illustrating the cost savings made possible by this approach, Intermountain's labor induction protocol, first introduced in 2001, is estimated to reduce health care costs in Utah by approximately $50 million each year (James and Savitz, 2011).

nation of traditional research methodologies and more nimble methods for generating knowledge from patient care experiences.

Fundamental to the concept of a rapidly learning health system is the use of patient data to generate clinical evidence through a continual process of action and reflection. Such a performance improvement process begins with data acquisition and the development of information that can be analyzed and results in actions that are incorporated into systems of practice. Performance improvement is a means of producing care that is more effective, efficient, and safe by minimizing unnecessary variation in care and preventing adverse effects. Performance improvement has been incorporated into health care systems and the delivery of care as a routine and ongoing process, assisting individual providers, groups, and institutions in advancing their care practices through the use of evidence-based analysis and intervention strategies (DHB, 2015). In a learning trauma care system, registries allow near-real-time analysis of patient data for such purposes.

Rapid-cycle performance improvement processes, although critical, do not eliminate the need for formal research investigations (e.g., trials, studies) whose primary aim is to answer questions or generate new knowledge. In medicine, doing no harm is a central tenet, and in some cases, well-designed trials will be needed to show that a change in trauma care practice does not in fact cause harm. Thus, a learning trauma care system requires a robust research enterprise for the generation of knowledge to guide decisions on trauma care delivery approaches, from both the system and individual patient perspectives. This research enterprise needs to be informed by an understanding of the value and limitations of different methodologies (discussed in more detail in Chapter 4) for answering different kinds of research questions so that trade-offs in agility and strength of evidence can be weighed and the appropriate methodology employed.

Finally, the ability to share information for purposes of knowledge generation and dissemination (discussed below) is paramount to the success of a learning trauma care system. In a learning trauma care system, such information sharing is supported by technological solutions, a culture of sharing, and a conducive regulatory environment.

Processes and Tools for Timely Dissemination of Trauma Knowledge

Although the continual pursuit of new knowledge through research and performance improvement is a critical aspect of a learning trauma care system, the generation of evidence on best care practices is not sufficient to drive improvements in patient outcomes. In such a learning system, the results of these efforts are disseminated and applied at the point of care.

In a learning trauma care system, knowledge is transmitted using a combination of synchronous and asynchronous[7] methodologies. To achieve improvements in trauma care, the system does not rely on individual providers to discover, assimilate, retain, and put into practice the ever-increasing supply of clinical evidence. Instead, trauma care providers have access to clinical practice guidelines and clinical decision support tools that capture, organize, and disseminate the best available information on trauma care practices to guide decision making at the point of care and reduce unwarranted variation in care and outcomes.

In the context of trauma, where rapid problem solving can make the difference between life and death, it is critical for providers to have just-in-time, synchronous access to experts in trauma care delivery—for example, through telemedicine—who can provide guidance to address questions and challenges at the point of care. The potential benefit of such synchronous access to expert knowledge is immediately improving patient outcomes.

Systems for Ensuring an Expert Trauma Care Workforce

At the heart of all health systems are the diverse teams of skilled professionals that make up the health care workforce. Achieving the vision laid out in the IOM's (2001) *Crossing the Quality Chasm* report—health care that is safe, effective, patient-centered, timely, efficient, and equitable—requires a workforce that is "educated to deliver patient-centered care as members of an interdisciplinary team, emphasizing evidence-based practice, quality improvement approaches, and informatics" (IOM, 2003, p. 45). To this end, the IOM (2013) report *Health Professions Education* proposed core competencies that all clinicians should possess, regardless of their discipline, to meet the needs of the 21st-century health care system. These include the capability to

- ***provide patient-centered care***—identify, respect, and care about patients' differences, values, preferences, and expressed needs; relieve pain and suffering; coordinate continuous care; listen to, clearly inform, communicate with, and educate patients; share decision making and management; and continuously advocate disease prevention, wellness, and promotion of healthy lifestyles, including a focus on population health.
- ***work in interdisciplinary teams***—cooperate, collaborate, communicate, and integrate care in teams to ensure that care is continuous and reliable.

[7] Synchronous learning occurs in real time through mechanisms that give the teacher and the learner simultaneous access to one another (e.g., one-to-one coaching via phone, classroom teaching), whereas asynchronous learning allows learners to access information whenever they would like to do so, not requiring the presence of an instructor (e.g., websites, guidelines).

- ***employ evidence-based practice***—integrate best research with clinical expertise and patient values for optimum care, and participate in learning and research activities to the extent feasible.
- ***apply quality improvement***—identify errors and hazards in care; understand and implement basic safety design principles, such as standardization and simplification; continually understand and measure quality of care in terms of structure, process, and outcomes in relation to patient and community needs; design and test interventions to change processes and systems of care, with the objective of improving quality.
- ***utilize informatics***—communicate, manage knowledge, mitigate error, and support decision making using information technology. (IOM, 2003, pp. 45-46)

A learning trauma care system supports all members of the trauma care team, including prehospital and hospital-based professionals, in achieving, sustaining, and demonstrating through credentialing discipline-specific expertise but also competencies surrounding continuous learning and improvement. Education, training, and skill sustainment programs evolve as new knowledge on best trauma care practices is generated. In addition, ensuring that trauma care providers have access to a sufficient volume of patient cases supports the development of tacit knowledge, a critical component of mastering any skill.

Patient-Centered Trauma Care

In a learning health system, the central focus is on those being served. A learning trauma care system ensures patient-centeredness by structuring trauma care around the patient experience and proactively engaging patients, families, and communities. The adoption of a patient-centered approach supports the following long-term outcomes:

- "survival is enhanced and morbidity is reduced;
- humanity and individual dignity are maintained and enhanced; and
- physical, functional, and psychological recovery and [quality of life] are maximized" (Richmond and Aitken, 2011, p. 2748).

Trauma Care Structured Around the Patient Experience

From the trauma patient's perspective, an optimal care experience entails timely access to high-quality prehospital, definitive, and rehabilitative care, with seamless transitions between each of these settings to ensure that the patient's physical and psychological health care needs are met. Breakdowns in or between any components of the system can negatively affect a patient's outcome, contributing to preventable morbidity and mortality. Seamless transitions across this continuum of care can be realized only in an environment of patient-centeredness.

Similarly, ongoing and effective communication is key to an effective patient-centered environment. Multiply injured trauma patients and their families often interact with multiple specialties, and it is imperative that a single individual be charged with ensuring that the needs of patients and families are met and that they are appropriately educated about the patient's condition and treatment. The way in which news of a sudden traumatic injury or death is delivered can significantly impact how patients and family members cope with their lives moving forward. The 2nd Trauma Course was developed by the American Trauma Society to help trauma providers deliver such information in the most effective and supportive manner possible.[8]

Patient-centered trauma care focuses holistically on the needs of the individual patient, combining immediate treatment processes with attention to longer-term needs such as pain management and, importantly, emotional support (Bradford et al., 2011; Gajewski and Granville, 2006; Marks et al., 2005; Wegener et al., 2009; Williams et al., 2002). The ways in which individuals adapt psychologically to the aftermath of a significant injury vary and depend on several interrelated factors associated with personal and family resources, coping styles and self-efficacy, and resiliency, as well as barriers and facilitators in the social, economic, and physical environments. However, symptoms of depression, acute anxiety, and posttraumatic stress are common in trauma patients, and if not managed early in the recovery process, can lead to poor long-term outcomes (Hoge et al., 2004; Wegener et al., 2011; Wiseman et al., 2013; Zatzick et al., 2008). Patient-centered trauma care therefore addresses the holistic needs of patients and their families, beginning early in the acute care setting, and the trauma team plays an important role in screening for these conditions in the early post-acute phase of care and referring patients to appropriate services and programs (Coimbra, 2013).

A focus on patient needs also necessitates consideration of and adequate preparation for all the patient populations a trauma system might be expected to serve. Trauma disproportionately affects the young and is increasing in prevalence among the elderly (Rhee et al., 2014). Trauma systems and their personnel need to be sufficiently equipped, trained, and supported to provide optimal care for these patients. While the treatment of special populations is more common in the civilian sector, the military trauma system needs to be equally prepared given the frequency with which

[8] See http://www.amtrauma.org/?page=2ndTrauma (accessed February 20, 2016).

military providers deliver care for host nationals, including children, in wartime (Borgman et al., 2012; Burnett et al., 2008).

Engagement of Patients, Families, and Communities

In a trauma care system that continuously learns and delivers improved outcomes, understanding of the priorities and unique perspectives of patients, families, and communities is reflected in the system's functioning and design.

While the nature of traumatic injury often limits the extent to which patients can engage in their own care in the acute phase, opportunities for shared decision making exist in the primary care setting (e.g., prior to deployment) and in the hospital. To the degree possible, trauma patients need to be engaged in decisions about their care. To this end, they need to understand the full range of treatment options and the risks and benefits of each so that the decisions to which they contribute will accord with their values, preferences, and life circumstances. As trauma patients may be physically incapable of engaging in their own care, the greater involvement of families is a crucial component of patient-centered trauma care.

Patients, families, and other caregivers can offer a firsthand account of their experiences within a trauma care system, contributing to the identification of areas in need of improvement. A patient-centered approach ensures that this unique perspective is leveraged to further improve the functioning and design of the trauma care system. Patient and family participation in trauma research, for example, is an important feature of a learning trauma care system (Faden et al., 2013). Patients and families can help identify clinical research questions. Furthermore, this research needs to be reflective of these stakeholders' priorities and concerns, particularly in those situations where decisions involve difficult trade-offs (e.g., high upfront risk but better potential long-term outcomes). Other opportunities to engage these stakeholders at the organization and system levels include

- the development of patient and family advisory councils,
- continuous measurement of patients' outcomes and experiences, and
- patient involvement in improvement initiatives.

Leadership-Instilled Culture of Learning

Organizational culture has a significant influence on the performance of a learning system. Leadership has the unique ability to facilitate a culture of learning, to engage multiple and diverse stakeholders, and to remove barriers to improving care across an entire system, but most notably at the point of care. Clear communication of leadership's commitment to continuous improvement is critical in driving the many actors within a learning trauma care system to work collaboratively toward the common goal of improving patient outcomes. Effective leadership defines and prioritizes learning as a central mission of the trauma care system and sets quantifiable aims against which progress can continually be measured, thereby invoking a sense of urgency and motivating change in performance that might otherwise be slower to occur. Also critical is promoting a nonpunitive environment in which experimentation can be embraced in the absence of fear. To this end, it is important that leaders celebrate the generation of knowledge that emerges through small-scale testing of new concepts, innovations and ideas. In such environments, leadership expects and welcomes the questioning of standard processes, assumptions, and "business as usual" patterns of behavior. In addition, leadership will regularly study the progress of the system alongside actors in the system, creating a safe environment in which there is shared responsibility for underperformance (thus avoiding time wasted in assigning blame). Promoting a culture of teamwork, cooperation, and inclusiveness ensures that the contributions of all actors in the system are valued.

Transparency and Aligned Incentives for Quality Trauma Care

A learning trauma care system has leadership that is committed to transparency and aligns incentives to ensure that learning takes place and is sustainable, while at the same time minimizing waste and variability in practice that contribute to suboptimal outcomes. Transparency—"ensuring that complete, timely, and understandable information is available to support wise decisions"—empowers providers and organizations to improve their performance over time (IOM, 2013, p. 142). Transparency of cost and outcomes also allows patients and consumers to make informed decisions regarding their own care. There are four different, though related, forms of transparency:

- clinician-to-patient
- clinician-to-clinician
- organization-to-organization
- public (NPSF, 2015)

Clinician-to-patient transparency enhances communication, disclosure, and patient engagement in decision making. Transparency of performance between peers—both clinician-to-clinician and organization-to-organization—drives performance improvement. Drawing on data from trauma registries and other information systems, performance improvement programs in a learning trauma care system make performance information available at the provider, team, center, and system levels. Such transparency assists individual providers in understanding and improving their personal performance, as well as their contribution to the overall trauma care system (DHB, 2015; IOM, 2007). Transparency at the organization level supports the evolution and improvement of the system through benchmarking against the performance of other similar organizations.

Broadly defined, benchmarking is the "systematic comparison of structure, process, or outcomes of similar organizations" (Camp, 1989; Nathens et al., 2012, p. 443). External benchmarking compares the performance of similar institutions, provides information on whether or to what extent an institution suffers from a performance issue, and suggests reasonable goals for performance improvement (Nathens et al., 2012). Information gleaned from external benchmarking can thus be highly motivating, particularly for those centers that may not even be aware that they are performing at a suboptimal level relative to their peer institutions. Benchmarking also identifies those who have achieved superior results, enabling the identification and adoption of best practices. This knowledge and awareness of a center's performance relative to that of another center can serve as a strong incentive to improve care and outcomes in today's competitive health care environment (Nathens et al., 2012).

While transparency is an important and powerful driver of change, a learning trauma care system employs a variety of levers to encourage and reward continuous improvement. These levers include financial incentives, personal recognition (e.g., promotion, rewards), regulatory requirements, tort, and competition.

Aligned Authority and Accountability for Trauma System Leadership

Strong, visible leadership is prerequisite to creating and sustaining a learning trauma care system that supports innovation and continuous improvements in care. The success of a learning trauma care system depends on the existence of defined leadership with comprehensive authority to maintain the system's infrastructure, oversight, planning, and future development; create and enforce policy; and serve as a point of accountability. This leadership needs to be in a position to deliver the resources, support, and incentives needed to drive change and encourage continuous improvement throughout the system. Defined trauma system leadership also is necessary to ensure that the many actors and stakeholders involved in the system work together seamlessly to provide quality trauma care.

CONCLUSION

To operationalize the framework of a learning trauma care system outlined in this chapter and to assess how effectively current military and civilian systems foster learning and improvement, the committee developed the questionnaire in Box 3-4, drawing on the components described above. In the following chapters, the committee uses this assessment tool to identify ways in which the military and/or civilian systems are optimized for learning and align with the framework for a learning trauma care system described in this chapter. In the ensuing chapters, the committee also describes gaps in the military and civilian systems that hinder the delivery of optimal care to injured patients and serve as barriers to continuous learning and improvement and the translation of best practices and lessons learned within and across the military and civilian sectors. This analysis is also informed by a paper commissioned by the committee, an excerpt of which is included in Appendix D.

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Box 3-4

QUESTIONS TO DETERMINE HOW WELL A SYSTEM ALIGNS WITH THE FRAMEWORK FOR A LEARNING TRAUMA CARE SYSTEM

- Digital Capture of the Trauma Patient Care Experience
  - Are data systems interoperable so that data from multiple sources can be easily combined and analyzed? Are the data displayed in such a way that actors can detect meaningful patterns and take action?
  - Are data on overall system performance available, combining information from multiple settings and commands for the purpose of comparison and learning?
  - Are data presented only in the aggregate? Is it possible to see the data at a geographic or a team level so that actors can study and improve their own performance? Do actors at every level of the trauma care system have access to timely data on their performance?
- Coordinated Performance Improvement and Research to Generate Evidence-Based Best Trauma Care Practices
  - Are data from the care experience translated into new care policies and procedures through a top-down or bottom-up approach?
  - Does this translation happen in real time, as is the goal of some high-performing systems?
- Processes and Tools for Timely Dissemination of Trauma Knowledge
  - Do actors in the trauma care system have access to tacit, practical guidance on how to address current questions and challenges through immediate (just-in-time) connection to other system actors, experts, and peers?
  - Do actors in the trauma care system have access to the latest studies and evidence-based literature, prepared in digested and actionable formats?
- Systems for Ensuring an Expert Trauma Care Workforce
  - Is an investment made in teaching trauma system actors the fundamentals of system improvement?
  - Does the system take advantage of multiple learning methods and approaches to facilitate information exchange and learning?
- Patient-Centered Trauma Care
  - Do patients have a voice in their care decisions to the extent possible?
  - Are patients' care experiences collected and valued as a source of critical learning? Are patients and families active in teams responsible for improving care?

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- Leadership-Instilled Culture of Learning
  - Do leaders have high expectations for system performance, embracing clear, quantifiable, time-bound aims for improvement?
  - Do actors in the system actively welcome input from other relevant systems (e.g., other military or civilian systems)? Is anyone with an interest able to join their discussions?
  - Is the learning network truly distributed, with expectations for active contributions and participation from all actors, including (especially) those at the periphery?
  - Is the learning network a part of existing work systems? Does it take advantage of existing infrastructure, networks, and work patterns, or is it set up as a parallel system and staffed by different personnel?
  - Do leaders empower all actors in the system to rapidly test new ideas and apply new knowledge without permission? Are improvisation and adjustment embraced, or is permission and/or consensus required to take action?
- Transparency and Aligned Incentives for Quality Trauma Care
  - Does the trauma system have clear and measurable improvement aims, both long and near term?
  - Does the trauma system create meaningful and actionable incentives (or disincentives) for providing the best possible care? Is there undue reliance on any one incentive (i.e., "theory lock")?
  - Do leaders recognize rapid learning and system improvements in both formal ways (e.g., factoring team effectiveness at improvement into professional advancement) and informal ways (e.g., celebration when a team or system goal is met)?
  - Does the trauma care system have a mechanism for regularly sharing breakthroughs and failures? Is transparency an expectation?
- Aligned Authority and Accountability for Trauma System Leadership
  - Do leaders regularly go to the field to understand challenges in front-line care delivery and actively remove barriers to progress, or do they rely on inspection—receiving reports on progress and censuring underperformers (i.e., are data used for learning or for judgment)?
  - Is the learning network managed and administered by a central group responsible for collecting and broadcasting information?

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Part II

Assessment

4

Generating and Applying Knowledge to Improve Trauma Outcomes

In a continuously learning health system, the collection of data and their use to generate knowledge are processes embedded within the practice of medicine. The capture of patient data in trauma registries and their use in trauma center performance improvement and patient safety programs have been standard practice for decades, driven in part by the trauma center verification requirements of the American College of Surgeons. These combined processes facilitate the measurement of trauma outcomes and system performance that is essential to a continuous learning environment for trauma care. The goal of trauma performance improvement is to decrease variations from the standard of care and promote optimal trauma outcomes for each patient, thereby reducing death and disability among injured individuals. Data from registries and performance improvement processes also can inform trauma research and drive the development of new best practices.

At the start of the wars in Afghanistan and Iraq, the military adopted these civilian-sector trauma system practices in the development of its Central Command (CENTCOM) Joint Theater Trauma System, and these learning processes were later centralized under the Joint Trauma System (JTS). Through the capture, collection, and review of trauma care and patient outcome data in the Department of Defense Trauma Registry (DoDTR) and the dissemination of evidence-based clinical practice guidelines designed to reduce practice variation, the JTS works to support continuous performance improvement across the continuum of care.[1] DoDTR data also support the development of new knowledge through research, identifying clinical needs and providing direction to the military's combat casualty care research program (Pruitt and Rasmussen, 2014), which in turn informs clinical care, closing the learning loop.

Using the learning trauma care system framework laid out in Chapter 3, this chapter presents an assessment of the cyclical process—in both the military and civilian sectors—by which data are captured, new knowledge is generated and transformed into evidence-based best trauma care practices, and those best practices are disseminated within and across systems.

DIGITAL CAPTURE OF THE TRAUMA PATIENT CARE EXPERIENCE

Trauma professionals have been leaders in the early use of data to improve care at the local, regional, state, and national levels. Data have a long-standing role in improving trauma care, facilitating research and performance improvement, necessitating the incorporation of individuals with appropriate data analytic skills as part of the trauma team (discussed in more detail in Chapter 5). The collection of trauma data across the continuum of care, their accurate capture in a registry, and the ability to share them between registries and across systems is critical to the success of a learning trauma care system.

Digital Capture of Military Trauma Data

The Department of Defense Trauma Registry

Trauma registries have been a standard part of civilian trauma system development for decades; at the start of the wars in Afghanistan and Iraq, however, the U.S. Department of Defense (DoD) (with the notable exception of the 75th Ranger Regiment's Prehospital Trauma Registry; see Chapter 1) had no registry to capture trauma data. As a result, little in the way of patient data was captured during the early years of the Global War on Terror (Bailey et al., 2013). In 2005, the JTS developed the DoDTR, then known as the Joint Theater Trauma Registry (JTTR), which was modeled after the National Trauma Data Bank (NTDB) (Eastridge et al., 2009; Pruitt and Rasmussen, 2014). The DoDTR is the largest repository of combat

[1] The mission of the JTS is to "improve trauma care delivery and patient outcomes across the continuum of care utilizing continuous performance improvement and evidence-based medicine driven by the concurrent collection and analysis of data maintained in the Department of Defense Trauma Registry" (USAISR, 2016).

injury and trauma management data in history, currently containing more than 130,000 records for nearly 80,000 distinct injury events (Haut et al., 2016).[2]

Data captured in the DoDTR include injury demographics, anatomic and physiologic parameters, and trauma care processes and outcomes (Blackbourne et al., 2012). These data direct military medical research to areas of greatest need and support continuous performance improvement processes (Bailey et al., 2013; Blackbourne et al., 2012). In addition to these traditional uses of a trauma registry, DoDTR data have been key to communicating battlefield medical issues to medical and line leadership (Eastridge, 2015). A monthly theater trauma surveillance report has guided injury prevention efforts and operational decision making (e.g., aligning trauma team staffing levels and composition, as well as equipment requirements, with battlefield needs) by facilitating the provision of timely advisories to combatant commanders (Blackbourne et al., 2012). The DoDTR also has played a role in policy development. Data from the registry informed then Defense Secretary Gates's 2009 mandate that medical evacuation times in Afghanistan be reduced to 60 minutes or less (Miles, 2013).

The DoDTR is populated by manual abstraction of data from a multitude of disparate information systems that yield, among other data sources, medical records collected from different points along the continuum of care (Haut et al., 2016). There is no direct link between the electronic medical record systems and the DoDTR; data therefore cannot populate the registry through automated transmission. Although there is redundancy across the different information systems, data from different sources can be inconsistent, necessitating review of each system for optimal comprehensiveness. One noted barrier to trauma data collection has been the reluctance of data source providers to grant access to data for the entire trauma patient population (Spott, 2015). Education on the distinction between the DoDTR and the electronic medical record, as well as the value of the registry, have been necessary to overcome this barrier.

Initially, abstraction of data into the DoDTR was carried out by deployed expert teams of nurses and physicians, but since December 2014, abstraction has occurred at the JTS central site in San Antonio, Texas (Spott, 2015). With the loss of abstraction teams in theater comes the risk of data loss, as registrars cannot have the same kinds of timely discussion with care providers about each case. The abstraction process entails a number of other problems; it is error prone and requires significant financial, human, and technical resources. However, the quality of DoD registry data has been rigorously pursued. Standard data definitions were instituted in 2007 (Spott, 2015), and data integrity has been maintained through stan-

[2] These numbers are accurate as of November 6, 2015.

dard data audits. As resources have diminished with the drawdown of U.S. troops, however, the capacity of the JTS to maintain previous levels of data fidelity has diminished (Eastridge, 2015).

The JTS also has developed specialty modules within the DoDTR that include orthopedics, infectious disease, traumatic brain injury, hearing, and vision. Shared data elements and standard data definitions allow data to be ported automatically into the specialty modules from the higher-level system. However, these modules are underutilized and, more concerning, additional registries are being developed by different subspecialties independently to provide a greater level of data granularity. The committee heard testimony that linkages between registries have not been built into the front-end design of the system and thus will have to be configured on the back end (Eastridge, 2015; Spott, 2015).

Trauma Data Collection Across the Continuum of Care

The military faces unique challenges when collecting data in theater. On the battlefield, medical personnel face hostile, austere, and underresourced environments (Butler and Blackbourne, 2012; Eastridge et al., 2011b). Personnel, logistical, and tactical constraints, in combination with the absence of formal requirements and command leadership ensuring the collection of trauma data across the continuum of care, have resulted in the fragmentation of trauma patient data across multiple data systems (see Figure 4-1).

Collection and integration of prehospital data The challenges of trauma data collection are especially marked in the military prehospital setting, where operational demands hinder documentation of injuries and care delivery by medics. As a result, DoD's prehospital data collection has been suboptimal, despite evidence that the greatest opportunities for improved outcomes through changes in care are in the prehospital setting (Butler and Blackbourne, 2012; Eastridge et al., 2012). Multiple sources have noted the lack of prehospital data, from point of injury to Role 3 care[3] (Butler and Blackbourne, 2012; DHB, 2015; Rotondo et al., 2011). In an analysis of more than 4,000 casualties entered into the DoDTR from 2007 to 2010, a large majority—87 percent— had no documentation of the mechanism and location of injury, prehospital vital signs, or interventions provided prior to arriving at a military treatment facility (MTF) (Eastridge et al., 2011b; Kotwal et al., 2013b). A similar retrospective analysis of DoDTR data entered from 2002 to 2009 showed that only 18.6 percent and 25.4 percent of casualty records for OEF and OIF, respectively, contained prehospital data (Therien et al., 2011).

[3] The echelons of care—Roles 1 through 5—are described in Chapter 2 (see Figure 2-6).

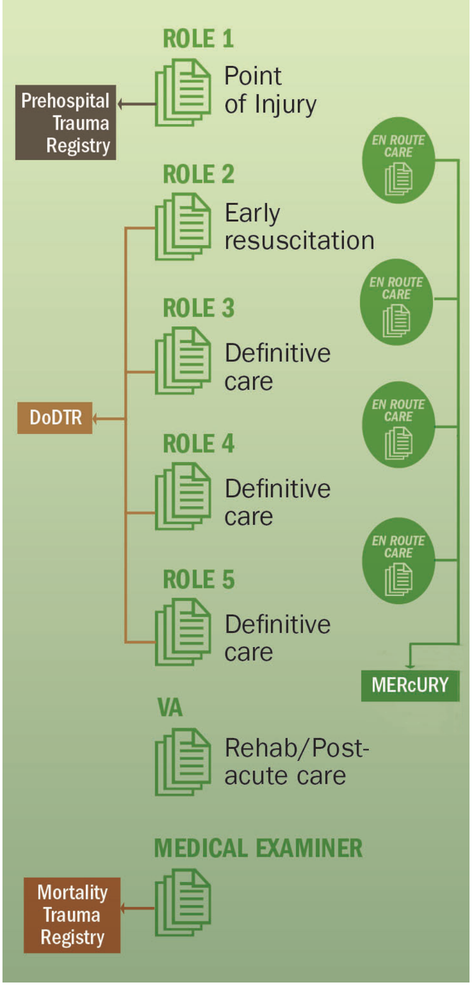

FIGURE 4-1 Digital capture of aggregate trauma patient data in multiple military data systems spanning the continuum of care.

NOTES: DoDTR = Department of Defense Trauma Registry; MERcURY = Military En Route Care Registry. MERcURY is a specialty registry integrated with the DoDTR.

One notable constraint on the collection and sharing of prehospital trauma data is the serious security concern that arises from the potential to link prehospital casualty data with military tactics, techniques, and procedures. As a result, some of these data are designated as sensitive and therefore must be kept in separate classified systems.

Despite the challenges of collecting prehospital data in the combat setting, the 75th Ranger Regiment demonstrated the feasibility and importance of doing so. In 2007, the Committee on Tactical Combat Casualty Care developed a tactical combat casualty care (TCCC) card for prehospital data collection based on the Ranger Casualty Card model (discussed in Chapter 1). The card was updated in 2013 (Kotwal et al., 2013b). Although this form has been endorsed by the Defense Health Board and adopted by DoD as the standard format for documenting prehospital care, it is not used consistently. Information assurance concerns delayed the establishment of the DoD-wide Prehospital Trauma Registry, which was finally fielded in 2013 to collect data on point-of-injury care. As of November 2015, the care records of approximately 750 patients had been entered into the Prehospital Trauma Registry (Haut et al., 2016). Yet despite a 2013 mandate requiring submission of prehospital data (Role 1) to the Prehospital Trauma Registry, documentation of prehospital care remains inconsistent as leadership mandates are not enforced (Kotwal et al., 2013b).

Collection and integration of en route care data In 2014, prehospital transport data, as well as intra- and intertheater transport data, were integrated into the DoDTR. A specialized military en route care registry (MERcURY) was created to document and support analysis of trauma care provided during patient transport by all modes (ground, air, water) (Haut et al., 2016).

Collection and integration of hospital-based acute care data Initially, data were collected for the DoDTR solely from in-theater Role 3 MTFs. Role 4 (Landstuhl Regional Medical Center) data were incorporated starting in 2007, followed by Role 2 (e.g., forward surgical teams) and Role 5 (U.S.-based military hospitals) data in 2008. However, the DoDTR inclusion criteria prior to 2013 required admission to a Role 3 MTF. For those casualties who received care at the Role 2 level and required evacuation to a Role 3 MTF, data on care provided at both the Role 2 and Role 3 facilities were abstracted into the DoDTR, when paper charts from Role 2 were available. Those casualties who did not require evacuation to a Role 3 MTF or who died at a Role 2 facility were therefore not abstracted into the DoDTR; rather, care provided to those patients was abstracted into a separate voluntary Role 2 database, funded as a research study by the U.S. Army Medical Research and Materiel Command (MRMC) (Haut et al., 2016). The U.S. forces commander in Afghanistan mandated prehospital documentation in 2013; however, DoD still has no mandate for Role 2 data collection, so capture of patient data from Role 2 sites has been suboptimal (Kotwal et al., 2016). Such data have been submitted intermittently and on a voluntary basis, primarily by providers who believed in the value of the registry—a "coalition of the willing" (Spott, 2015). In contrast, the data for Role 3 facilities are nearly complete.

Collection and integration of rehabilitation and post-acute care data For many severely injured military trauma patients, return to duty is not possible, and the patient is discharged from military service. At that point, the patient's rehabilitative and post-acute care becomes the responsibility of the U.S. Department of Veterans Affairs (VA), a civilian federal agency that operates independently from DoD. Consequently, the vast majority of long-term outcome data for patients treated by the military trauma system resides within the VA. At this time and despite extensive discussion dating to 2006, VA data have not been integrated into the DoDTR. As a result, a paucity of long-term outcome data (including quality-of-life indicators) is available with which to evaluate effects of acute phase interventions and inform performance improvement activities (Spott, 2015).

Collection and integration of Armed Forces Medical Examiner System data For service members killed in action (those who die before reaching an MTF), little to no data may be captured in the DoDTR. Whenever possible, all U.S. combat fatalities are recovered and transferred to the Armed Forces Medical Examiner System (AFMES) for forensic examination. AFMES data are entered into the DoD Mortality Trauma Registry, which enables analysis of service member deaths for trends and modifiable risk factors to inform improvements in equipment, tactics, and casualty care (DHB, 2015). At present, the DoDTR and the Mortality Trauma Registry are and must remain unlinked because of the sensitive nature of mortality data. Although AFMES data have been shared with JTS personnel to enable case-specific studies of preventable trauma deaths (Eastridge et al., 2011a, 2012; Holcomb et al., 2007; Kelly et al., 2008), data sharing is the result of collaborative collegial arrangements, not formal systems for such interface (Spott, 2015). Monthly case reviews of combat trauma deaths by JTS and AFMES personnel have supported performance improvement (DHB, 2015).

Sharing of Patient Data Along the Continuum of Care[4]

Throughout the wars in Afghanistan and Iraq, patient information from the point of injury to the initial MTF was transmitted primarily by verbal report from the flight medic to the receiving providers. In only 7 percent of cases could a TCCC card be identified in the medical chart. Records

[4] This section draws on information included in the dismounted complex blast injury case study submitted to the committee by DoD (see Appendix A).

from the Role 2 facility were copied and transferred physically with the casualty to the Role 3 MTF. Once the theater of operations became mature, nearly all Role 2 facilities had computers that could link to the Theater Medical Data Store, where medical records are stored. Data entries into the electronic medical record by Role 2 providers were eventually available to providers at Role 3 facilities, where information technology support was much more robust. However, because of bandwidth limitations and periods during which the Internet was blocked as a result of operational security concerns, the use of a hard-copy medical record often remained the most reliable means of ensuring that Role 3 providers received information regarding patient injuries and clinical care previously provided. Hard-copy medical records transferred with the patient were similarly useful to Critical Care Air Transport Teams during the 8- to 10-hour evacuation out of theater.

The reality of patient data sharing and access falls far short of the potential offered by current technology (see Annex 4-1 for an example of optimal data sharing across the continuum of care). Robust systems for both real-time data access and digital capture of care exist and have been implemented successfully in limited cases in the civilian sector. The barrier is one of will.

Digital Capture of Civilian Trauma Data

Civilian-Sector Trauma Registries

In the civilian sector, trauma data are captured in registries and other data repositories at multiple levels. Data roll up from individual trauma centers or emergency medical services (EMS) agencies and ultimately are aggregated in the National EMS Information System (NEMSIS) project's National EMS Database (prehospital data) and the NTDB (trauma center data).

The NEMSIS project's National EMS Database, funded by the National Highway Traffic Safety Administration (NHTSA), is the largest collection of prehospital trauma data in the United States. Submission of data to the National EMS Database is voluntary but in 2014, the registry contained nearly 26 million EMS activations submitted by more than 9,600 EMS agencies serving 48 states and territories (Haut et al., 2016). For participating agencies, submission will be automated under the newest version of NEMSIS (Version 3); once a patient care record is complete and has been closed by the local EMS agency, the electronic record is immediately exported to the state repository. A subset of national data elements is then sent from the state repository to the National EMS Database. Data from the National EMS Database are made publically available, and state and local EMS agencies increasingly use these data to conduct population health investigations and develop performance metrics (Haut et al., 2016). However, the use of these data is limited by the absence of any identifying information in the National EMS Database. While the absence of private information as defined by the Health Insurance Portability and Accountability Act (HIPAA) enables the exchange of information from the local to state to national level, it hinders the ability to associate multiple records over time for the same patient. In addition, the lack of geographic measures makes it impossible to conduct geographic analysis (Haut et al., 2016).

In the hospital setting, all trauma centers utilizing the American College of Surgeons' trauma center verification process are required to input data into their centers' trauma registries. As in the military, these trauma registries are populated primarily through manual abstraction of hospital medical records. Submission of hospital trauma registry data to the NTDB also is required for American College of Surgeons trauma center verification. Initiated in 1989 by the American College of Surgeons Committee on Trauma, the NTDB is by far the largest aggregation of civilian hospital trauma registry data, containing more than 6 million records (ACS, 2015). Trauma centers not verified by the American College of Surgeons (i.e., state-designated hospitals) can also submit their data. As of 2015, most Level I (237) and Level II (259) trauma centers were submitting data to the NTDB, although participation of Level III and IV centers was much lower (189) (ACS, 2015; Eastman et al., 2013). A National Trauma Data Standard (NTDS) Data Dictionary helps ensure standard data collection across hospital registries. While the NTDB includes a wealth of information on the acute phase of hospital care for trauma patients, however, it does not include additional data on any delayed complications.

Trauma Data Collection Across the Continuum of Care

The civilian sector faces challenges in aggregating trauma data similar to those experienced by the military, particularly across the phases of care that take place outside the trauma center (see Figure 4-2). As in the military, the civilian sector suffers from missing prehospital data and, with the exception of a few states, its prehospital data do not link to hospital data (Yee, 2015).

Collection and integration of prehospital data In the civilian sector, EMS captures patient data and transmits a record of care to hospital providers using paper or electronic patient care records (Landman et al., 2012). Prior to 2000, little had been accomplished to standardize the collection of prehospital data in the civilian sector. Initiated in 2001, the NEMSIS project

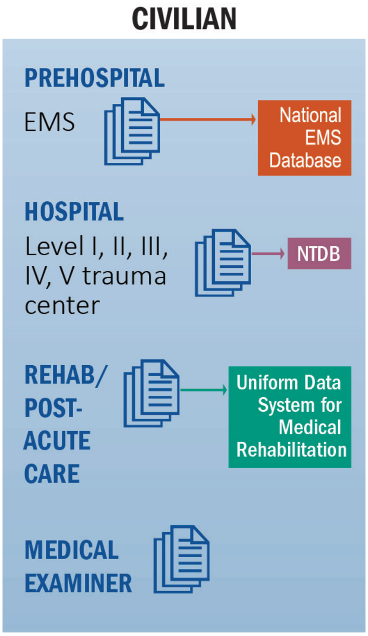

FIGURE 4-2 Digital capture of aggregate trauma patient data in multiple national-level civilian data systems spanning the continuum of care.

NOTE: EMS = emergency medical services; NTDB = National Trauma Data Bank.

developed a data standard.[5] While each local EMS agency has flexibility as to the elements it chooses to collect from the NEMSIS standard, it must include those mandated by the state and required by NEMSIS. Since NEMSIS was initiated, data from an estimated 87 percent of all 911-activated EMS responses have been collected (Haut et al., 2016). However, the NEMSIS project's National EMS Database does not adequately capture interfacility transfers, critical care transfers, and air medical care.

In addition, registries containing prehospital data are rarely linked to hospital trauma registries at the regional or state level, limiting the extent to which trauma care across the continuum can be analyzed. Although rarely implemented, these linkages are feasible, as demonstrated in a recent study by Seymour and colleagues (2014). In that regional effort, more than 95 percent of EMS records from 33 agencies were successfully linked to hospital electronic medical records within a nine-hospital single system

[5] NEMSIS replaced a smaller prehospital EMS data set (81 elements) developed by the National Highway Traffic Safety Administration in 1994 (NEMSIS, 2013).

in southwestern Pennsylvania, and more than 80 percent of EMS records were linked to long-term outcomes (2-year mortality). This effort offers a scalable model for supporting research and performance improvement at the state/regional level, as well as the eventual testing of financial incentives and reimbursement models for value-based EMS care delivery (Seymour et al., 2014).

Collection and integration of hospital-based data The collection and integration of civilian hospital-based trauma care data improved dramatically with the introduction of the National Trauma Data Standard by the American College of Surgeons Committee on Trauma in 2009. This standard for hospital trauma data collection was developed to avoid variability in data abstraction and reporting among trauma centers, and enables harmonization of data elements common to both NEMSIS and the NTDB. While the NTDB captures trauma data from all American College of Surgeons–verified trauma centers and a number of state-designated trauma centers, it does not capture trauma data from non-trauma center hospitals or state-designated trauma centers not voluntarily submitting their data. This is problematic in that it limits the extent to which it is possible to assess and compare outcomes after injury across all hospitals (trauma and non-trauma center). Furthermore, NTDB data are not linked to outpatient clinic visits, rehabilitation center admission data, or VA data (Haut et al., 2016).

Collection and integration of rehabilitation and post-acute care data Given that the vast majority of patients who sustain a traumatic injury will survive, maximizing an injured patient's chances of recovering lost function through timely access to rehabilitation services and post-acute care is essential. Unfortunately in the civilian sector, rehabilitation and post-acute care have been identified as the weakest link in a trauma system (Eastman et al., 2013). Data on rehabilitation and post-acute care are neither comprehensively collected[6] nor integrated with prehospital and hospital data, severely limiting the ability to conduct longitudinal analyses of patient outcomes across the continuum of care and to conduct system-wide performance improvement efforts.

Collection and integration of coroner and medical examiner data The NEMSIS project's National EMS Database and the NTDB provide excellent

[6] The Uniform Data System for Medical Rehabilitation, developed with support from the National Institute on Disability and Rehabilitation Research, represents one example of a database for rehabilitation outcomes. Data are aggregated from rehabilitation hospitals, long-term-care hospitals, skilled nursing facilities, as well as pediatric and outpatient rehabilitation programs (Granger et al., 2010).

sources of aggregated prehospital and hospital trauma data for analysis. There are, however, additional sources of data that can be used to gain a more complete understanding of a patient's care and outcomes across the trauma care continuum. In the military, all service members who die as a result of battle injuries are autopsied to derive information that can be used to improve clinical performance and prevention measures (e.g., change in personal protective equipment). No comparable effort exists in the civilian sector and as a result, little is known about the timing (phases of care) and predominant causes of preventable civilian trauma deaths. The civilian sector would benefit from additional studies of preventable trauma deaths, particularly in the prehospital setting. One study determined the number of preventable prehospital trauma deaths within a single county (Davis et al., 2014); however, this was a rare effort. A common lexicon also is needed to ensure that such analyses are comparable.

Sharing of Patient Data Along the Continuum of Care

The promise of technology has yet to be fully realized for and globally integrated into trauma care. As a result, data from care delivered earlier in the continuum are not reliably available to downstream providers, either for immediate care of the individual patient or in the aggregate for performance improvement or research purposes. Some EMS agencies have equipped their ambulances with GPS-enabled tablet computers that can capture time-stamped vital signs and procedures. However, these data often cannot be submitted electronically to hospitals en route or downloaded directly into the hospital electronic medical record or trauma registry once EMS providers arrive at a trauma center. The computer-generated documentation may need to be printed, scanned into a nonsearchable medical record at a later date, and then reabstracted by a trauma registrar, a process that compromises data fidelity and fails to provide the trauma team immediate access to the information. There are few federal or state incentives to integrate EMS data into electronic medical records (Haut et al., 2016). Gaps in communication are also evident between trauma centers, for example, during interfacility transfers.

Barriers to Data Sharing Within and Between Military and Civilian Data Systems

Complete and accurate collection of patient-level data across the continuum of trauma care is necessary but insufficient to enable the surveillance, performance improvement, and research required to sustain an effective learning trauma care system. To generate information on the effectiveness, quality, and value of care provided, data must also be shared across information systems. Both the military and civilian systems suffer from serious gaps in the extent to which data are, or even can be, integrated and shared across systems. For example, although national-level data repositories for both the prehospital and hospital settings have emerged, these systems are not reliably linked with each other or with the DoDTR (see Table 4-1).

Linkage of Military and Civilian Systems

The DoDTR was intentionally designed using the contemporary standards on which both NEMSIS and the NTDB are based, in many cases employing the same data fields and basic data collection techniques. This alignment was intended to facilitate the transfer of lessons learned from the battlefield to the civilian environment and then back from the civilian environment to the military trauma system (Eastridge, 2015). However, the potential for this transfer of information remains largely unrealized, despite the great potential research benefit of wider access to the wealth of trauma data collected over nearly 15 years of war. Currently, the DoDTR does not link to the civilian prehospital (the NEMSIS project's National EMS Database) or hospital-based (NTDB) data registry, in part because of operational and security concerns that have limited the DoD's ability to share its data with the civilian sector (Spott, 2015).

Data sharing between DoD and the VA represents a special case of data sharing between the military and civilian sectors, with the challenge arising from the patient's movement from the military to a civilian system. The failure to link DoD and VA data has been criticized repeatedly (Maldon et al., 2015), with lack of political will being identified as the most significant barrier to such linkage. To facilitate integration of VA data into the DoDTR, abstractors within the VA system could be given access to the DoDTR to port in patient-level rehabilitation and long-term outcome data, but this issue has not been addressed with any sense of urgency (Spott, 2015). Notably, patient data are transferred from DoD to the VA when patients change veteran status so barriers to data sharing appear to be largely unidirectional in nature.

Barriers to Data Sharing Within and Among Trauma Systems

Multiple, significant barriers impede the sharing of trauma data within and among trauma systems. Political and jurisdictional barriers (e.g., between municipal agencies, organizations, and disciplines) continue to delay data sharing. Technical barriers, although surmountable with existing technology, also play a role. Because data collection processes have generally not been designed with the goal of linking data, after-the-fact methods are

TABLE 4-1 Current Major Trauma-Specific Data Repositories in the United States

	NTDB	NEMSIS	JTS DoDTR and JTS PHTR
Owner	ACS COT	NHTSA	JTS
Time frame	In-hospital only	Prehospital only	Prehospital (Role 1); prehospital and inter-facility transport; hospital (Roles 2, 3, and 4)
Can data be collected electronically/imported from existing patient care records?	Yes for some elements, no for others	Yes	Yes, has this capability, but is limited by TMDS expeditionary framework
How much coverage by percentage of patients?	Moderate (all ACS COT trauma centers); in 2015, 746 hospitals submitted data to the NTDB: 237 Level I, 259 Level II, 189 Level III or IV centers, 36 Level I or II pediatric-only centers (ACS, 2015)	Near complete (includes an estimated 87 percent of all 911-activated EMS responses occurring in the United States)	100 percent for those admitted to a Role 3 facility that met inclusion criteria of DOA, DOW, transfer, admit of ICD-9 code 800-995 when JTTS teams were in combat theater; near complete for OCONUS combat and noncombat casualties; nominal for CONUS noncombat casualties

required to link independent data sources, a process that demands significant time and effort.

Effective data sharing requires universally accepted standards that provide consistent formats and meanings for data shared among different information systems. Abstraction allows for data system tailoring but results in nonstandard definitions and hence difficulty with sharing and comparing data across independent systems. Electronic data export is an efficient and technologically advanced process that offers reduced errors and real-time data transmission and availability. With electronic data transmission, information systems can be designed so that data capture is integrated seamlessly into the provider workflow. DoD is currently in the process of implementing a new electronic medical record system, providing an opportunity to design the new system using a bottom-up approach, as described in Chapter 3

TABLE 4-1 Continued

What are the coverage gaps?	Only trauma centers; covers a small percentage of Level III/IV trauma centers and does not cover non-trauma center hospitals; only index hospitalization—does not capture readmissions and long-term outcomes; does not include patients seen and discharged from emergency department; does not link data for transfers (cannot tell it is the same patient who left a Level III center and arrived at a Level I center); no prehospital deaths	Does not adequately capture interfacility transfers, critical care transfers, and air medical care; covers only patients transported by EMS; no data on patients transported by "self" transport mode or police vehicle	2012: mandate for Role 2 data, retrospective entry occurring now 2012: initiated Trauma Infectious Disease Outcome Study (TIDOS) module 2013: started including prehospital (Role 1) data 2013: initiated military orthopedic trauma registry (MOTR) module 2015: started including rehabilitation facility (VA) data 2015: initiated acoustic module

NOTE: ACS COT = American College of Surgeons Committee on Trauma; CONUS = continental United States; DOA = dead on arrival; DoDTR = Department of Defense Trauma Registry; DOW = died of wounds; EMS = emergency medical services; ICD = International Classification of Diseases; JTS = Joint Trauma System; JTTS = Joint Theater Trauma System; MOTR = military orthopedic trauma registry; NEMSIS = National EMS Information System; NHTSA = National Highway Traffic Safety Administration; NTDB = National Trauma Data Bank; OCONUS = outside the continental United States; PHTR = Pre-Hospital Trauma Registry; TIDOS = Trauma Infectious Disease Outcome Study; TMDS = Theater Medical Data Store; VA = U.S. Department of Veterans Affairs.

SOURCE: Adapted from Haut et al., 2016.

(Garamone, 2015). Use of this approach would enable seamless data capture, including data export into the DoDTR, and support the integration of data into the provider workflow to support continuous improvement and learning. Although some civilian health systems (e.g., Intermountain Healthcare) utilize this bottom-up design and have developed an electronic data export mechanism to populate disease-specific registries (James and Savitz, 2011), most civilian trauma systems rely on manual data abstraction by registrars. Additionally, federal regulations pose multiple barriers to the use and sharing of registry data, particularly for performance improvement (discussed in more detail later in this chapter). No regulations cover the use of preexisting registry data for operational analysis—for example, to examine workflow or numbers of patients to improve a hospital's efficiency or plan staffing and budgets. Researchers and institutions often have cited HIPAA as the reason for failing to share data. Yet the committee heard testimony that HIPAA does not limit the ability to share data as long as the appropriate business use agreements are in place (Heide, 2015). It is clear that at present, significant confusion surrounding HIPAA limits the willingness of researchers and institutions to share data, both between and within the military and civilian sectors, and guidance on how to be HIPAA compliant when engaging in both research and performance improvement activities would be of great benefit.

The barriers discussed above—political, operational, technical, and regulatory—all limit the extent to which data can be shared in a learning trauma care system. Inadequate data sharing in turn impedes research and performance improvement, limiting the extent to which new knowledge can be generated and providers/systems can continuously learn from each other to improve care and outcomes for traumatically injured patients. Seymour and colleagues (2014), who successfully linked prehospital and hospital data in southwestern Pennsylvania, propose a number of solutions to address specific policy, technical, and regulatory challenges that may limit the linking of data sets and their subsequent use for research (see Table 4-2).

TABLE 4-2 Barriers and Solutions to Linking Prehospital Data to Hospital Data for Research Use

OBSERVED BARRIERS	POTENTIAL SOLUTIONS
EMS records may not be electronic or uploaded into receiving hospital medical records.	Strive towards NEMSIS compliant, electronic prehospital records across all EMS agencies that are automatically uploaded to the receiving hospital records at completion.
Prehospital databases may lack capability to be sorted, cleaned, and queried.	Consider proprietary software or local programmers to develop relational databases suitable for cleaning, queries, and linking.
EMS agencies lack Data Use Agreements (DUAs) with researchers to participate in studies.	Multi-disciplinary process across university, health system, EMS agency, and legal to develop local DUAs generalizable for others.
Unable to access EMS records for patients outside of health system partnership.	Establish DUAs in advance of research questions, perhaps with regional or statewide mandates.

NOTE: DUA = data use agreement; EMS = emergency medical services; NEMSIS = National EMS Information System.

SOURCE: Reprinted with permission of John Wiley and Sons, from Seymour et al., 2014.

COORDINATED PERFORMANCE IMPROVEMENT AND RESEARCH TO GENERATE EVIDENCE-BASED BEST TRAUMA CARE PRACTICES

Expanding and improving the supply of knowledge is a critical component of a learning trauma care system. Empirical support for best care practices is essential to such a system, as it is to a system for any other serious disease or condition. Facing an unprecedented burden of injury during the wars in Afghanistan and Iraq, the military adopted a nimble approach to evidence generation as part of the learning cycle, termed *focused empiricism* (see Box 4-1). Evidence and insights derived from the military's use of this approach have led to the generation and modification of clinical practice guidelines, the identification of questions requiring further research, and the transfer of innovative care practices to the civilian sector (an example is damage control resuscitation, described in Box 4-2). Focused empiricism is part of a learning process that involves determining whether empirical gaps in care exist, and if so, how best to address them. The concept is an integral and pivotal component of the Military Health System's requirements-driven approach to trauma care evaluation and improvement, the urgency of which is magnified by the devastating effects of enemy weaponry improvisation on the battlefield.

The Military Health System recognizes the importance of obtaining the highest-quality information possible. When feasible, clinical practice guidelines are supported by rigorously acquired data. Infrastructure developed for the primary purpose of performance improvement (e.g., trauma registries) can enable retrospective, outcome-based analyses to identify best practices in trauma care, often driven by provider experiences and observa-

Box 4-1 **THE MILITARY'S FOCUSED EMPIRICISM APPROACH TO LEARNING AND CONTINUOUS IMPROVEMENT**

Empiricism is the theory that important knowledge can be derived from experiential learning. Focused empiricism is a concept embraced by U.S. military medical leadership to capture its approach to process improvement under circumstances in which (1) high-quality data are not available to inform clinical practice changes, (2) there is extreme urgency to improve outcomes because of high morbidity and mortality rates, and (3) data collection is possible (Elster et al., 2013). A key principle of focused empiricism is using the best data available in combination with experience to develop clinical practice guidelines that, through an iterative process, continue to be refined until high-quality data can be generated to further inform clinical practice and standards of care.

Box 4-2 CASE STUDY: DAMAGE CONTROL RESUSCITATION

Case

While on patrol, a 29-year-old soldier suffered traumatic amputation of his left leg and severe injury to his right leg. A medic on the field immediately administered several treatments, including tourniquets. During evacuation, the medics on the helicopter started transfusions of both red blood cells (RBCs) and plasma in a balanced manner, following the damage control resuscitation (DCR) approach designed to address both shock and the early coagulopathy of trauma.

Learning Context

Early approaches to resuscitation in the military were based on the civilian Advanced Trauma Life Support (ATLS) paradigm for acute trauma care, but were quickly found to be inadequate for battle. The standard ATLS approaches were likely worsening acidosis and coagulopathy in soldiers (Palm et al., 2012a). Early in the war (2004 time frame), the military, which has the opportunity to observe a high number of severe traumatic injuries in a short period of time, began to generate data supporting the alternative DCR approach.

Notably, the military did not pursue the traditional academic model of slowly developing evidence and disseminating knowledge about DCR over several decades. Instead, change in practice was champion-driven, relying on data from the Department of Defense Trauma Registry (DoDTR) showing the positive impact of this change (Borgman et al., 2007; Spinella and Holcomb, 2009). The change was also supported by concomitant research in the civilian sector. Two large-scale trials, for example—the 2013 Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) cohort study (Holcomb et al., 2013) and the 2015 Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) randomized controlled trial (Holcomb et al., 2015b)—provided strong, high-quality evidentiary support for early, balanced massive transfusion ratios.

tions in the field. Flexibility in the types of evidence collected and used to guide clinical care (e.g., trauma registries, retrospective chart reviews, observational studies) is imperative. In some areas of evolving care, however, use of such rigorous evidence is limited by, for example, infrequent injury types or nonstandardized approaches to care due to variable injuries and circumstances.

Focused empiricism is a useful and necessary feature of a learning trauma care system in both military and civilian settings, particularly in urgent circumstances when rapid advances in care are required. However, a balanced approach is important. Unchecked focused empiricism can be risky, and a risk-benefit analysis using best available data is important before implementing changes based on a focused empiricism approach. In

In just a few years, translation of DCR to civilian practice has shown encouraging progress. A number of national surveys suggest that military data supporting DCR have significantly altered civilian practice. A survey of trauma centers participating in the American College of Surgeons Trauma Quality Improvement Program found that mass transfusion protocols in the majority of centers (79 percent) follow DCR principles, including a high plasma:RBC ratio (Camazine et al., 2015). In a separate survey of trauma medical directors, 67 percent of respondents reported the use of a 1:1:1 ratio of RBCs:plasma:platelets in massive transfusions (Haider et al., 2015). Additional survey data led researchers to conclude that exposure to providers previously affiliated with the military along with demonstrated benefits in the civilian literature had contributed to the civilian uptake of DCR.

Lesson

DCR has enjoyed successful translation from military to civilian practice. Improvement in transfusion practices was initially spurred by provider experience, facilitated by data collected from the DoDTR and later validated by prospective civilian research studies. This research process ensured that innovations founded on combat experience were supported by high-quality research data, validating battlefield observations. This pathway can and should be leveraged to enhance civilian-sector awareness and, where appropriate, adoption of other battlefield innovations, including application of tourniquets, use of hemostatic agents, and many others.

SOURCE: This box draws on the dismounted complex blast injury case study in Appendix A, except where other citations are noted.

addition, it remains important whenever possible to acquire high-quality evidence more systematically; the history of medicine includes numerous cases in which systematic, formal research has refuted observations and expected outcomes. For example, colon injuries were treated by colostomy for decades based in large part on military experience from World War II (Causey et al., 2012). However, an unblinded randomized trial in 1979 initiated a shift in practice that was later validated by several higher-quality studies in the 1990s showing that primary repair of colon injuries was a safe and effective alternative (Chappuis et al., 1991; Sasaki et al., 1995; Stone and Fabian, 1979). In 1998, the Eastern Association for the Surgery of Trauma changed its practice management guidelines in support of primary repair for nondestructive colon wounds (Pasquale and Fabian, 1998).

The application of focused empiricism in the civilian world could undoubtedly be of great value, but again, it is equally important to develop high-quality data systematically. Hypothesis-driven research remains a necessary source of evidence to complement the experiential learning that characterizes focused empiricism. When it is timely and feasible to design a clinical trial and randomize, researchers need to carefully consider what ought to be included in the control (nonintervention) arm of the study. In the Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) trial, for example, researchers were unwilling to compare the previous, lower standard ratio of blood products due to the loss of equipoise from empirical experience with newer, higher ratios of blood products for patients with life-threatening bleeding. As a result, the trial compared only high to very high ratios (Holcomb et al., 2015b).

Experiential Learning

The length of time needed to generate evidence using traditional research methods poses significant problems in the wartime context. In the United States, estimates from some studies suggest that just 10-20 percent of clinical decisions are adequately informed by formal evidence generated by clinical research (Darst et al., 2010; IOM, 1985). The trauma community has long been a leader in the use of registry-driven performance improvement to advance best trauma care practices. In the late 1980s, for example, data from 139 North American hospitals were pooled as part of a large-scale effort to examine outcomes of care for injured patients (Champion et al., 1990). The military, driven by the urgency of reducing substantial numbers of battlefield deaths, has expanded this approach so that observations and experience in the clinical setting drive the generation of new knowledge.

Military Sector

Traditional research methodologies, including randomized controlled trials, are expensive and time-consuming (IOM, 2013). In the context of trauma research, an exception from informed consent would be required in most instances which, while possible, would be difficult, time-consuming, and ethically challenging to achieve in a military trauma setting. Given these challenges, traditional hypothesis-driven research does not provide the urgent solutions needed in a combat setting. Recognition of this fact, combined with the commitment of military providers to deliver the best possible care, encouraged military medicine to adopt a fundamentally different approach to trauma care. It is important that this focused empiricism approach, in which more flexible and timely methods are used in generating evidence to inform best practices in care, remain a paradigm of military medicine.

This process is often initiated by providers' experiences in the clinical setting and followed by observational studies or retrospective analysis of registry data to support or refute the evidence generated by those experiences. In this context, data from the DoDTR or hospital registries are at the core of the military's use of focused empiricism, allowing investigators to mine the trauma registry to identify injury trends and differences in patient outcomes. This approach has produced dozens of peer-reviewed papers (see selected examples in Table 4-3) and led to numerous improvements in care—and even breakthroughs (e.g., damage control resuscitation; see Box 4-2)—over the course of the wars in Afghanistan and Iraq.

Once generated, this evidence is integrated into JTS clinical practice guidelines and performance improvement processes at the local and system levels (Eastridge et al., 2010). These "tight decision-making cycles"—in which the identification of a problem is swiftly followed by data collection and analysis and the dissemination of corrective action—work to continuously refine and improve care practices in the combat setting (DHB, 2015). The military's experience with hemostatic agents (e.g., QuikClot) provides a useful example of the importance of continuous monitoring of patient data when changes in practice are made using a focused empiricism approach. The zeolite powder form of the QuikClot hemostatic agent was replaced

TABLE 4-3 Examples of Registry-Driven Retrospective and Observational Studies

Topic	Project	Published Research
Damage control resuscitation	Retrospective chart review—high ratio (1:1.4) of plasma to red blood cells associated with improved mortality (odds ratio 8.6, 95% confidence interval [CI] 2.1–35.2) (see Box 4-2)	Borgman et al., 2007
Tourniquets	Observational study—tourniquet use in the absence of shock strongly associated with survival (90% versus 10%; $p < 0.001$)	Kragh et al., 2009
Hypothermia	Retrospective review of registry data from 31st Combat Support Hospital—hypothermia found to be an independent predictor of mortality (odds ratio 3.8, 95% CI 2.1–6.9, $p < 0.05$)	Arthurs et al., 2006
Fasciotomy	Retrospective chart review—fasciotomy revision associated with a nearly fourfold increase in mortality (20% versus 6%, $p < 0.01$) and delayed fasciotomies associated with twice the rate of major amputation (31% versus 15%) and a threefold higher mortality (19% versus 5%, $p < 0.01$)	Ritenour et al., 2008

with an alternative combat gauze after a number of case reports associated zeolite use with thermal injury (McManus et al., 2007).

The application of this strategy is further demonstrated in the military's use of performance improvement initiatives to minimize complications related to traumatic injury. The DoDTR tracks more than 80 complications from point of injury through either death or discharge from an MTF (Palm et al., 2012b). In monitoring common posttraumatic complications, the JTS is able to assess emerging trends related to those complications and drive changes in provider care and system processes to reduce complication-related mortality and morbidity. The impact of these system interventions is then measured and used to identify "potential practices for future [performance improvement]" (Palm et al., 2012b, p. S465). Performance improvement initiatives related to three complications—extremity compartment syndrome, venous thromboembolism in amputation patients, and ventilator-associated pneumonia—highlight the unique features of the military's performance improvement process (Palm et al., 2012b) (see Box 4-3).

The military has successfully used rapid-cycle performance improvement processes to advance care and improve outcomes related to hypothermia, compartment syndrome, burn care, and hemorrhage (to name a few) (Blackbourne, 2009; Ennis et al., 2008; Palm et al., 2012a). Yet despite these successes, this alternative approach to knowledge generation has not been optimized within the military trauma system. Performance improvement depends upon accurate and complete data collection; as discussed in the previous section; however, data acquisition across the trauma care continuum is neither standardized nor centralized. Moreover, the existing performance improvement process is fragmented. While the JTS can and does support performance improvement activities, it does so in CENTCOM alone. Within CENTCOM, the awareness, implementation, and integration of these processes at the local level and across the various levels of care and services vary extensively (DHB, 2015; Rotondo et al., 2011).

Civilian Sector

Although less acknowledged, experiential learning is utilized in a similar fashion in the civilian sector, particularly when no high-quality evidence is available to guide best practices. This is the case in pediatric trauma, for which focused empiricism must be used to determine best practices for operative techniques and resuscitation because of the lack of clinical trial data. More generally, the publication of case reports and use of mortality and morbidity reviews, for example, represent efforts to learn from anecdotal experiences. However, the civilian sector is not driven by the same sense of urgency that motivates the military's flexibility in its reliance on experiential learning. Rather, the civilian sector's use of focused empiricism

Box 4-3 MILITARY PERFORMANCE IMPROVEMENT INITIATIVES RELATED TO THREE COMPLICATIONS

Extremity Compartment Syndrome

In the event of extremity compartment syndrome, the timely performance of a fasciotomy is intended to reduce complications and increase functional outcomes for affected patients. Delayed or incomplete fasciotomies can result in a two- to four-fold increase in mortality (Ritenour et al., 2008). Data collection in theater enabled evidence-based training for providers and subsequent research to establish best practices. Between 2006 and 2008, following establishment of the Joint Theater Trauma System, the rate of fasciotomy more than doubled, while the incidence of compartment syndrome dropped from 55.7 to 9.8. After the Joint Trauma System (JTS) clinical practice guideline for compartment syndrome and fasciotomy was published in 2009 and the accompanying education campaign was conducted, the rate of compartment syndrome fell by approximately 40 percent and the rate of fasciotomy increased by 40 percent. Although concerns have been raised regarding prophylactic fasciotomy generally (Dover et al., 2012), the balance of risks and benefits must be placed within the context of far-forward surgery in an austere environment, other coexisting injuries, expertise, the tactical environment, evacuation times, and the number of concurrent casualties.

Venous Thromboembolism (VTE) in Amputation Patients

VTE is a complication common in patients who have undergone amputation. The 2010 increase in amputations to record-high levels for the wars in Afghanistan and Iraq, as well as concerns voiced by physicians that the rate of VTE was increasing, prompted the launch of a 20-month system performance improvement initiative to determine what risk factors, if any, might be contributing to this increase. The results of that performance improvement review, including the potential association of massive transfusion with deep vein thrombosis, led to a more formal and extensive performance improvement initiative.

Ventilator-Associated Pneumonia (VAP)

In accordance with National Trauma Data Bank and the Centers for Disease Control and Prevention definitions, the annual rate of VAP per 1,000 ventilator days was calculated for 2003-2011. However, given patient movement along the trauma care continuum, an incidence of VAP could not be assigned to a specific role and was underreported. In 2011, a group of JTS and Landstuhl Regional Medical Center performance improvement staff identified that the VAP data collection definition should be changed and that the receiving military treatment facility would capture the VAP, regardless of the number of hours the patient was at this facility. This system-wide modification was implemented in April 2012 (JTS, 2012c). More honest measurement resulted in more accurate data capture, evidenced by a rising rate of VAP.

SOURCE: Palm et al., 2012b.

is less explicit and conscious, and thus more limited in shaping trauma care practices beyond the provider level.

Still, performance improvement programs linked to trauma center registries enable learning from outcomes associated with variation in care in civilian trauma centers. The American College of Surgeons' verification process ensures that every verified trauma center has a comprehensive, systematic trauma performance improvement and patient safety plan and concurrent registry (with patient information being completed within 60 days). Using trauma registry data, system processes are examined for compliance with national standards of care. These reviews include system, clinical, and individual performance measures. Variances from standards of care (identified through audit filters) are then reviewed in detail to determine whether harm occurred, what processes led to the event, and what measures could mitigate or prevent the event from reoccurring. In addition, the verified trauma centers submit data to the NTDB for national analysis and benchmarking comparison. Hospitals participating in the American College of Surgeons Trauma Quality Improvement Program conduct another level of review and analysis addressing trauma outcomes and benchmarking. These efforts align to foster best practice models for trauma care (ACS, 2014).

With the exception of a few systems (e.g., Intermountain Healthcare), the civilian sector is much slower than the military sector to change guidelines and policies based on experiential learning (Haider et al., 2015)—a reflection of the acknowledged risks of focused empiricism. In some instances, however, this more measured approach also limits the extent to which lessons learned in the military through experiential learning can be translated to the civilian sector. For example, while whole-blood collection kits are made available to all prehospital providers in the military, the availability of these kits in civilian EMS is limited (34 percent) because of the lack of high-quality data supporting whole-blood delivery (Camazine et al., 2015).

Hypothesis-Driven Research

Hypothesis-driven research, both clinical and systems based, is an important source of evidence that informs trauma care. Research drives innovation, including the development of new technologies, drugs, devices, and biological therapeutics, and thus plays a critical role in generating knowledge used to change care practices and improve patient outcomes. However, pragmatic, ethical, scientific, regulatory, and resource challenges may arise in the design, implementation, and funding of randomized controlled clinical trials. By their nature such trials require years to complete, which delays the deployment of the new therapeutic and diagnostic modalities being investigated. In addition, randomized controlled trials, although considered by many to be the gold standard, are not the most appropriate research methodology for every research question (Berwick, 2008) and have many limitations particular to the context of acute trauma care. Given the heterogeneity and complexity of traumatic injury, conducting a trial in which pure control is achieved is often impractical. In such cases, alternative study designs may be more appropriate (see Table 4-4). As a result of

TABLE 4-4 Traditional and Alternative Study Designs

Design	Definition
Traditional clinical trial	A prospective biomedical or behavioral research study that is designed to test the safety and effectiveness of a therapeutic agent or intervention (e.g., drug, vaccine, device) using consenting human subjects. These trials generally evaluate the use of a single treatment relative to the standard of care in a relatively homogeneous patient population.
Observational study	A study in which investigators observe one or more groups of subjects and measure characteristics and outcomes of interest about the subjects without assigning treatments to subjects as part of the research.
Cluster-randomized trial	A design in which groups (e.g., school, clinic, household) rather than individuals are randomized to a particular treatment or study arm. These trials are useful when individual randomization is unfeasible (IOM, 2010).
Randomized withdrawal trial	Experiments in which subjects who respond positively to an intervention are randomized to continue receiving that intervention or to receive a placebo. This trial design minimizes the time subjects spend receiving a placebo (IOM, 2001, p. 40) and focuses the comparison on the subset of subjects who demonstrate a response to treatment, potentially increasing the ability of the trial to demonstrate benefit.
Adaptive clinical trial	A clinical trial design that includes a prospectively planned opportunity for modification of one or more specified aspects of the study design (e.g., randomization ratios, sample size) based on analysis of interim data from study subjects (adapted from FDA, 2015).
Platform trial	A clinical trial designed to simultaneously evaluate multiple treatments or combinations of treatment. This design offers the possibility that some treatments may be removed from the trial and others may be added over time (Berry et al., 2015).
Pragmatic trial	This type of trial measures treatment effectiveness or the benefit the intervention produces in routine clinical practice, and it accurately reflects variation in patient populations and care delivery (Patsopoulos, 2011).
Randomized registry trial	A large-scale, randomized experiment based on data collected from registries and patient records. These trials are designed to minimize the burden of data collection, increase external validity, and reduce the time to dissemination when compared with traditional clinical trials (Lauer and D'Agostino, 2013).

SOURCE: Adapted from IOM, 2015.

Box 4-4 CASE STUDY: SEVERE TRAUMATIC BRAIN INJURY

Case

A 29-year-old soldier sustained a gunshot wound to the head while on patrol. At the point of injury, he was unresponsive and bleeding excessively. He also exhibited decorticate posture—bent arms, clenched fists, and legs held out straight—indicating severe damage to the brain. Upon arrival at a Role 3 military treatment facility, he underwent a hemicraniectomy, a neurosurgical operation designed to relieve building intracranial pressure as the brain swells. The patient survived his injuries and, despite some remaining difficulties with attention span and memory, was able to recover functional independence.

Learning Context

Although current Joint Trauma System clinical practice guidelines for severe traumatic brain injury (TBI) are based on civilian research and Brain Trauma Foundation guidelines (Badjatia et al., 2008; BTF, 2007), routine care provided differs in military and civilian settings (DuBose et al., 2011; Ling et al., 2009). A 2011 study found that among matched military and civilian patients with severe TBI, military casualties were approximately three times more likely than civilian casualties to undergo a neurosurgical operation (21.5 percent versus 7.2 percent, respectively). The military's use of a more aggressive approach may result in better outcomes: mortality rates were threefold lower in military patients relative to their civilian counterparts (7.7 percent versus 21.0 percent, respectively) (DuBose et al., 2011). However, comparisons between military and civilian patients that sustain severe TBI are inherently limited. Many additional factors may contribute to improved military outcomes, including soldiers' proximity to medics, access to highly trained Critical Care Air Transport Teams, exposure to damage control resuscitation strategies (see Box 4-2), and the existence of a mature trauma system (DuBose et al., 2011).

Even so, the improved survival of TBI patients in the military is worthy of note, as is encouraging functional outcome data. In one study, nearly a third of military casualties with penetrating brain injury and an admission Glasgow Coma Scale of 3 to 5 achieved functional independence within 2 years (Weisbrod et al., 2012). At present, the contribu-

these challenges, the military's trauma care practices and clinical guidelines are informed by a diverse evidence base that includes knowledge generated from basic science and large-animal preclinical research, in addition to the retrospective cohort analyses using DoDTR data discussed above and the consensus of subject matter experts (Elster et al., 2013).

On the other hand, formal research serves as an important complement to and check on the more informal and tacit mechanisms for generating knowledge encouraged in a learning trauma care system. While in some cases—for example, how to deal with unexploded ordinance in a casution of the military practice of aggressive surgical intervention (JTS, 2014) to these better outcomes is unknown, and the applicability of the military clinical practice guidelines to civilian TBI care is not well understood. Still, interventions like hemicraniectomy are increasingly being used in the civilian sector to treat victims of penetrating brain trauma who once might not have survived. Notably, on January 8, 2011, former U.S. Representative Gabrielle Giffords underwent a decompressive hemicraniectomy after sustaining a gunshot wound to the head in Tucson, Arizona (Hafner, 2013; Roberts, 2011). Of note, Giffords was cared for by a former military surgeon who adopted the same methods routinely used to treat soldiers with severe TBI on the battlefield (Starr, 2011).

Lesson

This case highlights the important role of research as a complement to and check on focused empiricism in a learning trauma care system. Further research on the interventions developed, refined, and incorporated into clinical practice guidelines during wartime is needed to confirm that the military's use of aggressive surgical interventions has contributed to improved mortality outcomes in military patients with severe TBI. Knowing that such types of injuries are inevitable in war, this research would ideally take the form of multiple clinical trials conducted in the civilian sector (with support from the U.S. Department of Defense) during the interwar period. This will ensure that, when the next war begins, high-quality data regarding the optimal treatment for penetrating TBI are available and, as a result, the military would not need to rely as heavily on a focused empiricism approach during the next conflict for optimizing the treatment of this injury pattern. Such research would have the added value of helping to determine the applicability of these interventions to civilian TBI care so that those benefits can be translated to the civilian sector.

SOURCE: This box draws on the severe traumatic brain injury case study in Appendix A, except where other citations are noted.

alty (Lein et al., 1999)[7]—it is simply not possible to generate supporting evidence through formal research, clinical guidelines should to the extent possible be supported by research studies of appropriate design. In the absence of a randomized controlled trial, it can be difficult to determine the safety and efficacy of a care practice that may have emerged from independent provider experience. A well-designed clinical trial can enable

[7] Personal communication, S. Shackelford, U.S. Department of Defense, to A. Downey, the National Academies of Sciences, Engineering, and Medicine, regarding the military's focused empiricism approach, December 17, 2015.

investigators to detect any harm and either confirm or refute conclusions derived from a focused empiricism approach, encouraging the widespread adoption of a practice thus derived (Borio, 2015; Holcomb and Hoyt, 2015) (see Box 4-4).

A significant challenge for a learning trauma care system is determining when hypothesis-driven research is imperative so that poorly evidenced or untested clinical practice guidelines and therapies are not implemented prematurely. This is not an easy call and may involve trade-offs between strength of evidence and time to implement changes in care. In part, this determination requires intensive assessment of existing evidence from a variety of sources of limited rigor (e.g., literature reviews, expert opinion, clinical case reports, case series, observational data, retrospective studies, clinical research, and querying of trauma registries), as well as evaluation of the feasibility of generating stronger evidence (e.g., randomized controlled trial data) in the face of practical or ethical considerations. The well-being of our service members who sacrifice significantly for our country invokes a sense of passion, urgency, and impatience in finding new therapeutic modalities to treat their horrific and life-altering injuries.

Military Sector

During the wars in Afghanistan and Iraq, the military invested significantly in requirements-driven, programmed trauma research. DoD's Combat Casualty Care Research Program addresses clinical gaps as well as research questions emerging from clinician experience and performance improvement data in theater. The program thereby serves as a key intermediary in efforts to advance trauma care capabilities, responding to the identification of knowledge gaps and augmenting the evidence base that supports the generation and dissemination of clinical practice guidelines (Rasmussen et al., 2014) (see Figure 4-3). The overall aim of the program is to deliver knowledge and readily deployable solutions to medical providers on the battlefield so as to reduce mortality and morbidity (Rasmussen et al., 2014). The program's approach to trauma research is organized around the following portfolios, identified as the areas of greatest need for innovative solutions to optimize outcomes for injured service members:

- neurotrauma and traumatic brain injury
- hemorrhage control and resuscitation
- en route care
- photonics and light-based innovation for severe injury (treatments for tissue injury)
- forward surgical care and intensive critical care (Baer, 2015; MRMC and DHA, 2015)

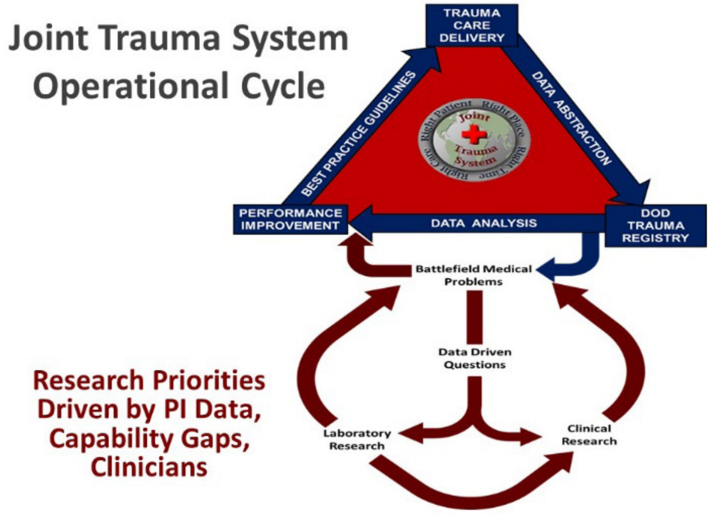

FIGURE 4-3 Joint Trauma System operational cycle and links to the U.S. Department of Defense's Combat Casualty Care Research Program.

NOTE: DoD = U.S. Department of Defense; PI = performance improvement.

SOURCE: Haut et al., 2016.

The military's use of a requirements-driven approach in which research is directed toward improving military medical capabilities and closing identified gaps is unique within the broader landscape of federal and private trauma research. In the civilian sector, research is generally investigator driven, and funding opportunities may influence the study topics (Brown, 2015; Rasmussen et al., 2014). DoD's Combat Casualty Care Research Program reacts directly to battlefield medical problems identified through the DoDTR. In addition, the 2008 DoD report *Guidance on Development of the Force* specifically identifies 28 gaps relevant to combat casualty care, further directing research priorities (DHB, 2015).

Within DoD, this programmatic research is carried out both individually by each of the services and jointly with funding support from the Defense Health Program (Rasmussen et al., 2014). The Air Force, Army, and Navy each have their own laboratories and facilities for conducting combat casualty care research; an example is the U.S. Army Institute of Surgical Research. The great majority of military research (approximately 80 percent), however, is carried out through the Defense Health Program in collaboration with or at civilian academic centers (Pruitt and Rasmussen, 2014; Rasmussen, 2015).

The development and maturation of the military's medical research program played a key role in the reduction in the case fatality rate observed over the course of U.S. engagement in Afghanistan and Iraq (Pruitt and Rasmussen, 2014; Rasmussen et al., 2014). At the start of Operation Enduring Freedom and Operation Iraqi Freedom, medical providers lacked basic information and knowledge about how to provide optimal care for trauma patients. Examples of such knowledge gaps included basic questions about resuscitation, such as how much fluid to give, what kind of fluid, and when to stop. The circumstances faced in these wars, including an unprecedented burden of injury and challenging logistical and clinical conditions, necessitated a strongly supported and coordinated military medical research program (Rasmussen et al., 2014). Since the start of these conflicts, military medical research has enabled significant advances in trauma care in such areas as the optimal use of extremity tourniquets, improved outcomes in casualties with traumatic brain injury, damage control resuscitation (see Box 4-2), and burn management (DHB, 2015).

Nonetheless, significant knowledge gaps remain. A 2013 qualitative assessment of the extent to which the gaps identified in DoD's *Guidance on Development of the Force* had been closed revealed that the gaps remained less than 50 percent resolved (Rasmussen and Shumacker, 2014). Continued investment in military combat casualty care research is required to achieve further progress and to close existing gaps in trauma care capability.

Civilian Sector

In the civilian sector, a major difference from the military's approach to research is the absence of a centralized institute dedicated to trauma and emergency care research. A number of research agendas and gap analyses have emerged (EMSC National Resource Center, 2009; NHTSA, 2001; Sayre et al., 2005), aimed at drawing attention to the need for more focused and requirements-driven trauma research in the civilian sector. This need has been highlighted in a number of assessments (see Figure 4-4), a central theme of which is the need for a centralized institute within the National Institutes of Health (NIH) focused on trauma and emergency care (see Table 4-5). NIH has established an Office of Emergency Care Research to coordinate and foster research efforts related to trauma and emergency care within its existing institutes. However, this office is unfunded, which severely limits its influence and ability to direct research to those areas of greatest need (Brown, 2015).

Within the civilian sector, there is some existing infrastructure to support trauma and emergency care research. The Strategies to Innovate

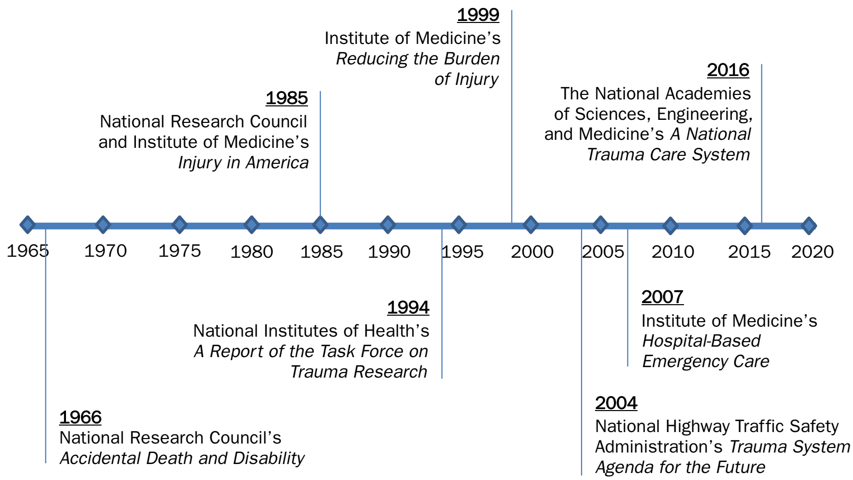

FIGURE 4-4 Timeline of assessments relevant to civilian trauma research.
SOURCES: IOM, 1999, 2007b; NHTSA, 2004; NIH, 1994; NRC, 1966; NRC and IOM, 1985.

EmeRgENcy Care Clinical Trials Network[8] (SIREN), led by NIH and funded by several institutes as well as DoD, will simultaneously conduct at least four randomized controlled trials focused on patients with neurological, cardiac, pulmonary, hematologic, and traumatic emergencies (Berger, 2016). Proposals for SIREN trials were due in mid 2016, with funds released in early 2017 (NIH, 2016c). In addition, NIH's National Heart, Lung, and Blood Institute funds the Clinical Trials Network for the Prevention and Early Treatment of Acute Lung Injury. This network conducts randomized controlled trials for acute respiratory distress syndrome, which may be triggered by trauma, infection, or sepsis (PETAL Network, 2015).

While the networks described above are positive examples of trauma and emergency care research under way in the civilian sector, it is important to note that critical systems research may require different kinds of infrastructure (e.g., linked prehospital and hospital databases as described earlier in this chapter) that does not currently exist on a wide scale. Further, no mechanism exists for directing research investments toward identified gaps, despite the repeated recommendations shown in Table 4-5. As highlighted by the Institute of Medicine (IOM, 2007b, p. 12) report *Hospital-Based Emergency Care*, "The current uncoordinated approach to organizing and

[8] This network replaces the Neurological Emergencies Treatment Trials Network, or NETT, and the Resuscitations Outcomes Consortium, or ROC (Berger, 2016). Among its numerous successes, ROC funded the Pragmatic Randomized Optimal Platelet and Plasma Ratios (PROPPR) trial highlighted in Box 4-2.

TABLE 4-5 Recommendations on the Need for a Centralized Research Institute to Address Knowledge Gaps in Trauma and Emergency Care

Report	Recommendations
NRC, 1966	"Expansion within the U.S. Public Health Service of research in shock, trauma, and emergency medical conditions, with the goal of establishing a National Institute of Trauma" (p. 34).
NRC and IOM, 1985	"The committee recommends that funding for research on injury be commensurate with the importance of injury as the largest cause of death and disability of children and young adults in the United States" (p. 3).
NIH, 1994	"Creation of an Office of Trauma Research at NIH reporting to the Director of NIH and, in addition, to Congress and the President on an annual basis. The purpose of the Office would be to update the national plan for trauma research and to ensure that this agenda is being addressed and funded" (p. 5). "If the goals and research priorities outlined here are not being substantially addressed . . . then the establishment of a National Institute of Trauma Research should be pursued" (p. 6).
IOM, 1999	"The committee supports a greater focus on trauma research and training at the National Institutes of Health (NIH) and recommends that the National Institute of General Medical Sciences (NIGMS) elevate its existing trauma and burn program to the level of a division" (p. 11).
NHTSA, 2004	"Congress will establish a National Institute for Injury, within the National Institutes of Health" (p. 26).
IOM, 2007b	"the Secretary of the Department of Health and Human Services [should] conduct a study to examine the gaps and opportunities in emergency and trauma care research, and recommend a strategy for the optimal organization and funding of the research effort. This study should include . . . improved research coordination through a dedicated center or institute" (p. 12).

funding emergency and trauma care has been inadequate. There are well-defined emergency and trauma care research questions that would benefit from a coordinated and well-funded research strategy." Examples of high-priority trauma research needs (clinical and systems research) compiled by the committee, applicable to both the military and civilian sectors, are presented in Table 4-6. As these research needs are consistent across both sectors, most of these questions can be studied in the civilian setting and applied in the military.

Military and Civilian Collaborative Research

DoD has only a single Level I trauma center that treats civilian patients. As a result, patient populations at MTFs are not large enough to support

TABLE 4-6 Examples of High-Priority Trauma Research Needs

Topic Area	Research Priorities
Prevention and epidemiology	• Develop data-driven strategies for mitigating morbidity and mortality due to potentially preventable injury. • Determine the epidemiology of preventable deaths after injury in the United States (adults and children).
Resuscitation	• Develop and clinically evaluate the efficacy and safety of dried or frozen blood products. • Evaluate the efficacy and safety of new devices and drugs for controlling life-threatening extremity, junctional, and truncal hemorrhage. • Determine whether measuring prehospital shock and coagulopathy would improve outcomes in the prehospital environment. • Develop safe and effective oxygen carriers. • Determine whether whole blood resuscitation is clinically superior to component therapy. • Determine the safety of low-titer Group O whole blood as a universal donor. • Determine the clinical and cost-effectiveness of pathogen reduction technology for blood products. • Develop methodology, training, and equipment to improve the ability of far-forward medical personnel to transfuse whole blood and blood products. • Determine how various endpoints of resuscitation affect clinical outcomes in patients with traumatic brain injury, hemorrhagic shock, or both. • Develop fail-safe methods for ensuring establishment of a casualty's airway. • Determine the efficacy and safety of permissive hypotensive strategies with blood product resuscitation and for prolonged prehospital transport times.
Prehospital care	• Develop predictive prehospital algorithms for early identification of prehospital and hospital life-saving interventions. • Fund the addition of prehospital and hospital blood product data to existing trauma registries. • Develop methods for and implement accurate automated meshing of prehospital trauma care, hospital, autopsy, fire, police, and rehabilitation data registries.
Burn care	• Develop novel methods for rapid skin replacement, minimizing scar formation.
Pain management	• Develop and test battlefield/prehospital analgesia techniques. • Develop strategies for optimizing perioperative pain management.

continued

TABLE 4-6 Continued

Topic Area	Research Priorities
Traumatic Brain Injury	• Develop new and innovative approaches for the classification of traumatic brain injury and its severity. • Determine the optimal methods of airway management and ventilation strategies for patients with acute traumatic brain injury. • Develop individualized strategies for treating the various manifestations of moderate and severe blunt and penetrating traumatic brain injury. • Develop therapeutics to improve outcomes of mild, moderate, and severe traumatic brain injury. • Develop animal and computer models for traumatic brain injury, especially those brain injuries resulting from blast injuries. • Identify biomarkers to identify mild traumatic brain injury and assays to discriminate between mild traumatic brain injury and posttraumatic stress disorder. • Evaluate effective traumatic brain injury treatments in the context of comorbidities (pain, amputation, hearing loss, and behavioral health disorders). • Determine the effectiveness of complementary and alternative medicines as part of an integrative health approach model for traumatic brain injury.
Spine	• Determine the optimal methods of spinal immobilization on the battlefield. • Determine whether stem-cell therapy results in improved outcomes after spinal cord injury and whether this is dependent on the injury type. • Determine whether early mobilization after surgical spinal column stabilization improves patient outcomes following spinal cord injury.
Critical care	• Develop and evaluate methods for rapidly diagnosing and treating patients with sepsis. • Develop, test, and optimize training in methods for transporting patients with pulmonary failure from the prehospital setting to definitive care.
Nursing	• Evaluate the staffing mix, nursing education, and certification models that yield best outcomes of trauma care. • Study interventions in the acute care setting that can be deployed by front-line providers to help mitigate the onset of depressive symptoms and posttraumatic stress.

TABLE 4-6 Continued

Topic Area	Research Priorities
Orthopedics	• Develop best practices for controlling junctional and pelvic fracture bleeding. • Develop methods for quantifying total tissue injury volume and the activation and recovery of inflammatory response. • Develop improved strategies for diagnosing, preventing, and treating deep-wound infections associated with extremity trauma. • Develop more effective strategies for the diagnosis and treatment of compartment syndrome. • Investigate improved strategies for reconstruction of major bone defects, nerve repair, and quantification of cartilage damage and later arthritis. • Develop new strategies for preventing contracture, heterotopic bone formation, and posttraumatic arthritis. • Develop a better understanding of the long-term physical health effects of major limb trauma, including the impact on obesity, cardiovascular disease, posttraumatic arthritis, and osteoporosis. • Develop evidence to support the dose, timing, frequency, duration, and intensity of physical therapy following major limb trauma. • As new regenerative medicine therapies are developed for treating major limb injuries, identify rehabilitation strategies for optimizing recovery following these therapies. • Develop strategies for optimizing the function, durability, and use of prosthetic and orthotic devices.
Rehabilitation	• Develop and evaluate data-driven recommendations and guidelines on strategies for optimizing return to preinjury functional levels after injury. • Evaluate cognitive-behavioral rehabilitation strategies for decreasing pain and fear of movement and increasing self-efficacy in patients following surgery for their injuries.
Systems research	• Determine the optimal number of trauma centers per population unit. • Determine optimal methods for transitioning proven clinical modalities into routine clinical practice.

SOURCES: The development of this list was informed by preexisting research priority lists, including but not limited to Butler et al., 2015; CDC, NIH, DoD, and VA Leadership Panel, 2013; Helmick et al., 2012; Kotwal et al., 2013a; NCIPC, 2005; NHTSA, 2001; Sauer et al., 2014; Sayre et al., 2005; van Middendorp et al., 2016.

high-quality trauma-related clinical trials and prospective research studies. Civilian partnerships are therefore essential for carrying out the research needed to deliver improvements in combat casualty care. A robust military–civilian research network is particularly relevant during times of low combat activity. Only when patients are pooled across a large number of civilian centers can requisite sample sizes be achieved. While these partnerships are pursued out of necessity, they offer the added benefit of facilitating the exchange of knowledge between the military and civilian sectors. Lessons learned from extramural research are "translatable from the beginning" and serve to improve outcomes for injured patients in both military and civilian settings (Rasmussen, 2015). METRC—the Major Extremity Trauma Research Consortium—is an example of a military–civilian partnership aimed at advancing the development of military best trauma care practices for limb trauma and to promote translation of military lessons learned to the civilian sector (see Box 4-5).

In addition to METRC, there are multiple examples of trauma research carried out through collaboration between the military and civilian sectors, funded in large part by DoD, including

- two clinical trials comparing the military-developed blood transfusion protocol—damage control resuscitation (see Box 4-2)—with a widely used blood transfusion method (the Prospective, Observational, Multicenter, Major Trauma Transfusion [PROMMTT] study [Holcomb et al., 2013] and the Pragmatic, Randomized Optimal Platelet and Plasma Ratios [PROPPR] study [Holcomb et al., 2015b]);
- three ongoing clinical trials evaluating the role, safety, and efficacy of tranexamic acid (ClinicalTrials.gov, 2015a,b,c); and
- multiple studies on the transfusion of plasma in the prehospital setting (Holcomb et al., 2015a).

The National Research Action Plan (discussed further in Box 7-8 in Chapter 7) has facilitated extensive military–civilian collaboration around traumatic brain injury, significantly increasing awareness of this specific trauma injury (DoD et al., 2013). Recently, for example, DoD and NIH collaboratively developed the Federal Interagency Traumatic Brain Injury Research (FITBIR) informatics system to serve as the secure, centralized database for research on traumatic brain injury. Building on current efforts to standardize data elements, FITBIR will serve as the repository for new data, link to current databases, and allow for data comparison across studies (NIH, 2016a).

Box 4-5 **METRC: A MODEL FOR A MILITARY–CIVILIAN RESEARCH NETWORK**

The Major Extremity Trauma Research Consortium (METRC) is a research network with a core of 22 Level I civilian trauma centers and 4 military treatment facilities and the ability to recruit research participants from more than 30 additional satellite trauma centers. The goal of METRC is "to produce the evidence needed to establish treatment guidelines for the optimal care of the wounded warrior and ultimately improve the clinical, functional, and quality of life outcomes of both service members and civilians who sustain high energy trauma to the extremities" (METRC, 2015). The network is anchored by a data coordinating center, housed at the Johns Hopkins Bloomberg School of Public Health.

METRC was established with U.S. Department of Defense Peer Reviewed Orthopaedic Research Program funding to enable high-quality and adequately powered randomized controlled trials and prospective observational studies. Success to date confirms the potential for civilian and military trauma centers to collaborate on critical research issues and leverage the strength that comes from engaging patients and providers from across multiple centers. METRC has initiated more than 18 prospective multicenter studies involving the participation of more than 5,000 active duty and civilian trauma patients. The studies range from the evaluation of new approaches for preventing infections, to modeling of the early risk of compartment syndrome, to evaluation of protocols for managing pain. METRC also is addressing issues relevant to rehabilitation, including approaches for reducing the incidence of posttraumatic stress disorder and depression, evaluation of a customized dynamic orthosis for severe foot and ankle injuries, and strategies for optimizing the benefits of physical therapy. Challenges relate to managing the regulatory process; designing trials sensitive to the realities of trauma research; and supporting the academic careers of multiple investigators in the context of large, multicenter trials.

SOURCES: METRC, 2015, 2016.

Barriers to Timely Generation of Evidence to Inform Best Trauma Care Practices

There is no question that the nation's investment in trauma research has saved lives, but the end of the wars in Afghanistan and Iraq does not signal a time to reduce that investment. As discussed above, numerous gaps in combat casualty care capabilities remain. The military's experiences in Afghanistan and Iraq have yielded a wealth of experiential knowledge and innovation in trauma care. The potential benefits of translating this knowledge to the civilian sector are significant, but an increased investment in rigorous, collaborative (military and civilian) research will be required to sustain recent advances, encourage further momentum in closing identified gaps in trauma care, and show definitively the safety and efficacy of new practices and products and their value in civilian trauma care. Yet barriers to research that can generate evidence to inform best trauma care practices—including inadequate funding for trauma research and federal regulations and their interpretation—will have to be overcome.

Inadequate Funding for Trauma Research

Military-sector trauma research investment There are two major sources of funding for medical research within DoD: the Defense Health Program and Army core funds (Baer, 2015; Rasmussen, 2015). Defense Health Program funding also includes Congressional Special Interest (CSI) funds directed to specific trauma research topics, such as burn care and orthopedic care (Pruitt and Rasmussen, 2014). In 2013, a total of $1.02 billion was allocated for military medical research, $200 million of which was directed toward research on combat casualty care. Of this amount, less than half originated from a core budget (Defense Health Program and Army core funds). The rest was provided by CSIs (Rasmussen, 2015) (see Figure 4-5).

The origin of funding directed at military trauma research threatens the sustainability and efficacy of DoD's Combat Casualty Care Research Program. Unlike core Defense Health Program and Army funds, CSI funds are distributed on a year-to-year basis, at the whim of politicians. Therefore, the military cannot depend on these funds for future, sustained funding (Rasmussen, 2015).

DoD's investment in research has declined consistently since the drawdown of troops from Afghanistan began (GAO, 2013) (see Figure 4-6). Competing military priorities (e.g., weapon systems) will only further

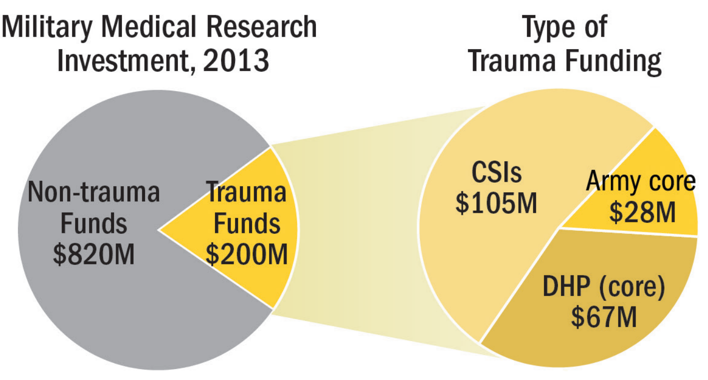

FIGURE 4-5 Funding sources for military medical research, 2013.

NOTE: CSI = Congressional Special Interest; DHP = Defense Health Program.

SOURCE: Data from Rasmussen, 2015.

FIGURE 4-6 Military medical research investment in trauma care, 2005-2013.
SOURCE: Adapted from GAO (2013, p. 5).

threaten research funding as the transition to an interwar period continues (Di Resta, 2015). Importantly, in contrast with other military research portfolios, such as infectious disease, there is no equivalent to DoD research on combat casualty care in the civilian sector. As a result, military research on combat casualty care has no safety net when DoD investment is cut (Baer, 2015; Rasmussen and Baer, 2014).

Civilian-sector trauma research investment Exacerbating the reality of dwindling military funds for trauma research is the paucity of civilian-sector investment in trauma research to sustain and further develop advances in trauma care. In 2013, NIH directed just $367 million of its $30 billion budget to trauma (NIH, 2016b), approximately $31.7 million of which was applied to clinical research on the acute phase of trauma care (Brown, 2015; Holcomb and Hoyt, 2015). Despite the significant burden of injury facing the civilian population (as outlined in Chapter 1), federal agencies and private foundations do not dedicate funding to injury research commensurate with its burden to society (Moses et al., 2015; Rhee et al., 2014; Richards, 2015; Trunkey, 1983). In a recent analysis of NIH funding for 27 disease conditions relative to their burden (as measured by disability-adjusted life years [DALYs]), injury was more disproportionately underfunded than any other condition (Moses et al., 2015) (see Figure 4-7). Injury accounts for

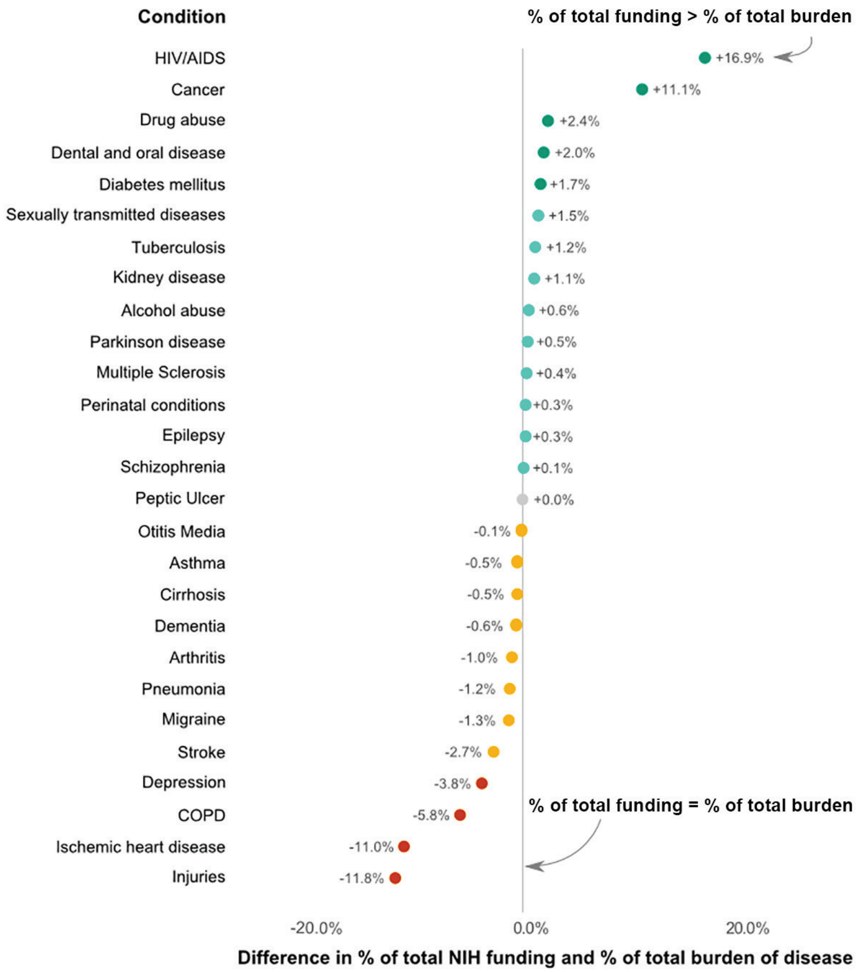

FIGURE 4-7 NIH funding for medical conditions relative to their total disease burden.

NOTE: COPD = chronic obstructive pulmonary disease; HIV/AIDS = human immunodeficiency virus/acquired immunodeficiency syndrome; NIH = National Institutes of Health.

SOURCES: Data from Moses et al., 2015. Created by Catherine A. Richards, Ph.D., M.P.H.

nearly 10 percent of total DALYs in the United States each year[9] but receives only about 1 percent of NIH's biomedical research budget, although the committee acknowledges that proportionality to disease burden is an overly

[9] Injuries accounted for 7,945,100 out of 81,834,600 all-cause DALYs in the United States in 2010 (U.S. Burden of Disease Collaborators, 2013).

simplistic method by which to set research budgets. This disparity between funding and disease burden (as measured by DALYs) may result in part from a lack of patient advocacy and public understanding of trauma and the role of research in addressing gaps in optimal trauma care.

The lack of funding for trauma research highlights a critical limitation of the civilian research enterprise's investigator-driven approach: "researchers . . . will not pursue clinical problems for which there is little or no funding" (Brown, 2015). As discussed previously, the absence of a designated institute within NIH devoted to trauma research exacerbates this challenge. As expressed to the committee by the director of NIH's unfunded Office of Emergency Care Research, Dr. Jeremy Brown, "if you are competing with other diseases for which there are institutes, I believe you are always going to lose" (Brown, 2015). Limited funding in the civilian sector results in few high-quality clinical research studies to further advances in trauma care. This is an unfortunate reality, particularly when one considers the history of research on HIV/AIDS, cardiac disease, and cancer, conditions for which increased funding has directly correlated with marked reductions in mortality (Holcomb and Hoyt, 2015).

Federal Regulations and Their Interpretation

The need to protect the rights, safety, and welfare of individual research participants is well accepted. Historical abuses surrounding human research, in particular studies that harmed and willfully exploited participants, gave rise to the federal regulatory landscape in existence today (see Box 4-6 for a brief summary of federal regulations on human subjects protections). In 2005, DoD developed its own human research protection program so that research could be conducted in theater in compliance with all federal regulatory requirements[10] (Brosch et al., 2008).

Medical research undoubtedly has clear value to society, particularly in the context of a disease or condition such as trauma for which the stakes are high (i.e., high mortality and morbidity) and there is a paucity of known effective therapies. The protection of individuals who are research subjects also has a clear value, both to the individuals themselves and to society. Trust in the research enterprise is of paramount importance; without it, there would be too few volunteers to sustain clinical research, which would directly and calamitously reduce and retard medical advances. Finding the right balance between providing regulatory protections for research subjects and enabling scientific progress is chal-

[10] Although the military is able to conduct some research in theater, it should be noted that policy, logistical, and ethical issues constrain the conduct of randomized controlled clinical trials on the battlefield.

Box 4-6 OVERVIEW OF FEDERAL REGULATIONS ON HUMAN SUBJECTS PROTECTIONS GOVERNING RESEARCH

U.S. Department of Health and Human Services (HHS) Regulations

The Common Rule (45 Code of Federal Regulations [CFR], Part 46, Subpart A) "applies to all research involving human subjects conducted, supported or otherwise subject to regulation by any federal department or agency which takes appropriate administrative action to make the policy applicable to such research. This includes research conducted by federal civilian employees or military personnel, except that each department or agency head may adopt such procedural modifications as may be appropriate from an administrative standpoint. It also includes research conducted, supported, or otherwise subject to regulation by the federal government outside the United States" (see 45 CFR § 46.101(a)). The Common Rule contains regulations addressing institutional review board (IRB) function, composition, and review, as well as provisions requiring informed consent from the research subject or the research subject's legally authorized representative and its documentation. The rule permits an IRB to determine that some or all elements of informed consent may be waived (see 45 CFR § 46.116(d)) for research that presents no more than minimal risk. Moreover, an IRB may waive the requirement for the investigator to obtain a signed consent form for some or all subjects under limited circumstances (see 45 CFR § 46.117(d)). Under specific conditions, an HHS secretarial waiver permits an exception from informed consent for emergency research (see NIH, 1996). This waiver is largely harmonized with the U.S. Food and Drug Administration's (FDA's) regulation under 21 CFR § 50.24.

FDA Regulations, 21 CFR Part 50 and Part 56

These regulations apply "to all clinical investigations regulated by FDA under sections 505(i) and 520(g) of the Federal Food, Drug and Cosmetic Act as well as clinical investigations that support applications for research of marketing permits for products regulated by FDA" (see 21 CFR § 50.1(a)). FDA regulations on human subjects protections are harmonized to the extent possible with the Common Rule, given the differing statutory authority and missions of HHS and FDA. Like the Common Rule, the FDA regulations address IRB function, composition, and review. In contrast with the Common Rule, the FDA regulations require that informed consent be obtained from the subject or the subject's legally authorized representative for all FDA-regulated clinical investigations except as provided in 21 CFR § 50.23 (involving certain life-threatening emergencies, military operations, or public health emergencies) and 21 CFR § 50.24 (exception from informed consent for emergency research). FDA's regulations do permit IRBs to waive the documentation of informed consent under limited circumstances involving research that presents no more than minimal risk (see 21 CFR § 56.109(c)).

Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule

The HIPAA Privacy Rule establishes national standards to protect individually identifiable health information held by covered entities and their business associates and provides patients' rights with respect to that information. The rule prohibits the use or disclosure of an individual's identifiable health information without specific written authorization (see 45 CFR § 164.508). Certain exceptions exist for research purposes, including waiver by an IRB (see 45 CFR § 164.512).

lenging and, understandably and appropriately, the source of ongoing discussion, scrutiny, and concern.

Through a review of the literature and discussions with researchers and regulatory agency representatives, the committee identified several barriers to research associated with federal regulations, discussed in the sections below. In some cases, the problem lies in ambiguity associated with or misunderstanding or misinterpretation of the regulations. Evolutionary and revolutionary changes in science, technology, and clinical research designs are often accompanied by the development of federal policy statements (i.e., "guidance"), which can reduce problems of ambiguity and misinterpretation, but these frequently can take many years to be issued. In other cases, the problem resides in regulatory silence; that is, the regulations do not address or did not anticipate current concerns. Finally, in some cases, the problem is due to regulations themselves, which can have a static quality and which, in some cases, may have their origin in discussions dating back to the 1970s (e.g., IRB and informed consent regulations). For example, when strong—even overwhelming—evidence has accumulated about the efficacy and safety of a trauma intervention, the inflexibility of the U.S. Food and Drug Administration's (FDA's) evidentiary rules has prevented or seriously delayed that real improvement from reaching trauma patients, particularly in the absence of more formal clinical trials. (An example is ketamine's use as an analgesic, described in Box 4-7.) FDA needs to take a more flexible approach to the nature of the evidence it uses for its determinations, in accordance with the developing epistemology of evidence itself in the scientific community. As discussed in the sections below, continued efforts to streamline regulatory processes would have a major impact on the ability to use limited trauma research funds efficiently and effectively.

Unclear distinction between quality improvement and research At the core of a continuously learning health system as envisioned by the Institute of Medicine is the imperative to learn from the everyday practice of medicine (IOM, 2013). Such learning often takes the form of continuous quality improvement cycles. The generation of knowledge through continuous quality improvement and how it is distinguished from research, however, is a subject of ongoing debate, particularly in light of the multiple federal regulations that govern the conduct of human subjects research (as described in Box 4-6).

The U.S. Department of Health and Human Services (HHS) defines research as "a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge."[11] Quality improvement is defined as "systematic data guided

[11] 45 CFR § 46.102(d).

Box 4-7 CASE STUDY: USE OF KETAMINE AS AN ANALGESIC

Case

A 29-year-old soldier sustained traumatic amputation of his left leg and a severely injured right leg as the result of an improvised explosive device. At the point of injury, a medic immediately worked to immobilize the soldier's lower extremities, stop the bleeding, and prevent hypothermia. To treat the soldier's extreme pain, the medic administered 50 mg of intravenous ketamine.

Learning Context

Ketamine is an excellent analgesic because it is highly effective and has a very wide therapeutic window (Black and McManus, 2009; DHB, 2012; Malchow and Black, 2008). Perhaps most important, ketamine does not depress breathing reflexes or blood pressure, as opioids such as morphine do. Cardiorespiratory depression is especially dangerous for patients with severe hemorrhage, which was associated with more than 80 percent of the preventable deaths in Afghanistan and Iraq (Kelly et al., 2008).

U.S. Special Operations Forces and coalition forces use ketamine as a preferred drug for pain control, but its overall use and availability in theater is very limited. In a meeting regarding prehospital trauma care, it was estimated that the ratio of ketamine to morphine use stood at about 1:25 (Kotwal et al., 2013a). A memorandum authored by the Defense Health Board obliquely blames the failure to build on the experience of early adopters and integrate ketamine into usual care on "service fielding decisions" (DHB, 2012), but a more significant challenge is regulatory in nature.

Ketamine is FDA-approved for several indications and uses as an anesthetic agent. Using ketamine for analgesia constitutes an "off-label" use of the drug, and logisticians are reluctant to order a drug for an unapproved use despite the substantial accumulation of empirical data showing its effectiveness and safety for that use. Clinical practice

activities designed to bring about immediate improvements in health care delivery" (Baily et al., 2006, p. S5). Given these definitions, there are any number of learning activities in which distinctions are blurred, including

- clinical research (controlled trials) versus medical practice,
- quality improvement research versus quality improvement,
- pragmatic clinical trials (comparative effectiveness research in real-life settings) versus medical practice,
- comparative effectiveness research versus medical practice, and
- research on medical practice versus medical practice.

guidelines (JTS, 2013b) and tactical combat casualty care (TCCC) guidelines (DHB, 2012) that encourage the use of ketamine to control pain in tactical settings often are not followed (Schauer et al., 2014). In many facilities, providers are well informed about TCCC principles, techniques, and technology but lack access to recommended equipment items and medications, such as ketamine (Kotwal et al., 2013a). As in the civilian health sector, military physicians can and often do choose to use an FDA-approved product in a manner other than its labeled indication. The decision to do so is considered professional judgment, and as a general matter, is an acceptable practice. However, first responders such as medics must restrict their use of ketamine to its labeled uses unless they are under the supervision of a physician who instructs them otherwise, which limits the use of ketamine in the prehospital setting. The ultimate solution to this problem is FDA approval of ketamine for use as an analgesic. However, obtaining this approval would require a significant investment in the generation of clinical trial data, a barrier that has yet to be overcome given the constraints of finite research funds.

Lesson

The history of ketamine use provides an example of how knowledge matures over time through clinical reporting and retrospective registry reviews. Diffusion of innovation and widespread implementation of clinical practices responsive to informal knowledge acquisition can be challenging when formal regulatory structures do not support labeling changes based on uncontrolled clinical studies and other less rigorous methodologies, even when the evidence base is strong. This challenge is particularly problematic given the limited research equity available in both the military and civilian sectors.

SOURCE: This box draws on the dismounted complex blast injury case study in Appendix A, except where other citations are noted.

Yet whether a given learning activity is classified as quality improvement or research has significant implications for the need to adhere to the human subjects protections outlined in Box 4-6. The "gray zone" in distinguishing between quality improvement and research slows and even impedes both quality improvement and research activities, limiting the effectiveness and impact of the learning system as a whole.

The ambiguity between quality improvement and research temporarily halted a successful initiative by Pronovost and colleagues (2006) to save lives and eliminate unnecessary costs by decreasing central line-associated bloodstream infections in intensive care units. In this case, HHS's Office for Human Research Protections disagreed with a Johns Hopkins IRB's conclusion that this was a quality improvement project and thus did not require full IRB review or informed consent (Baily, 2008; Faden et al., 2013; Miller and Emanuel, 2008).

Ironically, in many of these scenarios, the activities in question pose low risk to the individuals being studied (Miller and Emanuel, 2008). Clearer guidance is needed from HHS as the blurred distinction between quality improvement and research may impede the dissemination of worthwhile quality improvement activities or relegate those activities to added protections that may not be required. Regardless of this distinction, it is important that the regulatory environment not dampen these learning activities.

Multisite IRB review The federal regulations discussed in Box 4-6 were established in the 1980s and 1990s under a simpler research paradigm in which there was generally one institution conducting research to be reviewed by a single IRB. The current research enterprise is much more complex. Clinical trials and many other kinds of research studies often include many investigators working across multiple institutions. The Common Rule requires prior review and approval of nonexempt human subjects research by an IRB.[12] Approval by multiple IRBs is not required for multisite studies and may not be beneficial—for example, in research on public health disasters and rare diseases and in most emergency care research (Goldkind et al., 2014). Yet research has nonetheless been delayed by wary investigators, IRBs, and institutions feeling compelled to obtain IRB approval at each participating site (METRC, 2016). Multiple IRBs can produce conflicting results and require changes to the protocol or informed consent documents that are at cross-purposes. In some cases, the separate reviews occur sequentially, contributing to significant delays in the onset of research, at least locally. Centralized IRBs are one potential means of streamlining this regulatory process (Check et al., 2013; Flynn et al., 2013). Moreover, they can be a means of ensuring the application of scientific or medical expertise that may not exist widely, thus contributing to high-quality reviews and sophisticated science and clinical research designs (Goldkind et al., 2014). NIH has put forth for comment draft policy mandating the use of a single IRB for multisite studies.[13] In addition, HHS has published a Notice of Proposed Rulemaking[14] that would require, in most cases, the use of a single IRB. This proposal has been reiterated in a number of policy recommendations, including the National Academies of Sciences, Engineering, and Medicine (NASEM, 2015) report *Optimizing the Nation's Investment in*

[12] 45 CFR Part 46, Subpart A.

[13] The NIH draft policy on use of a single IRB for multisite studies is available at http://grants.nih.gov/grants/guide/notice-files/NOT-OD-15-026.html (accessed October 16, 2015).

[14] The HHS Notice of Proposed Rulemaking is available at https://www.federalregister.gov/articles/2015/09/08/2015-21756/federal-policy-for-the-protection-of-human-subjects (accessed April 11, 2016).

Academic Research, as well as the 21st Century Cures Act. However, these proposals are still under consideration and not yet reflected in the federal regulations.

Privacy protections for data sharing As discussed earlier in this chapter, HIPAA regulations present barriers to using and sharing trauma patient data across systems for research purposes and care within and between the military and civilian sectors (Baily et al., 2006; Seymour et al., 2014). Box 4-8 provides a catalog of facts that address common misperceptions about HIPAA that can impede research in both sectors.

The use of protected health information for both direct patient care and for research purposes is governed tightly by HIPAA regulations. Provider misperceptions regarding what HIPAA permits for the purposes of direct patient care are a barrier to disclosing patients' protected health information to those also providing treatment. In fact, HIPAA recognizes a relationship known as an organized health care arrangement, which allows covered entities to disclose protected health information for treatment activities. This arrangement also allows the disclosure of protected health information by covered entities with a legitimate need to reference patient data for the operation of the care delivery system, including quality assurance at the individual case level and quality improvement at the level of a defined process of care. The vast majority of information produced by a trauma registry takes the form of summary reports at the process level, where it is physically impossible to identify individual patients. However, individual clinicians need to see what happens to the patients they treat as those patients move through the complete care process. In this circumstance, a clinician has a legitimate patient–clinician relationship; patients' explicit consent typically exists for such uses of their data; and this use of patients' protected health information clearly falls under an organized health care arrangement recognized by the regulations (AMA, 2016; HHS, 2003).

By definition, research utilizing protected health information uses existing data, so the associated risks to patients center on autonomy (patients' control of their own data) and confidentiality. Deidentified data are not protected health information; as such, they are not protected under HIPAA. There are multiple ways in which covered entities can use and disclose protected health information for research purposes and remain HIPAA compliant. Covered entities may use and disclose protected health information with participants' written authorization. In addition, protected health information may be used and disclosed in the absence of authorization in a number of circumstances. HIPAA allows for a waiver of research participants' authorization in those circumstances in which (1) all risks to the patients are minimized; (2) the proposed investigation has the potential to contribute to better care; and (3) it is not possible or feasible to obtain

Box 4-8 HEALTH INSURANCE PORTABILITY AND ACCOUNTABILITY ACT (HIPAA) FACTS[a]

In the course of this study, the committee encountered a great deal of confusion and ambiguity regarding the impact of HIPAA on data sharing for the purposes of research and quality improvement. The following facts are offered to correct some of these common and costly misunderstandings about HIPAA:

- HIPAA does apply to U.S. military hospitals and other health care providers that are operating as part of the HIPAA-covered component(s) of the U.S. Department of Defense (DoD).
- HIPAA does not restrict the amount of protected health information that is stored by covered entities, including electronically.
- For research, HIPAA requires that certain conditions be met before a covered entity may use or disclose an individual's protected health information.
- HIPAA allows covered health care providers to exchange protected health information for the treatment of patients (or someone else) without having to obtain the patients' authorization, regardless of whether the providers being consulted are military or civilian, affiliated or unaffiliated, or covered by HIPAA.
- The HIPAA Privacy Rule does allow a physician, laboratory, or other health care provider to share patient health information for treatment purposes by fax, by e-mail, or over the phone without patient authorization as long as reasonable safeguards are used in doing so.
- HIPAA does permit covered health care providers, including the covered components of DoD and the U.S. Department of Veterans Affairs (VA), to exchange protected health information for treatment purposes.
- Under HIPAA, after the receiving physician has reviewed protected health information in accordance with HIPAA, the receiving physician, as a covered entity him- or herself,

direct, individual patient consent. Covered entities may also use and disclose protected health information as a limited data set with a data use agreement without an authorization. A data use agreement—entered with the intended recipient of the limited data set—specifies the ways in which the data set may be used and how it will be protected.[15]

Informed consent challenges for trauma research Trauma research involving human subjects is highly heterogeneous, ranging from minimal-risk epidemiological studies to clinical trials of experimental interventions for life-threatening conditions that must be administered shortly after injury (Goldkind et al., 2014). In the latter case, patients may be unconscious or otherwise incapable of providing informed consent to participate in a study,

[15] 45 CFR Part 164.

is responsible for safeguarding that information and otherwise complying with HIPAA, including with respect to subsequent uses or disclosures or any breaches that occur.
- HIPAA does support and permit the conduct of research with registry data.
- Under HIPAA, different conditions apply to quality assessment and improvement activities and to research activities utilizing registry data.
- HIPAA does distinguish between research and studies for quality assessment and improvement based on whether the primary purpose of the activity in question is to obtain generalizable knowledge.
- HIPAA does allow reviews of records preparatory to research, provided, among other things, that the researcher removes no protected health information from the covered entity during the review.
- HIPAA does contemplate that it may be impracticable in many cases to obtain the authorization of the subjects of the protected health information provided to a researcher by a covered entity.
- HIPAA does allow an institutional review board (IRB) or privacy board to waive the authorization requirements for a study.
- HIPAA does permit use of a limited data set if a data use agreement is in place to protect against reidentification and misuse of the data.
- HIPAA does permit the use of fully deidentified data for research purposes without the requirement for authorization, an IRB or privacy board waiver, or a data use agreement.

[a] The list in this box draws on information submitted to the committee by Christina Heide, Senior Advisor for HIPAA Policy, Office of Civil Rights, U.S. Department of Health and Human Services, in response to questions generated by the committee.

presenting a significant challenge to the conduct of such research in an ethically appropriate manner. There is general agreement about the degree and types of protections needed for clinical research entailing greater than minimal risk (e.g., an intervention study using an untested therapeutic). Such protections generally include IRB approval and advance informed consent of research participants, although FDA and other HHS regulations permit an exception from informed consent for emergency research under narrow circumstances, in which additional protections are required (e.g., establishment of a data monitoring committee, public disclosure prior to initiation and after completion of the research, community consultation). In the civilian sector, meeting such requirements is challenging. For combat casualty care research that is sponsored, conducted, or supported by DoD, even greater challenges arise in attempting to enroll military personnel in studies. For example, there is ongoing debate regarding the validity of the community consultation process in a military setting, including concerns about undue influence from higher-ranked members of the military (Perkins et al., 2012).

More controversial, however, is how to protect participants appropriately in minimal-risk research without creating unnecessary barriers to its conduct. Under the Common Rule, minimal-risk trauma research, such as retrospective studies using registry data, can qualify for a waiver of informed consent.[16] No provision exists, however, for waiving or altering informed consent processes for FDA-regulated minimal-risk research. Under these conditions, investigators cannot conduct an FDA-regulated clinical investigation, such as a study of a minimal-risk device, if the research offers no direct benefit to participants and does not otherwise qualify for the exception from informed consent under 21 CFR § 50.24 (see Box 4-9).

Human subjects research conducted using any funds appropriated to DoD is further governed and restricted by Title 10 of the United States Code, Section 980 (10 U.S.C. § 980, Limitation on Use of Humans as Experimental Subjects.), which prohibits research studies using human subjects without advance informed consent of the subjects or their legal representatives. The Secretary of Defense or his/her designee[17] has the authority under 10 U.S.C. § 980 to waive the requirement for informed consent for a specific research study if it is deemed necessary to the armed forces and may directly benefit the subjects (notably including subjects in control groups). This statute was passed in 1972, prior to DoD's adoption of the Common Rule,[18] which requires both IRB approval and informed consent (with exceptions for minimal-risk research[19]). Now obsolete, this statute serves as an added barrier to military research, delaying needed trauma research in both military and civilian settings[20] by 5 months or more and consuming precious study funds, to the detriment of trauma care delivered to servicemen and -women, injured host nationals, and civilian casualties (Brosch, 2015).

Thus FDA and DoD requirements for informed consent meant to protect individuals enrolled in research can have the untoward effect of impeding research necessary to provide evidentiary standards for ad-

[16] 45 CFR § 46.116(d).

[17] The Secretary of Defense has delegated this waiver authority to the heads of the DoD services.

[18] 32 CFR Part 219.

[19] 10 U.S.C. § 980 does not apply to research that is exempt from the Common Rule (DoD Directive 3216.02, Protection of Human Subjects and Adherence to Ethical Standards in DoD-Supported Research).

[20] Research studies conducted at civilian sites but supported by DoD (with funds or supplies) are also subject to 10 U.S.C. § 980.

Box 4-9

AN EXAMPLE OF REGULATORY BARRIERS TO MINIMAL-RISK RESEARCH

The U.S. Department of Defense (DoD) is interested in sponsoring a clinical investigation of a device approved by the U.S. Food and Drug Administration (FDA) for the detection of X. Typically, the device is used in the hospital setting for definitive diagnosis of X. Some preliminary evidence suggests that the device could also be used in the prehospital setting to detect Y, resulting in earlier diagnosis of a life-threatening complication of head injury and rapid organization of a surgical team during patient transport. A shorter time to surgical intervention could result in reduced patient morbidity and mortality.

A clinical investigation is being designed in which the device would be used in the field, and all information obtained would be stored and not used for treatment decisions. (Use of the device is not expected to delay transport.) A computed tomography (CT) scan of the head, the current diagnostic standard of care for detection of Y, would be obtained, based on clinical indications, upon the patient's arrival at the hospital. The need for surgery would be based on the results of the CT scan. Results from the diagnostic device would not affect clinical decision making. The device does not emit radiation, and its use is noninvasive.

The dilemma is that, since this is an FDA-regulated clinical investigation, informed consent must be obtained unless this investigation meets the requirements of 21 CFR § 50.24, which provided for an exception from the requirement for informed consent for emergency research. Among the many requirements of 21 CFR § 50.24 is that "participation in the research holds out the prospect of direct benefit to the subjects" (see 21 CFR § 50.24(a)(3)). However, use of the diagnostic device for the new indication does not hold out the prospect of direct benefit to the individuals who would be enrolled in this research. FDA regulations do not contain provisions permitting the waiver or alteration of informed consent for research that involves no more than minimal risk, similar to 45 CFR § 46.116(d). Additionally, Title 10 of the United States Code, Section 980 (DoD regulations) requires advance informed consent of subjects or their legal representatives unless a waiver is granted by the Secretary of Defense or his/her designee.

As a result of FDA and DoD regulations requiring informed consent, this minimal-risk research study cannot be conducted.

vances in therapeutic, diagnostic, and preventive clinical interventions. This dilemma is particularly problematic as these requirements ironically make the most innocuous research (from a subject's perspective) the most difficult to approve. Although a number of changes to these federal regulations are currently under consideration, including revisions to the Common Rule and changes to FDA regulatory processes under the 21st Century Cures Act, it remains to be seen whether these proposed changes will go into effect and ease the regulatory barriers delaying and preventing needed trauma research.

PROCESSES AND TOOLS FOR TIMELY DISSEMINATION OF TRAUMA KNOWLEDGE

Knowledge derived from performance improvement and research efforts will improve medical care and patient outcomes only if it is disseminated and applied in practice. Given the complexity and volume of clinical information available[21] and the extraordinary rate at which new knowledge is generated, a broad range of systematic processes and tools are needed to disseminate knowledge and assist front-line care providers in utilizing the best evidence and practices available. In the military, the capture and sharing of knowledge are necessary to sustain and advance trauma care not just in interwar periods but also in wartime, as deployed trauma teams rotate at approximately 6-month to 1-year intervals. The institutionalization of this experiential knowledge and processes for its dissemination ensure that the next team of providers deployed to theater (and their patients) can benefit from the lessons learned by their predecessors. Throughout the wars in Afghanistan and Iraq, the military utilized a number of innovative mechanisms to increase the rate at which new knowledge was disseminated to providers in the challenging battlefield environment (see Table 4-7).

Traditional channels for knowledge dissemination, such as publications in peer-reviewed journals and presentations at scientific conferences, are critically important in today's knowledge landscape. These channels foster increased collaboration between the military and civilian sectors and encourage the bidirectional exchange of information (Pruitt and Rasmussen, 2014). However, additional steps are necessary to promote and accelerate the translation of new evidence into changes in care.

In a learning trauma care system, improvements in trauma care do not depend on the ability of individual providers to discover, assimilate, retain, and put into practice the ever-increasing supply of clinical evidence. Instead, trauma care providers have access to such resources as evidence-based clinical practice guidelines and clinical decision support tools that capture, organize, and disseminate the best available information to guide decision making and reduce variation in care and outcomes (IOM, 2013). In addition, synchronous methods of learning[22] offer front-line providers timely access to high-quality tacit knowledge,[23] which plays an important role in improving

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[21] As an indicator of the increasing volume of clinical information, the number of medical journal articles published in 2010 (more than 750,000) was more than three times the number published in 1970 (IOM, 2013).

[22] Synchronous learning occurs in real time through mechanisms that give the teacher and the learner simultaneous access to one another (e.g., one-to-one coaching sessions via phone, classroom teaching), whereas asynchronous methods of learning allow learners to access information whenever they would like, not requiring the presence of an instructor (e.g., websites, guidelines).

[23] Tacit knowledge is knowledge that is acquired through practice and application.

TABLE 4-7 Summary of Mechanisms for Knowledge Dissemination Used in the Military Trauma System

	Individual Patient Care	Process Design and Execution	Tacit Knowledge
Senior Visiting Surgeon Program	✓	✓	✓
Joint Trauma System weekly teleconference	✓	✓	✓
Teleconsultation program (e.g., pediatric and severe burn patients)	✓		✓
Real-time telephone support with an expert (e.g., for burn treatment)	✓		✓
Full clinical decision support/embedded protocols (e.g., Burn Resuscitation Decision Support System)	✓		

practice in meaningful ways (Dixon, 1994; Nonaka, 1994). Timely access to information allows providers to ask detailed, context-specific questions, rapidly expediting care processes. The exchange of knowledge in real time enables providers to address challenges and questions at the point of care, offering immediate potential improvements to care delivery and patient outcomes. The following sections review four key mechanisms for timely dissemination of trauma knowledge: clinical guidelines, clinical decision support tools, telemedicine, and the Senior Visiting Surgeon Program.

Clinical Guidelines

Clinical guidelines provide a mechanism for changing practice and reducing unwarranted practice variations. Prehospital and hospital clinical practice guidelines can facilitate patient evaluations and help in determining an evidence-based course of action. The strongest guidelines are informed by evidence from hypothesis-driven research and knowledge derived from experiential learning and performance improvement efforts. At the same time, however (as discussed in Chapter 3), guidelines are not followed blindly in a learning system. Rather, optimal learning systems expect and even promote deviation from guidelines. Tracking such deviation and measuring outcomes enables validation and further improvement of the guidelines.

Guidelines in the Military

Codifying lessons learned and best practices into guidelines and developing tools and innovative strategies to assist front-line care providers are particularly important in the military, where brief deployments and the constant rotation of personnel, as well as interwar periods, challenge the ability to sustain institutional knowledge or operational memory. DoD develops and issues multiple sets of guidelines, including TCCC guidelines for the prehospital setting and JTS clinical practice guidelines for the hospital setting. The Defense and Veterans Brain Injury Center also issues clinical recommendations for mild traumatic brain injury. However, DoD does not mandate adherence to any set of guidelines. Military guidelines are more frequently updated and more responsive to advances in knowledge (including those emerging from experiential learning) relative to guidelines in the civilian sector (Gross, 2015).

Tactical combat casualty care (TCCC) guidelines Before the TCCC guidelines were developed in 1996, nominal improvements had been made in the prehospital phase of combat casualty care (Butler et al., 1996). TCCC is a "set of evidence-based, best-practice, prehospital trauma care guidelines customized for use on the battlefield," developed based on the need to unite good medicine and good tactics to avoid preventable death (Blackbourne et al., 2012; Butler and Blackbourne, 2012; Butler et al., 2015, p. 7). Established in 2001, the Committee on TCCC ensures that new technology, information, and evidence are incorporated into these guidelines on an ongoing basis.

TCCC guidelines are reviewed quarterly and updated as needed. Once approved by a two-thirds majority of voting members of the Committee on TCCC, individual changes are distributed to the committee members and published in the *Journal of Special Operations Medicine* (DHB, 2015).[24] Once per year, all the changes are compiled into an annually updated TCCC curriculum. This curriculum is then posted online, including the web pages of the JTS, the Military Health System, the National Association of Emergency Medical Technicians, the *Journal of Special Operations Medicine,* and the Special Operations Medical Association. The updated curriculum also is e-mailed to DoD schoolhouses and to the TCCC distribution list (more than 600 individuals across all the services). Included in each change packet are the updated guidelines, the position paper providing the evidence to support the change, and a set of PowerPoint training slides (DHB, 2015).

With the maturation of TCCC, the conflicts in Afghanistan and Iraq

[24] Personal communication, F. K. Butler, Committee on Tactical Combat Casualty Care, U.S. Department of Defense, July 17, 2015.

have seen dramatic changes in prehospital care (Butler and Blackbourne, 2012). The implementation of tourniquet recommendations from the TCCC guidelines, for example, sharply decreased mortality from extremity hemorrhage (Eastridge et al., 2012; Kelly et al., 2008; Kotwal et al., 2011). Despite formal endorsement of TCCC guidelines by medical leaders (e.g., the Defense Health Board, the service surgeons general) and some line leaders (e.g., then COL Stanley McChrystal), however, the implementation and use of updated TCCC guidelines and techniques are incomplete. While combat medics may be very familiar with TCCC, this same level of familiarity is not consistent across other medical personnel and nonmedical leadership (i.e., line leaders), resulting in part from the absence of a DoD-wide requirement for all personnel to receive TCCC training (Kotwal et al., 2013a).

JTS clinical practice guidelines (CPGs) The JTS curates its own set of hospital guidelines, called CPGs. These guidelines are developed by subject matter experts based on battlefield-generated needs and the identification of gaps whose resolution has the potential to drive change and improve performance. As with the prehospital TCCC guidelines, CPGs are evidence-based to the extent possible. Evidence is derived from the scientific literature and analysis of data captured in the DoDTR, supplemented with the consensus of subject matter experts, when necessary. In some instances (e.g., management of an unexploded device in a casualty), high-quality evidence will never be available to inform CPGs, which will be developed based entirely on lessons learned and expert consensus (JTS, 2012b). CPGs are updated by the JTS on an annual basis, with additional updates occurring as needed in response to new evidence or input from subject matter experts. New and updated CPGs are approved by the JTS director (Stockinger, 2015).

Once created or updated, CPGs are disseminated to providers in a combat theater through several mechanisms. They are made widely available online and posted on the U.S. Army Institute of Surgical Research and JTS website[25] (JTS, 2012a). In addition, the JTS works with predeployment training centers to incorporate these guidelines into the training curricula.

The DoDTR has developed the capacity to track compliance with many CPGs. Compliance with CPGs has repeatedly demonstrated positive outcomes, for example, in reducing abdominal compartment syndrome mortality (from 36 percent to 18 percent, with 94 percent compliance), hypothermia (from 7 percent to 1 percent, with 84 percent compliance), and mortality in those receiving massive transfusions (from 32 percent to 20 percent, with 85 percent compliance) (Eastridge et al., 2009).

While originally developed for use in CENTCOM alone, the JTS is

[25] Available at http://usaisr.amedd.army.mil/beta/cpgs.html (accessed February 16, 2016).

shifting away from CENTCOM CPGs and is in the process of updating the CPGs so they are no longer specific to any geographic command. These CPGs will then be distributed to each combatant commander for review and approval or modification (Stockinger, 2015). As of this writing, nine CPGs had been developed and approved for use in the Pacific Command (USAISR, 2015).

Guidelines in the Civilian Sector

In the civilian sector, evidence-based guidelines have proliferated in recent years, with the Agency for Healthcare Research and Quality's National Guidelines Clearinghouse listing more than 2,500 published guidelines. Unfortunately, adherence to clinical practice guidelines varies dramatically (McGlynn et al., 2003). In a recent study conducted at five Level I trauma centers across the United States, compliance with 22 recommended clinical practices ranged from 12 to 94 percent (Shafi et al., 2014). In addition, organizations that develop guidelines often use different methods for evaluating evidence, and the resulting recommendations sometimes conflict with each other (Kerwin et al., 2012). Numerous attempts have been made to address these inconsistencies, including the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system; the National Prehospital Evidence-Based Guideline Model Process, and the Institute of Medicine (IOM, 2011) report *Clinical Practice Guidelines We Can Trust*.

In 2007, the IOM recommended that a multidisciplinary panel establish a model for creating evidence-based guidelines for prehospital emergency care, having found that only 4 percent of EMS interventions were based on high-quality evidence, while half of interventions were based on very weak or no evidence (IOM, 2007a; Lang et al., 2012). The resulting National Prehospital Evidence-Based Guideline (EBG) Model Process was a joint project of the National EMS Advisory Council and the Federal Interagency Committee on EMS, with funding from the National Highway Traffic Safety Administration and the Health Resources and Services Administration's Emergency Medical Services for Children Program. The model that was developed emphasizes evidence-based recommendations rather than expert opinion, and outlines an eight-step process focused on the creation of broad EMS guidelines that can be customized for regional and local needs. This initiative has led to stepwise progress in developing EBGs for EMS, national EMS guidelines, and recommendations for a national consortium to warehouse and coordinate the incorporation of EMS-related EBGs into the EMS community (Martin-Gill et al., 2016). Recent progress includes the development of evidence-based guidelines using the National Prehospital Evidence-Based Guideline Model Process, such as the American College of Surgeons' hemorrhage control guideline, as well as research-informed clinical guidelines developed through expert consensus by the National Association of State EMS Officials' (NASEMSO's) National Model EMS Clinical Guidelines project.[26]

In the civilian sector, one of the leaders in the development of hospital-based trauma care guidelines is the Eastern Association for the Surgery of Trauma (EAST). EAST, through membership volunteer efforts, has published more than 60 practice management guidelines, all of which are available on the EAST website[27] and in the *Journal of Trauma and Acute Care Surgery*. The American College of Surgeons also has four trauma guidelines for hospital care (ACS, 2016), and other groups have begun creating trauma care guidelines as well (Bulger et al., 2014).

Military–Civilian Interface and Guideline Development

The development, maintenance, and dissemination of guidelines have offered unique opportunities to facilitate the interface between the military and civilian trauma systems and the transfer of innovations and lessons learned. The military's Committee on TCCC has an official partnership with the National Association of EMTs. In addition, TCCC guideline changes are posted on several civilian websites, and the *Prehospital Trauma Life Support* textbook includes multiple chapters on TCCC guidelines (DHB, 2015). The work of the Committee on TCCC also inspired the development of a counterpart civilian committee, the Committee on Tactical Emergency Casualty Care (C-TECC). C-TECC works to expedite the translation of military medical lessons learned into civilian crisis response by adapting TCCC guidelines for civilian use, taking into account differences in operational environments, resources, patient population, and scope of practice (Callaway et al., 2011). In addition, the JTS's CPGs are developed with input from civilian subject matter experts, and many of the early JTS CPGs were based on existing EAST guidelines. EAST now has its own Military Section, and offers a list of materials and literature relevant to deploying military surgeons (Stockinger, 2015).

Despite these opportunities, however, the dissemination and bidirectional translation of best practices and knowledge between the two sectors is slow and often incomplete. The civilian sector's adoption of tourniquet use is a case in point. Despite clear evidence of its benefit in preventing death from hemorrhage, uptake of this practice has been variable across the nation. Table 4-8 shows an overall increase in the reported use of tourniquets be-

[26] See https://nasemso.org/Projects/ModelEMSClinicalGuidelines/index.asp (accessed May 23, 2016).

[27] See https://www.east.org/education/practice-management-guidelines (accessed May 23, 2016).

TABLE 4-8 Civilian Tourniquet Use in 12 U.S. States, 2010-2014

	YEAR					
STATE	2010	2011	2012	2013	2014	TOTAL
A	7	19	13	23	36	**98**
B	0	0	0	0	20	**20**
C	0	1	0	0	0	**1**
D	7	14	27	37	30	**115**
E	4	10	13	53	63	**143**
F	2	0	0	0	4	**6**
G	4	3	278	138	18	**441**
H	0	2	3	2	13	**20**
I	10	10	55	98	146	**319**
J	6	18	36	59	76	**195**
K	0	7	8	16	29	**60**
L	30	39	25	19	30	**143**
TOTAL	**70**	**123**	**458**	**445**	**465**	**1,561**

NOTES: These data represent instances of tourniquet usage by 12 states that submitted reliable data to the National EMS Information System (NEMSIS) project's National EMS Database over the time period 2010-2014. The table excludes states that may now have reliable data, but were not reporting reliable data during this period. Data from the National EMS Database prior to 2010 were not considered reliable enough to include in this analysis.

SOURCE: Data extracted from the National EMS Database.

tween 2010 and 2012, with a subsequent plateau in total reported use (as seen, for example, in State D), but some states (e.g., states C and F) have not yet adopted this practice. In contrast, military tourniquet use increased significantly between 2002 and 2006 and then began to plateau (Kragh et al., 2015), indicating a 6-year lag between the time tourniquet use stabilized in the military and civilian sectors. In some places in the United States, however, adoption occurred earlier. For example, Pennsylvania changed statewide EMS protocols at the end of 2008—5 years before the American College of Surgeons' hemorrhage control guideline was published (Bulger et al., 2014)—to add a statewide basic life support bleeding control protocol that emphasizes the use of tourniquets "as initial method of bleeding control in severe extremity bleeding" (Pennsylvania Department of Health, Bureau of Emergency Medical Services, 2008). In 2011, Pennsylvania further began to require that every ambulance carry commercial tourniquets instead of relying on improvised versions (PA Bulletin, 2011).

Differences among states may in part explain this variation in uptake of tourniquet use. In "home rule" states where there is local discretion in the use of protocols, incorporation of a new paradigm for tourniquet use by following national guidelines and changing protocols and training would fall to local EMS agencies and medical directors, likely resulting in variable uptake. In states that use statewide protocols, by contrast, the protocols and training can be altered across the entire state with a single protocol change.

Clinical Decision Support Tools

Clinical decision support tools make knowledge of best trauma care practices, including clinical practice guidelines, available in real time at the point of care. These tools provide patient-specific care recommendations, helping medical providers deliver the best care possible and generate optimal outcomes for injured patients (IOM, 2001, 2013). Some of the most successful decision support tools have been simple, paper-based checklists, such as those used to virtually eliminate central-line-associated bloodstream infections (Pronovost et al., 2006). In other cases, the tools can be stand-alone devices. The military's Burn Resuscitation Decision Support System (described in Box 4-10), for example, is an FDA-approved device that provides fluid intake recommendations for burn patients. The tool is designed specifically to assist providers who do not routinely provide burn care so as to avoid over- or underresuscitation of patients (Galvan, 2013). Another example of a computerized clinical decision support tool is used in prevention of venous thromboembolism (VTE) (see Box 4-11). As discussed in Chapter 3, however, the integration of these tools into workflow by embedding them in electronic health records represents the pinnacle of real-time access to knowledge based on a learning health system approach.

In the VTE prevention example cited above, the decision support tool assumes that there is little variation among individual patients, and optimal VTE prophylaxis suggestions are based only on clinical and demographic data. However, new data suggest that there is in fact wide variation among individual patients as regards the baseline thrombotic state and response to VTE prevention therapy. Augmenting this decision support tool with laboratory data could bring precision medicine to the bedside, enabling personalized care of injured patients (Haut et al., 2016). To realize the promise of such advances, however, availability of the vast amounts of data of many types that would be required to ensure that patients received optimal care would have to be made a priority.

Overall, while there are isolated examples of successful application of clinical decision support tools to improve real-time access to best practices in trauma care, this remains an area for growth in both military and civilian settings as electronic health records evolve. DoD recently awarded Cerner (in partnership with Leidos and Accenture) a contract to procure Cerner's

Box 4-10 CASE STUDY: BURN

Case

In fall 2004, a vehicle exploded at a Bagdad checkpoint, leaving a 2-year-old boy with severe burns over at least one-third of his body. His mother and brother did not survive the explosion. The boy was rushed to the 31st Combat Support Hospital Emergency Room in Baghdad, Iraq. At the hospital, he underwent a series of complex and intensive procedures to control blood loss, clean and dress his burns, graft skin, and provide continuous ventilation and monitoring for his acute respiratory distress syndrome. He remained on a ventilator for 25 days, and was ultimately discharged after 40 days in the hospital.

Context

U.S. coalition and military patients with severe burns are quickly evacuated out of theater by critical care air transport teams to specialized burn centers. Because this option is not available to local nationals who sustain severe burns, many stay in deployed military treatment facilities (MTFs) for extended periods of time, receiving intensive care that requires many resources and special expertise. This patient was treated by a pediatric intensivist who happened to be deployed to Baghdad, but MTFs in theater often do not have providers with burn care specialties or training in advanced fluid resuscitation practices. Additionally, MTFs may not stock supplies or equipment for long-term care of burn patients, including dressings, medications, advanced modes of ventilation, or renal replacement devices. Since this case occurred, analysis of clinical data from the Department of Defense Trauma Registry has informed modification of the JTS Burn Care Clinical Practice Guideline (JTS, 2013a) and several quality improvement projects.

One major improvement was the development of a computerized decision support tool to help guide fluid management (CCCRP, 2015). The Burn Resuscitation Decision Support System (BRDSS) helps prevent shock and organ failure in severe burn patients (Ennis et al., 2008; Markell et al., 2009) by guiding combat providers who may have limited experience with treating such patients or are triaging multiple casualties (Salinas et al., 2011). The rugged, transportable version of the BRDSS achieved U.S. Food and Drug Administration clearance and Army airworthiness certification in 2013 (CCCRP, 2015; Meador, 2014).

Another improvement was the establishment of a phone line so that deployed providers could consult with specialists at the U.S. Army Institute of Surgical Research Burn Center in San Antonio, Texas (JTS, 2013a).

Lesson

Both the BRDSS and the phone consult line give deployed providers with little to no specialty burn care experience real-time access to the information they need. The phone consult, in particular, allows for person-to-person sharing of tacit knowledge. These tools offer the opportunity to improve and standardize care by less experienced providers during the early, critical period of care management for patients with severe burns.

SOURCE: This box draws on the pediatric burn case study in Appendix A, except where other citations are noted.

Box 4-11 CLINICAL DECISION SUPPORT FOR PREVENTION OF VENOUS THROMBOEMBOLISM (VTE)

Numerous evidence-based guidelines have been written on best-practice prevention of VTE. Many hospitalized patients are at elevated risk for this deadly complication. Injured patients are one of the patient groups at highest risk for VTE, and need to be treated appropriately with prophylactic medications (Rogers et al., 2002). Unfortunately, it is well known that many hospitalized patients do not receive the preventive care they require (APHA, 2003); rates of appropriate care have been reported to be in the 40-60 percent range (Cohen et al., 2008; Goldhaber and Tapson, 2004).

In 2008, a multidisciplinary VTE collaborative implemented a mandatory clinical decision support tool within a hospital's computerized order entry system (Streiff et al., 2012). This tool forced clinicians to perform a rapid, checklist-based assessment of risk for VTE and contraindications to pharmacologic prophylaxis. VTE prevention was inserted into the workflow, allowing rapid, accurate risk stratification and risk-appropriate VTE prophylaxis. The tool enabled physicians to apply evidence directly to clinical care in a real-time fashion in a real-world setting. The analytic power of the tool was also harnessed to directly pull data for performance monitoring and research publication purposes. In fact, the first research published on the program was a comparative effectiveness study involving trauma patients at the hospital's academic Level I trauma center. This pre-post study showed a significant increase in the proportion of trauma patients receiving guideline-appropriate VTE prophylaxis (from 62.2 percent to 84.4 percent, $p < 0.001$). There was also an associated drop in preventable harm from VTE (from 1.0 percent to 0.17 percent, $p = 0.04$) (Haut et al., 2012).

electronic health record system (Garamone, 2015; Monegain, 2015). Intermountain Healthcare, which is in the process of rolling out its own build of the Cerner electronic health record (called iCentra) to all of its hospitals and clinics, is also a strategic partner in this deal and will advise Cerner throughout the project on topics including clinical systems architecture, governance, and workflow (Monegain, 2015). The acquisition of an electronic health record optimized for protocol-based clinical decision support with integrated data capture to feed condition-specific clinical registries may hasten the evolution of the DoD trauma system toward this key feature of a learning system for trauma care.

Telemedicine

Effective communication along the continuum of care is essential to directing the best care, dispatching appropriate transport, and preparing receiving treatment facilities by providing information on the number of incoming casualties and the severity and types of injuries (DHB, 2015).

Such communication among providers also facilitates real-time performance improvement (Pruitt and Rasmussen, 2014). On the battlefield and in operational theaters, the military often works with limited resources in austere and remote locations and lacks specialized medical expertise (McManus et al., 2008). In these challenging conditions, the use of telemedicine improves communication and offers providers access to clinical expertise and advice in near real time.

At the start of the wars in Afghanistan and Iraq, communication between medical providers and receiving treatment facilities and between facilities along the continuum of care was nearly nonexistent. In 2006, the JTS established a weekly teleconference to discuss active patients as they were moved through the system. These system-wide forums link trauma teams working in theater, including medics at the point of injury and evacuation, with providers at Landstuhl Regional Medical Center in Germany and treatment facilities in the continental United States (Bailey et al., 2013). The teleconferences, which still take place and today serve as educational forums, afford providers at all levels the opportunity to discuss patient issues, receive feedback, and better understand care provided at previous facilities (Bailey et al., 2013; Eastridge et al., 2009). From the forum's initiation to October 15, 2015, 485 teleconferences featuring 3,600 case studies took place (Haut et al., 2016). These teleconferences serve as a conduit for disseminating clinical practice guidelines and system advances in trauma care, optimizing best practices in data collection, and improving the validity of the DoDTR (Pruitt and Rasmussen, 2014). Importantly, the forum facilitates performance improvement through both vertical connections (from the individual facility level to the joint theater trauma system level to the DoD trauma system level) and horizontal connections (e.g., peer learning from colleagues at other facilities as well as international partners).

While deployed, military physicians frequently must perform care outside their area of expertise (Fuenfer et al., 2009). Given this reality, the military made use of an extensive e-mail-based teleconsultation program during the wars in Afghanistan and Iraq (Eastridge et al., 2009; McManus et al., 2008). Developed in 2004, this program is run by the Army Office of the Surgeon General with participation from all services. Deployed providers e-mail consultation requests (which may include questions on diagnoses and treatment options), which are directed to the appropriate specialty group. Recommendations are returned to the requester within 24 hours (McManus et al., 2008). Between 2004 and 2015, the program facilitated more than 12,000 consultations globally and helped to both facilitate and prevent evacuations. Despite the demonstrated value of a teleconsultation program, challenges include lack of provider awareness about the program, lack of central funding, and threats to continuity due to inadequate institutionalization.[28]

As the theater of operations matured over the course of the conflicts in Afghanistan and Iraq, the military increasingly made use of telemedicine to great effect. However, it must be noted that early in a conflict, limited bandwidth may constrain the extent to which it is feasible to utilize more advanced forms of telemedicine. In such an environment, rudimentary forms of telemedicine (e.g., telephone consultation) may be the most reliable.

In the context of civilian trauma care, telemedicine has great potential to transform care, costs, and patient visit cycle times.[29] For example, telemedicine offers a possible solution to improve communication and the sharing of patient data along the trauma continuum of care, particularly between the prehospital and hospital settings. Technology that enables two-way video and voice communication and data transmission between ambulances and hospitals facilitates collaboration between emergency medical technicians and receiving facility physicians on prehospital care of the patient and also helps the receiving trauma team to better prepare for the patient's arrival (Latifi et al., 2007). Telemedicine programs also help effectively leverage the time of specialists, particularly in regions (e.g., rural areas) where access to trauma centers and trauma specialists (e.g., trauma surgeons, burn specialists) is limited. In one interhospital teletrauma program (hub and spoke model), centrally located trauma surgeons with video, audio, and data (e.g., vital signs) access to remote sites are able to assist in early survey and care decisions—for example, to help get the patient sufficiently stabilized for transfer to the trauma center (Latifi et al., 2007). In some cases, remote consultations help avoid costly and unnecessary patient transfers (Amadi-Obi et al., 2014; Latifi et al., 2009). The role of telemedicine in trauma care will undoubtedly continue to evolve as advances in technology yield reliable capabilities to support remote care and collaboration such as three-dimensional telepresence (Welch et al., 2009) and teleoperation (Garcia et al., 2009). Beyond real-time assistance with patient care, however, telemedicine technology also offers health care providers an invaluable opportunity to expand their knowledge and expertise through education, training, and peer mentoring (see the description of Project Extension for Community Healthcare Outcomes [ECHO] in Box 3-1). For example, in recent years, the Military Health System has adopted the Project ECHO model in its approach to pain management, working to improve its

[28] Personal communication, C. Lappan, U.S. Department of Defense, to E. Cornett, the National Academies of Sciences, Engineering, and Medicine, December 21, 2015.

[29] Cycle time refers to the amount of time that a patient spends at a primary care office visit (IHI, 2016).

providers' skill sets and capacity to effectively manage and treat complex, chronic pain conditions (discussed further in Chapter 6). Telemedicine, mobile health, and telehealth supports and technologies are rapidly maturing enabling more immediate and more local outreach to patients, and decreasing demand for face-to-face visits. But despite their promise, policy and payment are lagging behind these innovations, although payers are becoming more receptive to these modes of care and more innovative in finding ways to support them.

Senior Visiting Surgeon Program

The Senior Visiting Surgeon (SVS) Program exemplifies how military–civilian collaboration results in bidirectional translation of knowledge and experience, advancing trauma care in both sectors. In the SVS Program, military and senior civilian surgeons worked side by side at a single location, collaboratively providing care to those wounded in combat. The program was developed in 2005 in response to a growing need for experienced, hands-on expertise in providing trauma care during the wars in Afghanistan and Iraq and to such problems as insufficient research infrastructure within the military and a lack of academic mentoring in military trauma research (Knudson and Rasmussen, 2012; Knudson et al., 2014). The program was intended to advance trauma care by bringing experience and expertise in civilian trauma care to the military sector, developing the practices of the military trauma system, providing mentorship for military physicians, and encouraging scientific exchange between military providers and civilian trauma care leaders (Blackbourne et al., 2012).

In the SVS Program, civilian trauma care surgeons spent 2-4 weeks at the military's Landstuhl Regional Medical Center in Germany. In addition to providing care alongside their military colleagues, visiting surgeons gave grand rounds lectures on various topics, advancing the education of deployed physicians, nurses, and physician assistants (Knudson and Rasmussen, 2012; Moore et al., 2007). Since its induction, the program has contributed to the initiation of research in theater, as well as independent documentation and validation of advances made in combat casualty care achieved under the JTS (Knudson et al., 2014; Moore et al., 2007). While evidently a successful program of value to participating individuals (Knudson et al., 2014), a notable limitation of SVS is that civilian participation was restricted to surgeons alone. Expansion of the program to include other disciplines (e.g., emergency medicine physicians, nurses) could improve cross-fertilization across a broader group of stakeholders.

SUMMARY OF FINDINGS AND CONCLUSIONS

CONCLUSION: In the military and civilian sectors, the failure to collect, integrate, and share trauma data from the entire continuum of care limits the ability to analyze long-term patient outcomes and use that information to improve performance at the front lines of care. The collection and integration of data on the full spectrum of patient care and long-term outcomes using patient-centric, integrated registry systems need to be a priority in both sectors if the full potential of a learning trauma care system is to be realized, and if deaths from survivable injuries are to be reduced and functional outcomes maximized.

Related findings:

- *The collection and integration of trauma data across the care continuum is incomplete in both the military and civilian sectors.*
- *Military and civilian trauma management information systems rely on inefficient and error-prone manual data abstraction to populate registries.*
- *Existing trauma registries and other data systems are not linked, and sharing data across the military and civilian sectors is impeded by political, operational, technical, regulatory, and security-related barriers.*

CONCLUSION: The military uses a flexible and agile approach to guideline development distinct from that used in the civilian sector. This pragmatic, focused empiricism approach enables rapid guideline development using best available data. However, the safety and effectiveness of care practices based on low-quality evidence need to be validated in due time through higher-quality studies carried out in conjunction with the civilian sector. Additionally, more formal processes are needed to encourage joint military–civilian discussion of guidelines so as to enhance bidirectional translation of knowledge and innovation between the two sectors.

Related findings:

- *Processes for guideline development in the civilian sector are much more rigid (and rigorous), thorough, and time-consuming compared with military guidelines; therefore, civilian guidelines are less responsive to change and updated less frequently.*
- *The dissemination and bidirectional translation of knowledge and best practices (e.g., tourniquet use) between the military and civilian sectors is slow and often incomplete.*

CONCLUSION: Investment in trauma research is not commensurate with the burden of traumatic injury. To address critical gaps in knowledge of optimal trauma care practices and delivery systems, the United States needs a coordinated trauma research program with defined objectives, a focus on high-priority needs, and adequate resourcing from both the military and civilian sectors.

Related findings:

- *Despite the significant burden that trauma places on society, the sustainment of DoD's trauma research program is threatened, and civilian investment in trauma research is limited.*
- *Gaps identified in DoD's Guidance on Development of the Force remain less than 50 percent resolved.*
- *In the civilian sector, no mechanism exists for directing research investments toward identified gaps, a problem exacerbated by the absence of a centralized institute dedicated to trauma and emergency care research.*

CONCLUSION: A learning trauma care system cannot function optimally in the current federal regulatory landscape. Federal regulations or their interpretations often present unnecessary barriers to quality improvement and research activities. Lack of understanding of relevant provisions of the Health Insurance Portability and Accountability Act has resulted in missed opportunities to share data across the continuum of care in both the military and civilian sectors.

Related findings:

- *The ambiguity between quality improvement and research slows and even impedes quality improvement and research activities.*
- *FDA and DoD requirements for informed consent impede needed trauma research; ironically, these regulations make minimal risk research the most difficult to perform.*
- *Common misperceptions about HIPAA regulations present barriers to using and sharing data across systems for both direct patient care and research purposes.*

CONCLUSION: The provision of tacit knowledge improves practice to reduce variation in patient care and outcomes. Yet participation in and support for resourcing of the processes and technologies that provide this knowledge remain limited in both the military and civilian sectors.

Related findings:

- *The small size and scope of the Senior Visiting Surgeon Program (192 participants between 2005 and 2012, surgeons only [Knudson et al., 2014]) limits its impact and the exchange of tacit knowledge between military and civilian providers.*
- *The military's teleconsultation programs in theater are jeopardized by a lack of funding and institutionalization.*
- *While best practices in telemedicine exist within the United States (e.g., Project ECHO), its use related to civilian trauma care is limited.*

ANNEX 4-1

CASE REPORT: THE OPTIMAL USE OF DATA ACROSS THE CONTINUUM OF CARE[30]

This real-life case exemplifies how data could be used to improve care of a severely injured military service member. Through optimized data sharing and clinical decision support, the service member receives optimal, timely trauma care along a continuum of multiple levels of medical capability across three continents. *Everything shown in italics is currently feasible from an information technology and electronics perspective, although not all systems are currently implemented in practice.*

Care Under Fire

A 29-year-old male service member sustains a gunshot wound (GSW) to the head while on patrol following a .50 caliber sniper rifle projectile penetration of the right side of his helmet. A nonmedical but first-responder-trained member of his squad immediately assesses the opportunity for bleeding control, moves the casualty to a hasty casualty collection point (CCP) with cover and concealment, and notifies the squad leader of the casualty and his injury. The squad leader immediately contacts the platoon sergeant, who directs his platoon medic to the casualty to provide additional care.

Tactical Field Care

On arrival, the medic opens his tablet and establishes a linkage with the appropriate medical command center (MCC). At the MCC, a "smart map" identifies and displays the location of the call. An emergency medical communicator (EMC) instructs the medic to identify the potential patient, conduct a primary assessment, convey a "MIST" report (Mechanism of Injury, Injury, Signs/Symptoms, Treatments), and initiate a request for urgent transport and links this information stream to the patient's existing medical database identifiers in the MCC computer.

[30] This annex was adapted from a paper commissioned by the Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector, written by Elliott R. Haut, Johns Hopkins University School of Medicine and the Johns Hopkins Bloomberg School of Public Health; N. Clay Mann, University of Utah School of Medicine; and COL (ret) Russ S. Kotwal, Uniformed Services University of the Health Sciences and Texas A&M Health Science Center. The paper in its entirety is available on the study website at nationalacademies.org/TraumaCare.

At the CCP, the patient is noted to have strong carotid pulses, a heart rate (HR) of 130 beats per minute (bpm), and a respiratory rate (RR) of 75 breaths per minute. He is unresponsive and exhibits decorticate posturing. *In the meantime, the "smart map" has identified and dispatched the closest acute care response vehicle to the patient. Patient information is linked to an existing health care record, giving the medic access to the patient's health care database, current health problem list, current medications, allergies, and blood type. As patient care information is collected, it is automatically copied to the responding ground medic's patient care record, to the responding transport medic's patient care record, to the closest Role 2 military treatment facility (MTF), to the closest Role 3 MTF, and to the MCC. A real-time clinical decision support tool prompts the field medic to control the patient's airway because of his depressed Glasgow Coma Scale score.* A cricothyroidotomy is performed, and the casualty is placed on a mini-ventilator. The casualty is wrapped in a hypothermia prevention management kit, *and an electronic tactical combat casualty care (TCCC) card is completed and transmitted.*

Tactical Evacuation

An air transport vehicle arrives within 5 minutes of the evacuation request. *The flight paramedic has received and reviewed all patient care documentation prior to arrival.* A Role 2 MTF is located 45 minutes away, and a Role 3 MTF with a neurosurgeon is located 60 minutes away. *Based on his decision support matrix, the flight paramedic directs the pilots to fly to the Role 3 MTF*, provides supplemental oxygen to the casualty, *and attaches an all-systems monitor to the casualty's arm and across his chest. Physiologic data are acquired by the monitor's computer chip, then analyzed on the scene and transmitted to the medic's tablet and the MCC collocated with the Role 3 MTF. The flight medics are able to acquire the patient's medical history electronically and treat accordingly.*

Through the medic's tablet, a video connection is established with the Role 3 MTF and MCC. An MCC emergency medical services (EMS) physician views the patient and his associated vital signs and requests additional Level III monitoring. The patient's vital signs are blood pressure (BP) 80 mmHg (systolic only), HR 135 bpm, RR 30, Glasgow Coma Scale (GCS) score 3, and oxygen saturation (SpO_2) 95 percent. His right pupil is measured at 3 mm and reactive. His left pupil is measured at 4 mm and also reactive. The patient exhibits decorticate posturing. His head wound dressing rapidly becomes soaked with blood. *Analysis of all the data and active surveillance of decision support tools by the MCC computer and EMS physician* lead to dosing with tranexamic acid, transfusion of 2 units of red blood cells (RBCs), and infusion of 3 percent hypertonic NaCl en route. Ventilation is maintained by mini-vent, and SpO_2 is sustained at 100 percent. *An electronic tactical evacuation patient care record is completed and transmitted. The receiving MTF has received all patient vitals and physical exam and care documentation before the patient's arrival. Accordingly, personnel at the MTF plan for a very brief emergency department assessment, empty the computed tomography (CT) scanner, and prepare a surgical suite with a waiting neurosurgeon.*

Receiving Role 3 Military Treatment Facility

Upon arrival at the Role 3 MTF, the patient is noted to have the following vital signs: BP 153/108 mmHg, HR 69 bpm, RR set by ventilator, rectal temperature (T) 99.8°F, and GCS 3T. A cervical spine collar placed on the patient prior to arrival *is rapidly removed in accordance with an evidence-based clinical practice guideline that summarizes the medical literature on the topic*. A CT scan reveals a GSW to the head at the vertex of the skull with displacement of multiple bone fragments and evidence of diffuse cerebral edema, intraparenchymal hematoma, subarachnoid hemorrhage (SAH), subdural hemorrhage (SDH), and epidural hemorrhage (EDH) at the vertex in association with disruption of the mid third superior sagittal sinus.

The patient is taken to the operating room for decompressive hemicraniectomy, evacuation of subdural hematoma, placement of a right-sided external ventricular drain (EVD), and switch from a 7.5F field cricothyroidotomy tube to placement of an 8.0F tracheostomy. His postoperative CT reveals postsurgical changes, enlargement of right frontal lobe parenchymal hematoma, bilateral enlargement of the lateral ventricular horns, effacement of all basal cisterns, persistent subarachnoid and parafalcine SDH, a 3- to 4-mm midline shift rightward, multiple bone fragments within the brain parenchyma, and extensive scalp edema. He is administered thyroxin on a standard T4 protocol, as well as 3 percent NaCl. A second EVD is placed on the left side because of increasing bifrontal cerebral hemorrhaging reflected in an intracranial pressure (ICP) measurement of 23 mmHg. Following this intervention, ICP improves to 8-10 cmH_2O and a cerebral perfusion pressure (CPP) of 60 mmHg. Repeat CT shows transcranial herniation at the site of the craniectomy with evidence of impending tonsillar and uncal herniation, as well as a small amount of right subfalcine herniation. The patient is transfused 2 units of RBCs, 2 units of fresh frozen plasma (FFP), and 1 unit of apheresis platelets. Tranexamic acid is also infused in an effort to control bleeding. Ultimately, the patient's GCS improves to 7T, with a motor score of 4. He undergoes bronchoscopy to evaluate the effects of the surgical airway procedures and is found to have no evidence of tracheal injury. *All medical charting is completed electroni-*

cally during the patient's stay and automatically uploaded to the MCC computer. An abbreviated medical status report is exported to the critical care air transport team's tablet for use during transport care.

Critical Care Air Transport Team: Movement Out of Theater (Postinjury Day #1)

The patient is transported to the flight line without incident. Sedation is increased prior to transport, resulting in a drop in GCS from 6T to GCS 3T. *Tele-ICU monitoring is initiated and monitored by a Role 4 MTF. Answers to questions raised by the Tele-ICU team are provided instantaneously and care is modified based on those recommendations.* In flight, CPP is maintained at greater than 60 mmHg with low-dose vasopressors, and ICP is maintained at less than 20 mmHg. The patient is transfused two units of RBCs and a 300-mL bolus of normal saline (NS). His hemoglobin increases from 8.2 to 9.2 g/dL. *All patient care data collected during the flight are automatically uploaded to the MCC computer. Ventilation is provided via closed-loop ventilation that automatically adjusts the inspired oxygen content and RR in response to changes in oxygenation and end-tidal carbon dioxide monitoring.* Upon arrival at Landstuhl Regional Medical Center in Germany, GCS has returned to 6T.

Role 4 Military Treatment Facility: Germany (Arrival Postinjury Day #1)

The patient is hemodynamically stable on arrival and is rapidly weaned off vasopressors. His GCS is initially 5T, with ICP of less than 20 mmHg; brainstem reflexes are intact. He is evaluated by a neurosurgeon, and a repeat CT is performed. The CT reveals intraventricular and large intraparenchymal hemorrhages. His ICP gradually increases to greater than 20 mmHg, and he is taken back to the operating room for evacuation of hematomas and drain placement. ICP improves, and GCS post-op is 4T. Enteral feeding is begun. Prophylaxis for deep venous thrombosis (DVT) *and pulmonary embolism (PE) is begun early based on a personalized medicine approach utilizing the patient's demographics, thromboelastography data, and precision genomics.* Baseline duplex ultrasound of the extremities reveals no thrombi.

All medical charting is completed electronically during the patient's stay and automatically uploaded to the MCC computer. An abbreviated medical status report is exported to the flight care team's tablet for use during transport care. The patient is evacuated to the United States with a GCS of 4T. The flight is uneventful.

Role 5 Military Treatment Facility: United States

The initial care team in the United States has full access to the patient's past and current care medical record, including CT images and intra-operative photographs, through the MCC. A patient care conference is held days before the patient arrives, and care plans are prepared and initiated upon his arrival. The patient is hemodynamically stable on admission, *but transport trend vital signs suggest a slight but growing fever.* The infectious diseases service is available upon the patient's arrival, and its evaluation reveals pneumonia with a focus in the right lower lobe. Organisms isolated include *Hemolytic streptococcus* and *Serratia rubidaea*. The patient is administered antibiotics and antifungals. His GCS improves to 5T and ICP remains within normal range. His anasarca and brain edema improve, and he is able to tolerate enteric feeding.

The patient is transitioned to emerging consciousness rehabilitation after removal of the ventriculostomies on postinjury day 35. His pneumonia has resolved. Long-term follow-up demonstrates dramatically improved mental status. The patient can communicate reliably and is fully oriented. He does exhibit several cognitive deficits, such as reduced attention span and ability to concentrate, reduced visual spatial skills, and left-sided neglect, as well as some memory impairment. His physical status has also improved. He is able to use his right upper extremity and has modest antigravity strength in his right lower extremity. He has little use of his left upper or lower extremities as a result of the site of brain injury. He tolerates sitting for greater than 4 hours per day and can stand for 40 minutes at a time. His tracheostomy is decannulated and he can eat a regular diet.

This case represents an appropriate use of a learning health system to ensure seamless transitions of care between care teams, resulting in the best possible outcome for a severely injured patient.

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5

Creating and Sustaining an Expert Trauma Care Workforce

"He who wishes to be a surgeon, must first go to war."

—Hippocrates

Trauma is complex. It can result in life- and limb-threatening injury, multiorgan failure, massive tissue damage, and physiologic dysfunction. To save lives and minimize disability in the face of such destruction requires a system of care with a diverse network of professionals capable of rapidly responding and delivering lifesaving interventions. In the military, the survival and well-being of service members depends on the creation and sustainment of a coalition of medical providers and allied health professionals[1] with expertise in trauma care. This chapter presents the committee's assessment of the extent to which the current education, training, and career development approach of the U.S. Department of Defense (DoD) is sufficient to ensure a ready military trauma care workforce[2] and how that system facilitates knowledge sharing between the military and civilian sectors.

THE MILITARY HEALTH SYSTEM READINESS MISSION

The principle mission of the Military Health System is readiness (MHS, 2014). Increased readiness is one of four goals captured in the Military

[1] Allied health professionals are the "segment of the workforce that delivers services involving the identification, evaluation and prevention of diseases and disorders; dietary and nutrition services; and rehabilitation and health systems management" (ASAHP, 2014).

[2] A full analysis of systems for ensuring the competency of the civilian trauma care workforce is beyond the scope of this report.

Health System Quadruple Aim,[3] which also includes better health, better care, and lower cost (DoD, 2014). Readiness is multifaceted; in the medical context, however, it means that the total military workforce is medically ready to deploy and, most relevant to the work of this committee, that the military medical force is ready to deliver *expert* health care (including combat casualty care) in support of the full range of military operations, domestically and abroad (DoD, 2014; Maldon et al., 2015). To sustain a medically ready force, the Military Health System delivers comprehensive health care to DoD service members, but health care services are also made available to other eligible beneficiaries. In fact, DoD provides health care to 9.6 million people worldwide, including active duty service members, dependents, retired service members, employees, and others. Currently, beneficiary care consumes approximately 10 percent of the annual DoD budget, approaching $50 billion (DoD, 2014). Because of its size, scope, expense, and everyday presence, beneficiary care drives the Military Health System, dwarfing its mission of providing a trained and ready medical force. Some exceptions exist, but in general, the Military Health System functions like a large health maintenance organization until wartime, when the need to care for those in harm's way generates an urgency to save lives (Mabry, 2015). It should be emphasized that although beneficiary care can be and, in some cases, has been contracted to civilian-sector health systems, the readiness mission can be carried out only by the DoD.

Readiness to deliver medical care in support of the combat mission necessitates both a sufficient number of providers to meet battlefield needs and that those providers have expertise in combat casualty care. Notably, however, there is no common definition among the services for readiness of the medical force,[4] nor is there a core set of standards for the acquisition and maintenance of trauma care skills (Maldon et al., 2015).

Provision of the highest-quality trauma care for the wounded is an expectation of the nation's service members and the American public. As stated by General Peter Chiarelli (2015), the U.S. Army's former vice chief of staff, "I know if I am providing [servicemen and -women] the kind of combat casualty care that they expect on a battlefield, every single one of them is going to be so much more a solider that is able to accomplish their mission than they would be if I did not." Failure to sustain the readiness of the medical force threatens the total deployed force and national security (Maldon et al., 2015). When the next military conflict inevitably transpires,

[3] The quadruple aim represents an adaption of the Triple Aim of the Institute for Healthcare Improvement (IHI, 2016).

[4] A common definition and reporting metrics exist for individual medical readiness (i.e., the workforce is medically ready to deploy). This is distinct from a common definition for readiness of the medical force, which does not exist.

there will be little time to reconstruct and ensure an optimal combat casualty care capability from a diminished state of readiness. DoD cannot wait until the next war to begin the process of generating a ready medical force to meets its wartime needs. If the lessons learned over the past 15 years are not sustained and history repeats itself, the next war will see the loss of lives and limbs that should have been saved.

THE TRAUMA CARE WORKFORCE

Optimal trauma care and patient outcomes require careful coordination of prehospital and hospital-based services. Thus while the term "trauma team" is often used to describe the in-hospital group of medical professionals responsible for the initial assessment, resuscitation, and surgical management of critically injured patients, the complete team of professionals responsible for trauma care spans both the prehospital and hospital environments. In the military and civilian sectors, the clinical trauma care workforce includes surgeons, emergency physicians, nurses, prehospital providers, technicians, anesthesiologists, intensivists, radiologists, and rehabilitation specialists, among others. Equally critical, however, is the wide range of professionals who directly support the clinical mission (supply, operations, information technology, management, administration), and those who collect and analyze data for performance improvement and research purposes (see Figure 5-1). This multidisciplinary approach to trauma care ensures the successful integration of knowledge and resources across the continuum of care and among different specialties and has been shown to improve outcomes (MacKenzie et al., 2006).

The Civilian Trauma Care Workforce

Initial trauma care in the prehospital setting is delivered by emergency medical technicians and paramedics. Although emergency physicians, advanced practice providers, and other specialists may handle many injuries in the hospital setting, most severe trauma cases that arrive at U.S. civilian trauma centers are ultimately cared for by trauma surgeons. Trauma surgeons possess not only general surgery training but also additional fellowship training in surgical critical care, and have demonstrated broader interest in trauma research and trauma systems. While the trauma specialty is relatively new, the development of such expertise has improved outcomes for critically injured patients in the civilian sector (Knudson, 2010). Patients sustaining serious trauma require a larger group of specialists than is required to treat less severe cases, including orthopedic surgery, anesthesiology, surgical critical care, radiology, blood banking/coagulation, infectious disease, and neurological surgery, among others. In addition, the expertise

FIGURE 5-1 The trauma care workforce comprises the clinical team as well as a much larger number of support personnel.

of nursing and allied health professionals in resuscitation, operating room procedures, and critical care is essential for optimizing the care of the most critically injured. Accordingly, civilian Level I trauma centers are designed, resourced, and prepared to deliver immediate lifesaving surgical procedures across a wide range of specialties; for example, they are required to have a trauma surgeon, surgical specialists, and all other medical specialists and providers available at all times (ACS, 2014).

The Military Trauma Care Workforce

The military trauma care workforce is far more complex in structure than its civilian counterpart. Although the interdisciplinary nature of the trauma care workforce is common to both sectors, added complexity arises from the multiservice nature of the military's medical force and the augmentation of active duty personnel with reservists and members of the National Guard (Cannon, 2016).

The military also deploys providers with a diverse array of medical backgrounds, specialties, and experience (Gawande, 2004). The vast majority of these providers, whose daily practice typically consists of delivering beneficiary care at military treatment facilities (MTFs), rarely encounter trauma and thus lack the necessary expertise to deliver trauma care on the battlefield (see Table 5-1 for an overview of the variable levels of clinical competence). In this respect they differ from their civilian counterparts: the trauma care workforce in the civilian sector includes a set of core professionals whose primary focus is the daily delivery of trauma care (e.g., emergency physicians, trauma surgeons, trauma nurses, EMS providers). It is important to acknowledge the psychological effects of assigning physicians, nurses, technicians, and medics with non-trauma-related specialties to combat care. Many will likely witness and feel professionally responsible for the deaths of young soldiers and civilians under their care, and as a result are likely to suffer increased psychological stress, emotional trauma, and professional burnout (Lang et al., 2010; Lester et al., 2015).

While the management of civilian trauma patients is similar in some respects to the management of battlefield trauma, the evaluation, resuscitation, and treatment of wounded combatants present a unique challenge

TABLE 5-1 Five Levels of Clinical Competence

Skill Level	Description	Trauma-Related Example
Novice	The novice has no experience in the environment in which he or she are expected to perform.	Administrator or technician who has never worked in a trauma center.
Advanced beginner	The advanced beginner demonstrates marginally acceptable performance and has enough experience to note recurrent meaningful situational components.	Medic that has had didactic trauma training but no clinical trauma experience.
Competent	Competence is achieved when one begins to see one's actions in terms of long-range goals or plans. This individual demonstrates efficiency, coordination, and confidence in his/her actions.	Board-eligible/certified physician, but has only rotated as a resident at a trauma center.
Proficient	The proficient individual perceives situations holistically and possesses the experience to understand what to expect in a given situation.	Board-eligible/certified physician or new nurse, starting their career at a high-volume and best-quality Level I trauma center.
Expert	The expert has an intuitive and deep understanding of the total situation and is able to deliver complex medical care under highly stressful circumstances.	Trauma nurse coordinator or fellowship trained trauma surgeon with years of experience at a high-volume and best-quality Level I trauma center.

SOURCES: Adapted from Benner, 1982; Dreyfus, 1981; Dreyfus and Dreyfus, 1980.

when military teams are deployed to theater. In the civilian sector, medical care is provided along specialty lines that have emerged based on disease type, organ dysfunction, or procedural expertise. In a 2008 survey of civilian trauma centers, only 18 percent of Level I centers indicated that their trauma surgeons could perform "a full complement of vascular, thoracic, and abdominal procedures" (Cothren et al., 2008, p. 955). In contrast to cases seen in civilian trauma centers, battlefield injury patterns—including a higher concentration of massive body destruction and exsanguination—require a broad set of surgical skills and competencies that can be applied in difficult environments and conditions (Mabry et al., 2000). As noted by Schwab (2015), however, there is no defined skill set required to deploy and serve as a combat surgeon. Throughout the wars in Afghanistan and Iraq, general surgeons who have been deployed have had backgrounds in a variety of specialty domains within the classification of general surgery, including pediatric, thoracic, and vascular surgery (Sorbero et al., 2013). This challenge is not limited to surgeons. It is not unusual to have members of the trauma team inexperienced and uncomfortable in trauma care deployed to the battlefield without an assessment of their competence to care for severely injured casualties. The Air Force has made the greatest strides in addressing this issue through the creation of a series of readiness skills verification checklists, which provide guidance on the clinical competencies different providers (e.g., nurses) need to have and what care they may be expected to provide upon deployment (Bridges, 2016).

Additionally, the military's surgical workforce is notably young, with a mean age of 36 at the time of first deployment (Schwab, 2015). In a survey of 137 military surgeons across all three services, 65 percent had been deployed for the first time without completing a fellowship (Tyler et al., 2012). This represents another notable difference from the civilian sector, where senior-level trauma and surgical critical care experts (almost all of whom are fellowship trained) provide leadership and oversight at Level I and II trauma centers.

Within the trauma care workforce, nurses are crucial members of multidisciplinary clinical teams and often assume responsibility for managing patient flow between phases of care (Richmond, 2016), thus faciitating a patient-centered approach to trauma care (discussed in more detail in Chapter 6). Nurses also serve as trauma nurse coordinators (TNCs) in Role 3 (e.g., combat support hospitals), Role 4 (e.g., Landstuhl Regional Medical Center), and Role 5 (continental United States) MTFs[5] and as Air Force flight nurses within the aeromedical evacuation system (Fecura et al., 2008). In the deployed setting, TNCs manage the Joint Trauma System's

[5] In military Role 4 and Role 5 facilities, trauma nurse coordinators are civilian trauma nurses.

(JTS's) performance improvement program and the DoD Trauma Registry (DoDTR). In preparation for this role, nurses from all the services may take the Trauma Outcomes and Performance Improvement Course-Military (discussed in more detail below) (Fecura et al., 2008).

Medical personnel in the enlisted corps can serve as medics (Army), medical technicians (Air Force), hospital corpsmen (Navy), independent duty medical technicians (Air Force), or licensed practical nurses (Army). These individuals are high school graduates (or possess the equivalent of a high school diploma) and have completed basic military training (Cannon, 2016). Many of these prehospital providers that deploy to an active combat zone have provided little to no care to trauma patients. The first trauma patient a military medic cares for may be on the battlefield (Bier et al., 2012; Cannon, 2016).

As of 2012, approximately 280 providers (Air Force, 78; Army, 100; Navy, 100) were able to deploy as fully trained, active duty general surgeons to combat or other operational zones. This group includes 30 to 35 surgeons fellowship trained in trauma and surgical critical care or burn care (DuBose et al., 2012). The military trauma care workforce further consists of nearly 4,000 members of the Nurse Corps and 36,000 members of the Enlisted Corps (Sorbero et al., 2013). The active duty trauma workforce is supplemented by National Guard members and reservists. The National Guard and reserve units deploy physicians, nurses, and medics; some of them bring a high level of quality and significant expertise (Cannon, 2016), while others do not regularly provide trauma care or perform general surgery in their daily practice (DuBose et al., 2012).

The composition of military clinical teams in the deployed setting varies across the echelons of care (see Box 5-1). The optimal composition of the medical team in Role 1 (e.g., battalion aid stations), Role 2 (e.g., forward surgical teams), and Role 3 (e.g., combat support hospitals) facilities has been debated (Schoenfeld, 2012). What is clear is that a large proportion of preventable trauma deaths are associated with hemorrhage and exsanguination—often from junctional and torso wounds—necessitating prehospital providers and forward surgical teams armed with trauma care expertise.

The importance of having trained providers with experience and expertise relevant to their assigned roles is highlighted in multiple studies. In an observational analysis by Gerhardt and colleagues (2009), a battalion aid station augmented with providers with emergency medicine expertise experienced a lower case fatality rate compared to the aggregate theater-wide case fatality rate (7.14 percent versus 10.45 percent). At this battalion aid station, a board-certified emergency physician and emergency medicine physician assistant delivered care, provided medical direction to medics, and mentored other providers (Gerhardt et al., 2009). A separate study

Box 5-1 **CHARACTERISTICS OF THE MILITARY TRAUMA CARE WORKFORCE IN THE DEPLOYED SETTING**

Within the military are five roles of care encompassing treatment from the point of injury to tertiary care and rehabilitation (see Chapter 2). Role 1 care occurs in the prehospital setting, where care is provided by medical and nonmedical personnel. In-hospital military trauma care (Roles 2-5) is staffed by a diverse workforce similar to that of civilian hospitals.

Role 1 (prehospital) Immediate lifesaving care is administered by self-aid, nonmedical first responders (buddy care), or the military medic, whose function is somewhat analogous to that of the civilian emergency medical technician (EMT). At a Role 1 battalion aid station, care is provided by a physician, physician assistant, and/or a medic.

Role 2 At the Role 2 facility (e.g., forward surgical team [FST]), patients are stabilized by immediate life- and limb-saving surgical procedures. An FST typically consists of 10 officers and 10 enlisted members and includes 3 general surgeons, 1 orthopedic surgeon, 1 critical care/head nurse, 1 operating room nurse, 2 nurse anesthetists, 1 emergency nurse, 3 vocational nurses, 3 surgical technicians, and 3 combat medics. The team is designed to be very mobile and can set up an operating room within an hour. Procedures performed include laparotomy, thoracotomy, open fracture repair, and external fixation placement.

Role 3 The Role 3 hospital (e.g., a combat support hospital) is set up in a large series of tents, in a building, or on board a ship. Role 3 hospitals typically maintain up to eight operating rooms and can provide 24-hour surgical services. Usual staffing consists of 3 to 4 general surgeons, 2 orthopedic surgeons, 4 anesthesia providers, 1 emergency physician, and 3 internal medicine providers. Subspecialists such as radiologists, otolaryngologists, and neurosurgeons may be available depending on the mission. Ultrasound, computed tomography, blood bank, laboratory, and pharmacy services are also available at the hospital.

Roles 4 and 5 These large hospitals, within and outside of the United States (e.g., Landstuhl Regional Medical Center in Germany), offer continuing intensive care, secondary operations, and rehabilitation. At these military treatment facilities, most surgical specialties are represented, and required expertise encompasses definitive war injury repair and reconstruction.

En Route Care En route care is provided during transport (air or ground) between different roles of care. Critical care air transport teams, which consist of a critical care physician, a critical care nurse, and a respiratory therapist, provide ongoing management of ventilated, critically ill patients during air transport between facilities in theater or during evacuation out of theater to Role 4 or 5 facilities. They utilize hemodynamic monitoring, vasoactive drugs, negative pressure wound therapy, and other lifesaving therapies while transporting wounded combatants over long distances. Military flight crews are required to take the critical care air transport course offered by the Air Force. Transport personnel in the civilian sector are required to be certified in basic life support, advanced life support, and advanced trauma life support.

SOURCE: Schoenfeld, 2012.

identified a disparity in outcomes based on the level of expertise available on helicopter transports. Standard Army MEDEVAC transport helicopters were staffed by a single medic trained as an emergency medical technician (EMT)-basic. In contrast, some deploying medics from the National Guard were certified as critical care flight paramedics (CCFPs)—the standard required to transport patients on civilian helicopters. Comparing outcomes in patients transported by standard Army MEDEVAC units and CCFP-staffed units, 48-hour mortality was 15 percent versus 8 percent, respectively, and transport by a CCFP was independently associated with a 66 percent estimated lower risk of mortality relative to the standard MEDEVAC system (Mabry et al., 2012). These results spurred efforts to implement higher training requirements for prehospital military medics, alternative staffing models, and expert medical direction for MEDEVAC transports going forward (Ficke et al., 2012).

CHALLENGES TO ENSURING AN EXPERT MILITARY TRAUMA CARE WORKFORCE

In an expert military trauma care workforce, as envisioned by the committee, every military provider is not expected to be an expert (as defined in Table 5-1) in trauma. An expert workforce will include providers with variable levels of expertise, as is the case in the civilian sector. However, to eliminate preventable deaths after injury and ensure the provision of the highest-quality trauma care, each interdisciplinary trauma team at all roles of care needs to include an expert for every discipline represented. These expert-level providers will oversee the care provided by their team members, all of whom must be minimally proficient in trauma care (i.e., appropriately credentialed with current experience caring for trauma patients).

At this time, a number of policy and operational barriers impede the military's ability to ensure such an expert trauma care workforce, including an oscillating trauma workload, a challenging work environment in theater, providers' beneficiary care responsibilities, and challenges with recruitment and retention in the absence of career paths for trauma providers.

Trauma Workload and Environment

Notable differences characterize the delivery of trauma care in the military and civilian sectors. The work environment in theater is very different from that experienced by civilian surgeons: the workload is higher, the traumas are more severe, and surgeons must deal with limited resources in an environment that is sometimes hostile. The nature of the traumas frequently encountered in theater—"multiply injured patients with high-energy transfer fragment, projectile, and blast wounds"—demands a unique level of skill and damage control (Ramasamy et al., 2010, p. 455; Rosenfeld, 2010).

In addition to dealing with high-acuity, polytrauma cases and multiple-casualty events,[6] the military faces challenges not seen in civilian settings as a result of the episodic nature of wartime trauma care requirements (see Figure 5-2). The volume of trauma patients seen by military providers varies dramatically depending on whether the United States is actively engaged in combat operations. In contrast, the civilian sector sees a more sustained volume of trauma cases over time, particularly in Level I and II trauma centers. Deployed military medical providers can face a sustained high trauma workload not commonly experienced by their civilian counterparts, depending on operational tempo. Ramasamy and colleagues (2010) found that a 6-week deployment to Afghanistan provided exposure to penetrating trauma equivalent to 3 years of working in a United Kingdom hospital. Those kinds of trauma patients are rarely seen in stateside MTFs. However, with the exception of regular exposure to the severe soft tissue injuries and amputation seen from combat, the case mix in civilian Level I and II centers more closely resembles that seen on the battlefield (Schreiber et al., 2008).

Competing Roles for Military Medical Providers

The military medical workforce is not large enough to simultaneously meet staffing requirements for both beneficiary care and the readiness mission of the Military Health System. Instead, most active duty medical personnel, including general surgeons, are permanently assigned to MTFs, including community hospitals and clinics, where they are responsible for beneficiary care. When the military is engaged in combat operations, medical personnel from MTFs can be temporarily reassigned to fill slots in deploying combat units. The Professional Filler System (PROFIS), for example, is used by the Army Medical Department to manage the reassignment process (DoD, 2015b; Sorbero et al., 2013).

The Military Health System is unique within the military with regard to its approach to readiness. Line units train constantly for their wartime missions (e.g., working on marksmanship or maneuvers), using repetition to develop and sustain skills so that when they must engage in combat, they can respond with world class precision and can adapt and overcome obstacles (Beekley, 2015). In the educational vernacular, they are expert, not just familiar. Repetition is equally critical to ensuring the competency

[6] Although high-acuity, polytrauma cases and multiple-casualty events may be seen in certain civilian settings (e.g., Level I trauma centers within major urban areas), such cases occur with more frequency on the battlefield (McCunn et al., 2011).

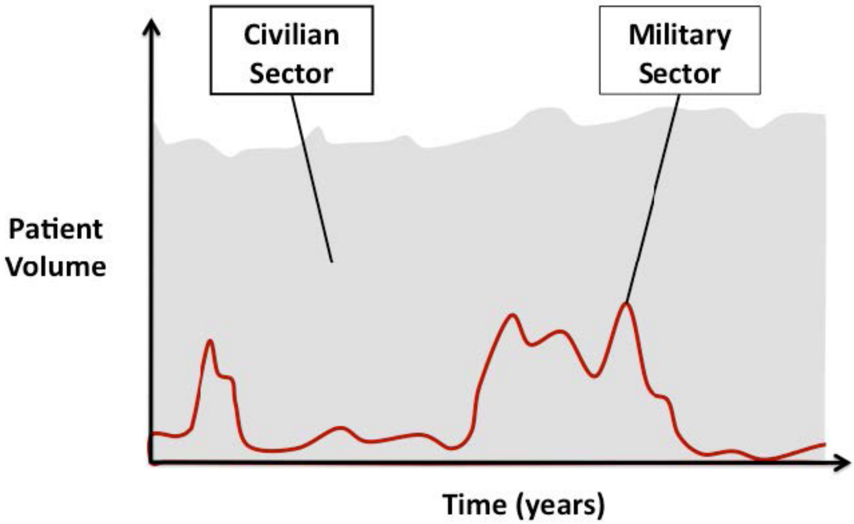

FIGURE 5-2 The episodic nature of trauma care in the military sector as compared with the civilian sector.
SOURCE: Cannon, 2016.

of medical providers; patient volume has been identified as a key factor associated with patient outcomes in both military and civilian trauma care settings (Nathens and Maier, 2001; Schreiber et al., 2002). However, military medical providers maintain their clinical skills through in-garrison care, which is largely devoid of trauma patients. Although this dual role of medical providers helps the Military Health System achieve cost efficiencies, it exacts a toll on the combat casualty care readiness mission. The common types of beneficiary surgical care provided at MTFs—obstetric, general, and elective—are rarely applicable to combat care (Eibner, 2008; Maldon et al., 2015) (see Figure 5-3). The military has only a handful of trauma centers in which medical personnel see sufficient volumes of trauma patients to maintain combat-relevant skill sets. Only one, San Antonio Military Medical Center, is currently verified as a Level I trauma center. As a result, the average infantry soldier is much better prepared for a combat mission than the average military general surgeon (Beekley, 2015). For prehospital providers, sustainment of skills is similarly challenging, as medics may be assigned to nonmedical duties (e.g., detailed to the motor pool) when they are not deployed. These front-line medical personnel have potentially the most significant mismatch between their daily (nondeployed) experience and the job expected of them on the battlefield. It is not unusual for these young medics to not be allowed to perform their medical tasks, even within

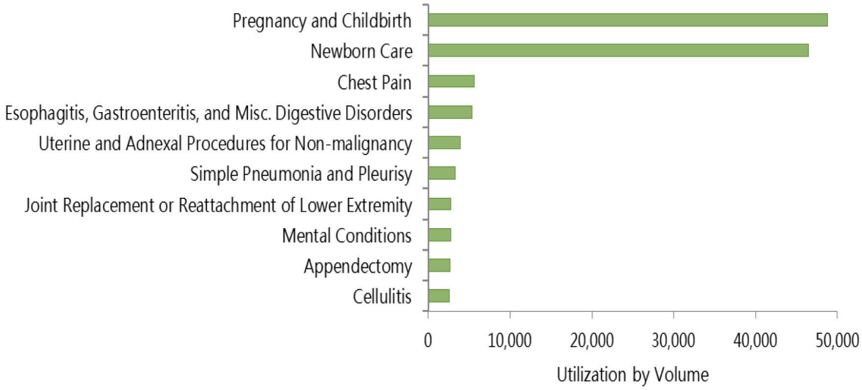

FIGURE 5-3 Top 10 inpatient procedures in military treatment facilities, fiscal year 2014.
SOURCE: Data from DoD, 2015a.

military hospitals, yet are expected to function effectively under the most extreme circumstances on a hostile battlefield.

The misalignment of skill sets needed for beneficiary care and combat casualty care and the impact of the current system on medical readiness have been the subject of a number of investigations and reports. In 1992 and 1993, the U.S. Government Accountability Office (GAO) (at the time called the U.S. General Accounting Office) issued reports on deficiencies in medical readiness identified during the Gulf War in each of the services and resultant examples of substandard care (GAO, 1992, 1993a,b). The reports cited cases of deployed nurses and physicians who had never treated trauma patients, many of whom had not even received training in combat casualty care (GAO, 1998). Also highlighted were inappropriate staffing selections, such as the assignment of a gynecologist to fill a thoracic surgeon slot. These deficiencies were due in part to the depletion of combat-relevant specialties in the medical ranks in the years leading up to the Gulf War. In 2008, a RAND report similarly identified a significant gap between the skills needed to meet beneficiary needs at MTFs and the skills needed for deployment to a combat zone (Eibner, 2008). Many of these same issues still exist today.

Recruitment and Retention in the Absence of Career Paths for Trauma Providers

Since the transition to an all-volunteer military medical force, recruitment and retention of physicians, nurses, medics, and other allied health professionals has been challenging, particularly in times of war, when the likelihood of deployment can serve as a deterrent. Competition with the lucrative private sector[7] poses a considerable impediment to meeting military medical staffing needs, despite recruitment strategies such as signing bonuses and medical education scholarships (Holmes et al., 2009; Mundell, 2010).

Beyond these general challenges, the recruitment and retention of trauma and critical care specialists are impeded by additional hurdles that have received inadequate attention—a surprising observation given the core readiness mission of the Military Health System. The trauma and critical care specialties are relatively new (early 1990s) and despite being associated with improved outcomes for seriously injured individuals in the civilian sector, have not been embraced by the military services as a specific career path. For example, across the services, there is no skill identifier for nurses with specific trauma expertise, including trauma nurse coordinators, who serve a critical role in civilian trauma centers (Bridges, 2016). At only one DoD Level I trauma center can a senior military physician serve as the trauma medical director. As a result of the absence of defined trauma career pathways, a notable difference between the military and civilian sectors is the routine delivery of trauma and critical care by nonspecialists in the deployed setting. This lack of specialty expertise is not limited to the surgical teams but is a broader problem for combat casualty care, much of which is delivered after patients leave the operating room (e.g., within the intensive care unit) (Cap, 2015).

Relatedly, promotion requirements can impede the professional development of senior-level military clinicians. For example, the committee heard that nurses wishing to be promoted beyond the O4 level[8] may have to leave clinical practice (Wilmoth, 2016), resulting in a dearth of senior-level individuals able to serve as trauma nurse coordinators.

The paucity of opportunities to sustain trauma and critical care skills during assignment to stateside MTFs poses additional challenges to retention of clinicians with these skills (Cannon, 2016). Members of the military (medics, technicians, nurses, and physicians) who desire a career in the trauma field have limited opportunities within the Military Health System to practice their chosen specialty or to advance to leadership positions. By contrast, the civilian sector has abundant professional career opportunities for medical, nursing, and EMS professionals who wish to spend their careers caring for trauma patients and leading the development of trauma systems. With the end of the wars and the return to a focus on beneficiary

[7] Physician wages in the civilian sector, for example, may be as much as three times those of equivalent military physicians (Mundell, 2010).

[8] O4 represents field grade officers at the rank of major (Air Force, Army, Marines) or lieutenant commander (Navy).

care, the loss of opportunities to exercise trauma care skills has already spurred many of these military experts to transition to the civilian sector (Mullen, 2015). Financial incentives and opportunities to train or practice (full- or part-time) at civilian trauma centers (discussed below) have the potential to positively influence these clinicians to remain in the military (Eibner, 2008; Schwab, 2015).

The development of an expert trauma workforce requires a significant investment of both time and resources, necessitating in some cases more than a decade of education and specialty medical training. The committee recognizes that the entire military medical system need not be combat care oriented; however, given that combat care can be delivered only by the Military Health System, that system needs to allocate the necessary resources to maintain a well-trained and adequately staffed workforce.

CURRENT MILITARY APPROACHES TO ACHIEVING A READY MEDICAL FORCE

To address deficiencies in combat casualty care capabilities noted during the Gulf War, a number of changes were instituted to improve the readiness of the medical force. An evaluation of the military's current approach to readiness and a description of opportunities for exchange of trauma care knowledge with the civilian sector are presented in the sections below.

The Medical Education and Training Pipeline

Trauma care providers undergo their education and training through a number of possible combinations of military and civilian experiences. This training pipeline provides some opportunity for cross-sector pollination (see Figure 5-4). However, one's course along this pipeline will determine the degree of one's exposure to military concepts and the extent of one's interface with civilian counterparts.

Physician and Nursing Education and Training

Like the civilian trauma care workforce, the vast majority of military physicians and nurses receive initial medical education in civilian academic programs, although the military offers graduate-level medical, dental, and nursing education through the Uniformed Services University of the Health Sciences (USUHS). Military physicians who receive their medical education at civilian academic medical centers often (though not always) do so under the Armed Forces Health Professionals Scholarship Program (HPSP). This program pays tuition, fees, and a stipend for students attending accredited health professional programs; after graduation, students are obligated to

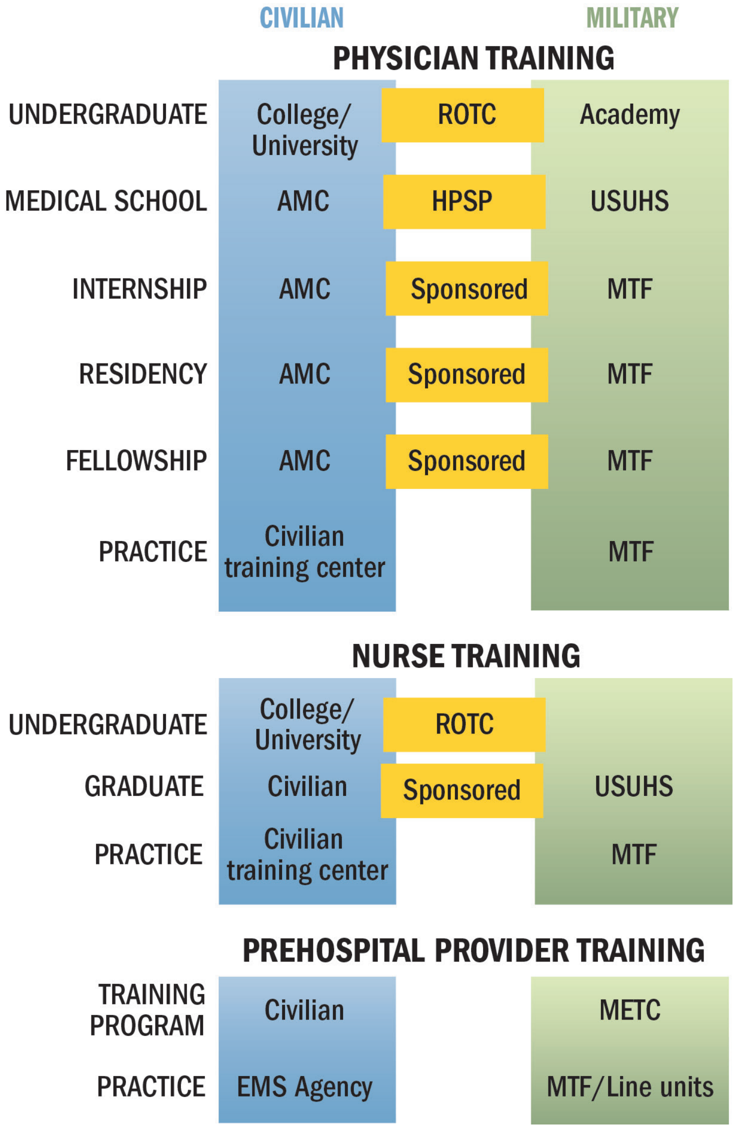

FIGURE 5-4 Training pipeline for military physicians, nurses, and prehospital providers.

NOTES: Training provided in the civilian sector is shown in blue, while that conducted in the military sector is shown in green. Training conducted in the civilian sector with a military obligation (e.g., HPSP) or sponsorship is shown in orange. Transition between military and civilian training pathways can occur at any number of points along the pipeline, not just through those mechanisms labeled in orange. For example, civilians finishing medical school can volunteer for military service without HPSP.

AMC = academic medical center; EMS = emergency medical services; HPSP = Health Professionals Scholarship Program; METC = Medical Education & Training Campus; MTF = military treatment facility; ROTC = Reserve Officer Training Corps; USUHS = Uniformed Services University of the Health Sciences.

SOURCE: Adapted from Cannon, 2016.

enter active duty unless it is deferred for the purposes of further medical training. During their civilian medical education, HPSP students have no organized military medicine curriculum (including military medical history and combat casualty care) and have limited exposure to military physicians (Cannon, 2016). Similarly, an undergraduate nursing degree can be pursued under a Reserve Officer Training Corps (ROTC) scholarship, but beyond fundamental military training required of all ROTC candidates, such nurses receive little to no exposure to military nursing mentors during that time period.

Civilian academic medical centers also host military physicians for residency and fellowship training, although residency and fellowships are more commonly completed at MTFs, depending on the service requirements and the specialty. However, there is only one military trauma and surgical critical care fellowship (at San Antonio Military Medical Center), so all other training in these specialties is provided in civilian academic medical centers. Even those physicians selected for military residency may complete their trauma requirements (1- to 2-month rotations) at a civilian trauma center. The military has unquestionably benefited from trauma surgeons trained in the civilian sector—such individuals were key in applying the principles of systems-based approaches to trauma care to the creation of an in-theater trauma system. As with graduate medical education, however, exposure to combat casualty care-relevant experiences (e.g., through contact with experienced military trauma faculty) is limited for residents and fellows trained at civilian academic medical centers. According to Cannon (2016), in a paper commissioned for this study, "In the absence of any military-specific training or educational requirements, even those who are on a pathway for deployment soon after graduation are not afforded relevant military educational opportunities in the current military medical training pipeline."

The best possible combat training experience comes from deployment, but there currently is no mechanism for deployment of residents or fellows in military training programs. This contrasts with the British model, in which surgical residents are routinely sent into combat zones to gain combat casualty care experience (Ramasamy et al., 2010), although such deployments might significantly extend the training timeline.

USUHS is a federal health science university with graduate programs in medicine, nursing, and dentistry. It educates a comparatively small number of military medical physicians and nurses each year: there have been about 7,200 total graduates since its establishment in 1972. Frequent deployments and a long service commitment may make USUHS less appealing to some medical applicants (Holmes et al., 2009). However, USUHS graduates tend to stay in military service longer than other service members (perhaps related to their obligations) and often rise to leadership roles (Rice, 2015). USUHS feeds military physicians into all three services, providing opportunities to cross-pollinate innovations and best practices among the services. The training it offers is unique in several ways. Students are active duty military during their studies and are exposed early on to military-relevant topics. They also participate in field training exercises to prepare for the field environment in which they will be practicing. USUHS makes extensive use of its Simulation Center, which allows students to gain hands-on clinical experience in a safe environment.

Education and Training of Military Medics

Basic medic training is completed over 14 to 20 weeks (depending on the service) at the Medical Education & Training Campus, and most medics must subsequently maintain national registry certification (METC, 2016; Sohn et al., 2007). Looking at performance over time on a national certification exam, one sees that military medics outpace their civilian counterparts (see Figure 5-5). However, with the notable exception of Special Forces medics, whose training lasts 1 year and who sustain their skills

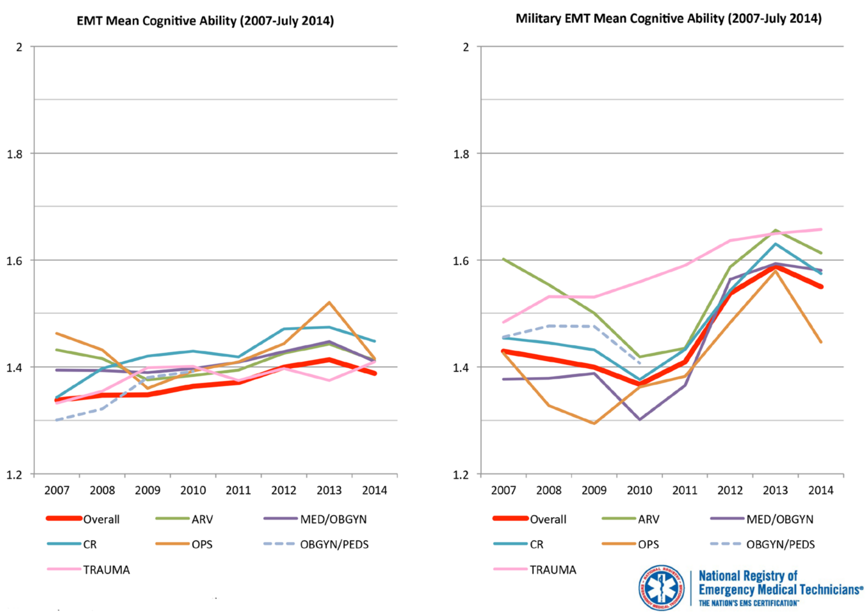

FIGURE 5-5 Comparison of civilian and military emergency medical technician (EMT) performance on the National Registry assessment.

NOTE = ARV = airway, respiration, ventilation; CR = cardiology; EMT = emergency medical technician; MED = medical; OBGYN = obstetrics and gynecology; OPS = operations; PEDS = pediatrics.

SOURCE: Reprinted, with permission, from the National Registry of Emergency Medical Technicians (NREMT). 2015. Civilian EMT to Military EMT Cognitive Exam Performance. Produced by the NREMT.

through training agreements with civilian trauma centers (e.g., University of Alabama), most of these individuals have no contact with civilian personnel throughout their training, nor do they commonly interact with civilian prehospital providers or civilian medical technicians in their career fields (Cannon, 2016). Furthermore, despite the requirement to function in a high-stress environment (i.e., delivering tactical care under fire) and limited resources, military medics are not required to have had any patient contact prior to deployment (Cannon, 2016). Minimal training and capability requirements for prehospital personnel reflect legacy paradigms for combat casualty care focused heavily on transport of casualties to a hospital. Investigations during the wars in Afghanistan and Iraq showed that prehospital care is the phase of care with the greatest potential for reducing deaths from survivable injuries (Eastridge et al., 2012; Kotwal et al., 2011), but this potential is only realized if the medics can perform the interventions necessary to improve outcomes. This conundrum of prehospital training versus real clinical expertise for military medics has been described for many years. Refocusing of military medics away from nonmedical tasks toward actual patient care in a trauma setting is imperative.

Clinical Practice

Following medical education and training, physicians, nurses, and allied health professionals generally are assigned to an MTF. Of the Military Health System's 56 hospitals and medical centers (DoD, 2014),[9] only 6 are either verified by the American College of Surgeons or state-designated as trauma centers:

- Level I—San Antonio Military Medical Center (ACS verified)
- Level II—Walter Reed National Medical Center (ACS verified) and Madigan Army Medical Center (state designated—Washington)
- Level III—Darnall Army Medical Center (state designated—Texas) and Landstuhl Regional Medical Center (ACS verified)[10]
- Level IV—Tripler Army Medical Center (state designated—Hawaii) (ACS, 2016a; DHB, 2015)

As discussed earlier in this chapter, surgical cases managed within most MTFs bear little resemblance to those faced on the battlefield. In addition,

[9] This number excludes the hundreds of military outpatient facilities that also make up the Military Health System.

[10] It should be noted that Landstuhl Regional Medical Center was verified as a Level I center by ACS in 2011. Due to decreased trauma patient volume, the facility voluntarily stepped down to a Level III center, but at any pivot point, could step up to a Level I again.

the Level III and IV centers referenced above provide minimal trauma experience (relative to Level I/II centers) for military medical personnel assigned to them. To maintain adequate caseloads for verification as a Level I center, San Antonio Military Medical Center has a partnership with the local civilian community that enables it to provide care to nonbeneficiary trauma patients (Cannon, 2016). Madigan Army Medical Center in Washington has a similar arrangement that enables it to maintain patient volumes appropriate for a Level II trauma center.

Providers also can be assigned to oversee predeployment training at a civilian trauma center, where injury types and patient clustering better approximate combat casualty scenarios (McCunn et al., 2011). Military personnel assigned to trauma training programs at civilian trauma centers see trauma patients on a daily basis and develop expert-level knowledge, skills, and capabilities. However, if these embedded personnel deploy, it is important that they be replaced with experienced providers so that the training mission of these centers is not compromised.

Predeployment Training and Combat-Relevant Trauma Courses

Given the differing roles of peacetime and deployed military medical providers, the military has developed a number of training mechanisms with the goal of sustaining skills in combat casualty care. These mechanisms include just-in-time training through joint military–civilian predeployment programs and a range of training courses. Periodic, short-term trauma center assignments and the completion of training courses also are part of the military's continuing education programs.

Joint Military–Civilian Predeployment Training Programs

To address the disparity between the number of military trauma specialists (in all provider categories) and the battlefield requirements for combat casualty care, the majority of military trauma training is outsourced as just-in-time training (2- to 4-week rotations) at five civilian trauma centers (Thorson et al., 2012). In 1996, following the publication of the series of GAO reports referenced above highlighting deficiencies in the military's ability to maintain the medical readiness necessary to fulfill its wartime mission (GAO, 1992, 1993a,b), Congress mandated that DoD conduct trauma care training in civilian hospitals (GAO, 1998). To comply with this mandate, military medical personnel were permanently assigned to Ben Taub General Hospital, an urban Level I trauma center that treats patients with penetrating injuries whose treatment could prepare trauma teams for the battlefield. Army, Navy, and Air Force surgical teams rotated through Ben Taub on a monthly basis. Over the course of this month-long training program, military surgeons saw more than twice as many trauma cases as they had in an entire year at their home station. This course resulted in increased confidence among individual providers and the entire trauma team (Schreiber et al., 2002). When the Joint Trauma Training Center at Ben Taub closed, the services opened separate trauma training centers in high-volume civilian facilities (see Table 5-2).

Trauma Courses

A number of trauma training courses are designed to support the readiness of trauma care providers prior to deployment. These courses vary in length, topic area, and training methods (see Table 5-3). Within the military, joint and service-specific courses related to combat casualty care use a combination of didactic and hands-on training methods and have content focused on specific roles of care (prehospital, Role 1, Role 2, etc.) or subspecialties such as orthopedics, emergency medicine, general surgery, anesthesia, and nursing (McManus et al., 2007). Through the Defense Medical Readiness Training Institute (DMRTI), DoD offers 26 jointly sponsored courses with 6 instructor training programs (AMEDD, 2016). DMRTI works with each service and USUHS to develop curriculum and updated content. It is working to streamline readiness training efforts across the services, reduce duplication of training programs, and coordinate readiness training efforts between the military and civilian sectors. DMRTI sponsors the Emergency War Surgery Course and the Tactical Combat Casualty Care Course (Miller, 2015).

Some courses, such as the National Association of Emergency Medical Technicians' (NAEMT) Prehospital Trauma Life Support and the American

TABLE 5-2 Military–Civilian Predeployment Training Programs

	ARMY	NAVY	AIR FORCE
Program	Army Trauma Training Center	Navy Trauma Team Center	Center for Sustainment of Trauma and Readiness Skills
Location	University of Miami Ryder Trauma Center	Los Angeles County Medical Center	Baltimore Shock Trauma, University of Cincinnati, St. Louis University
Duration	14 days	21 days	19 days
Program highlights	Mass casualty exercise, emphasis on team training	Didactic session, simulation, mass casualty exercise, emphasis on team training for those assigned to Role 2	Didactic session, simulation, cadaver procedure laboratory, mass casualty exercise

SOURCE: Thorson et al., 2012.

TABLE 5-3 Combat-Relevant Training Courses Provided by Military and Civilian Organizations

		Course Name	Duration	Provider Type	Topic	Training Methods
MILITARY	ARMY	Tactical Combat Medical Care	5 days	Physician assistants, nurse practitioners assigned to Role 2 facilities	Role 2 advanced lifesaving interventions	Live tissue, didactic sessions, and simulation
MILITARY	ARMY	Joint Force Combat Trauma Management Course	5 days	Combat support hospital care providers	Role 3 training—critical care, patient transport, and operative management	Simulated casualty scenarios using cadaver and live tissue models, and didactic sessions
MILITARY	JOINT	Tactical Combat Casualty Care (TCCC)	2 days	First responders, including nonmedical personnel	Role 1—TCCC	Casualty scenarios and didactic sessions
MILITARY	JOINT	Emergency War Surgery Course	3 days	General and orthopedic surgeons	Various military field topics and surgical skills	Cadaver laboratory and various animal models, mass casualty exercise
MILITARY	JOINT	Trauma Outcomes and Performance Improvement Course-Military	1 day	Physicians, nurses, trauma registrars	Performance improvement	Didactic sessions and military-specific case studies
CIVILIAN	ACS	Advanced Trauma Life Support (ATLS)	2–2.5 days	Physicians, physician assistants, advanced practice nurses	Early patient management and resuscitation	Didactic sessions, skill stations
CIVILIAN	ACS	Advanced Trauma Operative Management	1 day	Surgeons	Operative management of penetrating injuries to the chest and abdomen	Didactic sessions, simulated casualty scenarios using cadaver and live tissue models
CIVILIAN	ACS	Advanced Surgical Skills for Exposure in Trauma	1 day	Surgeons	Surgical exposures in key areas: neck, chest, abdomen and pelvis, and upper and lower extremities	Didactic sessions, simulated casualty scenarios using cadaver and live tissue models

continued

TABLE 5-3 Continued

		Course Name	Duration	Provider Type	Topic	Training Methods
CIVILIAN	STN	Advanced Trauma Care for Nurses (taught concurrently with ATLS course)	2–2.5 days	Registered nurses	Management of the multiple-trauma patient	Didactic sessions, skill stations
	NAEMT	Prehospital Trauma Life Support	2 days	Emergency medical responders, emergency medical technicians, paramedics, nurses, physician assistants, physicians	Trauma patient management in the prehospital setting	Didactic sessions, skill stations
		Tactical Combat Casualty Care for Military Medical Personnel	2 days	Combat emergency medical services/military personnel, including medics, corpsmen, and pararescue personnel	Trauma patient management on the battlefield in accordance with tactical combat casualty care (TCCC) guidelines	Didactic sessions, skill stations
		Tactical Combat Casualty Care for All Combatants	1 day	Nonmedical military personnel	Trauma patient management on the battlefield in accordance with TCCC guidelines	Didactic sessions, skill stations

NOTE: ACS = American College of Surgeons; NAEMT = National Association of Emergency Medical Technicians; STN = Society of Trauma Nurses.

SOURCES: ACS, 2016b; ATRRS, 2016; DMRTI, 2016; Fecura et al., 2008; NAEMT, 2015; STN, 2016.

College of Surgeons' Advanced Trauma Life Support, were developed in the civilian sector and later adapted for greater relevance to the combat context (DHB, 2015). A notable example is tactical combat casualty care (TCCC), which originated in Special Operations Forces and was expanded to the broader military starting in 2003 (DHB, 2015). It is now the only course that is required as predeployment training prior to being sent into theater (for CENTCOM). TCCC has been broadly adopted for application in the civilian prehospital setting as well, through both the original TCCC curriculum and a civilian adaptation called tactical emergency casualty care. The Trauma Outcomes and Performance Improvement Course-Military (TOPIC-M) also is noteworthy in that it focuses on educating military medical professionals about quality improvement, a process critical to supporting continuous learning and improvement in a learning trauma care system. Modeled after the Society of Trauma Nurses' TOPIC course, TOPIC-M breaks down the performance improvement cycle and offers practical strategies for implementing performance improvement initiatives across the echelons of care (Fecura et al., 2008; Fitzpatrick, 2016).

LIMITATIONS OF CURRENT MEDICAL READINESS APPROACHES

The committee observed numerous examples of the deep commitment among medical and health services support personnel from all the services to providing state-of-the-art care to the nation's wounded service members. The professional excellence and personal dedication of these men and women have yielded transformational advances in trauma care. These accomplishments have been achieved despite a system that often has failed to provide the preparation necessary to meet battlefield casualty care needs. Maintaining a well-trained and adequately staffed military trauma care workforce is crucial given that the volume and degree of trauma found in combat generally will not allow for an on-deployment learning curve (Ramasamy et al., 2010). In the sections below, the committee describes the limitations of current medical readiness approaches.

Inadequate Team Training

The outcome of the multiply injured patient is optimized by the presence of an effective trauma system and multidisciplinary teams. Successfully moving wounded combatants through the five roles of battlefield care requires coordination and teamwork. Excellent communication and team management are crucial to avoiding clinical pitfalls (Bach et al., 2012). As with individuals, there is a team learning curve, and it is helpful to rehearse scenarios as a team before encountering casualties in theater. Pereira and colleagues (2010) demonstrated that during a forward surgical team training exercise at the Army Trauma Training Center, members' awareness of their role within the team improved from 71 percent to 95 percent, suggesting that functioning as a team during mass casualty training exercises is beneficial. In addition, belief in the ability of the team to function in a trauma scenario improved from 26 percent to 84 percent (Pereira et al., 2010). In a recent survey, respondents overwhelmingly favored team training and supported maintaining team integrity (Schwab, 2015). With few exceptions, however, trauma teams do not train together (especially with real trauma patients) prior to deployment. The effects of inadequate team training are reflected in that same survey, in which 56.8 percent of respondents indicated that their trauma team was not prepared (Schwab, 2015).

Lack of Standardized and Validated Training Modalities

Training is a critical component of a continuous performance improvement cycle, ensuring that advances in knowledge are translated into practice in a timely manner. Successful training requires the development of and adherence to training standards. There is no consistent predeployment training for medical personnel deploying to theater (Rotondo et al., 2011). As described below, the committee found a lack of joint service and role-based standards for trauma training, resulting in variability in the content and utilization of predeployment training courses and programs (see Figure 5-6). Furthermore, although survey data show the perceived benefit of training programs among respondents, the committee is unaware of any data validating the effectiveness of these programs. As a result, military personnel providing care for combat casualties are not universally prepared to deliver optimal care (DHB, 2015). Great potential exists to save lives and decrease disability through a common approach to trauma care readiness training.

Variability Across Military–Civilian Predeployment Training Programs

As shown in Table 5-2, there is significant variation in the scope and duration of the service-specific just-in-time trauma training programs, with no standardized curriculum. Also, these programs are underutilized—very few deploying physicians report undergoing this training. In a recent survey of 137 military surgeons, only 23 percent had attended a Center for Sustainment of Trauma and Readiness Skills (C-STARS), Army Trauma Training Center (ATTC), or Navy Trauma Training Center (NTTC) course, and fewer than half (42 percent) of respondents had attended any predeployment surgical training course prior to their first deployment (Tyler et al., 2012).

While participants praise and value their participation in C-STARS, ATTC, and NTTC training (Tyler et al., 2012), these centers have neither been objectively assessed and verified nor optimized for training, refresher skill enhancement, and team training. Although best practices and innovative methods for teaching have emerged at each site, no formal mechanisms exist for sharing such advances, either among sites or with USUHS and other military training programs (Schwab, 2015). Although conferences, including DoD's annual research symposium, and peer-reviewed publications offer informal mechanisms for exchanging information, structured

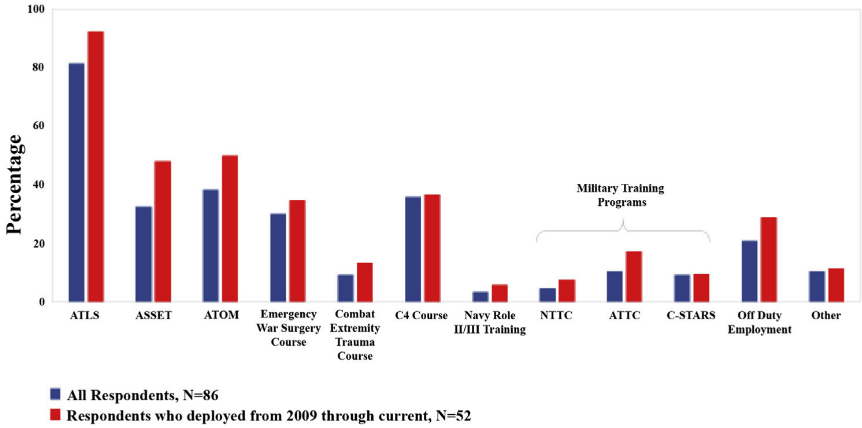

FIGURE 5-6 Utilization of predeployment trauma training courses and programs.

NOTES: These data are from a 2014 survey of 174 military-affiliated members (physicians) of the Eastern Association for the Surgery of Trauma (EAST). The 28-question survey was approved by the University of Pennsylvania's institutional review board. One hundred surveys were returned, 86 of which contained complete data for analysis.

ASSET = Advanced Surgical Skills for Exposure in Trauma; ATLS = Advanced Trauma Life Support; ATOM = Advanced Trauma Operative Management; ATTC = Army Trauma Training Center; C-STARS = Center for Sustainment of Trauma and Readiness Skills; NTTC = Navy Trauma Training Center.

SOURCE: Reprinted from Schwab, 2015, with permission from Elsevier.

processes and incentives are needed to promote a collaborative approach to the identification and widespread adoption of best practices in training paradigms. Furthermore, the centers lack consistent expert staffing, a problem exacerbated during those instances in which military trainers have been required to deploy and the centers have been left without a senior military trauma surgeon. The programs also appear to be "out of the mainstream of military medicine and seem poorly valued 'up the chain of command'" (Schwab, 2015, p. 248). This observation is reflected in the convoluted command structure for each center, which occupies a low position in the hierarchy under each service surgeon general.

Variability in each service's predeployment training programs often is justified on the basis of differences in mission. However, opportunities exist to harmonize trauma training across the services by reviewing existing programs and standardizing best practices across all centers (DHB, 2015). Several studies have called for the standardization of predeployment training (DuBose et al., 2012; Thorson et al., 2012).

Variability Across Trauma Courses

A number of military and civilian courses are available for development and maintenance of combat casualty care skills. However, course attendance requirements, and in some cases content, are variable. TCCC training is a useful case in point. The experience of the 75th Ranger Regiment (discussed in Chapter 1) demonstrates the value of TCCC in saving lives on the battlefield. The Defense Health Board and the Assistant Secretary of Defense for Health Affairs have recommended TCCC training, and all of the services have directed that their deploying members obtain such training. However, training in and implementation of TCCC are not consistent or standardized throughout the military (JTS, 2015), as noted in two recent assessments of prehospital trauma care in Afghanistan that documented inconsistent or absent TCCC training among combat forces deployed to CENTCOM (Kotwal et al., 2013; Sauer et al., 2014). A skills sustainment program also is lacking for those who have completed TCCC training in the remote past. The failure to adhere to current TCCC principles and guidelines has resulted in adverse outcomes for casualties (see, e.g., the extremity hemorrhage case in Appendix A). As documented in JTS performance improvement initiatives, these events occurred even in those units that reportedly had been trained in TCCC, as a result of misinformation provided during that training—a reflection of the significant variation in TCCC courses at present (JTS, 2015). The need for standardization is further apparent from recent media reports of providers who were exposed to inappropriate and potentially dangerous training events (JTS, 2015).

The committee also found that best practices in combat casualty care as defined within TCCC and JTS clinical practice guidelines have not been integrated into training courses in a systematic way (Miller, 2015). This represents a major gap in the performance improvement cycle, impeding the reliable transmission of best care practices to clinical providers.

Reliance on Just-in-Time and On-the-Job Training

At the start of Operation Enduring Freedom and Operation Iraqi Freedom, the military medical force was overstaffed with specialists in pediatrics and obstetrics/gynecology but understaffed in specialties critical for combat casualty care. In 2004, the military medical force was short 59 anesthesiologists and 242 general surgeons (Maldon et al., 2015). During the latter years of the wars, additional general surgeons completed trauma and surgical critical care fellowships and deployed to forward areas (Cannon, 2016), but it was still common for nontrauma specialists—for example, specialists in obstetrics/gynecology—to fill in to meet the trauma care needs of forward surgical teams and combat support hospitals

(Maldon et al., 2015; Moran, 2005). Many of these physicians were not appropriately credentialed for the kind of care they were required to deliver and did not receive appropriate predeployment training. It is important to realize that these providers would not be credentialed to care for civilian trauma patients in the United States, but are allowed to care for military trauma casualties when deployed. In effect, the standard of care for trauma patients in the United States was not being met on the battlefield.

From the first year of the war to the last (Chiarelli, 2015), the military's ability to deliver trauma care showed great variability, due in part to deployed military providers learning on the job rather than entering the combat zone prepared. A survey of military-affiliated physicians, many of whom had experienced multiple deployments, found that more than 50 percent felt that their deployed trauma team was inadequately prepared to operate in the combat environment (Schwab, 2015).

Joint military–civilian training programs such as those offered through ATTC, NTTC, and C-STARS benefit both the civilian and military workforces: they provide some level of skill sustainment for military trauma care providers and augment labor for the civilian center. In addition, they offer opportunities for bidirectional translation of innovative and best practices as embedded military training faculty interface with their civilian colleagues. As an approach to readiness, however, relying on just-in-time training (2-4 weeks) is fundamentally flawed. Outsourced short-duration training just prior to deployment results in teams that have had some exposure to trauma patients, allowing the Military Health System to "check the box" on training, but does not provide the sustained volume of patients required over a longer period of time to ensure an expert level trauma care capability. A short course in trauma, regardless of how excellent, cannot transform a novice into an expert trauma care provider.

Tyler and colleagues (2010) compared the experiences of military surgical residents at civilian trauma centers with the types of surgical cases experienced in theater, and found that the residents could have benefited from further training in injuries and procedures likely to occur in a combat context (e.g., skeletal fixation, genitourinary trauma, and craniotomy). In a recent survey of 246 active duty surgeons deployed at least once in the past decade, 80 percent of respondents indicated they would have liked additional training prior to deployment, particularly in extremity vascular repair (46 percent), neurosurgery (29.9 percent), and orthopedics (28.5 percent) (Tyler et al., 2012). More than a quarter of military surgeons requesting additional experience with general surgery, particularly with mediastinal trauma, vascular injuries, and inferior vena cava and pulmonary trauma (Tyler et al., 2012). Surgeons requested this further training either because they had not been exposed to these types of trauma during their civilian training or because a significant amount of time had passed since they last treated these types of injuries (Schwab, 2015; Tyler et al., 2012). The lack of competency in combat-relevant skills manifested in suboptimal care on the battlefield and associated preventable morbidity and mortality (see Box 5-2). Martin and colleagues (2009) found that provider competency, particularly related to hemorrhage control, was a factor in 70 percent of preventable deaths.

Variability in Readiness of the Reserves and National Guard

The challenges of sustaining expert-level trauma care skills are magnified in the Reserves and the National Guard. Reservist physicians, nurses, and medics who deploy to combat zones represent a diverse group with respect to both their military background (e.g., recently separated versus no

Box 5-2 CASE STUDY: FASCIOTOMY FOLLOWING BLUNT TRAUMA

Case

While on patrol, a 27-year-old soldier was thrown from the gunner turret of his vehicle when it rolled over, sustaining bilateral upper extremity injuries. Bulky dressings were applied to an open fracture of the patient's right arm, and he was quickly evacuated to a Role 3 combat support hospital. One of the many surgical interventions he received to save his right arm was a fasciotomy—a life- and limb-saving procedure that is necessary to relieve pressure from swelling and prevent loss of circulation (compartment syndrome). The soldier was then transferred to a Role 3 air hub, where surgeons noted that the fasciotomy was incomplete and completed the procedure.

Learning Context

In the case of this soldier and many others in the early phases of Operation Iraqi Freedom, a trauma team in a forward hospital found themselves lacking competency in fasciotomy, a key surgical skill for combat casualty care. General surgeons as well as nurses, anesthesiologists, medics, and other members of trauma teams who deploy to war come from diverse backgrounds; many do not receive training in or experience with extremity injuries in routine civilian practice or during in-garrison care, as these wounds are frequently managed by colleagues with orthopedic or vascular specialties. In a recent survey of general surgeons regarding readiness to deliver combat casualty care, more than 56 percent said they believed their trauma team was not prepared for deployment. Of note, almost 15 percent of those surveyed requested additional experience with fasciotomy (Schwab, 2015).

The higher-than-expected rate of incomplete fasciotomies noted in the early phases of Operation Iraqi Freedom was associated with significant morbidity and mortality;

prior military experience), practice setting, and civilian trauma care experience. In many cases, providers in these positions participate in high-volume, high-acuity clinical care in their civilian practices that readily translates to a high level of deployment readiness and expertise (Cannon, 2016). In one notable case discussed earlier in this chapter, a deployed National Guard unit raised the standard of care for MEDEVAC units when comparatively better outcomes were observed in patients transported by the National Guard CCFP-certified medics (Mabry et al., 2012), prompting efforts to align the military's hospital evacuation policies with the civilian medical standard (Ficke et al., 2012).

Like their active duty counterparts, some reservists and National Guard members deploy from a busy trauma practice, but many others have seen few trauma patients (DuBose et al., 2012). For the latter, the lack of stan-

fasciotomy revision was associated with a fourfold increase in mortality (Ritenour et al., 2008). A fasciotomy education program comprising educational alerts, classroom training, and video instruction was initiated in 2007 as a performance improvement effort. This program, which promoted increased performance of prophylactic fasciotomies in high-risk extremity injuries and provided instruction on proper surgical technique, resulted in an increase in total fasciotomies, fewer incomplete fasciotomies, and improved survival rates (Kragh et al., 2013). However, rates of delayed fasciotomy did not change, indicating a need for continued education focused on identification of compartment syndrome. Another performance improvement mechanism—weekly teleconferences connecting in-theater military treatment facilities with Landstuhl Regional Medical Center and U.S. military treatment facilities—enabled more rapid feedback to upstream providers on such problems with care delivered as incomplete fasciotomies.

Lesson

The types of wounds seen on the battlefield are remarkably consistent across wars. Prior to deployment, military trauma teams need to become expert at procedures they will encounter on the battlefield to ensure that they can deliver the best possible care to even the earliest casualties. The incomplete fasciotomy performed in this case might have cost the soldier his arm or his life (Ritenour et al., 2008). Although performance improvement initiatives are an important means of addressing skill deficiencies, front-line surgeons and other members of deployed trauma teams need to arrive fully proficient in combat casualty care to avoid preventable death and disability on the battlefield.

SOURCE: This box draws on the blunt trauma with vascular injury case study in Appendix A, except where other citations are noted.

dardized predeployment training requirements results in variable levels of readiness. For surgeons, for example, the minimum criterion for deployment is completion of a general surgery residency, and their deployment station in theater generally is not dependent on their civilian practice. Army general surgeon reservists deploy to theater directly from the Replacement Center at Fort Benning, Georgia, where they receive very generalized predeployment training (e.g., weapons, equipment, cultural preparation). Air Force predeployment requirements include the Advanced Trauma Life Support (ATLS) and Emergency War Surgery courses, as well as knowledge of JTS clinical practice guidelines. All deploying Air Force reservists must be involved regularly in civilian trauma care or undergo predeployment training at a C-STARS site. The deployment requirements for Navy reservists include a combat casualty care course and in some cases training at the Naval Trauma Training Center at Los Angeles County Hospital (DuBose et al., 2012). Issues of predeployment training for reservists and National Guard members will only become more pressing as the military increasingly relies on these part-time service members to sustain a ready and effective force in times of fiscal austerity.

Gaps in Leadership Education, Awareness, and Accountability

Under Title 10 of the United States Code, the services are responsible for training and equipping the personnel that will be assigned to a geographic combatant command to meet wartime medical support needs. Once medical forces are delivered in theater, line leadership within the combatant command is responsible for the execution of the theater trauma system, including the quality of care delivered by the trauma workforce. To assume this responsibility effectively, line leaders and the unit surgeons[11] (e.g., battalion surgeons) that advise them require a thorough understanding of the fundamentals of combat casualty care, trauma systems, and their tactical relevance (DHB, 2015). Officer and enlisted leadership courses attended by senior line and medical leaders, however, do not provide education and training on trauma system concepts, resulting in a lack of understanding of military trauma care and the importance of sustaining and continuously improving the military trauma system by those who are ultimately accountable for the quality of the system (Mullen, 2015).

As discussed in Chapter 1, the concept of preventable death after injury and key aspects of tactical medicine were incorporated into all com-

[11] Contrary to the name, unit surgeons generally are not trained surgeons but typically are generalists (e.g., primary care physicians). In theater, they are responsible for sick call, light trauma care, and providing medical advice to the unit leadership (DHB, 2015; Sorbero et al., 2013).

mand training and education programs as a critical element of the Israel Defense Force's initiative to eliminate preventable death on the battlefield (Glassberg et al., 2014). The casualty response system of the 75th Ranger Regiment, which tracked first responders' training achievement, is an exemplary model (DHB, 2015), but the committee found no evidence that this level of line leadership accountability is widespread across DoD. Outside of the Special Operations Command, a tracking system that provides line leaders with visibility on predeployment trauma training would require support from the service surgeons general and the Defense Health Agency.

WORKFORCE OPPORTUNITIES TO FACILITATE BIDIRECTIONAL EXCHANGE OF TRAUMA CARE INNOVATIONS AND BEST PRACTICES

Historically, the exchange of innovations and best practices between the military and civilian sectors has been informal, based on individuals practicing in both realms and professional meetings where members of the two communities have shared knowledge and ideas. Military trauma professionals returning to civilian practice have brought wartime lessons and practices with them. During the Afghanistan and Iraq wars, a formalized program to facilitate the exchange of trauma care knowledge and experience—the Senior Visiting Surgeon Program (described in Chapter 4) was established, but there remains a lack of robust collaboration between the two sectors, except in the few civilian trauma centers with assigned military personnel or recently retired or separated personnel. Although many military physicians are trained in civilian academic medical centers, they have little exposure to civilian physicians or practice once they enter military practice. In addition, there are financial and policy barriers to military participation in academic conferences and restrictions on the military's use of civilian consultants (Cannon, 2016).

Numerous opportunities exist in both education and practice to improve collaboration and promote dissemination of lessons learned and best practices across the military and civilian sectors (see Appendix C). For example, rotations of military residents through civilian trauma centers could be increased, or all combat-deployable personnel (physicians, nurses, and medics) could be required to routinely practice in civilian trauma centers. Building on the model of the Senior Visiting Surgeon Program, regular opportunities for civilians (beyond just surgeons) to practice temporarily in military trauma centers during wartime could be considered, as could the establishment of joint military–civilian programs to facilitate collaborative approaches to addressing high-priority challenges and developing best practice models (Richmond, 2016).

Similar opportunities exist to promote the exchange of lessons learned and best practices in prehospital trauma care between the military and civilian sectors. However, structural barriers make it challenging to exploit these opportunities. As with other medical licensure and certification, states regulate the scopes of practice for prehospital EMS providers (NHTSA, 2007). State scopes of practice vary not only from state to state but also at the local level, making the opportunity for military medics to practice critical skills in the civilian sector dependent upon state and local requirements and protocols. Moreover, prehospital military trauma care is often more advanced than what civilian EMS protocols allow, making it challenging for medics to practice their skills in the civilian sector and limiting bidirectional sharing of knowledge (Rodriguez, 2015). For example, pain medications (e.g., trans-oral fentanyl, ketamine) are routinely administered by military medics in the prehospital environment in theater to minimize pain and reduce risk of post-injury mental health sequelae. However, providing these medications in a civilian hospital (or even a military one) in the United States, even under physician guidance, is considered outside their scope of practice and is thus not permitted, even for training purposes (Cannon, 2016). These challenges could be overcome through clinical learning agreements and system approaches whereby military medics could practice with civilian EMS personnel in the prehospital setting, while also participating in in-hospital trauma team training in emergency departments and operating suites, where they could gain experience with the specific skills required for military trauma care. States also could consider permitting military medics to exercise trauma skills not normally associated with EMTs under the guidance and precepting of a civilian paramedic. At the same time, military medics often have more limited exposure to treating civilian medical conditions (e.g., hypertension, diabetes, stroke), and state and local issues limit their movement directly into civilian EMS positions when they return from military service. National-, state-, and local-level programs are emerging to generate a pathway for this transition (FICEMS, 2013; McCallion, 2013).

At the national level, the translation of prehospital lessons learned from the military to the civilian sector is challenging, even cumbersome. Changes in civilian practice could be incorporated through states' certification requirements, which are driven largely by the National Registry for EMTs; however, National Registry recertification operates on a 2-year cycle, limiting rapid translation through this mechanism (Rodriguez, 2015). More rapid changes in clinical practice are dependent on local or state EMS system leadership. Within the civilian sector, local (and even state) EMS systems monitor national and organizational evidence-based guidelines so they can make changes to their own protocols accordingly, with corresponding continuing education for providers.

The incorporation of civilian prehospital trauma practices into military care is even less structured and refined. The overall paucity of prehospital research applies to prehospital trauma research. The national variation in EMS and trauma systems is an additional limitation. Even among the best trauma systems, prehospital trauma care varies based on the system's components, structure, protocols, and degree of integration of EMS. This variation makes the identification and generalization of best practices challenging even within the civilian sector, much less across the military and civilian sectors.

SUMMARY OF FINDINGS AND CONCLUSIONS

CONCLUSION: To eliminate preventable mortality and morbidity at the start of and throughout future conflicts, comprehensive trauma training, education, and sustainment programs throughout DoD are needed for battlefield-critical physicians, nurses, medics, administrators, and other allied health professionals who comprise military trauma teams. This effort will ensure that a ready military medical force with expert combat casualty care skills is sustained throughout peacetime. A single military leader (general officer) needs to be accountable for generating and sustaining this education and training platform across the Military Health System to deliver trauma experts to the battlefield. In addition, line and medical leaders need to be held accountable for the results delivered by their trauma teams on the battlefield.

Related findings:

- *A number of policy and operational barriers—including an oscillating trauma workload, providers' beneficiary care responsibilities, and recruitment and retention challenges in the absence of defined trauma care career paths—impede the military's ability to ensure an expert trauma care workforce.*
- *DoD lacks validated, standardized training and skill sustainment programs.*
- *The military's reliance on just-in-time (e.g., trauma courses, short-duration predeployment training programs at civilian trauma centers) and on-the-job (i.e., on-deployment) training does not provide the experience necessary to ensure an expert trauma care workforce.*
- *Officer and enlisted leadership courses attended by senior line and medical leaders do not provide education and training on trauma system concepts, resulting in a lack of understanding of military trauma care by those who are responsible for the execution of the theater trauma system.*

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6 Delivering Patient-Centered Trauma Care

Responding to patients' needs and delivering optimal outcomes along the continuum of care demands a central focus on the patient. Patient-centered care—defined as "the experience (to the extent the informed, individual patient desires it) of transparency, individualization, recognition, respect, dignity, and choice in all matters, without exception, related to one's person, circumstances, and relationships in health care" (Berwick, 2009, p. 560)—has long been recognized as a core aim of a health care system; however, patient-centered care is far from the norm (Berwick, 2009; IOM, 2001, 2013a). For providers, a system's structure, incentives, and culture commonly are insufficiently aligned to support patient-centered care. Too often, patients face uncoordinated care and difficulties in navigating health care systems. Patients, families, and communities are afforded only limited opportunities to engage in and shape their own care or to help in the design and functioning of a learning health system (IOM, 2013a). These challenges are especially acute in the trauma setting, which is typically seen as a crisis environment characterized by loss of control and helplessness for patients and their support networks (Hasse, 2013).

Even though trauma care is highly complex, particularly on the battlefield, patient-centeredness is an essential component of a learning trauma care system. Only a trauma care system structured around the patient experience, one that considers and actively engages the patient, family, and community, can achieve optimal short- and long-term outcomes for injured patients. This chapter analyzes the extent to which military and civilian trauma systems have adopted a patient-centered approach, identifying gaps and opportunities to improve.

TRAUMA CARE STRUCTURED AROUND THE PATIENT EXPERIENCE

Trauma care structured around the patient experience encompasses seamless care across the continuum of care, a holistic focus on patients' needs, and proactive consideration of the needs of special populations. Each of these aspects is discussed in the sections below.

Seamless Transitions Across the Continuum of Care

As discussed in Chapter 2, a patient's journey from point of injury to rehabilitation and community reentry[1] is complex, involving numerous providers and multiple transitions between care settings. Transition points pose the greatest risk in terms of degradation in quality of care (e.g., treatment interruption, handoff errors) (IOM, 2013a). With insufficient attention to patient centeredness, these transitions can be abrupt and disorganized, with too little communication among providers, the patients, and their family members at different levels of care.

In the early years of the wars in Afghanistan and Iraq, the military's continuum of care was particularly fragmented, with limited communication among the various roles of care (the roles of care are described in Chapter 2). In the absence of effective information management systems, military providers would use a variety of improvised communication strategies, such as writing clinical information on patients' dressings (Eastridge et al., 2006). Gaps in communication were attributed to a multitude of factors, including the fast operational tempo, immature theater infrastructure, high casualty load, and limited prehospital data collection (DHB, 2015; Eastridge et al., 2006; Rotondo et al., 2011).

As the wars progressed, communication and the overall functioning of the care continuum improved in efficiency and efficacy, facilitated in the later years by the efforts of the Joint Trauma System (JTS). The JTS established weekly patient management video teleconferences so that medical providers at all levels could review and discuss patients' treatments and outcomes in real time as they moved along the evacuation chain (Blackbourne et al., 2012; Pruitt and Rasmussen, 2014). This served not only as a performance improvement mechanism, but also afforded care providers at receiving treatment facilities a deeper understanding of earlier patient management strategies. Over time, casualty evacuations improved substantially in both speed and capability, driven by the recognition that patient outcomes could be improved by reducing time to definitive care

[1] Community reentry refers to reintegration into one's previous lifestyle—returning to work and resuming former leisure activities, for example (Richmond and Aitken, 2011).

and providing earlier advanced care. Median prehospital evacuation times[2] in Afghanistan were reduced from 90 to 43 minutes after a 2009 mandate for prehospital helicopter evacuation in 60 minutes or less (Kotwal et al., 2016). Further, adopting civilian air ambulance standards—staffing medical evacuation (MEDEVAC) helicopters with critical care-trained flight paramedics—was shown to reduce the risk of mortality by 66 percent as compared to standard MEDEVAC practices where helicopters are staffed by emergency medical technicians certified at the emergency medical technician (EMT)-Basic level (Mabry et al., 2012).

Despite progress over the course of the wars in Afghanistan and Iraq, opportunities remain to further improve communication and the coordination of care. Multiple assessments conducted by the military have noted persistent barriers to effective communication and seamless care transitions (DHB, 2015; Rotondo et al., 2011). In the absence of a common communication portal and knowledge of currently deployed medical providers, clinicians cannot communicate consistently with one another. The Defense Health Board has emphasized that communication is particularly limited among the services, an alarming reality given that the management and execution of casualty evacuation is a joint operation (DHB, 2015). On the battlefield, the flow of information is predominantly unidirectional up to the JTS; there is far less transmission of important clinical information and advances in care to front-line providers (Rotondo et al., 2011). The use of data-sharing technologies and telemedicine to improve communication among prehospital and hospital-based providers in both military and civilian sectors is discussed in Chapter 4.

In both military and civilian settings, seamless transition to rehabilitation is arguably the weakest link in the trauma continuum of care (Eastman et al., 2013). Although rehabilitation is often thought of as a phase of care that begins following completion of the acute medical and surgical interventions, initiating rehabilitation during the acute care phase is essential to optimize recovery from both physical impairments (e.g., prevention of secondary complications associated with immobility) and psychosocial consequences (e.g., building confidence, independence, and motivation) (Ficke et al., 2012). During recent conflicts in Afghanistan and Iraq, more attention has been paid to early and comprehensive rehabilitation. Examples of efforts to expand the military trauma system to incorporate multidisciplinary, state-of-the-art rehabilitation are the advanced rehabilitation programs located at the three military treatment facilities that treat a large proportion of the most severe combat casualties: the Center for the Intrepid in San Antonio, Texas; the Military Advanced Training Center at

[2] In this context, evacuation times were defined as time elapsed from initial call to arrival at the treatment facility (Kotwal et al., 2016).

Walter Reed National Military Medical Center in Bethesda, Maryland; and the Comprehensive Combat and Complex Casualty Care (C5) program at Naval Medical Center San Diego in California. These three centers employ interdisciplinary teams, innovative technologies, and a sports medicine model to deliver holistic and patient-centered care. The use of a sports medicine model represents a paradigm shift in the military's approach to rehabilitative care, expanding well beyond restoring basic functionality to pushing patients to the limits of possibility with the goal of returning them to duty and as active participants in society. The Advanced Rehabilitation Centers participate in research, coordinate with the Uniformed Services University of the Health Sciences (USUHS) and the U.S. Department of Veterans Affairs (VA), and leverage public and private partnerships to provide and advance state-of-the-art care.

The VA Polytrauma/TBI System of Care (PSC) provides an integrated continuum of rehabilitation services to address the physical and mental health needs of veterans and service members with impairments resulting from polytrauma and traumatic brain injury. The PSC coordinates and delivers care at a variety of sites across the United States, linking specialized rehabilitation services provided at regional referral centers, network sites, and VA facilities (VA, 2016b).

Although the military learned over time to build capacity and capability for effective transition support, the policies and infrastructure needed to deliver such support were slow in coming and challenges persist in the transition of ongoing care from the military to the VA and in the capacity within the military to meet the needs of all injured service members, especially with regards to behavioral health and well-being (GAO, 2012). Care coordination and case management programs that assist recovering service members and their caregivers and families by facilitating access to care, services, and benefits (e.g., service-specific wounded warrior programs) were strengthened following the highly publicized exposure of deficiencies at Walter Reed Army Medical Center in 2007 (GAO, 2012). In 2009, the U.S. Department of Defense (DoD) sought to improve quality of care and transition of recovering service members by establishing uniform guidelines, procedures, and standards for Recovery Coordination Programs, management of which was assigned to the Service Wounded Warrior Program commanders (DoD, 2009). Similarly, a Federal Recovery Coordination Program, jointly developed by DoD and VA, assists with interdepartmental coordination and continuity of rehabilitative care for service members who are unlikely to return to duty and veterans, in part by establishing a federal recovery coordinator as a single point of contact for DoD and VA case managers, as well as patients and their families (GAO, 2012). Although an evaluation of these and other DoD and VA rehabilitation support programs is beyond the scope of this report,[3] the committee emphasizes that, as with acute trauma care advances, there is great need and opportunity for military lessons learned and best practices related to rehabilitative care to be translated to the civilian sector.

It must be acknowledged, however, that application of military lessons learned on seamless transition to rehabilitation is constrained by significant differences in health care delivery between military and civilian sectors. Unlike the civilian sector, where health care is largely privatized, the military offers service members universal health care through the Military Health System. This affects care in two major ways. First, DoD can establish policy requiring the services to offer programs that smooth the transition to rehabilitation. In the civilian sector, the burden of managing the overwhelming process of transitioning to one of the many different types of rehabilitation facilities[4] or appropriate outpatient services most often falls to patients, their families, and their health care providers. Second, access to rehabilitative care for wounded service members is not limited by insurance coverage. In the civilian sector, however, lack of access to high-quality rehabilitative care for uninsured and underinsured individuals has been associated with poorer long-term outcomes for trauma patients (Davidson et al., 2011; Mackersie, 2014). As a result, even optimal acute care delivered in the prehospital setting and at the trauma center may be undermined by lack of effective rehabilitative care and support after discharge.

Despite these challenges, some programs to facilitate more seamless transitions to rehabilitation have been developed in the civilian sector. Multidisciplinary discharge rounds[5] represent a promising practice by which the transition to rehabilitation can be enhanced for trauma patients. At Baltimore Shock Trauma, the implementation of multidisciplinary discharge rounds was associated with a 15 percent decrease in length of stay, which likely contributed to a 36 percent increase in patient volume and a dramatic reduction in the number of instances the trauma center went on bypass status (i.e., was not able to accept admissions), revealing other benefits of greater care coordination beyond those that may be experienced by the patient (Dutton et al., 2003). Further, a growing body of research funded by the National Institutes of Health (NIH) shows that a transitional

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[3] Evaluations of DoD and VA rehabilitation programs can be found in recent GAO (2012) and Institute of Medicine reports (2013b).

[4] Upon trauma patient discharge from the acute care hospital, post-acute care settings may include inpatient rehabilitation facilities, skilled nursing facilities, outpatient facilities, or the patient's home (e.g., home health agencies).

[5] Multidisciplinary teams—consisting of the trauma physician, "an orthopedic surgeon, the hospital bed manager, the unit's discharge planner, the unit nursing staff, and physical, occupational, and speech therapists"—review the patient's plan of care (Dutton et al., 2003, p. 913).

care model[6] in which an advanced practice nurse assumes responsibility for managing the flow between phases of care within a clinical team enhances the transition out of acute care, reduces readmissions, and increases cost savings in patients with chronic illnesses and complex treatment regimens (Coleman et al., 2006; Naylor et al., 1994, 1999, 2004). This model highlights an opportunity to reduce fragmentation across the phases of trauma care if applied to injured patients as they transition from acute care to rehabilitation (Richmond, 2016). Despite the demonstrated success of such strategies, implementation of these kinds of programs to ensure a seamless transition to rehabilitation is nowhere near universal.

A Holistic Focus on Patients' Needs

In the deployed setting, the driving aim of military medicine is to save lives. Indeed, trauma care providers in both military and civilian settings have made extraordinary progress in reducing mortality among severely injured patients. The record number of soldiers with triple limb amputations in the latter years of the wars in Afghanistan and Iraq attests to the increased capacity of medical providers to keep wounded warriors alive despite the severity of their injuries (DCBI Task Force, 2011). However, patients, families, and medical providers all acknowledge that a focus on survival alone is insufficient; functional recovery, quality of life, and reintegration into society are important outcomes (Richmond and Aitken, 2011).

The scope of trauma's impact is vast. Its immediate physical and psychosocial effects influence a patient's functional outcomes and quality of life for years to come. In a civilian study of long-term outcomes among patients who had experienced a prolonged stay in the surgical intensive care unit, only 55 percent of patients contacted at follow-up had achieved maximum function 3 years after sustaining a severe injury (Livingston et al., 2009). In another analysis, trauma patients reported limitations in mobility (48 percent), daily activities (55 percent), and self-care (18 percent), as well as pain (63 percent) and cognitive complaints (65 percent) (Holtslag et al., 2007). Trauma patients who have been hospitalized for serious injuries are at high risk for posttraumatic stress disorder (PTSD) and other mental health disorders like depression (O'Donnell et al., 2010). The National Study on the Costs and Outcomes of Trauma found that 20.7 percent of patients with an injury scoring 3 or higher on the Abbreviated Injury Scale screened positive for PTSD 1 year after injury and 6.6 percent had symptoms consistent with depression (Zatzick et al., 2008). These findings are echoed in the military sector (Grieger et al., 2006; Hoge et al., 2006; Milliken et

[6] In this model, an advanced practice nurse assumes responsibility for discharge planning and follow-up care (Naylor and Keating, 2008).

al., 2007) and incidence rates may be higher in certain subpopulations of wounded warriors such as amputees and survivors with traumatic brain injuries and severe genitourinary injuries. For example, nearly 66 percent of combat amputees have received one or more behavioral health diagnoses (Melcer et al., 2010).

To achieve maximum recovery and reintegration, survivors of severe injuries will require significant rehabilitative care and psychosocial support focused on healing the whole person—physical, emotional, cognitive and spiritual aspects—including survivor support networks (families, loved ones, and other care providers). The findings and recommendations of the Army Dismounted Complex Blast Injury (DCBI) Task Force concerning DCBI and its associated physical and psychosocial consequences exemplify how the military has taken a holistic approach to addressing the needs of wounded warriors (see Box 6-1). The task force specifies four areas of focus for all battle injuries: "(1) comprehensive pain management at the [point of injury], (2) complex behavioral health challenges facing . . . warriors and their families, (3) the incorporation of a rehabilitation mindset and philosophy throughout the spectrum of care, and (4) spiritual considerations for long-term care and rehabilitation" (DCBI Task Force, 2011, p. E-1). Currently, the JTS lacks access to long-term outcome data, including functional recovery and quality-of-life indicators. To assess the effectiveness of a holistic approach to care, a systematic process for collecting information on patient-reported quality-of-life outcomes is needed.

Psychosocial Support

The behavioral health impacts of traumatic injury are particularly insidious because of the wide-ranging effects of psychosocial disorders on survivors' functional outcomes and long-term quality of life. Zatzick et al. (2008) showed that symptoms consistent with a diagnosis of depression or PTSD were associated with impairments in physical function, activities of daily living, and return to work 12 months after injury (Zatzick et al., 2008). Consequently, effective mental health screening and early intervention are important secondary prevention strategies to mitigate the development of such disorders and their downstream effects.[7] Since onset of PTSD, depression, and other psychological disorders may occur months after injury (Grieger et al., 2006), it is important to continue providing proactive support and monitoring for symptoms throughout the post-acute care period.

A holistic approach to the care of trauma survivors means integrating supportive behavioral health efforts with the treatment and restoration of

[7] A comprehensive evaluation of screening tools and treatment options for PTSD and other mental health sequelae of traumatic injury is beyond the scope of this report.

Box 6-1 CASE STUDY: DISMOUNTED COMPLEX BLAST INJURY

Case

A 29-year-old soldier sustained traumatic amputation of one leg, severe injury to the other leg, and pelvic wounding from the detonation of an improvised explosive device while he was on patrol. The patient received seamless treatment across the continuum of combat casualty care, beginning at the point of injury and continuing through a Role 3 military treatment facility (MTF), critical care air transport, a Role 4 MTF (in Germany), and a Role 5 MTF (in the United States). His tactical evaluation and initial care at the Role 3 MTF focused on controlling hemorrhage and coagulopathy. Ketamine was administered at the point of injury and during tactical evacuation to control pain. The patient remained stable during air transport; and he underwent a series of successful procedures at Role 4 and 5 MTFs to mend fractures and finally amputate both legs above the knee.

Learning Context

Through summer and fall 2010, data from the DoD Trauma Registry (DoDTR) identified a trend of soldiers experiencing similarly severe and complex injuries, prompting the Army Surgeon General to assemble a task force that could formally characterize the injury pattern and make recommendations for improving care management. The task force's report formally describes the severe injury pattern as dismounted complex blast injury (DCBI), characterized by traumatic amputation of at least one leg; severe injury to another extremity; and pelvic, abdominal, or urogenital wounding (DCBI Task Force, 2011). DCBI generally is caused by blast and high-velocity fragments from ground-level explosive devices to soldiers on foot patrol, as was the soldier in this case.

The report goes on to present a thorough analysis of DoDTR casualty data and an examination of challenges presented by DCBI to the medical and military communities, including the coexistence of traumatic brain injury, the subsequent risk of deep vein thrombosis, the inadequacy of some types of prosthetics, and the need for genitourinary reconstruction, as well as the emotional, spiritual, and cognitive aspects of recovery. It concludes by highlighting patient-centered care as the key to effective management of the immediate-, near- and long-term care of DCBI patients. The report offers recommendations addressing the entire continuum of care, arguing that a comprehensive, seamless approach to treatment would "maintain the highest survivability and functionality possible" (DCBI Task Force, 2011).

Lesson

On the battlefield, the focus often is on stabilizing and treating a casualty and then transporting the patient to definitive care. Ensuring continuity and seamless transitions across the continuum of care is necessary—but not sufficient—to achieve the best possible outcomes. The DCBI Task Force's emphasis on addressing the physical, psychosocial, and spiritual needs of a casualty reaffirms the critical importance of caring for trauma patients holistically, beginning in the acute phase of trauma care.

SOURCE: This box draws on the dismounted complex blast injury case study in Appendix A, except where other citations are noted.

physical functions in trauma management. The military learned the importance of embedding behavioral health specialists as integral members of treatment teams during acute (definitive) and post-acute care to assist patients and their loved ones with the psychological recovery from injury (Ficke et al., 2012; Gajewski and Granville, 2006). Civilian-sector research on the associated benefits has shown promising results. A recent clinical trial showed that patients receiving a stepped care intervention—care management, psychopharmacology, and cognitive behavioral psychotherapy as needed—from a trauma center-based mental health team during inpatient and outpatient care had significantly reduced PTSD symptoms and improvements in physical function over the course of the 1-year study period as compared to controls who received standard care (Zatzick et al., 2013). Similar collaborative care approaches that link trauma survivors to evidence-based behavioral health services have been implemented in military and civilian trauma centers (see Box 6-2). The integration of behavioral health care as a standard component of treatment for severe injury may help to break down barriers to care associated with stigma concerns (Hoge et al., 2006).

In addition to integrating professional behavioral health specialists into clinical trauma teams, peer support programs are used in both military and civilian sectors, particularly for amputees (Gajewski and Granville, 2006; Marzen-Groller and Bartman, 2005). Such programs have been shown to encourage an optimistic future outlook, decrease the sense of isolation, and promote coping abilities and self-management (Marzen-Groller and Bartman, 2005; May et al., 1979). The military uses peer visitors trained through the Amputee Coalition of America (Gajewski and Granville, 2006). These peer visitors, amputees themselves, augment the support provided by a patient's family. Often, peer visitors serve as role models for patients, and can provide a unique firsthand account of the rehabilitation process and offer practical suggestions for managing the difficulties associated with an amputation. These peer visitors consistently receive the highest satisfaction rating from patients attending the Amputee Clinic at the Walter Reed Army Medical Center in Bethesda, Maryland (Pasquina et al., 2008).

Peer support can also be obtained remotely. For example, the Trauma Survivors Network is an online network through which trauma patients and families connect with one another and obtain advice, support, and information needed to advance the rehabilitation and recovery process. Developed by the American Trauma Society, a leading trauma advocacy organization, the Network provides resources and programs requested by patients and their families (TSN, 2016a).

White House–led efforts to address the needs of military service members and veterans related to mental health, traumatic brain injury, and substance abuse have led to significant investments in research and a pro-

Box 6-2
HOLISTIC CARE: EXAMPLES OF MILITARY AND CIVILIAN COLLABORATIVE CARE MODELS

Parkland Memorial Hospital

In Parkland Memorial Hospital's Trauma Program, a trauma psychologist leads the trauma psychosocial team, which includes licensed counselors and a child life specialist. These individuals evaluate each admitted trauma patient for crisis intervention and screen the patient for patterns consistent with alcohol- and drug-related injuries, as well as for suicide potential and partner-related violence. The team provides interventions and referrals for patients and families as appropriate. The team is fully integrated with the trauma physician and trauma nursing teams (Parkland, 2016). In addition, collaboration with social workers and chaplain services has led to the development of programs to assist in breaking bad news and to the integration of children into family psychosocial evaluations and interventions. The team also has developed a trauma family support booklet and psychological first-aid pamphlet, and assists with psychological first aid and interventions for staff.

Comprehensive Combat and Complex Casualty Care (C5) Program

In the military, one example of a collaborative care approach is the C5 program at Naval Medical Center San Diego. At C5, a multidisciplinary team provides inpatient clinical management; orthopedics; amputee care and prosthetics; and physical, occupational, and recreational therapy for severely injured service members. C5 also offers mental health assessment and treatment, including specialized treatment programs for mild traumatic brain injury and posttraumatic stress disorder (PTSD) (IOM, 2014). PTSD treatment includes a combination of cognitive processing therapy, group therapy sessions, bereavement counseling, and alternative therapies (e.g., art therapy). Other aspects of comprehensive psychosocial support at C5 include family support services and chaplains for spiritual care. If patients will be leaving the military, a federal recovery coordinator can assist patients with the continuation of behavioral health services during the transition to the U.S. Department of Veterans Affairs care (IOM, 2014).

liferation of programs to facilitate access to services (Weinick et al., 2011). However, the committee found little evaluation of such programs targeted specifically to survivors of traumatic injury beyond TBI patients. Further focus on optimal methods for providing holistic care and improving behavioral health outcomes in wounded warriors more broadly is warranted given the higher risk of behavioral health disorders in this population. Such investigations would also have relevance to the civilian sector where the burden of trauma is significantly higher.

Pain Management

A key aspect of care that needs to be structured around the patient experience is pain control, beginning in the prehospital environment and continuing through evacuation, definitive care, and post-acute care (Ficke et al., 2012). Thus, effective pain management necessitates coordination of all medical providers throughout the patient transport system (JTS, 2013b). Early delivery of pain medication not only relieves suffering but also is associated with a reduced risk of PTSD in both military and civilian settings (Bryant et al., 2009; Holbrook et al., 2010; McGhee et al., 2008). Pain management therefore is an important secondary prevention strategy in the context of mitigating mental health sequelae of physical trauma. However, attention must also be paid to the substance abuse risks associated with pain medication (e.g., opioids). The military has observed an association between prescription drug misuse and the rising number of prescriptions written for chronic pain management among service members wounded during the wars in Afghanistan and Iraq (IOM, 2013c). Nonphysician prehospital providers and physicians alike need to be educated on the risks of opioid medications related to substance abuse and the value of a multimodal approach for increasing the effectiveness of pain management medications while reducing adverse effects (e.g., hypotension) and the risk of narcotic dependence (JTS, 2013b). The challenges associated with pain medication misuse are not limited to the military. Opioid abuse has risen to epidemic proportions in the United States, prompting action from the White House to address the rising incidence of substance abuse disorders and overdose-related deaths (White House, 2016).

The military has made significant advances in the care of acute pain, including the development of JTS and tactical combat casualty care (TCCC) pain management guidelines and the use of oral transmucosal fentanyl[8] (fentanyl lollipops) to deliver rapid pain control on the battlefield (DCBI Task Force, 2011). In 2009, the Army Surgeon General chartered the Army Pain Management Task Force to develop recommendations for a comprehensive pain management strategy that applies principles of holistic and multimodal care, employs state of the art science and technology, and synchronizes pain management efforts and approaches across DoD and the VA in order to optimize quality of life for service members suffering from acute and chronic pain (DoD, 2010). One initiative that emerged from the Task Force report is an adaption of the Project Extension for Community Healthcare Outcomes (ECHO) model (discussed in Box 3-1) to better fa-

[8] Oral transmucosal fentanyl provides pain relief more quickly than morphine. Oral delivery also eliminates the need to obtain intravenous access on the battlefield. At this time, however, only Special Operations Forces medics are equipped with this medication, limiting its use throughout the military (DCBI Task Force, 2011).

cilitate a team approach to complex pain management. In September 2015, the Defense Health Agency initiated a formal collaboration with Project ECHO, building on the success of an Army pilot program (Army Pain ECHO) focused on pain management (Katzman and Olivas, 2016).

Yet despite these efforts, pain associated with traumatic injury remains a significant challenge, particularly in the prehospital setting. In an evaluation of a convenience sample of 309 casualties evacuated to Role 2 or Role 3 facilities in Afghanistan from October 2012 to March 2013, less than 40 percent of the casualties received pain medication at the point of injury[9] (Shackelford et al., 2015). Recent initiatives aimed at tracking pain levels upon soldiers' entry to Role 2 and 3 military treatment facilities (MTFs) have found that 71 percent experience pain at a level of 5 or greater on a scale of 0-10. Pain control is one of 10 major areas of emphasis within DoD's Combat Casualty Care Research Program (MRMC, 2016). The Defense and Veterans Center for Integrative Pain Management, located within the Uniformed Services University of the Health Sciences, was established in 2003 to improve pain management in military and civilian sectors through research and policy (DVCIPM, 2016).

Supporting the Needs of Special Populations

A focus on the patient requires consideration of the subpopulations of patients that a trauma system may be expected to serve, including pediatric patients, the elderly, women, and vulnerable populations.

Pediatric Patients

Tragically, children are frequently killed and injured in wartime. The Geneva Convention dictates that host national casualties receive adequate medical care.[10] DoD doctrine further stipulates that the "commitment of resources should be decided first based on the mission and immediate tactical situation and then by medical necessity, irrespective of the casualty's national or combatant status" (Cubano et al., 2013, p. 30). Thus, pediatric care is a critical aspect of the military medical mission and needs to be planned for and resourced as such.

Throughout Operation Enduring Freedom and Operation Iraqi Freedom, U.S. military medical personnel cared for thousands of injured host national children (Matos et al., 2008). From 2001 to 2011, children ac-

[9] This figure may represent an underestimate caused by incomplete documentation of care delivered at the point of injury (Shackelford et al., 2015).

[10] Geneva Convention I and II, Article 12; Geneva Convention III, Article 13; Geneva Convention IV, Article 27; Additional Protocol I, 1977, Articles 9, 10, and 11.

counted for 5.8 percent of admissions and 11 percent of bed days[11] in combat support hospitals (Borgman et al., 2012). These data show that pediatric trauma care represents an important and unavoidable component of the military's medical mission. While the provision of pediatric care fulfills a number of ethical obligations, in some instances it can also support the military's combat mission. In one anecdote shared with the committee, an Iraqi sheik provided U.S. personnel with information that led directly to the capture of numerous insurgents after a military physician provided care for that sheik's child (Burnett et al., 2008).

Despite the foreseeable need to provide pediatric care in the battlefield environment, the military was largely unprepared for the realities of its pediatric mission at the start of the wars in Afghanistan and Iraq. Hospitals across the two countries lacked the personnel, equipment, and training required to support the effective delivery of pediatric care (Matos et al., 2008). These gaps were highlighted in testimony presented to the committee, with military nurses strongly asserting a lack of preparation for the challenges of pediatric care (Bridges, 2016). Pediatric support for in-theater hospitals has seen improvement, including the development of a pediatric critical care teleconsultation service and the addition of pediatric information to clinical practice guidelines, but numerous challenges to providing advanced care for pediatric patients in the deployed setting remain (Borgman et al., 2012; Burnett et al., 2008). For example, although pediatric supply kits were developed to augment combat support hospital resources, the kits had to be requested by hospital commanders, who may not have known that such resources were available (Cubano et al., 2013).

The military's recent operations reconfirm a lesson learned repeatedly throughout the history of warfare: the injury and death of children is an inevitable consequence of battle. Throughout Operation Enduring Freedom and Operation Iraqi Freedom, pediatric casualties often were more severely injured than their adult counterparts, remained in the hospital longer, and required significant unanticipated logistical supplies and resources (Borgman et al., 2012). While the military has adapted to the challenge of pediatric trauma care (see Box 6-3), additional improvements are necessary, particularly in the use of pediatric specialists and the predeployment training of clinical teams (Borgman et al., 2012). Pediatricians may be deployed to fill slots at MTFs in theater, but there currently are no specific requirements for placement of pediatricians at combat support hospitals. Numerous reports and surveys of deployed surgeons reaffirm the need for greater pediatric training and preparation. It is important that these lessons not be lost by medical planners and policy makers during preparation for future operations.

[11] The percentage of bed days reflects a provider's workload.

Box 6-3 CASE STUDY: PEDIATRIC TRAUMA

Case

In fall 2004, a vehicle exploded at a Baghdad, Iraq, checkpoint, leaving a 2-year-old boy with severe burns covering more than a third of his body. His mother and brother did not survive the explosion. The boy was rushed to the 31st Combat Support Hospital Emergency Room in Baghdad. At the hospital, he underwent a series of complex and intensive procedures to control blood loss, clean and dress his burns, and graft skin. He received continuous ventilation and monitoring for his acute respiratory distress syndrome, remained on a ventilator for 25 days, and was ultimately discharged after 40 days in the hospital.

Learning Context

This patient received care from a deployed pediatric intensivist, but access to specialized pediatric care is rare on the battlefield. No advanced ventilation apparatus was available to treat the boy's worsening respiration—clinicians treating him had to improvise pediatric-sized medical equipment. At the time of this case, there was also no definitive guidance on the care of pediatric burns. Still, the care the child in this case report received far exceeded that which was and is available in Baghdad.

War results in significant collateral damage, often disabling and killing many civilians. Local nationals injured on the battlefield are cared for at military treatment facilities (MTFs), with no options for evacuation to hospitals with specialized burn teams out of theater. During the wars in Afghanistan and Iraq, for example, host nation children stayed for a median of 3 days at MTFs, compared with 1 day for coalition soldiers. Although

As discussed in Chapter 1, in the civilian sector, trauma is the most common single cause of mortality and morbidity among individuals under age 46. In 2014, approximately 10,000 children and adolescents died as a result of traumatic injury (NCIPC, 2015a). More than 7.8 million were treated in emergency departments (NCIPC, 2015b), of which 166,000 were hospitalized (NCIPC, 2015c). Several factors are known to affect the occurrence of childhood injuries, including age, sex, behavior, and environment. Relative to their female counterparts, male children younger than 18 have higher rates of injury (Borse et al., 2008), a finding thought to reflect greater risk-taking behavior and exposure to contact sports (Fabricant et al., 2013; Sorenson, 2011). Among infants and toddlers, falls are a common mechanism of injury, while bicycle- and motor vehicle-related injuries become more common as pediatric patients age (NCIPC, 2015e). While blunt injuries represent the majority of traumatic presentations among pediatric children made up less than 6 percent of admissions, they accounted for more than 11 percent of all bed days (Borgman et al., 2012).

Since this case occurred, several deficits in pediatric care in theater have been addressed. Data from the Department of Defense Trauma Registry have been used for epidemiologic study of pediatric burn injuries in combat (Borgman et al., 2015), the Joint Trauma System burn care clinical practice guideline has evolved to include issues specific to pediatric burn care (JTS, 2013a), and the U.S. Army Medical Materiel Agency has made pediatric supplies available as a humanitarian assistance augmentation medical equipment set (Fuenfer et al., 2009) that can be requested by hospital commanders.

Lesson

Combat support hospitals tend to focus preparations on adult combatant casualties, but the very real need for care of infants and children must be accounted for as well. Given that pediatric patients with traumatic injuries make up a significant number of admissions at combat support hospitals, the military trauma system needs to be prepared with the appropriate clinical knowledge, workforce expertise, guidelines, and equipment. The recent experience in Afghanistan and Iraq has led to significant improvements in the U.S. military's ability to provide advanced care to pediatric trauma patients in the deployed setting. Research on optimal clinician training, configuration of equipment sets, and systems-level integration of host national pediatric trauma care into the overall DoD trauma system represent opportunities for further refinement of expeditionary medicine.

SOURCE: This box draws on the pediatric burn case study in Appendix A, except where other citations are noted.

patients, penetrating injuries account for 10-20 percent of pediatric admissions (Cotton and Nance, 2004). Like older-adult patients (discussed below), pediatric patients often have limited physiological reserves and tend to be at increased risk for poor outcomes after injury.

Facilities specifically designed to manage pediatric trauma can better meet the unique health needs of younger patients, including providing access to age- and physiologically appropriate postdischarge care. In many states, there are special designations for pediatric hospitals that do not treat adults and Level I trauma centers that do not treat pediatric patients (ATS, 2016; Potoka et al., 2000). Proximal facilities work collectively with emergency medical services (EMS) agencies and the trauma system to ensure that injured children are transported to and treated at pediatric trauma centers. In Pennsylvania, for example, the University of Pittsburgh Medical Center–Presbyterian has an affiliation with the Children's Hospital of Pittsburgh (University of Pittsburgh, 2016). Recently, a pediatric trauma quality improvement program (TQIP) was launched by the American College of Surgeons and made available to Level I and II trauma centers to support benchmarking and quality improvement activities specific to this patient population (ACS, 2016).

Despite the prominence of pediatric trauma and efforts to promote readier access to specialized pediatric care, very limited research is currently available on pediatric trauma and the unique care preferences and needs of pediatric trauma patients (Upperman et al., 2010). Understandings of adult trauma may not be applicable to younger injured patients. Therefore, creating patient-centered approaches appropriate to younger trauma patients will require developing interventions and quality improvement measures relevant to this population.

The Elderly

Among the increasing number of adults older than 64 within the U.S. population, trauma represents a leading and growing cause of death and disability, often associated with a loss of independence (Rhee et al., 2014). In 2014, more than 4.3 million nonfatal injuries occurred among adults over the age of 65 (NCIPC, 2015d). The risk of traumatic injury increases with age as people experience pronounced changes in the sensory apparatus, cognition, and strength (Perdue et al., 1998). Following injury, older adults have higher rates of complications and mortality relative to younger trauma patients (Champion et al., 1989). Declining physiological reserves limit these patients' ability to survive minor injuries and alter their trajectories for postinjury recovery (CDC, 2012; Champion et al., 1989). A higher prevalence of preexisting comorbid conditions also complicates clinical presentations and outcomes for these patients (CDC, 2012). Traumatic brain injury (Thompson et al., 2006) and hip fracture (MacKenzie et al., 2006) are two of the most common and debilitating injuries occurring among older adults, and are associated with long-term functional impairment, nursing home admission, decreased independence, and shortened life expectancy (Hall et al., 2000; Magaziner et al., 2000; Thompson et al., 2006; Wolinsky et al., 1997). In one study following a specific population of women, one-fifth of hip-fracture patients died within 1 year (Farahmand et al., 2005). A separate analysis found that one-third of those who lived independently before their injury remain in a nursing home for at least 1 year (Zafar et al., 2015).

In light of the burden of geriatric trauma, minimal information is available on where and how older adults should be managed for traumatic injuries. Although there is some evidence to suggest that injured persons over the age of 65 should lower the threshold for field triage directly to a trauma center (Calland et al., 2012), several studies have shown that the older patient is much less likely to get to a Level I/II center compared to a younger patient with similar injuries (Chang et al., 2008; Nakamura et al., 2012). The reasons for this apparent undertriage of the elderly trauma patient are not well understood but could be related to the inadequacy of current triage criteria, an implicit bias against the benefits of trauma center care for the elderly, and in some cases, a preference on the part of the older patient for treatment at the hospital with which they are most familiar, regardless of its status as a trauma center. At the same time, there is controversy as to how elderly patients can benefit from care at a Level I hospital and how aggressively to manage the severely compromised elderly trauma patient. In the absence of data, the Eastern Association for the Surgery of Trauma (EAST) guideline for the evaluation and management of geriatric trauma concludes that patients should "receive care at centers that have devoted specific resources to attaining excellence in the care of the injured using similar criteria to those used in younger patients" (Calland et al., 2012, p. S348).

Also unknown is how patient preferences within this population can and should be incorporated in treatment decisions, especially when it involves end-of-life decisions (Lilley et al., 2016). Better understanding is needed of what older trauma patients want from their care in terms of location, continuity, and resources in order to ensure that the care they receive aligns with both what they want and with what they need physiologically.

Women

There is a dearth of research with which to understand the gender-specific predictors of trauma outcomes and posttraumatic recovery in women (Sethuraman et al., 2014). Differences in outcomes according to biological sex have been reported (Magnotti et al., 2008; Wohltmann et al., 2001; Yang et al., 2014), but the mechanisms and factors underlying these associations are poorly understood.

Currently, a lack of understanding of women's unique health care needs hinders the delivery of patient-centered, evidence-based care for women with traumatic injuries. In the United States, 7 percent of women experience traumatic injuries during pregnancy; moreover, traumatic injuries are the most common cause of nonobstetric death among pregnant women (Barraco et al., 2010). Women also are more likely than men to experience intimate partner violence and PTSD, and less likely to seek care following trauma (Tolin and Foa, 2006). Biological sex-based and socially constructed gender-based differences are known to affect health care utilization patterns, health care outcomes, and access to postdischarge care (Sethuraman et al., 2014). Scientifically rigorous research is needed to address sex- and gender-based differences in trauma and trauma care needed among female patients, and to produce evidence that can be used to provide care that accounts for these differences.

Vulnerable Populations

Numerous studies have pointed to differential health outcomes in vulnerable populations, such as racial and ethnic minorities and patients who are uninsured. Data suggest, for example, that non-Hispanic black versus non-Hispanic white patients and uninsured versus commercially or publicly insured patients sustain higher risk-adjusted rates of mortality after injury (Haider et al., 2008, 2013b). Insured black patients are nearly 20 percent more likely to die after severe injury than equivalently injured insured white patients, and injured uninsured white patients are nearly 50 percent more likely to die than similarly injured white insured patients (Haider et al., 2008). Minority patients use more emergency services relative to white patients, and uninsured, urban, and nonwhite patients experience particularly high rates of traumatic injury, especially penetrating injuries (Haider et al., 2008). These groups have special health needs, and their care needs to be culturally dexterous and patient-centered if it is to achieve the best possible outcomes. Variations in hospital-level factors (Zafar et al., 2015, 2016) and a myriad of interrelated patient-, provider- and, systems-level characteristics (Haider et al., 2013a) have been associated with differential outcomes experienced by vulnerable groups of patients. Despite widespread recognition of these disparities, however, little is known about the patient perspective of these groups, how such factors affect the experiences of patients sustaining a traumatic injury, or what can be done to address these special needs in meaningful ways.

Vulnerable populations in many instances also suffer lack of access to trauma care, even in America's largest cites. For example, the south side of Chicago, which is currently suffering from an epidemic of violence and intentional injury, has not had a trauma center since the last one closed due to financial difficulties nearly two decades ago, earning it the label "trauma desert" (Crandall et al., 2013). After suffering a traumatic injury such as a gunshot wound, patients injured in that part of the city need to be transported several miles in city traffic to reach the nearest trauma center. The resultant delays in access to care have been associated with increased mortality. Crandall et al. (2013) demonstrated a 23 percent increase in the odds of death for patients in Chicago who suffered a gunshot wound and had to be transported more than 5 miles.

ENGAGING PATIENTS, FAMILIES, AND COMMUNITIES

Patient-centered care for trauma, as for all conditions, requires proactive engagement of patients, families, and communities in care, system design, and trauma research.

Engagement in Care

To continuously improve and to deliver better patient outcomes, a trauma system needs to reflect understanding of the needs and wants of injured patients. True patient-centered care engages patients and their families in both clinical decision making and the design of care processes. In such a model, patients and providers work together, making care decisions that take into account a patient's preferences, life circumstances, and values, as well as the best available scientific evidence (IOM, 2013a).

Given the nature of trauma, patients often lack the physical and mental capacity to engage in shared decision making at the time of injury; as a result, decisions may be made with little to no patient input (Willis et al., 2013). In the military, for example, one report documents soldiers developing "do not resuscitate" pacts with their fellow service members in the event of a particularly damaging traumatic injury (DCBI Task Force, 2011). That soldiers felt driven to make these unofficial arrangements suggests that the military's trauma system and its providers neither sufficiently understood nor adequately took into account the preferences of those it served. In civilian hospitals, residents spend on average only 2.7 minutes with a surgical patient during morning rounds, with teams inviting questions from patients only 7.7 percent of the time (Gupta, 2013). When consulted on their hospital experience, patients emphasize the "lack of time with residents, fragmentation of care among teams, poor communication with patients/family members, lack of appropriate explanations of the care plan, and the need for better patient-centered care among hospital staff" (Gupta, 2013).

Nurses often are particular champions of patient-centered approaches to the care of trauma survivors, helping to ensure the alignment of clinical decisions with patient values and preferences (Hasse, 2013). In the intense trauma setting, a critical role for all providers but one that is especially well suited to nurses is helping patients and their families understand what is happening in a timely manner so that critical clinical decisions can be made. This may include explanation of medical jargon, purposes of tests, treatment options, and what to expect during treatment (Hasse, 2013). Educating patients and their families about the patient's injury and its associated effects (e.g., clinical, financial, social) prior to the transition to rehabilitation also helps address the patient's holistic needs and optimize recovery. This mindset needs to permeate all actors and processes within a trauma care system, particularly in light of evidence that interventions provided in the prehospital and hospital settings influence a patient's long-term outcomes and quality of life.

There are ample opportunities, even with trauma, to engage patients and families in care decisions. Examples include documenting patients' preferences in the primary care setting (in the military, prior to deployment), consulting and involving families in the event of a traumatic injury, and working with patients and their caregivers during the transition to rehabilitation. Involvement of families and caregivers is a particularly important component of patient-centered trauma care that enhances a patient's motivation to recover, encourages independence, and fosters family support (DCBI Task Force, 2011). Family involvement also bolsters communication, understanding, and shared decision making; family-centered rounds, for example, which incorporate patients and their caregivers into the care team, improve the bidirectional exchange of information between families and providers (Davidson et al., 2007; Mangram et al., 2005; Williams, 2005).

Engagement in System Design

Patient-centered trauma care is not limited to patient–provider interactions; it also extends to patient, family, and community engagement at the organizational and system levels. Having experienced trauma care firsthand, patients, families, and other caregivers possess unique and invaluable perspectives on the design and care delivery of trauma systems. A learning trauma care system leverages these insights to improve the system's design and care processes, and ultimately, patient outcomes (see Box 6-4). The involvement of patients, families, and communities as advocates for improvement initiatives will help ensure that the patient remains the focus of such efforts and that patients' feedback and values guide system design (IOM, 2013a).

One strategy for promoting patient engagement is the use of patient and family advisory councils. These councils offer patients and families opportunities to engage directly with an organization's decision-making structures. Through involvement with such councils, patients and families can participate in performance improvement initiatives, help reform service delivery practices, participate in the selection of new executives, and assist in the development of educational programs for care providers. Patient and family advisory councils can also advise a hospital on how to improve the efficiency and patient-centeredness of its operations. Participation on patient rounds, for example, may generate new suggestions and ideas for improvement (Balik et al., 2011; Johnson et al., 2008; Ponte et al., 2003). A number of patient and family advisory councils have been established in civilian trauma centers (Willis et al., 2013) and VA hospitals (VA, 2016a,c).

Box 6-4
EXAMPLES OF PATIENT AND FAMILY ENGAGEMENT IMPROVING SYSTEM DESIGN[a]

Ongoing communication with trauma patients and their families assists in identifying opportunities for improvement. As told to the committee during its January 2016 meeting, an example occurred in a trauma support group meeting at Parkland Memorial Hospital in Dallas, Texas. A family member attending the support session described her previous experience as a patient following a motor vehicle crash, explaining that the pain management was inadequate and that she could remember this bad experience in the intensive care unit (ICU). The woman was angry and hostile regarding her treatment. The trauma leaders met with her to hear her story and learn from her experience, which prompted a review of practice. The family member was asked to engage in sharing her experience and educating the nursing and medical staff. The education she provided over the next 3 months led to changes in pain management practices in all ICUs at Parkland.

Another example of engaging trauma patients and their families in education occurred in 2005. An individual involved in a motor vehicle crash related to alcohol returned to Parkland Memorial Hospital to thank the trauma program staff. The staff encouraged the patient and his mother to share their story with others. The goal was to assist in educational programs targeting teens and young adults regarding the consequences of drinking and driving. The patient and his mother became local, state, and national advocates for traumatic brain injury survivors and for trauma center and trauma system funding, research, and access to rehabilitation. Their story is available at whenseanspeaks.com. These individuals continue to spearhead advocacy programs and educate others on the impact of trauma.

[a] Personal communication, J. Klein, Parkland Health & Hospital System, to A. Downey, the National Academies of Sciences, Engineering, and Medicine, February 5, 2016.

In one example, a patient and family advisory council established at York Hospital in York, Pennsylvania (a Level I trauma center), identified and completed four improvement projects: (1) the revision of an informational handbook for trauma patients and their families, (2) the use of whiteboards to inform patients and families about the patient's daily care plan and identify members of the clinical team, (3) improved communication techniques for nonverbal (e.g., intubated) patients, and (4) an exploration of the impact of PTSD on trauma patients (Willis et al., 2013). At this time, however, the use of these councils in military treatment facilities and civilian trauma centers remains limited.

Another approach for engaging patients, families, and communities is transparent measurement, in which the system commits to gathering and responding to outcome and experience measures provided by patients and families. The collection and use of these measures (assessed in Chapter 7) not only support quality improvement activities but also demonstrate to patients and families that their experiences and opinions matter.

Engagement in Trauma Research

Within a learning trauma care system, research generates new knowledge and drives innovative advances in care. Trauma research is enhanced when its design and execution are patient centered. Everyone is at risk of trauma. Thus there is an imperative for all members of the public to participate in processes that work to improve trauma care. In this context, patient and other stakeholder involvement is helpful in prioritizing research topics and outcome measures.

Patient-centered outcomes research, as defined by the Patient-Centered Outcomes Research Institute (PCORI), "is the evaluation of questions and outcomes meaningful and important to patients and caregivers" (Frank et al., 2014, p. 1513). Information derived from the engagement of patients, families, and caregivers in the design of clinical research is predicted to increase the relevance of the research to their health decisions. By addressing those clinical questions most important to these stakeholders, PCORI aims to advance the uptake of this information and its use to improve patient outcomes (Frank et al., 2014). While still evolving, evidence demonstrates a variety of positive results emerging from such engagement in research, including not only enhanced relevance of research results to patients but also improved study recruitment and retention rates, and increased validity of outcome measures (Brett et al., 2014; Cashman et al., 2008; Edwards et al., 2011). PCORI is currently funding a 3-year study on trauma in the civilian sector—A Comparative Effectiveness Trial of Optimal Patient-Centered Care for U.S. Trauma Care Systems (PCORI, 2016).

The type of patient–researcher partnership encouraged by PCORI, whereby investigators and patients identify clinical questions together is not inconsistent with the more traditional approach to research funded by other federal entities, including the National Institutes of Health and DoD (Greenberg et al., 2014). In the past decade, for example, institutional review boards for many of the proposed DoD research studies involving trauma methods and practices included patient advocates and/or former patients.

SUMMARY OF FINDINGS AND CONCLUSIONS

CONCLUSION: A patient-centered approach to trauma care is necessary to achieve optimal immediate-, near-, and long-term outcomes for trauma patients. Thus, it is essential for military and civilian trauma systems to

proactively maximize patient, family, and community engagement and continue to refine the delivery of trauma care so that patients' holistic needs are supported seamlessly across the continuum of care.

Related findings:

- *In both the military and civilian sectors, patient care across the trauma continuum of care is fragmented, particularly during the latter stages in which a patient is transitioning from hospital-based care to rehabilitation and recovery.*
- *Opportunities exist to improve patient, family, and community engagement in trauma care delivery, trauma system design and improvement processes, and trauma research.*

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7

Leveraging Leadership and Fostering a Culture of Learning

Trauma care, properly performed, involves an extremely complex system of interactions, handoffs, and teams. In military trauma care, for example, the doctrines of forward care, rapid transfer, and tiered levels of capability require highly reliable orchestration that spans multiple geographies, ranks, and roles. Similarly, high-quality civilian trauma care within the United States bridges numerous federal, state, and local agencies; prehospital and tiered inpatient systems; professional organizations; and academic societies. In such a cross-cutting and interconnected endeavor, knowledgeable and effective leadership at all levels is essential to success. The need for leadership is even greater in pursuit of a *learning* trauma care system, since the elements of a learning system promulgated by the Institute of Medicine (IOM, 2013) report *Best Care at Lower Cost* do not occur spontaneously; only leaders can plan, maintain, and support them. The challenges to the accomplishment of such a system include technical issues (such as ensuring the availability of proper real-time data systems); cultural concerns (such as avoiding fear in the workforce, which is inimical to curiosity, ambition, and transparency); and a paucity of leadership, policy, and resources to animate a national system. If the aims for the system include, as they should, continued bidirectional exchange between the military and civilian systems to continually improve and ensure the best trauma care possible in both sectors, national and regional leaders will have to commit to that communication and cooperation.

Leadership (inclusive of health leaders) is uniquely positioned to define and communicate the aims of a system, make continuous learning and improvement a priority, and provide the resources and environment necessary to achieve the system's aims. Accountability, culture, transparency, and incentives are powerful catalysts for change that can be leveraged to promote a learning trauma care system and drive all actors within the system to work cooperatively toward shared goals, ultimately saving lives. In contrast, a culture inhospitable to improvement and the absence of transparency and accountability can result in preventable deaths after injury (see Box 7-1). In this chapter, the committee examines the extent to which these catalysts are employed and aligned in the military and civilian sectors as a demonstration of leadership's visible commitment to and rewarding of learning and improvement.

FOSTERING A CULTURE OF LEARNING

A culture of learning is driven by a belief in the value of continuous improvement. As discussed in Chapter 3, organizational culture can act as either a strong enabler or a deterrent for continuous learning and improvement. A learning trauma care system will function optimally in an environment that embraces teamwork and partnership, and in which actors are encouraged to improvise without fear (IOM, 2013). Within such a setting, leadership is responsible for defining and supporting an aim of continuous learning, translating that aim into practice at all levels, and removing cultural barriers that threaten to stall improvement.

The history of the 75th Ranger Regiment (also discussed in Chapter 1) attests to the positive outcomes that can be achieved in trauma care when leadership at the highest level makes improvement a priority and supports a culture of learning. In 1998, the commander of the 75th Ranger Regiment, then COL Stanley McChrystal, issued a directive that all rangers make four major areas of training a priority: marksmanship, physical training, small unit tactics, and medical training (Kotwal et al., 2011). This elevation of medical training to a tactical priority on par with a unit's capability to shoot, move, and communicate drove the regiment to establish a casualty response system integrating tactical combat casualty care (TCCC) training at all levels (Pappas, 2001; Veliz et al., 2010). The result was zero medically preventable deaths in the prehospital setting (Kotwal et al., 2011). Unfortunately, this example of formal command leadership of trauma care learning and improvement appears to be more the exception than the rule. Across the military, service parochialisms and an inconsistent level of understanding by senior medical and line leadership of the value of a learning trauma care system impede continuous learning and improvement. The success of the 75th Ranger Regiment at the same time that nearly 25 percent of battlefield fatalities within the broader U.S. Department of Defense (DoD) resulted from potentially survivable injuries demonstrates the need for combatant commanders and line leaders along the chain of command

Box 7-1 THE CHALLENGE OF CULTURE

On January 29, 2016, Dr. Jullette Saussy resigned from her position as emergency medical services (EMS) medical director/assistant fire chief for DC Fire and EMS. In her resignation letter, excerpted below, Dr. Saussy describes the challenges and realities facing a number of low-performing prehospital systems, including that of the nation's capital. Most significant, Dr. Saussy's findings underscore the wide variation in structure and performance that exists across trauma systems and the extent to which improvements in the nation's trauma system capabilities and outcomes for injured patients will require leadership, accountability, transparency, and a culture of learning.

> The last six months have been filled with trying to understand exactly what has plagued this department for decades and to better comprehend why people die needlessly in the District of Columbia. The answers are clear, as I will share below.
>
> First, the **culture** of the DC Fire and EMS Department is highly toxic to the delivery of any semblance of quality prehospital patient-care. EMS reform, even attempts to make basic changes, are met with resistance from the top down.
>
> The Department **refuses to measure true performance**. . . . You cannot fix what you do not measure honestly and this is one main reason the system continues to fail the people we are here to serve.
>
> **A lack of accountability** at all levels has created a workforce that is undisciplined and unchecked. Major infractions result in virtually no discipline and the "practice of medicine" is "overseen" by people with no authority, no medical expertise or teeth to drive change. Yet, it is that very "practice of medicine" for which this Department is so infamously known to be deficient.
>
> **The organizational chart** and the lines of authority are not reflective of the work that is done daily. Over 80% of what DC Fire and EMS does daily is prehospital care and there are three people on the EMS "leadership side": only two have any significant experience in the practice of prehospital emergency medicine. Only one (me), has ever reformed a failing system. However, I have no authority, no direct EMS provider reports and no ability to make policy change that would ensure the immediate improvement in patient care. Ultimately, I have no ability to hold our providers accountable for the care they deliver.

SOURCE: Excerpt from the resignation letter of Dr. Jullette Saussy from her position as EMS Medical Director/Assistant Fire Chief for DC Fire and EMS. Used with permission of Jullette M. Saussy, M.D., FACEP, and The Associated Press. Copyright © 2016. All rights reserved.

to assume responsibility for the performance of the trauma care system in theater (Butler et al., 2015; Eastridge et al., 2012).

A culture of teamwork and cooperation is a fundamental component of a learning trauma care system, in which an injured patient must be managed across a lengthy continuum of care entailing multiple transitions and handoffs between providers. The Joint Trauma System's (JTS's) use of weekly teleconferences in which all levels of medical personnel discuss casualties as they actively move across the evacuation chain exemplifies how such a culture fosters strong communication and coordination among providers (Bailey et al., 2013; Butler et al., 2015; Eastridge et al., 2009; Pruitt and Rasmussen, 2014). However, this level of partnership is far from universal. With regard to the civilian sector, the committee heard testimony that competition, particularly among emergency medical services (EMS) agencies (Osborn, 2015) and private health systems, remains a problem in civilian trauma care. The expansion of competing for-profit trauma centers in the civilian sector also threatens outcomes for injured patients (Johnson, 2015).

It is important to note that most, if not all, modern views of an effective learning organization emphasize the toxic effects of fear. When members of a workforce are afraid of what might happen to them should defects arise and become known, should they speak up with new ideas, or should a test of change fail, information is hidden, teamwork suffers, and self-defense displaces honesty (Garvin et al., 2008; IOM, 2013). These principles are well known in the military in, for example, the culture of after-action reviews, in which rank and hierarchy give way to open and honest exchange among all participants who may have information and ideas to offer (Garvin et al., 2008; Morrison and Meliza, 1999). As the military seeks to accelerate improvements in trauma care through learning, it is imperative that leaders—at all levels—understand and continually reduce those insidious forces—including fear, departmental politics, internal competition, egos and agendas, an unwillingness to accept responsibility, and a culture of blame—that threaten to undermine teamwork, progress, and the larger enterprise of continuous learning and improvement.

For a culture of learning to truly permeate a system, leadership must be willing to invest the time, resources, energy, and infrastructure necessary to facilitate learning. This support for learning rests on a belief in the value of continuous improvement. The efforts and accomplishments of the JTS, the Committee on Tactical Combat Casualty Care, and medical providers at all levels demonstrate the military's commitment to these principles, driven by wartime's immense burden of injury. The challenge at hand is whether an institutional commitment to continuous improvement in trauma care can be sustained throughout interwar periods. The military has been much lauded for reducing its case fatality rate to an unprecedented low over the course of wars in Afghanistan and Iraq. What has not been emphasized, however, is the fact that in 2006, the case fatality rate in Afghanistan reached above 15 percent (Bailey et al., 2013). During the war in Vietnam, the case fatality rate was 15.8 percent (Holcomb et al., 2006). The startling consistency in these case fatality rates reveals the dangers of compliance and of the absence of a culture in which learning and constant improvement in trauma care are priorities. As the military transitions to an interwar period, it is essential that the wartime culture of learning and drive to improve persist so that the case fatality rate at the start of the next war is lower than or at least equal to that achieved at the end of the wars in Afghanistan and Iraq.

DEMONSTRATING A COMMITMENT TO TRANSPARENCY

Transparency incentivizes providers, hospitals, and systems to reassess their practices in order to improve (IOM, 2013) and thus plays an important role in a learning trauma care system. In addition, transparency of costs and outcomes enables patients and consumers to make well-informed decisions, encouraging continuous improvement and the delivery of high-quality care as providers and organizations respond to this external motivation. Transparency for the purposes of performance improvement is not possible, however, without a standard set of performance indicators. Equally important, as discussed above, is a culture in which fear—of disciplinary action, liability, or embarrassment—is not permitted to impede continuous learning (Garvin et al., 2008; IOM, 2007b).

As discussed in Chapter 3, four different but interrelated domains of transparency have been shown to improve outcomes, reduce errors, improve patient satisfaction, and lower costs:

- **Clinician-to-patient—**includes better communication, disclosure (cost and potential clinical outcomes), and patient engagement in decision making.
- **Clinician-to-clinician—**includes peer reviews such as regular and comprehensive morbidity and mortality conferences, sharing of best practices and lessons learned, open discussion of adverse events, and assurance that providers have access to their own performance data (e.g., expected versus actual mortality). Equally important are data comparing the performance of individual clinicians with that of their peers.
- **Organization-to-organization—**includes participation in national and regional collaboratives for data sharing and benchmarking across organizations.
- **Public—**includes public reporting on outcomes and costs (NPSF, 2015).

An assessment of communication with and engagement of patients in trauma care is presented in Chapter 6. The discussion here focuses on transparency and public reporting at the provider and organization levels.

The incorporation of performance improvement processes into health care systems and the delivery of care as a routine and ongoing process is an invaluable tool that can assist individual providers in understanding and improving their personal performance, as well as their contribution to the entire trauma care system (DHB, 2015; IOM, 2007b). To encourage this individual-level performance improvement, providers need access to their own data. Morbidity and mortality conferences are well-established processes that facilitate transparency at the provider level (Seigel et al., 2010). Open discussion among providers on medical errors and adverse events is a critical component of patient safety improvement efforts (ACS, 2014). However, this process does not provide clinicians with real-time data on their performance relative to that of their peers. The American College of Surgeons (ACS) and Vizient[1] (formerly the University HealthSystem Consortium) both provide national-level quality improvement programs that facilitate transparency through external benchmarking.

The ACS Trauma Quality Improvement Program (TQIP) provides participating trauma centers with risk-adjusted benchmark reports, online tools for drilling down into the data, and an opportunity to share successes and challenges at the annual TQIP meeting and training (ACS, 2015d) (see Figure 7-1). To take part in TQIP, centers must use the National Trauma Data Bank, be fully compliant with the National Trauma Data Standard (NTDS), pay an annual fee, and submit data quarterly (ACS, 2015a). Use of the NTDS ensures that data across centers are standardized and comparable. However, some issues with data may remain. For example, centers or providers may classify similar trauma outcomes differently, or preexisting classification fields may have to be "mapped" onto NTDS fields. ACS has attempted to address these issues through ongoing registrar training and data quality assessments (Nathens et al., 2012). In addition, ACS uses risk adjustment models to standardize data. These models help account for variation among trauma centers, such as differences in transport times to the centers, local patterns of injury or patient characteristics, and different policies regarding pronouncement of death. Risk adjustment also allows ACS to create models that can be used to compare expected and observed mortality and lengths of stay across centers (Nathens et al., 2012). This information allows centers to see how they compare with other centers and facilitates the identification of high-performing centers.

[1] Vizient is the new member-owned health care services company formed following the 2015 merger of the VHA and University HealthSystem Consortium (UHC) hospital networks (Vizient, 2016b).

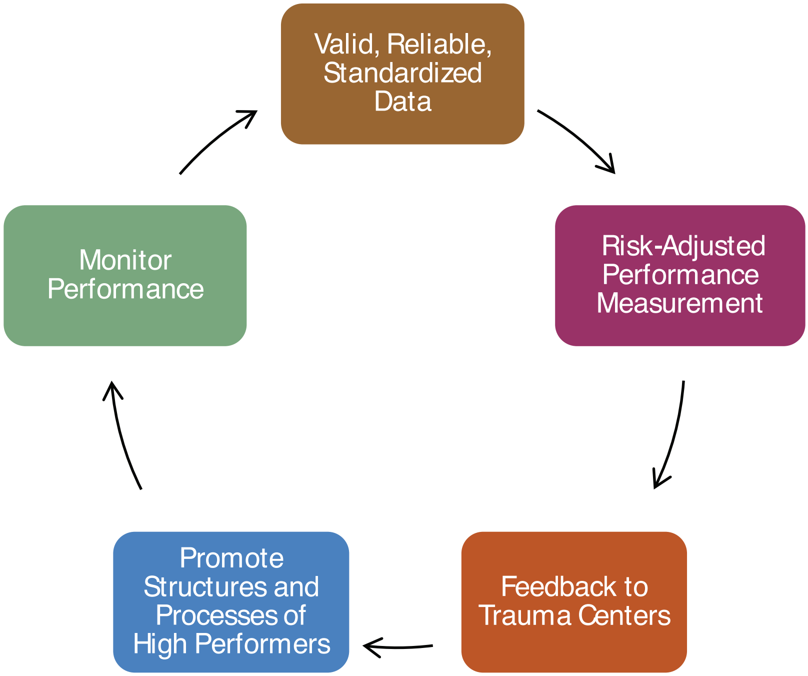

FIGURE 7-1 The conceptual framework of continuous quality improvement underlying ACS TQIP and other quality collaboratives.

SOURCE: Reprinted from Nathens et al., 2012, with permission from Elsevier.

Similarly, participation in a Vizient learning network (e.g., academic medical center network) allows member organizations to benchmark their organizations, comparing outcomes and identifying areas for improvement (Vizient, 2016a).

Military Sector

In the military, the challenges associated with fragmented data repositories and the abstraction process—discussed in more detail in Chapter 4—limit the extent to which timely individual provider performance improvement is possible. A 2011 assessment of the military's trauma system included the following observations about performance improvement processes in theater:

- The trauma performance improvement and patient safety process is fragmented. The awareness, implementation and integration of structured [performance improvement] processes vary by level of care,

> branch of service and coalition partners. This less than desirable state results in a loss of transparency and creates difficulty in performing concurrent, multidisciplinary [performance improvement] and stifles the communication and learning between and amongst levels of care.
>
> - Efforts to implement rudimentary trauma related [performance improvement] were present at each military trauma facility. Morbidity and mortality review varied widely from no review, to an exclusionary physician only review with little documented analysis or corrective actions, to a casual multidisciplinary verbal debriefing with no recorded corrective actions or loop closure documented in any of these observed systems. (Rotondo et al., 2011, pp. 11-12)

The JTS holds weekly teleconferences to review the treatment and outcomes for all casualties across the continuum of care. In the absence of easily accessible data on provider performance, this exercise fosters communication among the various providers for a single casualty, providing the opportunity to receive feedback (Bailey et al., 2013; Eastridge et al., 2009). System-wide, however, DoD lacks a codified and standardized approach to performance improvement, which results in a lack of transparency and hinders learning. To improve transparency and learning, it is important for deployed hospitals to conduct weekly morbidity and mortality conferences, with patient-specific information flowing between hospitals and across levels of care. These reports could be collated by the JTS and lessons learned rapidly distributed back to all providers in the system.

Military participation in national collaboratives such as TQIP is severely limited. At this time, only a single military hospital (Carl R. Darnall Army Medical Center) participates in the ACS TQIP Level III pilot benchmarking program.[2] This lack of transparency at the organization level highlights an opportunity to improve the learning system for military trauma care through adoption of civilian best practices. Although only trauma centers are eligible to participate in TQIP, military treatment facilities (MTFs) that are not trauma centers may still be able to participate in Vizient's quality improvement program.

Civilian Sector

In the civilian sector, the trauma performance improvement process—supported by a trauma registry—is a hallmark function of trauma centers, second only to trauma patient care. This process entails monitoring compliance with evidence-based practice, care delivered, and system performance

[2] Personal communication, J. Dodd, American College of Surgeons, to E. Cornett, the National Academies of Sciences, Engineering, and Medicine, regarding the National Trauma Data Bank and Trauma Quality Improvement Program, March 18, 2016.

to ensure that opportunities for improvement are quickly identified and addressed, optimizing patient outcomes. The ACS Committee on Trauma requires that all verified trauma centers have a performance improvement and patient safety program that demonstrates a process of monitoring, assessment, and management to continuously improve care (ACS, 2014). This process helps identify unnecessary variation in care and adverse events that can subsequently be addressed through corrective actions, but it does not ensure that providers have access to timely and continuous information on their performance relative to that of their peers.

At the hospital level, ACS-verified and state-designated trauma centers are eligible to participate in TQIP. Currently more than 350 Level I and II centers are participating, and a program for Level III centers was launched in July 2016 (ACS, 2015e). Starting in January 2017, all centers seeking ACS verification or reverification must be TQIP participants.[3] During a pilot study of 23 Level I and II trauma centers, 90 percent of survey respondents said they found the performance data report useful, and 63 percent indicated that they would take action based on the information it provided (Hemmila et al., 2010).

Although the ACS has been successful in establishing a system for performance improvement across trauma centers, an equivalent national program is notably lacking for prehospital care (challenges to benchmarking whole trauma systems are discussed in the next section). The problem has been largely cultural. While some success has been achieved at the state and regional levels in establishing programs to support the quality improvement of EMS care (see Box 7-2), a culture of continuous improvement has not yet been uniformly embraced by the EMS community.

An ongoing National Highway Traffic Safety Administration Office of EMS-funded initiative, EMS Compass, is developing measures for civilian prehospital care (see Box 7-3). The establishment of evidence-based measures through EMS Compass could enable benchmarking of EMS performance, serving as the first step toward the creation of a program similar to TQIP for comparing and assessing EMS systems. However, because EMS systems vary considerably in structure across the United States and their regulation is based at the state and local levels, enacting such a national program could be difficult. State EMS agencies could facilitate a national benchmarking program by requiring licensed agencies to use and report on the EMS Compass measures (Gainor, 2015).

[3] Personal communication, M. Neal, American College of Surgeons, to E. Cornett, the National Academies of Sciences, Engineering, and Medicine, regarding the National Trauma Data Bank and Trauma Quality Improvement Program, April 12, 2016.

Box 7-2 **A QUALITY PROGRAM FOR EMERGENCY MEDICAL SERVICES (EMS): THE EMS PERFORMANCE IMPROVEMENT CENTER'S PREHOSPITAL MEDICAL INFORMATION SYSTEM**

North Carolina's Prehospital Medical Information System (PreMIS) is a state-mandated electronic record collection and storage system. PreMIS is used by more than 700 EMS agencies and 400,000 EMS personnel in North Carolina. Between 2008 and 2010, North Carolina's EMS Performance Improvement Center worked with West Virginia and South Carolina to implement PreMIS within these states, where the system is used by an additional 100,000 EMS personnel. EMS agencies from these three states submit records to PreMIS daily, with more than 2,000,000 call reports being collected each year (EMSPIC, 2016b). PreMIS includes a reporting feature that enables EMS administrators to assess trends within their respective agencies and to evaluate individual performance. By adhering to the National EMS Information System data standard, PreMIS also enables the evaluation and benchmarking of EMS system performance (EMSPIC, 2016a; Mears et al., 2010).

Box 7-3 **EMS COMPASS**

Launched in October 2014, EMS Compass is part of a 2-year cooperative agreement between the National Association of State EMS Officials and the National Highway Traffic Safety Administration Office of EMS. The aim of EMS Compass is to facilitate meaningful measurement and evaluation of emergency medical services (EMS) care, which entails establishing a process by which performance measures can be developed, as well as identifying a core set of initial measures. In developing measures, EMS Compass focuses on the practicability and usefulness of each measure. For example, priority is given to indicators that can be measured using data already available through existing systems, such as the National EMS Information System (EMS Compass, 2015b).

While there have been previous efforts to develop performance measures for EMS, EMS Compass is "the largest national effort ever undertaken to develop EMS performance measures and the first in more than a decade" (EMS Compass, 2015a). One of the earliest measures for EMS care was based on a study demonstrating that survival increased for cardiac arrest patients if advanced life support was administered within 8 minutes (Al-Shaqsi, 2010). The measure born from this study—ambulance response time—has been widely adopted by EMS agencies, and an 8-minute response time has become the standard for assessing EMS system performance (Al-Shaqsi, 2010). Yet while response time is easy to measure and easy for policy makers and the public to understand, up-to-date evidence that it is correlated with patient outcomes is lacking, and the use of response time as a sole indicator may mask other inadequacies in the system (Al-Shaqsi, 2010). To address this gap, EMS Compass is developing a set of measures that have a strong evidence base, are clearly correlated with patient outcomes, and can be continually reassessed. This effort represents a significant step forward toward greater transparency but will require continued investment to ensure that the measures developed are refined over time.

Benchmarking Across the Military and Civilian Systems

The ability to benchmark performance across trauma systems is comparatively undeveloped, if not altogether lacking. TQIP's Collaborative Initiative enables a health system, region, or state to be evaluated as a single entity, comparing its outcomes with those at the national level as well as those of other similar collaboratives (Nathens et al., 2012). Trauma systems encompassing the entire continuum of care, however, cannot compare their outcomes against one another. Thus the military cannot compare its trauma system with those found in the civilian sector and vice versa. In addition, civilian trauma systems cannot compare their performance with that of other civilian systems. This lack of transparency at the regional and state levels inhibits the transfer of best practices from high-performing systems.

The absence of standard, national metrics for trauma care is a barrier to greater transparency and benchmarking at the system level. The National Quality Forum, which grew out of the President's Advisory Commission on Consumer Protection and Quality in the Health Care Industry, has reviewed and endorsed numerous sets of measures, including those for hospital care, home health care, nursing home care, cardiac surgery, diabetes care, and emergency care (NQF, 2005, 2006, 2009, 2010, 2011). Currently, however, it has endorsed no measures of trauma care quality.

Metrics for Trauma

Throughout the development of regionalized trauma systems, rates of preventable death after injury and risk-adjusted mortality have served as the primary standards by which trauma center performance has been measured and compared (Gruen et al., 2012; Mann et al., 1999). Mortality is a simple metric to define and capture in a hospital setting. Using this measure, multiple studies have demonstrated a reduced risk of mortality when care is received at a trauma center (Haas et al., 2010; MacKenzie et al., 2006, 2010; Nathens et al., 2000). Evaluations of trauma system performance, however, tend to focus largely on hospital mortality data, often failing to capture and take into account outcomes across the trauma care continuum (particularly in the prehospital and out-of-hospital settings). At present, data on posttrauma health status and functional outcomes are sparse. In the context of a learning trauma care system, mortality is not a sufficient metric with which to measure care and encourage future improvements (Gruen et al., 2012; Mann et al., 1999). There is a need for validated measures that capture process and morbidity outcomes, including "functional and quality of life outcome measures as well as patient experience and indicators such as return to work, education, and social dependency" (Ardolino et al., 2012, p. 1662). Measures need to be time based, linked to outcomes, system and provider oriented, and refined over time.

Public Reporting of Performance Data

Public dissemination of data on trauma system performance (both military and civilian) currently represents a notable gap in transparency. The reason is likely multifaceted, including a lack of data and quality measures for trauma care, competition among provider organizations, and tort concerns. Reports from national-level quality improvement programs, including those offered by ACS and Vizient, are not made publicly available. Although research has been conducted to demonstrate variability in trauma center performance, such information is publicized largely through journal articles, a channel unlikely to reach the public. The lack of public reporting may contribute to the documented misalignment of Americans' perception that they will receive the best possible care after injury and the reality regarding variability in regional trauma care capabilities and patient outcomes across the nation (Champion et al., 2006). Given the nature of traumatic injury, increased public reporting likely would not guide individual choice of where to receive care, but it could raise awareness of the overall burden of injury and lead to greater public engagement in and advocacy for trauma system development, quality improvement, and research. Similarly, public reporting would inform community and policy leaders regarding geographic differences and potential gaps in the care and outcomes among trauma patients.

PROMOTING AND REWARDING HIGH-QUALITY TRAUMA CARE

Transparency is arguably one of the most powerful levers for effecting change in practices and improvement in trauma care outcomes, but as discussed in Chapter 3, high-performing learning systems apply an array of stimulants to encourage and reward continuous quality improvement. Although there has been increasing focus on the use of financial incentives to drive higher-quality medical care and lower costs in the United States, other levers include personal recognition (e.g., promotion, bonuses), regulatory requirements, tort, and competition. The best approach to improving trauma care in both the civilian and military sectors is to use multiple levers in a comprehensive effort.

Military Sector

Military trauma care providers are driven to improve first and foremost by the desire to help their fellow service members achieve the best possible outcomes after injury. While financial incentives (e.g., variable reimbursement) are a powerful driver of change in the civilian sector, they have a much lesser role in the military. The military essentially functions as a single-payer system, which in theory should help align financial incentives across the continuum of care. However, a large budget for health care coupled with little financial accountability may encourage spending rather than pushing the system to reduce waste and reward high-quality care (Haut et al., 2016).

The backbone of the U.S. military is its system of rank and chain of command. Recognition in the form of promotions serves as one of the strongest incentives for military personnel who value the authority and prestige associated with a higher rank (Baker et al., 1988). Merit-based promotions in the military have received increasing attention in recent years. Defense Secretary Ash Carter has proposed a major overhaul of the way the military evaluates and promotes its service members, stressing merit over seniority (Tilghman, 2015). For line officers, promotions based on merit depend on evaluation of service members' readiness for their combat mission. For medical personnel, however, promotions are not based on readiness for their combat medical mission. Therefore, while promotion serves as a strong incentive for line and infantry personnel to perform optimally and make readiness a priority, promotion incentives for medical personnel are misaligned. The absence of a clear measure by which line and medical leaders can be held accountable for the trauma system's performance and casualty outcomes (Rotondo et al., 2011) is a barrier to leveraging this incentive mechanism to drive improvement.

In some cases, requirements for promotion can act as a disincentive. The committee heard, for example, that experienced nurses must shift from patient care to administrative positions in order to obtain the experience necessary for continued promotion[4] (Wilmoth, 2016). Physicians face similar pressures (LaFraniere, 2014). Current promotion structures thus do not encourage or reward the growth of clinical trauma-focused expertise, reducing the pool of senior-level clinicians available at the point of care to shepherd continuous performance improvement efforts.

Civilian Sector

In the civilian sector, measures and financial incentives play a large role in current health care reform initiatives. For decades, the civilian sector operated under a largely fee-for-service payment system. Fee-for-service, however, leads to increased costs by rewarding providers for the complex-

[4] Unlike the medical corps, nursing is not exempt from the promotion system of the Defense Officer Personnel Management Act.

ity and number of medical services provided (James, 2012). Unsurprisingly, more intense care does not necessarily equate to better outcomes, and can even prove harmful to patients (Chen et al., 2010; Fisher et al., 2003).

In the face of widespread recognition of serious deficiencies in the U.S. health care system, highlighted in the landmark IOM (2001) report *Crossing the Quality Chasm: A New Health System for the 21st Century*, policy makers and private and public payers have encouraged pay-for-performance initiatives as a way to realign the system's incentive structure to encourage improvement in the quality, efficiency, and value of care (Miller, 2009). As a result, experimentation with a variety of financial incentives is under way. Payment-based strategies include incentive payments for processes (e.g., care coordination), penalties for unwanted outcomes (e.g., hospital-acquired infections), and shared accountability payment methods (e.g., bundled payment) (IOM, 2013). However, the evidence base is not yet robust enough to demonstrate the effectiveness of current strategies, and further investigation of different care delivery and financing approaches (e.g., through pilots) is needed and is under way to gauge impacts on health and cost measures and identify unintended consequences. Although pilots are being conducted on a small scale by private payers, the Center for Medicare & Medicaid Innovation at the Centers for Medicare & Medicaid Services (CMS) was established to identify, test, and diffuse new payment and service delivery models to reduce expenditures while maintaining or improving quality of care for CMS beneficiaries. If innovative care delivery models demonstrate evidence of cost reductions and/or improvements in outcomes, the U.S. Department of Health and Human Services (HHS) has the authority to expand those models without congressional action (CMS, 2015).

Trauma care is not encompassed within current health care reform efforts. CMS, as the nation's largest payer organization for trauma care,[5] has significant influence over how such care is delivered through the use of health care payment policies, and thus is well positioned to lead the development of innovative approaches to improving trauma care while lowering costs. However, the distribution of trauma care across the prehospital, hospital, and outpatient (post-acute care) settings raises some challenges to the use of financial incentives to drive changes in trauma care practice. As discussed above, there is currently no standard set of quality measures (e.g., National Quality Forum measures) that can be used to evaluate the performance of trauma systems. One can imagine a shared savings model applied to trauma care—for example, with a bundled payment to a region's EMS organizations, emergency departments, and trauma center or centers—that

[5] Combined, Medicare and Medicaid account for more than half of trauma care reimbursements (Velopulos et al., 2013).

would entail measuring the contribution of the system in the aggregate and each provider type to patient outcomes. However, given the current state of data capture and integration across the trauma care continuum (see Chapter 4), implementing regional measures, although optimal, is currently not feasible. In the face of these challenges, an alternative to pay-for-performance incentives that has been piloted as a means of improving trauma care is the pay-for-participation model, a minimal-risk method of encouraging engagement in regional quality initiatives (see Box 7-4).

Beyond bundled payment, another particularly powerful lever available to CMS for effecting change is its "conditions of participation" for designated provider types.[6] To qualify for Medicare certification and reimbursement, health services providers must comply with these minimum health and safety standards, which are considered baseline requirements. Trauma system elements critical to continuous quality improvement (data collection systems, performance improvement programs) could be considered conditions of participation for all components of the care continuum. For the prehospital care component of the continuum, however, use of this approach would require including EMS as a provider type through legislative changes to the Social Security Act. EMS is currently considered a supplier of transportation under the Social Security Act and therefore is not subject to conditions of participation for providers.

The EMS reimbursement model used by CMS reimburses on the basis of transport to a medical facility (miles traveled to an emergency department and the level of service provided while en route). This "fee-for-transport" model, emulated by many other payers, ignores the increasingly complex care and lifesaving interventions performed by EMS providers at the point of injury and while en route (IOM, 2007a). This model thus represents an extreme misalignment of incentives. The fact that payers will deny reimbursement should transport not occur discourages EMS agencies from making determinations regarding the need for transport to a hospital, and as many as 11 to 61 percent of EMS transports to emergency departments are medically unnecessary (Gratton et al., 2003). These unnecessary transports add costs to the health care system, further burden hospital-based providers, limit the ability to respond to disasters, and hinder the implementation of processes that would allow EMS providers to transport patients to a more appropriate setting or treat and release (IOM, 2007a). Present EMS reimbursement practices thus act in direct opposition to the committee's vision of a learning trauma care system. As national efforts to link health care to quality proceed, EMS is being left behind.

[6] Provider types are specified in the Social Security Act.

Box 7-4
A PAY-FOR-PARTICIPATION MODEL FOR TRAUMA CARE QUALITY IMPROVEMENT

In Michigan, a partnership between the state's trauma centers and Blue Cross Blue Shield of Michigan/Blue Care Network (BCBSM/BCN) led to the establishment of the Michigan Trauma Quality Improvement Program (MTQIP), which leverages the American College of Surgeons TQIP learning infrastructure. Using a pay-for-participation approach, BCBSM/BCN incentivizes Michigan trauma centers to engage in national and regional trauma care quality initiatives. Regional collaboratives may have added value beyond the national TQIP by facilitating better sharing of information and best practices across centers as a result of stronger local networks with better communication (e.g., in-person meetings) and greater trust. Collaboratives like MTQIP also can feed lessons learned up to the national TQIP, thereby facilitating the identification and broader dissemination of trauma care practices associated with better patient outcomes.

SOURCE: Nathens et al., 2012.

ESTABLISHING OWNERSHIP

Defined leadership with comprehensive authority is necessary to shape and maintain a learning system's culture, infrastructure, planning, oversight, and future development and to create and enforce policy and guidelines (DHB, 2015). Absent clear, consolidated leadership, limited progress will be made. With regard to leadership for trauma care, the committee observed the same fundamental challenge in the military and at the national level: no one owns trauma care. Fragmentation, silos, competing political interests, ambiguity of leadership, and conflicting aims are far too common in trauma care in both the military and civilian sectors and across the care continuum.

Military Sector

The gains in military trauma care made over the past two decades are significant. The refinement of a joint and successful tiered system of battlefield care and transport required learning, innovation, and attention to details of logistics and design. Similarly, advances in technical, clinical trauma care—such as new fluid resuscitation methods and tourniquet use—arose from agility, knowledge management, and the use of focused empiricism (described in Chapter 4) as an invaluable learning method. Many of these advances could not have occurred without assistance and encouragement (or at least tacit permission) from military leaders, but many appear to have come in fact from rather informal, entrepreneurial, emergent bottom-up activities by people at various levels of seniority and without official guidance or direction. In effect, with respect to improvement in military trauma care, deep commitment from individuals has substituted in some ways for formal programs, systems, and command structures. This bottom-up change is an integral component of a learning system.

At the same time, a result of this process for change is that structures and offices that have emerged report to entities that may not have the ability to effect change, and they appear to have a somewhat ambiguous status and uncertain longevity within DoD's Military Health System. The JTS, for example, has produced measureable success in advancing trauma care and saving lives on the battlefield over the past decade, yet despite this success, its influence, its scope, and even its very existence are threatened at present, given its lack of doctrinal authority,[7] resources, and reporting structure (DHB, 2015; Rotondo et al., 2011). Although it was conceptually designed to serve as a consulting agency, the JTS's impact is limited largely to Central Command (CENTCOM) because DoD has neither formalized its role nor developed any requirements for it to take part in or help develop a DoD-wide trauma system. With the exception of the Pacific Command, which is working proactively with the JTS to establish a Joint Theater Trauma System, the efforts of the JTS to engage other combatant commands have received limited response (Gross, 2015). *Thus, the committee sees a paradox: creditable and necessary gains in trauma care during both wars in Afghanistan and Iraq, but weak or nonexistent formal joint structures to ensure that those gains are perpetuated (particularly during the interwar period), stable, and distributed uniformly across the combatant commands and services.*

In the absence of standardization of a formal trauma system across all combatant commands, the many lessons learned over the course of the wars in Afghanistan and Iraq and the improvements made in combat casualty care may be lost. Maintaining these advances and a state of readiness will require continuous investment and commitment from the highest levels of DoD leadership. Otherwise, capabilities and outcomes will remain the same or deteriorate, instead of improving (Hoyt, 2015a; Winchell et al., 2015). This capability gap could be addressed if the Joint Requirements Oversight Council utilized the Joint Capabilities Integration and Development System process (see CJCSI, 2015) and made an all-of-DoD approach to trauma care a priority.

Ambiguity in trauma care ownership and instability of the nascent

[7] Doctrine is the formal documentation of how military forces are to execute a specific military task. It establishes a framework for standardizing the conduct of operations and describes theory, history, practice, and lessons learned to ensure that operations across the military departments are consistent, repeatable, and reliable in their desired outcomes (DoD, 2016).

trauma system infrastructure are especially consequential with regard to an essential role of the Military Health System: readiness to deliver trauma care in support of the full range of military operations. Evidence of suboptimal trauma care and outcomes at the start of the wars in Afghanistan and Iraq—including a high rate of preventable battlefield deaths—testifies to gaps in trauma care readiness and a workforce inadequately trained to ensure that expert trauma care would be available for the very first (and last) casualty on the battlefield. As discussed in Chapter 5, it is not difficult to see why: the Military Health System lacks a sufficient volume of trauma cases to train and preserve expertise in a mission-ready trauma care workforce. Briefly put, line commanders assume Military Health System leaders will deliver providers expert in trauma care, while Military Health System leaders' priority is beneficiary care, and they have limited financial resources and personnel to develop programs that would create a robust cadre of multidisciplinary trauma experts.

This conundrum is pervasive across the military, yet no single agent or agency appears to be responsible for addressing this gap. Despite several recent evaluations (summarized in Table 7-1) recommending the establishment of a unified medical command or the designation of a senior medical leader, directorate, or division solely responsible for combat casualty care, DoD continues to lack a unifying lead agency with the authority, oversight, and resources to lead all aspects of combat casualty care and readiness (DHB, 2015; Mabry, 2015; Maldon et al., 2015; Rotondo et al., 2011). Responsibility for the training and delivery of combat casualty care remains widely distributed across the Assistant Secretary of Defense for Health Affairs, the Defense Health Agency, the services, and the combatant

TABLE 7-1 Recent Recommendations on the Need for a Single Point of Accountability Responsible for Combat Casualty Care and Military Medical Readiness

Key Findings	Recommendations
Rotondo et al., 2011 ***The United States Military Joint Trauma System Assessment***	
"The Joint Trauma System (JTS) has no authority to develop or set policy or standards for trauma care."	The JTS should be established as the statutory lead agency, authorized to set policy and enforce standards of care. It should be elevated within the U.S. Department of Defense (DoD) and given sustained support to be better aligned with its considerable responsibilities.

continued

TABLE 7-1 Continued

Key Findings	Recommendations
Kotwal et al., 2013 ***Saving Lives on the Battlefield***	
Best practices in prehospital military trauma care were implemented unevenly and sporadically, in part because of the lack of a "clearly responsible organization" and ownership of casualty care.	The JTS should be designated as the lead agency for trauma care.
Defense Health Board, 2015 ***Combat Trauma Lessons Learned from Military Operations of 2001–2013***	
"Despite vast improvements in the military trauma care system achieved over the past decade, no unifying agency has oversight over all aspects of the combat casualty care system." The Defense Health Board concurs with assessment of earlier reports regarding the need for a lead agency for the combat casualty care system.	A senior-level organization should be established as the lead agency. This agency should "continually assess the system's structure, function, resources, and outcomes," and be able to recommend policies that would standardize trauma care across DoD.
Maldon et al., 2015 ***Report of the Military Compensation and Retirement Modernization Commission***	
Advances in combat care have been unevenly implemented, and these advances are in danger of degrading during peacetime.	A Joint Readiness Command, led by a four-star general/flag officer, should be established and held responsible for the readiness of the military medical force and for the development of joint policies and requirements for medical care.
Butler et al., 2015 ***Implementing and Preserving the Advances in Combat Casualty Care from Iraq and Afghanistan Throughout the U.S. Military***	
"Divided and overlapping responsibilities and authorities create challenges to optimizing trauma care across an enterprise as large and complex as DoD."	"The JTS should be a permanent entity within the Military Health System. Responsibility for managing and overseeing the JTS should rest at a senior and joint position within the DoD. The JTS should be empowered and resourced to act as the DoD's lead organization for trauma care. The JTS should serve as a direct resource for the battlefield trauma care provider, senior military medical leaders, the military Services, and the Combatant Commands."

commands (see Box 7-5), with the consequence that no single organization or agency official "owns" or is accountable for DoD's medical readiness mission (Butler et al., 2015). With respect to the assurance of continuous practice improvement, learning, and readiness in battlefield trauma care, no one is in charge—a reality at odds with a military system known and revered for the integrity and quality of its command and control methods.

This diffusion of responsibility is especially poignant on the battlefield. While the surgeons general have oversight over policy within their respective services, final authority and responsibility for the delivery of combat casualty care—including control over budget, personnel, training, and equipment—is assigned to combatant commanders (Mabry, 2015). These line leaders are highly focused on mission (national defense) and lack medical expertise, while medical leaders are focused on maximizing fitness and health and optimizing ways to reduce health risks. Although combatant commanders are structurally tasked with delivering optimal health and trauma care, they lack the numbers of trained personnel needed to deliver expert trauma care at all levels across the battlefield. While medical risks are considered, mission needs appropriately take precedence over medical concerns (e.g., diversion of helicopters from operations for casualty evacuation). Thus there is an ongoing tension between the medical and combat missions that, in some cases, can be resolved only with commitment and a clear message from the highest level, as exemplified by Secretary Gates's Golden Hour Policy (see Box 7-6). The critical importance of direction originating from the Secretary of Defense has been recognized from within DoD itself—without it, "there is no assurance that advances in trauma care will be implemented consistently throughout the various components of the U.S. Military" (Butler et al., 2015, p. 323).

The consequences of the lack of ownership for combat casualty care include ineffective investment in trauma readiness and variation within and across combatant commands. Successful combat casualty care is a blend of both tactics and medicine, and it thus ideally would have the attention and support of combatant commanders (Kotwal et al., 2013). The successful history of the 75th Ranger Regiment, summarized previously, offers a compelling and informative counterexample of the unsurpassed outcomes that can emerge when the line commander takes full responsibility for the vitality and aims of a combat casualty care system: lives are saved. Equally compelling are the results when line leadership does not take this responsibility (see Box 7-7).

There have been efforts by some Military Health System leaders to change the current situation. However, structures and culture need to change if this deficit is to be addressed. Initially, greater clarity will be necessary to identify who in the military is responsible, in the final analysis, for the quality, learning processes, and readiness of military trauma care both in

Box 7-5
DIFFUSION OF MILITARY LEADERSHIP RESPONSIBILITY FOR THE DELIVERY OF COMBAT CASUALTY CARE

Assistant Secretary of Defense for Health Affairs (ASD(HA)): The ASD(HA) is responsible for the development, approval, and oversight of policy and serves as the principal advisor for health issues within the U.S. Department of Defense. As the Defense Health Program appropriation holder, the ASD(HA) is also responsible for administering the Military Health System (MHS) budget, including managing the resources that fund the service medical departments for peacetime health care delivery for eligible beneficiaries.

Defense Health Agency (DHA): The DHA is a recent addition to the organizational structure of the MHS. It is important to emphasize that the DHA is not a joint medical command; it is a combat support agency. As such, it has by definition responsibility for developing processes and frameworks for the joint implementation of such elements as research, training, and information systems. While designed to coordinate and facilitate joint programs, activities, and operations, the DHA at this time remains in an immature state of transition to full operational capability. As a result, the relationship to and understanding of DHA missions among military departments are still evolving. This ongoing evolution is reflected in the fact that the MHS is still in the process of transferring control of research and operations to the DHA from those agencies (often service-specific) that previously carried out and held control over these functions for years.

Service Surgeons General: The service surgeons general have authority over their respective medical commands and the responsibility to man, train, and equip those commands to meet mission requirements. While this role includes supporting and developing a combat-ready workforce, the surgeons general focus is primarily on managing the delivery of beneficiary care through their military treatment facilities. The surgeons general are held accountable for ensuring joint medical readiness but this does not include the delivery of an expert trauma care workforce to the combatant commanders.

Combatant Commanders: Combatant commanders are responsible for the operational direction and preparedness of all forces assigned to their geographic combatant command (e.g., Central Command [CENTCOM]) and the execution of any assigned missions. This authority extends to medical personnel; as a result, it is line leadership, not medical leadership, that maintains control over joint personnel, training, and equipment assigned to support the delivery of combat casualty care in theater (Roles 1-3).

Line Commanders: These nonmedical military general officers are responsible for direction and preparedness of all personnel assigned to accomplish specific military department missions. This responsibility includes control over the budget, personnel, training, and equipment assigned to support fulfillment of the mission in combat theaters (which includes medical personnel).

SOURCES: DHA, 2014; DHB, 2015; DoD, 2014; Mabry, 2015.

Box 7-6
359 LIVES: IMPACTS OF SECRETARY GATES'S GOLDEN HOUR POLICY

Under the current leadership structure of the U.S. Department of Defense, the Secretary of Defense represents the highest point in the chain of command with the authority to hold both service and combatant command leadership accountable for the standards of medical care provided and combat casualty care outcomes (Butler et al., 2015). In 2009, "with the premise that battlefield casualties would gain additional benefit from further reduced time between injury and care and a firm belief that 1 hour was a matter of morale and moral obligation to the troops," then Secretary of Defense Robert Gates issued a directive mandating the prehospital evacuation of critically injured combat casualties within 60 minutes or less (Gates, 2014; Kotwal et al., 2016, p. 16). This directive was implemented quickly throughout Afghanistan, with median transport times decreasing from 90 to 43 minutes after the mandate. The resulting increase in the percentage of casualties transported within the "golden hour" was associated with a reduction in the case fatality rate from 13.7 to 7.6. This reduction equates to 359 lives saved (Kotwal et al., 2016).

peacetime and during conflicts. As always, with that responsibility must come the relevant authorities and resources—when those are unlinked, the responsibility lacks relevance. Further, as exemplified by the 75th Ranger Regiment, the culture of accountability will have to shift such that there is widespread understanding and acceptance among medical and nonmedical leadership that line commanders have a primary role in and must be engaged in the readiness of their forces to deliver optimal combat casualty care.

Civilian Sector

Since 1966, civilian trauma systems have developed in many areas of the country to varying degrees of maturity, resulting in varying levels of outcomes. This variation is due largely to a lack of national leadership, policy guidance, standardization, coordination, and metrics and incentives tied to outcomes. As discussed in Chapter 2, no single federal entity is accountable for trauma care or trauma system development in the United States. Most trauma systems are regional, coordinated at the state level through respective department of health or EMS offices. Consequently, the role of local, state, and federal government in U.S. civilian trauma care systems is variable and inconsistent, leaving authority and accountability for trauma capabilities fragmented and varying from location to location. Government leadership at the state and federal levels is highly variable with respect to knowledge of the need for and the value and function of a trauma system. Other critical constituents, including academic health systems, the

Box 7-7 **CASE STUDY: TOURNIQUET USE AND THE LIFE-OR-DEATH DECISIONS OF MILITARY LINE LEADERSHIP**

Case 1

In a mid-2006 explosion, a male American soldier sustained traumatic injuries to both lower limbs. He immediately began experiencing severe blood loss, but no attempts were made to control bleeding at the point of injury or during air transport. The first attempt to stop his bleeding was at the combat support hospital in Baghdad, Iraq, by which time the soldier already lacked a pulse and was in hemorrhagic shock. He did not survive.

Case 2

In a separate mid-2006 explosion, another male American soldier sustained similar traumatic injuries to both lower limbs. A fellow soldier, who was not a medic, applied field tourniquets at the point of injury. Upon arrival at the combat support hospital, the soldier underwent surgery and survived.

Learning Context

The stark difference between life and death in the above two cases highlights the role of leadership in implementing tourniquet use. Treatment for both of these soldiers occurred well after the development of tactical combat casualty care (TCCC) guidelines, which recommended tourniquet use to control extremity hemorrhage, and after the Pentagon had moved to equip every American soldier with a tourniquet in 2005 (Kragh et al., 2013; Walters et al., 2005). The first soldier's death was preventable had tourniquets been applied in the field, but line leaders for that unit did not equip or train their soldiers in tourniquet use as part of a core readiness capability. In the second case, line leaders had noted the importance of hemorrhage control and trained and equipped every soldier—not just medics—to control bleeding with tourniquets. In the second case, the soldier survived traumatic amputation of both lower limbs because his fellow soldier (not a medic) had applied tourniquets early.

Lesson

Line leadership needs to make the delivery of combat casualty care a priority and be held accountable for ensuring that medical and nonmedical service members under their command are trained and equipped to execute TCCC guidelines. Similarly, medical officers in positions of responsibility (e.g., unit surgeons) need to have a deep knowledge of battlefield trauma care and utilize the guidance of the Joint Trauma System.

SOURCE: This box draws on the extremity hemorrhage case study in Appendix A, except where other citations are noted.

insurance industry, professional societies, and private industry, may have divergent values, contributing further to fragmentation. *The result of this patchwork of systems for trauma care is mortality that varies twofold between the best and worst trauma centers in the nation (Hashmi et al., 2013). Mechanisms for examining variability across entire trauma systems do not even exist.*

As in the military, the civilian trauma care sector appears to be ill equipped at present to set bold aims, as counseled by the IOM (2013) report *Best Care at Lower Cost* in its description of a learning health system. Advances do unquestionably occur, but it would be difficult under current circumstances to imagine anyone with the authority to declare, for example, that "zero preventable deaths after injury" ought to become a national goal. This represents a loss for the nation, since trauma deaths that could be averted with uniform best practices certainly number in the tens of thousands every year (Hashmi et al., 2016). Strong and capable civil society organizations[8] do what they can to improve the quality of trauma care, but none has the authority to require the pursuit of this improvement.

In principle, the gaps in civilian trauma care practice and learning highlighted throughout this report suggest that clearer and more cogent leadership is needed, supported by a framework that defines national aims and system designs and includes trauma care in health care delivery reform efforts. As noted, this leadership appointment needs to be accompanied by responsibility, funding, and authority. This need for leadership is exemplified at present by the proliferation of trauma centers in some geographic areas, driven by business opportunities rather than true regional needs (Johnson, 2015). In some areas, the number of Level I and II trauma centers exceeds the number needed to concentrate the patient volumes shown to correlate with improved trauma care quality and outcomes (ACS, 2015b; Eastman et al., 2013). Absent leadership in planning at the national, state, and regional levels, this costly and disruptive trend may proceed unabated, with unfavorable implications for public health, costs, and safety. To determine the future course of trauma care in the United States, the following question must be answered: Is the American public willing to accept that, after a severe injury, where one lives may determine whether one lives? If the nation's expectation is that variability in quality and outcomes based purely on geography is unacceptable, current systems for accountability need to be reexamined.

As in the military, the trauma care system in the civilian sector has witnessed a strong record of inaction or inadequate action in response to

[8] While not comprehensive, a list of trauma-related associations is noted on the National Trauma Institute website: http://www.nationaltraumainstitute.org/home/trauma_related_organizations.html (accessed May 23, 2016).

widespread calls for more national-level leadership. The National Highway Traffic Safety Administration's *Trauma System Agenda for the Future*, released in 2004, envisions a National Trauma System Leadership Council "to advocate for system development, serve as the locus for policy development and support, and coordinate the work of Federal agencies and professional organizations with injury-related programs" (NHTSA, 2004). However, no such council has been established. Likewise, the IOM's *Future of Emergency Care* series recommends that Congress establish a lead federal agency for trauma and emergency care[9] (inclusive of prehospital care) to be housed within HHS. The IOM Committee on the Future of Emergency Care in the United States deemed this lead federal agency necessary to

- serve as a federal advocate for trauma and emergency care, increasing its visibility within the government and among the public;
- move existing fragmented systems toward improved integration;
- provide unified and consistent federal leadership on policy development and funding;
- represent all providers and settings (to include the entire continuum of care); and
- create unified accountability for the performance of the trauma and emergency care system (IOM, 2007b).

Other individuals and organizations have called for the establishment of a federal home for emergency care within the federal government, but again, no such entity has emerged. While executive action did prompt the creation of the Emergency Care Coordination Center, this center is unfunded and thus extremely limited in its effect (Carr, 2015). Lacking authority and resources, by no means does this center approach the intent of the lead agency envisioned 10 years ago by the IOM Committee on the Future of Emergency Care in the United States. The present committee agrees with and supports previous assessments regarding the need for defined leadership for trauma and emergency care within HHS that serves to promote the integration of services across the continuum of care, from prehospital to rehabilitation and post-acute care.

[9] Civilian trauma care differs from military trauma care in that it is more fully part of a larger emergency response system that provides care for many other time-critical health problems (e.g., stroke and myocardial infarction). Although needs related to the larger civilian emergency care system are beyond the scope of this report, the committee acknowledges that the leadership structures that can help improve civilian trauma care are highly likely to have overall emergency care improvement in mind.

Military–Civilian Leadership Partnerships

From the viewpoint of the committee, given its charge, the one inescapable conclusion about the need for stronger trauma system leadership and accountability at the national level relates to the core trauma care readiness mission of the military. As discussed in Chapter 5, the Military Health System lacks sufficient volumes of trauma patients within MTFs to train and maintain a mission-ready trauma care workforce. Consequently, the military needs to work with the civilian sector to advance best trauma care practices through collaborative research initiatives (see Chapter 4). Through its research and deliberations for this study, the committee determined that the only feasible solution is to forge a significant and ambitious partnership between the military and civilian sectors such that the civilian sector can serve as a reservoir and innovative engine for trauma care knowledge and a training platform for the military trauma care workforce during the interwar period. In addition, the integration of military and civilian trauma care is necessary to ensure the full transfer of lessons learned between the two sectors and thereby improve civilian trauma care outcomes. This latter point is important, since (as discussed in Chapter 1) the burden of trauma in the civilian sector (approximately 148,000 deaths per year) numerically dwarfs the burden among military personnel (approximately 6,850 deaths over a decade of war); thus ensuring that the best conceivable civilian trauma care can avert tremendous morbidity and mortality.

The committee discovered a number of formal and informal pathways through which the military and civilian trauma care systems currently exchange ideas and knowledge (as discussed in Chapter 2). Instances of formalized leadership-level collaboration have emerged, for example, in the prehospital setting with the Federal Interagency Committee on EMS (FICEMS, 2013; IOM, 2007a) and, for trauma surgery, the Military Health System/ACS Strategic Partnership (Hoyt, 2015b). However, where successful collaboration has occurred, it has depended largely on the drive, good will, and personal investment of key individuals in leadership positions. As a result, the sustainability of collaborative efforts is threatened when changes in personnel take place (IOM, 2007b).

As yet, a durable collaborative effort encompassing the entire continuum of trauma care with representation of all stakeholders, military and civilian, does not exist. Consequently, diffusion of knowledge across sectors is slow and incomplete, care is not optimal, and lives are placed in jeopardy. As discussed in Chapter 4, for example, tourniquet use in civilian trauma care is growing, but its penetration is far from complete (Haider et al., 2015). The absence of such all-encompassing collaboration does not signal that this task is impossible and not worth attempting. Successful examples of the emergence of defined leadership and national collaboration on related aspects of trauma care (e.g., hemorrhage control) or on specific subsets of traumatic injury (e.g., traumatic brain injury) demonstrate that this type of collaboration is possible and impactful. The obstacle has not been the good will of individuals, but the institutional lack of will among leadership.

The enormous burden of trauma and the importance of an optimally functioning national trauma system to the nation's health and national security make the need for national leadership that cuts across both military and civilian sectors all the more pressing and relevant. National leadership would help unify and ensure collaboration among existing efforts and points of authority spread not just across federal agencies but among state and local governments and professional organizations as well. The success of the hemorrhage control and traumatic brain injury movements suggests strategies and mechanisms for encouraging effective collaborative action as well as national leadership on trauma care in its entirety (see Box 7-8 for an overview of these positive examples).

SUMMARY OF FINDINGS AND CONCLUSIONS

CONCLUSION: The absence of a comprehensive, standardized process by which the military and civilian sectors engage in system-level trauma care quality improvement impedes learning, continuous improvement, and the bidirectional translation of best practices and lessons learned.

Related findings:

- *In both the military and civilian sectors, performance transparency at the provider and system levels is lacking.*
- *Military participation in national trauma quality improvement collaboratives is minimal; only a single military hospital participates in an ACS TQIP benchmarking program.*

CONCLUSION: A national system-based and patient-centered approach to prehospital trauma care is needed in the civilian sector to incentivize improved care delivery, the rapid broad translation of military best practices, reduced provider and system variability, uniform data collection and performance improvement, and integration with hospital trauma systems so that comprehensive trauma care can be evaluated for quality performance. However, designation of emergency medical services as a supplier of transportation under the Social Security Act impedes the seamless integration of prehospital care into the trauma care continuum and its alignment with health care reform efforts.

Box 7-8

EXAMPLES OF SUCCESSFUL WHITE HOUSE–LED MILITARY–CIVILIAN COLLABORATION TO IMPROVE TRAUMA CARE

Trauma Response Capability for Mass Casualty Incidents

Following the 2012 mass shooting at Sandy Hook Elementary School in Newtown, Connecticut, the American College of Surgeons convened a joint committee to discuss and recommend how to improve the response to mass casualty incidents. The group, which included health care leaders and representatives from the federal government and the military, developed the "Hartford Consensus," a protocol for improving survivability from active shooter and intentional mass casualty incidents. The committee found that the injuries resulting from these types of incidents were similar to those encountered in combat settings, and recommended that the civilian sector adopt tactics used by the military, including guidelines for external hemorrhage control and the use of tactical emergency medical support for trauma management in a danger zone. The committee's first report established an algorithm for response known as THREAT (Threat suppression, Hemorrhage control, Rapid Extrication to safety, Assessment by medical providers, and Transport to definitive care) (ACS, 2015c).

Recognizing that the initial response to a mass casualty incident will be provided by bystanders, the committee urged that the public be trained in hemorrhage control methods (ACS, 2015c). A notable difference between the military and civilian sectors is the extent to which the military has invested in training nonmedical personnel so that they are able to provide buddy care or self-aid. It is important that this same emphasis and investment translate to the civilian sector, so that civilian bystanders are similarly prepared for and capable of delivering immediate lifesaving care. In response, the White House launched the "Stop the Bleed" campaign in October 2015 (White House, 2015). This campaign is intended to improve public awareness of how to stop severe bleeding (compress, tourniquet, compress again) and encourages bystanders to "be a hero and stop the bleed" (DHS, 2015; White House, 2015). The campaign is supported by over 40 partner organiza-

Related findings:

- *No process exists for benchmarking trauma system performance across the entire continuum of care within, across, and between the military and civilian sectors.*
- *The absence of standard, national quality metrics for trauma care and present reimbursement practices for civilian EMS (i.e., pay-for-transport) are major impediments to the integration of prehospital care into the trauma care continuum.*

CONCLUSION: Given current structures and diffusion of authority within DoD, the Military Health System and the line commands are not able to ensure and maintain trauma care readiness in peacetime, ensure

tions through such efforts as providing training to the public, distributing bleeding control kits, and promoting the initiative in materials and social media (DHS, 2016).

Service Member and Veteran's Mental Health

President Obama issued an executive order in August 2012 that directed the U.S. Department of Defense, the U.S. Department of Veterans Affairs, and the U.S. Department of Health and Human Services to strengthen mental health and substance abuse services for current military members and veterans. The result of this order has been action by each agency—including implementation of new initiatives, hiring of staff, and increased capacity—as well as the creation of an interagency task force (White House, 2012). The executive order also called for the development of a National Research Action Plan (NRAP), which was released in 2013 and identifies priority areas for research and describes the agencies' vision for collaborative work (DoD et al., 2013; White House, 2012). Specifically, the NRAP outlines immediate, short-term, and long-term actions to accelerate research on posttraumatic stress disorder (PTSD), traumatic brain injury (TBI), and suicide prevention as well as a comprehensive longitudinal study on mental health (DoD et al., 2013). In March 2014, progress on these issues was accelerated through the announcement of service members and veterans mental health as a Cross-Agency Priority goal, part of a White House program addressing a limited number of priority areas that require active collaboration among federal agencies. Progress under this goal has included the ongoing development and integration of common data elements for PTSD, TBI, and suicide prevention research to facilitate data sharing. To build on the agencies' work, President Obama announced 19 additional executive actions in August 2014, which included initiatives to improve access to care and to support research on PTSD and TBI (Performance.gov, 2015).

rapid transfer of best trauma care knowledge across DoD commands or between the military and civilian sectors, or ensure the availability of the infrastructure needed to support a learning trauma care system.

Related findings:

- *Promotion incentives for military medical personnel are misaligned; current promotion structures do not encourage or reward the growth of clinical trauma-focused expertise.*
- *Within the military leadership structure, there is no overarching authority responsible for ensuring medical readiness to deliver combat casualty care.*

CONCLUSION: The lack of formal, funded mechanisms for coordination, communication, and translation has led to inefficiency and variation across the civilian sector in clinical care practices, education and training, research efforts, and continuous performance improvement. Collectively, these deficiencies have contributed to suboptimal outcomes for injured patients in the United States and tens of thousands of preventable deaths after injury each year.

Related findings:

- *Authority and accountability for civilian trauma care capabilities are fragmented and vary from location to location, resulting in a patchwork of systems for trauma care in which mortality varies twofold between the best and worst trauma centers in the nation.*
- *There is no single federal entity accountable for trauma care or trauma system development in the United States.*

CONCLUSION: Despite the tremendous societal burden of trauma, the absence of a unified authority to encourage coordination, collaboration, and alignment across and within the military and civilian sectors has led to variation in practice, suboptimal outcomes for injured patients, and a lack of national attention and resources directed toward trauma care.

Related findings:

- *The lack of integration of military and civilian trauma care has impeded a highly functioning military trauma care system and the full transfer of lessons learned between the two sectors.*
- *Previous White House-led national initiatives have helped unify and ensure collaboration among existing efforts and points of authority spread across military and civilian federal agencies, state and local governments, and professional organizations.*

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Part III

Recommendations

8 A Vision for a National Trauma Care System

The committee was tasked with recommending how trauma care advances from the last decade of war in Afghanistan and Iraq can be sustained and built upon to ensure readiness for the military's next combat engagement, and how lessons learned by the military can be better translated to the civilian sector. In the course of this study, it became clear that these two objectives are inextricably linked and can best be achieved through a systematic and coordinated approach. This chapter presents the committee's recommendations for a national trauma care system that would simultaneously support a ready military trauma care capability and establish systematic processes for the transfer of knowledge between the military and civilian sectors.

THE NEED FOR COORDINATED MILITARY AND CIVILIAN TRAUMA CARE SYSTEMS

Trauma care in the military and civilian sectors is a portrait of contradiction—lethal contradiction. In the military setting, survival rates of service members injured in war over the past 50 years have improved dramatically and nearly continuously (Pruitt and Rasmussen, 2014). Much of this gain has come from new approaches to trauma care, both managerial and clinical. Important breakthroughs have included, for example, refinement of the tiered system of evacuation from the point of injury to definitive treatment in a major center, new approaches to fluid management, effective prehospital combat casualty care training and control of hemorrhage, iterative knowledge growth resulting from the communication and review procedures of the Joint Trauma System (JTS), deployment of sound clinical guidelines, and limited but effective use of clinical registries (Eastridge et al., 2006, 2009). Such improvements in military trauma care appear, in retrospect, to be due in large measure to the use of effective approaches to learning coupled with a bias toward rapid, but disciplined, cycles of inference and testing in the field, which the military terms "focused empiricism" (see Chapter 4) (Elster et al., 2013a,b).

Many of these cultural and systemic attributes of military trauma care mirror those of a learning health system as described within the Institute of Medicine (IOM, 2013) report *Best Care at Lower Cost*. In fact, the learning processes in the military preceded that report's articulation of a learning system by many years. However, the committee found that although many of the individual components of a learning system are in place, the full potential of such a system is not being realized in either the military or the civilian sector, and the contradiction between excellence and striking results in pockets of military and civilian trauma care on the one hand and gaps in consistency, clarity, and leadership on the other has deadly implications. Thousands or more lives could likely be saved over the course of future wars if military trauma care were improved (Eastridge et al., 2012). That potential gain soars into the tens of thousands of lives if similar improvements could be achieved in civilian trauma care (Hashmi et al., 2016), given that civilian trauma deaths numerically dwarf military combat deaths.

Gaps in the military and civilian trauma care systems include the following:

- Lessons learned by U.S. military personnel that improve the care and recovery of service members injured on the battlefield have been neither thoroughly nor adequately disseminated throughout the military, nor have they been translated reliably into civilian trauma care. The result has been many thousands of instances of preventable death and needless disability across the two sectors, along with excessive costs.
- Effective components of the military's learning trauma care system—most notably registries, research, and the JTS—lack sustained commitment and ongoing support, and therefore are degrading and could even disappear at any time.
- Experience shows that many of the hard-earned improvements in trauma care techniques and skills achieved during wartime are lost during the periods between wars. The result is needless mortality and morbidity during the "relearning" period in the early phases of new conflicts.
- In neither the military nor the civilian setting is documentation of

care across the trauma care continuum adequate, from the point of injury through rehabilitation, recovery, and reintegration. This gap compromises the care of individuals and impedes learning by caregivers in the pursuit of improved trauma care and outcomes.

- The continuum of care for service members may ultimately span the military and civilian (i.e., the U.S. Department of Veterans Affairs [VA]) sectors. Inadequate bidirectional sharing of trauma patient data (including long-term outcome data) between the Military Health System and the Veterans Health Administration care system compromises the care of individuals who transition between those systems (Maldon et al., 2015) and impedes learning and continuous improvement.
- Within the present military command structure, authority, responsibility, "ownership," and accountability for combat casualty care are fragmented and this fragmentation can seriously compromise care of the wounded. Key decision makers in the line of command lack the knowledge, skills, clarity of responsibility, and perspective to address problems in the trauma care system.
- Presently, most military trauma care teams are not ready to provide the highest-quality care to wounded service members. The existing training and deployment system is incapable of providing readiness for the best possible trauma care in future conflicts, and current levels of readiness are decreasing over time.
- Civilian capabilities to care for trauma patients, both on an everyday basis and during mass casualty incidents, are geographically uneven and largely inadequate. After a serious injury, disaster, or terrorist attack, where one lives may determine whether one lives.
- Current levels of investment in research to improve trauma care and rehabilitation are not commensurate with the societal burden of trauma. Although this has been known for decades, political and administrative barriers and the absence of effective advocacy groups perpetuate this unwise imbalance.

Without major corrective action to address these gaps on the part of numerous stakeholders, especially the highest levels of civilian and military leadership in the United States, tens of thousands of injured service members and civilians will lose lives and limbs that could have been saved. The committee takes as its beacon the accomplishments of the 75th Ranger Regiment, a U.S. Army Special Operations Force. Driven by the vision and action of its commanding officer, this regiment implemented a learning trauma care system that led to unprecedented results, driving the rate of preventable trauma deaths close to zero even under dangerous and austere conditions (Kotwal et al., 2011).

Improvements in all of the above deficiencies will require two significant changes: (1) an entirely new level of competent, committed leadership for trauma care in the military command structure, and (2) an unprecedented and redesigned collaboration between military and civilian trauma care providers and systems. This imperative resonates most strongly with respect to the key military mission of "readiness"—the requirement that the capabilities of military trauma care, including but not limited to the supply of expert clinicians and teams, be available to support combatant commands as needed, where needed, and when needed at all times. Combat readiness of military trauma care cannot be achieved within the current structures of training and workforce support.

Some significant improvements in military trauma care and learning can be achieved within the military sector alone, especially with more thorough engagement of combatant commanders similar to that exemplified by 75th Ranger Regiment, the standardization of best practices across all commands, and uniform data collection. However, it is neither feasible nor, in the face of the evidence, rational to attempt to address the deficiencies in military trauma care and learning more broadly without extending change efforts to encompass the civilian trauma system and the relationships between military and civilian trauma care in the areas of leadership, research, guidelines and standards, registry use, workforce training, and the regional roles of trauma centers. Military and civilian trauma care and learning will be optimized together, or not at all.

> ***Conclusion:*** *A national strategy and joint military and civilian approach for improving trauma care is lacking, placing lives unnecessarily at risk. A unified effort is needed to address this gap and ensure the delivery of optimal trauma care to save the lives of Americans injured within the United States and on the battlefield.*

A VISION FOR A NATIONAL TRAUMA CARE SYSTEM

Given the significant burden of traumatic injury, it is in the nation's best interest to implement a new collaborative paradigm between military and civilian trauma systems, thus ensuring that the lessons learned over the course of the wars in Afghanistan and Iraq are not lost. Though tenuous, there now exists a military trauma system built on a learning system framework and an organized civilian trauma system well positioned to assimilate the recent wartime trauma lessons learned and to serve as a repository and incubator for innovation in trauma care during interwar periods. Together, these developments provide opportunities to systematically integrate military and civilian efforts aimed at improving trauma care and eliminating preventable deaths after injury—whether the trauma occurs on the battlefield or within the United States. This integration would not only ensure trauma expertise within the military is sustained and improved, but also would galvanize continuous bidirectional learning. To that end, the committee believes a national strategy for trauma care—one that describes an integrated civilian and military approach—is needed to drive the coordination and continuous improvement of our nation's trauma care capability. The potential benefits are clear: the first casualties of the next war would experience better outcomes than the casualties of the last war, and all civilians would benefit from the hard-won lessons learned on the battlefield.

A national trauma care system would need to be grounded in sound learning health system principles (IOM, 2013) applied across the full continuum of care, from point of injury to definitive care, rehabilitation, and beyond. Success will require the development of a systems approach within and between the military and civilian sectors that synergizes the efforts of both and ensures the continuous bidirectional exchange of lessons learned, best practices, personnel, and data (see Figure 8-1). To achieve optimal integration, this approach must be informed by a complete evaluation of capabilities, education, system design, team qualities, gaps, and inhibitory factors in each domain. Properly linked—through shared aims, common standards, an integrated framework, clear lines of knowledge transfer, and shared points of accountability—the two systems would improve trauma outcomes and advance innovation through a unified effort. For maximum

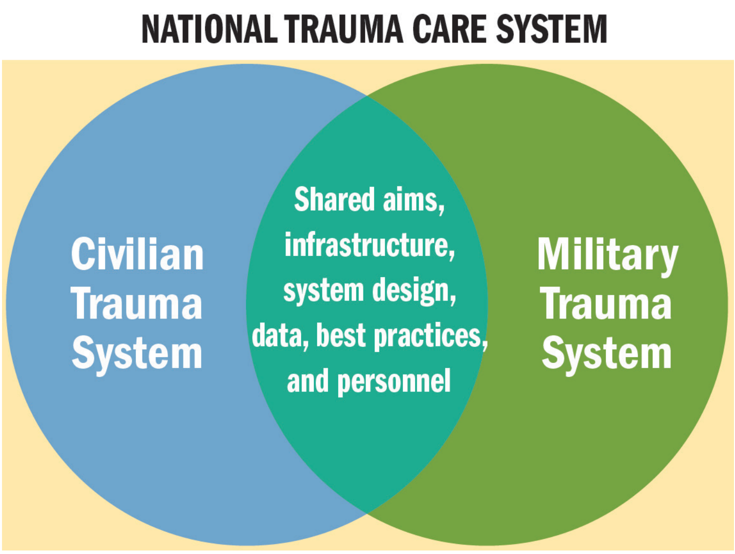

FIGURE 8-1 A conceptual model for a national trauma care system.

impact, such an effort would need to interface with national injury prevention efforts at the Centers for Disease Control and Prevention, national preparedness efforts, and the broad range of White House-led initiatives around service member and veterans mental health (see Box 7-8 in Chapter 7).

Importantly, this national approach is consistent with the nation's efforts to reform the health care delivery system and warrants inclusion as an explicit component of those efforts. Many of the challenges discussed in this report—such as fragmentation across the continuum of care and ensuring the delivery of quality care—are not specific to trauma. In addition, a trauma system both relies upon and participates in the overall health care delivery system, from prevention to acute care and rehabilitation; as such, it is important that the established national trauma care system is integrated with the larger delivery system. Standards, measures and incentives (e.g., those developed by the Centers for Medicare & Medicaid Services [CMS] and the Office of the National Coordinator for Health Information Technology [ONC]) currently applied to other fields of medicine also need to be applied to trauma care. With such integration, the improvements in trauma care delivery envisioned by the committee may also strengthen the health delivery system more generally. For example, integrating acute and long-term care systems will not only improve the transitions of care for trauma patients but may also create efficiencies and second-order effects (i.e., halo effect) for other emergent, time-sensitive conditions (Utter et al., 2006). Yet, trauma care is also distinct in that it extends beyond health care to interface with public health, public safety, and emergency management. Thus, a national approach to trauma care also further readies our civilian trauma and emergency response systems for disasters and other mass casualty incidents.

The benefits of a national trauma care system are myriad (see Box 8-1). Underpinning this proposed national system is the expectation that the military and civilian trauma systems would work seamlessly together toward optimal outcomes, which this committee defines as zero preventable deaths after injury and the pursuit of the best possible recovery for trauma survivors. Achieving this vision will require committed leadership from the military and civilian sectors and a joint framework for learning to advance trauma care.

THE ROLE OF LEADERSHIP

Neither high-functioning complex care systems nor active and agile learning systems can thrive without strong, dedicated, and continuous expert leadership. Good-hearted volunteerism is important but not enough. In Chapters 4-7, military and civilian trauma systems are examined through the lens of a learning health system. The discussion in those chapters reveals that although many of the components of a learning system are in place,

Box 8-1 THE BENEFITS OF A NATIONAL TRAUMA CARE SYSTEM

The creation of a national trauma care system as envisioned by the committee is a significant undertaking and warrants a clear understanding of the value of such an integrated approach over two systems (military and civilian) operating independently and in parallel. In considering the strategic, operational, and tactical implications of a national approach to trauma care, the committee identified the following benefits:

- **Communication:** A stronger model for military–civilian partnership through more effective and supported local, operational, and strategic partnerships and communication flow.
- **Best Practice Development:** Increased power to detect patterns and trends (positive and negative) from aggregate data and information and to use this information to inform efforts to address problems and spread best practices.
- **Research:** Establishment of a platform for large multi-institutional clinical trials, thus supporting focused empiricism when necessary. Improved shared data access and analysis for research and quality improvement activities.
- **Personnel:** Improved understanding of the mission, environment (operating environment and community trauma needs), and needed workforce characteristics to promote an interchangeable trauma care workforce that enables seamless flow of personnel between military and civilian sectors. New pathways for advanced degrees to promote career development populated by military and civilian students and integrated faculty. Joint military (all services) and civilian training environments and courses including consistent training techniques, tactics, and procedures.
- **Innovation:** Greater opportunity for innovation (through varied perspectives) and enhanced ability to identify such innovation occurring in pockets across the system, allowing localized advances to be captured, distilled, and widely distributed to improve services for both civilians and the military.
- **Economics:** Reduced redundancies at multiple levels and opportunities to reduce costs and achieve economies of scale by leveraging each system's resources more effectively, including more effective asset management and identification of shared gaps to target research funding.
- **Readiness:** Promote patriotism among civilian health care stakeholders as they engage with the Military Health System to ensure readiness through the development of shared services (trauma centers in the United States and abroad [e.g., Landstuhl Regional Medical Center] staffed by military and civilian personnel) and standard operating procedures where applicable.
- **Knowledge Dissemination:** Design, processes, and infrastructure harmonization for efficient spread of knowledge and innovation within and across sectors.
- **System Design:** The continuous shared ability to understand trauma system development, designs, reengineering, processes, workflows, deployment, organization, performance measures, roles, needed research, and capabilities for improved outcomes. Clearer and more consistent policies for treating trauma patients within and across sectors (prehospital, hospital-based, rehabilitation, and mental health care).

the full potential of such a system is not being realized in either sector. In many cases, shortfalls stem not from technical barriers but from a deficiency of leadership will.

National-Level Leadership

Currently, military trauma data, education and training, systems design, and performance improvement activities remain largely isolated from their civilian counterparts. Despite the interdependence of the civilian and military trauma care systems, no sufficient national effort exists to improve coordination and synergy between them. There is no common leadership structure with influence over policy in the military and civilian sectors, and leaders from the stakeholder federal agencies have inadequate incentives to work collaboratively toward a national approach to trauma care delivery. As a result, the United States lacks a unified, cohesive vision and comprehensive strategy and regulatory framework for ensuring the delivery of optimal care for injured patients.

> ***Conclusion:*** *Despite the tremendous societal burden of trauma, the absence of a unified authority to encourage coordination, collaboration, and alignment across and within the military and civilian sectors has led to variation in practice, suboptimal outcomes for injured patients, and a lack of national attention and resources directed toward trauma care.*

To eliminate the 20,000-30,000 preventable deaths after injury that occur annually in the United States (Hashmi et al., 2016; Kwon et al., 2014) and to ensure a national trauma response capability for all intentional and unintentional mass casualty incidents, high-level executive branch leadership will be needed in catalyzing processes for improving civilian trauma care and the exchange of trauma care knowledge between the military and civilian sectors. One key step would be for a presidentially authorized body or process to declare national aims for improving the processes and outcomes of trauma care, and then to support the convening, planning, and monitoring efforts necessary to achieve those aims.

> **Recommendation 1: The White House should set a national aim of achieving zero preventable deaths after injury and minimizing trauma-related disability.**

> **Recommendation 2: The White House should lead the integration of military and civilian trauma care to establish a national trauma care system. This initiative would include assigning a locus of accountability**

and responsibility that would ensure the development of common best practices, data standards, research, and workflow across the continuum of trauma care.

To achieve the national aim (Recommendation 1), the White House should take responsibility for

- creating a national trauma system comprising all characteristics of a learning organization as described by the IOM;
- convening federal agencies (including the U.S. Department of Health and Human Services, the U.S. Department of Transportation, the VA, the U.S. Department of Homeland Security, and the U.S. Department of Defense) and other governmental, academic, and private-sector stakeholders to agree on the aims, design, and governance of a national trauma care system capable of continuous learning and improvement;
- establishing accountability for the system;
- ensuring appropriate funding to develop and support the system;
- ensuring the development of a data-driven research agenda and its execution;
- ensuring the reduction of regulatory and legal barriers to system implementation and success;
- ensuring that the system is capable of responding domestically to any (intentional or unintentional) mass casualty incident; and
- strategically communicating the value of a national trauma care system.

Military Leadership

Military trauma care has made substantial advances, but the committee found that many of these advances have occurred not because of formal leadership, but despite the absence of clear leadership. The military has no unified medical command, no single senior military medical leader, directorate, or division solely responsible for combat casualty care. Combatant commanders responsible for the delivery of care on the battlefield rely on the services to provide a ready medical force, but lack a clear understanding of that process and its current deficiencies, as well as any mechanism for accountability. To carry out their responsibilities, it is necessary for military leadership to receive education and training on trauma system components and the importance of sustaining and improving the military trauma system.

Overall, DoD's existing trauma care system and resources (1) are not aligned with or accountable to a specific Defense Health Agency leader in support of the combat support agency mission, (2) lack consistency in training and practice across the services and combatant commands, and (3) fail to hold service and line leadership accountable for the standards of medical care provided and for combat casualty care outcomes. The result is a military trauma care system that functions largely independently from line understanding and without the stability, standardization, and resources that would allow it to deliver on the nation's promise to its men and women sent into combat: that the trauma care they receive will be the best in the world, regardless of when and where they are injured—in short, that preventable deaths after injury from combat and military service will be avoided, from the first to the last casualty.

> ***Conclusion:*** *Given current structures and diffusion of authority within DoD, the Military Health System and the line commands are not able to ensure and maintain trauma care readiness in peacetime, ensure rapid transfer of best trauma care knowledge across DoD commands or between the military and civilian sectors, or ensure the availability of the infrastructure needed to support a learning trauma care system.*

DoD could solve some of these leadership problems on its own initiative by clarifying doctrine and establishing stronger lines of responsibility and authority, especially between the line leadership and the Military Health System. This task appropriately would fall to the Secretary of Defense as the only executive in the chain of command with oversight over the Secretaries of the military departments, the combatant commanders, the Assistant Secretary of Defense for Health Affairs, and the Defense Health Agency. However, the major challenges to the readiness mission cannot be solved within DoD alone, but will require expanding existing relationships and developing new ones with civilian trauma systems at the national and regional levels.

> **Recommendation 3: The Secretary of Defense should ensure combatant commanders and the Defense Health Agency (DHA) Director are responsible and held accountable for the integrity and quality of the execution of the trauma care system in support of the aim of zero preventable deaths after injury and minimizing disability. To this end**
>
> - **The Secretary of Defense also should ensure the DHA Director has the responsibility and authority and is held accountable for defining the capabilities necessary to meet the requirements specified by the combatant commanders with regard to expert combat casualty care personnel and system support infrastructure.**
> - **The Secretary of Defense should hold the Secretaries of the military departments accountable for fully supporting DHA in that mission.**

- **The Secretary of Defense should direct the DHA Director to expand and stabilize long-term support for the Joint Trauma System so its functionality can be improved and utilized across all combatant commands, giving actors in the system access to timely evidence, data, educational opportunities, research, and performance improvement activities.**

To meet the needs of the combatant commanders, the accountable DHA leader should sustain and fund elements of a learning trauma care system that are performing well within DoD, and better align efforts that today are fragmented or insufficiently supported. Steps to take to these ends include

- developing policies to support and foster effective engagement in the national learning trauma care system;
- integrating existing elements of a learning system into a national trauma care system;
- maintaining and monitoring trauma care readiness for combat and, when needed, for domestic response to mass casualty incidents;
- continuously surveying, adopting, improving and, as needed, creating novel best trauma care practices, and ensuring their consistent implementation across combatant commands;
- supporting systems-based and patient-centered trauma care research;
- ensuring integration across DoD and, where appropriate, with the VA, for joint approaches to trauma care and development of a unified learning trauma care system;
- arranging for the development of performance metrics for trauma care, including metrics for variation in care, patient engagement/satisfaction, preventable deaths, morbidity, and mortality; and
- demonstrating the effectiveness of the learning trauma care system by each year diffusing across the entire system one or two deeply evidence-based interventions (such as tourniquets) known to improve the quality of trauma care.

As noted in a previous evaluation of the Joint Trauma System, through the JTS,

> America has demonstrated its commitment to provide state of the art care for wounded warriors and expects that the system will achieve optimal outcomes. Therefore, the JTS and all future Joint Theater Trauma Systems [JTTSs] must continue to be immediately responsive, adaptable, and fully capable of achieving this mission in all aspects of U.S. military combat, humanitarian, and other contingency operations. To accomplish this, a

> highly sophisticated enduring system must continue to be refined and supported during times of peace and of war. (Rotondo et al., 2011, p. 6)

Further institutionalization of the JTS is needed to ensure that the best practices, lessons learned, and systems proven successful in one combatant command (e.g., U.S. Central Command [CENTCOM] Joint Theater Trauma System) will be disseminated and applied at the system level across DoD, in any theater in which the military might be deployed and expected to deliver expert trauma care (see Figure 8-2). Beyond this needed standardization, there may be value in further expanding the mission of the JTS to include trauma system design and planning for future combat operations in different areas of operation (Ediger, 2016). During the interwar period, the JTS could function and hone its mission by reviewing and managing the thousands of nonbattle injuries that are seen every year within the Military Health System. This experience would enable the JTS to be ready when combat operations develop.

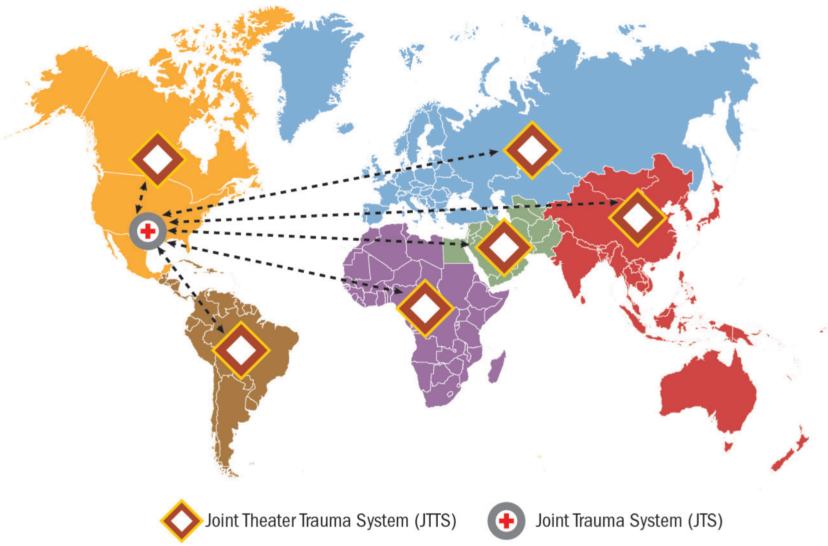

FIGURE 8-2 The Joint Trauma System as a central repository that disseminates information, lessons learned, and best practices to combatant command Joint Theater Trauma Systems, as needed.

NOTES: Different colored regions on the map represent individual geographic combatant commands. U.S. Central Command, for example, is colored green. Arrows between each JTTS and the JTS are double headed to indicate the importance of bidirectional information sharing. As best practices and lessons learned are identified within a JTTS, they should be shared with the JTS and from that central body disseminated as appropriate to all other JTTSs.

Civilian-Sector Leadership

As difficult as clarifying responsibility and authority for trauma care and readiness may be in the military, it is even more challenging in the civilian sector, where leadership has been left mainly to states, counties, and municipalities, with little federal oversight to ensure national goals or consistent practices. No single federal entity is accountable for the full continuum of trauma capabilities in the United States. At the federal and national level, coordinating bodies and processes are fragmented and severely underresourced for the magnitude of the task.

> ***Conclusion:*** *The lack of formal, funded mechanisms for coordination, communication, and translation has led to inefficiency and variation across the civilian sector in clinical care practices, education and training, research efforts, and continuous performance improvement. Collectively, these deficiencies have contributed to suboptimal outcomes for injured patients in the United States and tens of thousands of preventable deaths after injury each year.*

Efforts parallel to those recommended above for DoD are needed in the civilian sector, led by HHS. The committee recommends HHS as the lead actor based on its conviction that the improvement and optimization of civilian trauma systems spanning the continuum of care can be accomplished only if the entire system is organized within a framework of health care delivery. Trauma care is unquestionably linked to the arenas of public safety and emergency management, and DHS and DOT both are important stakeholders engaged in trauma and emergency care; however, their foci are too narrow to encompass trauma care in its entirety. As the agency responsible for the nation's public health and medical care, HHS can provide accountability and drive needed improvements in system-wide communication, data collection and sharing, and quality of care, but it is important for this to be accomplished through a coordinated effort that engages the other federal, private, and professional society stakeholders.

> **Recommendation 4: The Secretary of Health and Human Services (HHS) should designate and fully support a locus of responsibility and authority within HHS for leading a sustained effort to achieve the national aim of zero preventable deaths after injury and minimizing disability. This leadership role should include coordination with governmental (federal, state, and local), academic, and private-sector partners and should address care from the point of injury to rehabilitation and post-acute care.**

The designated locus of responsibility and authority within HHS should be empowered and held accountable for

- convening a consortium of federal (including HHS, DOT, the VA, DHS, and DoD) and other governmental, academic, and private-sector stakeholders, including trauma patient representatives (survivors and family members), to jointly define a framework for the recommended national trauma care system, including the designation of stakeholder roles and responsibilities, authorities, and accountabilities;
- developing a national approach to improving care for trauma patients, to include standards of care and competencies for prehospital and hospital-based care;
- ensuring that trauma care is included in health care delivery reform efforts;
- developing policies and incentives, defining and addressing gaps, resourcing solutions, and creating regulatory and information technology frameworks as necessary to support a national trauma care system of systems committed to continuous learning and improvement;
- developing and implementing guidelines for establishment of the appropriate number, level, and location of trauma care centers within a region based on the needs of the population;
- improving and maintaining trauma care readiness for any (intentional or unintentional) mass casualty incident, using associated readiness metrics;
- ensuring appropriate levels of systems-based and patient-centered trauma care research;
- developing trauma care outcome metrics, including metrics for variation in care, patient engagement/satisfaction, preventable deaths, morbidity, and mortality; and
- demonstrating the effectiveness of the learning trauma care system by each year diffusing across the entire system one or two deeply evidence-based interventions (such as tourniquets) known to improve the quality of trauma care.

Demonstrating System Effectiveness

The measure of a learning system's effectiveness is whether it is capable of supporting broad, rapid, meaningful change in practice. Accordingly, as directed in Recommendations 3 and 4, military and civilian stakeholders should commit to diffusing specific improvements in trauma care (e.g., broad availability of tourniquets or reliable application of a key trauma response protocol) every year throughout the system, and setting explicit, numeric aims for their adoption within aggressive time frames (e.g., within 6 months or 1 year). Diffusing straightforward, evidence-based practices—or attempting to do so—would test whether the learning trauma care system actually has value and impact, serve to highlight its deficiencies, and support its improvement. If successful, such efforts also could build confidence in the system among key actors (e.g., clinicians, medics) and increase its use. The absence of a process for ensuring that newly recommended technologies, techniques, and therapeutics reach combat casualty care providers in a reliable and timely way has been identified as a critical gap within DoD (Butler et al., 2015).

While significant improvements to the learning system for trauma care are required, a complete redesign of the entire system (with all the consensus building and resource mobilization entailed) will not be accomplished overnight. Yet the urgent need to avoid preventable deaths after injury demands concomitantly urgent action. It is by no means wise or necessary to wait for a full redesign of the system before taking action. Setting aims for the near term would be an efficient way to drive broad and needed improvement now. A beneficial by-product would be immediate continuous innovation in the learning system generated in pursuit of such aims.

AN INTEGRATED MILITARY–CIVILIAN FRAMEWORK FOR LEARNING TO ADVANCE TRAUMA CARE

As envisioned by the committee, a national trauma care system encompasses both military and civilian trauma care systems—thus representing a system of systems. Centralized management of such a system by a single entity would be impracticable. Instead, an integrated framework defining roles and responsibilities at the various tiers of a national trauma care system (see Figure 8-3) is needed to implement this vision and to promote continuous learning at all levels, while holding leaders accountable for the successful functioning of the system. As described in Recommendations 1 and 2, the White House would direct the vision and aims and, through the Office of Management and Budget, ensure appropriate funding for the national system. Under the oversight of the White House, designated entities from both military and civilian sectors, working collaboratively with their governmental, private, and academic partners, would define the requirements, standards, policies, and procedures that the integrated system would execute to coordinate and advance trauma care (see Recommendations 3 and 4). To address the current fragmentation within the trauma care delivery system within and across prehospital, hospital-based, and post-acute care (which reflects the fragmentation of the health delivery system at large), the focus of these stakeholders would include the following areas:

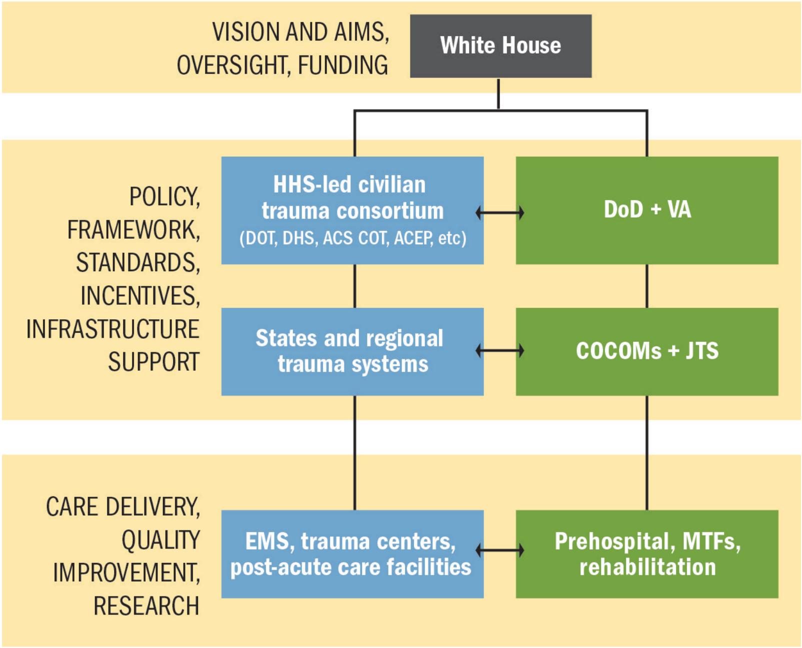

FIGURE 8-3 Tiered roles and responsibilities for military and civilian stakeholders in a national trauma care system implicit in Recommendations 1-4.

NOTES: Blue boxes represent the civilian sector; green boxes represent the military sector. ACEP = American College of Emergency Physicians; ACS COT = American College of Surgeons Committee on Trauma; CoCOM = combatant command; DHS = U.S. Department of Homeland Security; DoD = U.S. Department of Defense; DOT = U.S. Department of Transportation; EMS = emergency medical services; HHS = U.S Department of Health and Human Services; JTS = Joint Trauma System; MTF = military treatment facility; VA = U.S. Department of Veterans Affairs.

(1) capabilities, (2) education and training, (3) data collection, (4) performance improvement activities, (5) system-based and patient-centered research, (6) remediation of regulatory barriers, (7) resolution of financial challenges, (8) system design (e.g., infrastructure support), and (9) oversight. As depicted in Figure 8-3, the development of policies, standards, incentives, and support infrastructure would occur at multiple levels—both nationally and at the state/regional[1] (civilian) or combatant command

[1] Maryland's Trauma Center Network—TraumaNet (see Box 2-1)—represents an example of a multidisciplinary organizational structure enabling a state-level collaborative approach to addressing all facets of trauma care delivery including systems of care (e.g., interhospital protocols and patient transfer policies), data collection, quality improvement, education, and research. Such a structure supports coordination and collaboration across up- and downstream components of the care continuum, as well as peer learning, from the state system level down to the individual trauma team.

(military) level. The recommendations that follow detail actions that can be taken to implement a joint framework that facilitates continuous learning and enables stakeholders to act in a coordinated manner to achieve the vision of an integrated national trauma care system. Potential operational-level strategies for better integrating military and civilian trauma care are included Appendix C.

A Framework for Transparency of Trauma Data

Learning and improvement are difficult, if not impossible, without a continual supply of data and narrative information, including but not limited to real-time assessments of performance against goals; process-related information, such as conformance to standards and guidelines; scientific studies and meta-analyses; and narratives from the actual field of practice. Learning systems are avid for such information, digest it rapidly, and maintain memory over time so that information accumulates and lessons are retained. Such an information environment has strong cultural characteristics as well, nurturing curiosity, disclosure, trust, and shared learning and always attending to minimizing fear. The emphasis is on data use for learning, not judgment. In a learning trauma care system, this bias toward information and data in the service of learning would take several forms, including robust and continuous registry-driven analyses, systems for communication and exchange of ideas, access to scientific insights, and total workforce engagement.

In both the military and civilian sectors, however, patient data are fragmented across independent data systems and registries, limiting the extent to which patient care and systems of care can be evaluated and improved. Linkages are incomplete or entirely missing among prehospital care, hospital-based acute care, rehabilitation/post-acute care, and medical examiner data. Such data, if collected at all, often reside in independent repositories. This design is suboptimal.

> ***Conclusion:*** *In the military and civilian sectors, the failure to collect, integrate, and share trauma data from the entire continuum of care limits the ability to analyze long-term patient outcomes and use that information to improve performance at the front lines of care. The collection and integration of data on the full spectrum of patient care and long-term outcomes using patient-centric, integrated registry systems need to be a priority in both sectors if the full potential of a learning trauma care system is to be realized, and if deaths from survivable injuries are to be reduced and functional outcomes maximized.*

Given the fragmentation of current data systems, both military and civilian trauma care would benefit from a national architecture and framework for the collection, integration, and sharing of trauma data spanning the full continuum of care across the military and civilian trauma systems to support the refinement of evidence-based trauma care practices. Such systems would enable well-validated measures of clinical processes and outcomes to be tracked and tied to performance. Interoperable, longitudinal registries could be used to track care processes and outcomes for many years, from the point of injury, including prehospital phases of care, to acute care; rehabilitation; and long-term physical, functional, and psychological outcomes. It would be important for this framework to provide experience in data collection, educating those responsible for capturing data across the trauma care continuum on the importance and value of doing so. A critical but often neglected source of data—particularly in civilian systems—is autopsy reports on trauma deaths, which could be used to determine the preventability of fatalities based on a common, accepted lexicon.

Recommendation 5: The Secretary of Health and Human Services and the Secretary of Defense, together with their governmental, private, and academic partners, should work jointly to ensure that military and civilian trauma systems collect and share common data spanning the entire continuum of care. Within that integrated data network, measures related to prevention, mortality, disability, mental health, patient experience, and other intermediate and final clinical and cost outcomes should be made readily accessible and useful to all relevant providers and agencies.

To implement this recommendation, the following specific actions should be taken:

- Congress and the White House should hold DoD and the VA accountable for enabling the linking of patient data stored in their respective systems, providing a full longitudinal view of trauma care delivery and related outcomes for each patient.
- The Office of the National Coordinator for Health Information Technology should work to improve the integration of prehospital and in-hospital trauma care data into electronic health records for all patient populations, including children.
- The American College of Surgeons, the National Highway Traffic Safety Administration, and the National Association of State EMS Officials should work jointly to enable patient-level linkages across the National EMS Information System project's National EMS Database and the National Trauma Data Bank.
- Existing trauma registries should develop mechanisms for incorporating long-term outcomes (e.g., patient-centered functional outcomes, mortality data at 1 year, cost data).

- Efforts should be made to link existing rehabilitation data maintained by such systems as the Uniform Data System for Medical Rehabilitation to trauma registry data.
- HHS, DoD, and their professional society partners should jointly engage the National Quality Forum in the development of measures of the overall quality of trauma care. These measures should include those that reflect process, structure, outcomes, access, and patient experience across the continuum of trauma care, from the point of injury, to emergency and in-patient care, to rehabilitation. These measures should be used in trauma quality improvement programs, including the American College of Surgeons Trauma Quality Improvement Program (TQIP).

Processes and Tools for Disseminating Trauma Knowledge

Given the intermittent nature of war, the nation requires a platform that can be used by the military to sustain the readiness of its medical force and advance best practices in trauma care during interwar periods. Such a platform would require formal conduits for the continuous and seamless exchange of knowledge and innovation between the military and civilian sectors. This system would offer the added benefit of facilitating more timely transfer of military lessons learned and innovations to the civilian sector to help address the nation's tremendous burden of trauma.

Conduits for sharing knowledge can be synchronous or asynchronous.[2] Clinical guidelines represent a form of explicit knowledge that can be diffused and implemented within and across sectors. The establishment of guidelines alone is not sufficient to reduce variation in care; guidelines must be maintained, distributed, and socialized to facilitate their widespread adoption. Furthermore, providers need near-real-time feedback on their performance (e.g., compliance with or deviation from the guidelines and associated patient outcomes) relative to that of their peers. Currently, however, information systems are not optimally designed or used to give providers real-time access to their (individual or team) performance data for improvement purposes.

Given the unique pragmatic considerations that inform guidelines for combat casualty care (e.g., disrupted care, care delivered over several health care facilities, time and distance), military and civilian guideline develop-

[2] Synchronous learning occurs in real time through mechanisms that give the teacher and the learner simultaneous access to one another (e.g., one-to-one coaching sessions via telephone, classroom teaching), whereas asynchronous methods of learning allow learners to access information whenever they would like, not requiring the presence of an instructor (e.g., websites, guidelines).

ment processes need to remain separate efforts. By ensuring formal and robust processes for the exchange of information and ideas, however, DoD could support a national approach to the development of trauma care guidelines that would embrace the continuous learning process, enabling guidelines to be updated in real time in response to new evidence, facilitating continuous quality improvement, helping to inform policy, and saving lives.

Whereas explicit knowledge in the form of clinical guidelines can create familiarity with a concept, tacit knowledge comes from mastery through repetition. Relative to explicit knowledge, less attention typically is given to building conduits for the sharing of tacit knowledge—the kind of practical know-how that comes from experience at the front lines of care delivery and is much less easily codified. Yet timely access to this kind of knowledge is critical so that care providers can ask detailed, context-specific questions of those who have gained mastery in the process of doing their work instead of having to look the information up later. This access to "just-in-time" knowledge with a direct bearing on current challenges is extremely valuable, helping to reduce suffering and save lives. Telemedicine in particular has significantly advanced opportunities to disseminate best practices by ensuring real-time access to trauma experts.

Conclusion: *The provision of tacit knowledge improves practice to reduce variation in patient care and outcomes. Yet participation in and support for resourcing of the processes and technologies that provide this knowledge remain limited in both the military and civilian sectors.*

Conclusion: *The military uses a flexible and agile approach to guideline development distinct from that used in the civilian sector. This pragmatic, focused empiricism approach enables rapid guideline development using best available data. However, the safety and effectiveness of care practices based on low-quality evidence need to be validated in due time through higher-quality studies carried out in conjunction with the civilian sector. Additionally, more formal processes are needed to encourage joint military–civilian discussion of guidelines so as to enhance bidirectional translation of knowledge and innovation between the two sectors.*

Recommendation 6: To support the development, continuous refinement, and dissemination of best practices, the designated leaders of the recommended national trauma care system should establish processes for real-time access to patient-level data from across the continuum of care and just-in-time access to high-quality knowledge for trauma care teams and those who support them.

The following specific actions should be taken to implement this recommendation:

- DoD and HHS should prioritize the development and support of programs that provide health service support and trauma care teams with ready access to practical, expert knowledge (i.e., tacit knowledge) on best trauma care practices, benchmarking effective programs from within and outside of the medical field and applying multiple educational approaches and technologies (e.g., telemedicine).
- Military and civilian trauma management information systems should be designed, first and foremost, for the purpose of improving the real-time front-line delivery of care. These systems should follow the principles of bottom-up design, built around key clinical processes and supporting actors at all levels through clinical transparency, performance tracking, and systematic improvement within a learning trauma care system. Therefore, the greater trauma community, with representation from all clinical and allied disciplines, as well as electronic medical record and trauma registry vendors, should, through a consensus process, lead the development of a bottom-up data system design around focused processes for trauma care.
- HHS and DoD should work jointly to ensure the development, review, curation, maintenance, and validation of evidence-based guidelines for prehospital, hospital, and rehabilitation trauma care through existing processes and professional organizations.
- Military and civilian trauma system leaders should employ a multipronged approach to ensure the adoption of guidelines and best practices by trauma care providers. This approach should encompass clinical decision support tools, performance improvement programs, mandatory predeployment training, and continuing education. Information from guidelines should be included in national certification testing at all levels (e.g., administrators, physicians, nurses, physician assistants, technicians, emergency medical services).

One example of a program that could be institutionalized and expanded to facilitate the transfer of tacit knowledge as suggested in Recommendation 6 is the Senior Visiting Surgeon Program. The expansion of this best practice beyond surgeons to include other critical members of the trauma team (e.g., emergency medicine physicians, nurses, medics, technicians) presents opportunities for developing stronger links between military and civilian sectors across all disciplines, facilitating deeper integration in the context of a national trauma care system.

A Collaborative Military–Civilian Research Infrastructure in a Supportive Regulatory Environment

Unlike other fields (e.g., infectious disease) challenged by emerging threats, trauma is, in many ways, highly predictable. For example, it has been recognized for decades that hemorrhage is the leading cause of preventable death on the battlefield (Bellamy, 1984; Lindsey, 1957). Great progress has been made over the last 15 years in the development of innovative devices, therapeutics, and knowledge that can improve the delivery of trauma care (DHB, 2015). However, many remaining gaps need to be addressed before the next major conflict so that lives will not continue to be lost as a result of the same preventable and foreseeable causes. As stated by Dr. Luciana Borio, the U.S. Food and Drug Administration's (FDA's) acting chief scientist,

> The time to contemplate the research portfolio for hemorrhage for the DoD is not right before deployment. It's going to be the number one or two or three problem for the DoD in the warfighter, and the warfighter being the most precious resource for DoD, I think we need to really put a lot of energy into making sure we have a robust national portfolio to deal with the problem with hemorrhage. (Borio, 2015)

DoD and its civilian partners also need to be preparing for new challenges that different kinds of warfare may bring in the future. Extremity trauma and head injury due to blast injuries, for example, were encountered far more frequently during Operation Enduring Freedom and Operation Iraqi Freedom than in past wars, and have generated an increased need for research on rehabilitative care.

The sense of urgency to develop solutions to address preventable death and disability after injury needs to be sustained through the interwar period. "Even in austere times, the military remains uniquely obligated to maintain its commitment to trauma research as a matter of national security" (Rasmussen and Baer, 2014, p. 221). Resolving remaining capability gaps will require a collaborative research infrastructure and research investment commensurate with the importance of the problem and the potential for improvement in trauma patient outcomes. Models for collaborative research, such as the Major Extremity Trauma Research Consortium (see Box 4-5), have the potential to yield lifesaving and life-changing advances for severely injured patients in both military and civilian settings but require sustained support. Current infrastructure and funding levels clearly fall far short of the mark, perpetuating fundamental knowledge gaps that impede the delivery of optimal trauma care.

Conclusion: *Investment in trauma research is not commensurate with the burden of traumatic injury. To address critical gaps in knowledge of* *optimal trauma care practices and delivery systems, the United States needs a coordinated trauma research program with defined objectives, a focus on high-priority needs, and adequate resourcing from both the military and civilian sectors.*

In 2012, President Obama issued an executive order directing federal agencies to create a National Research Action Plan (NRAP) on posttraumatic stress disorder (PTSD), other mental health conditions, and traumatic brain injury (TBI) (White House, 2012). This presidential directive, although an unfunded mandate, has been successful in drawing attention to the issue of TBI; generating additional research investment; and requiring government agencies to coordinate their efforts, both in the development of the NRAP (which was released in August 2013) and in future research efforts. The success of the NRAP effort demonstrates how executive action from the White House can draw attention to overlooked areas of research in the absence of a funded congressional mandate and could serve as a model for a broader all-of-trauma initiative aimed at inducing federal agencies to better coordinate their research efforts.

Recommendation 7: To strengthen trauma research and ensure that the resources available for this research are commensurate with the importance of injury and the potential for improvement in patient outcomes, the White House should issue an executive order mandating the establishment of a National Trauma Research Action Plan requiring a resourced, coordinated, joint approach to trauma care research across the U.S. Department of Defense, the U.S. Department of Health and Human Services (National Institutes of Health, Agency for Healthcare Research and Quality, Centers for Disease Control and Prevention, U.S. Food and Drug Administration, Patient-Centered Outcomes Research Institute), the U.S. Department of Transportation, the U.S. Department of Veterans Affairs, and others (academic institutions, professional societies, foundations).

This National Trauma Research Action Plan should build upon experience with the successful model of the NRAP and should

- direct the performance of a gap analysis in the military and civilian sectors that builds on previous analyses, looking at both treatment (clinical outcome studies) and systems research to identify gaps across the full continuum of care (prehospital and hospital-based care and rehabilitation) and considering needs specific to mass casualty incidents (e.g., natural disasters, terrorist attacks) and special patient populations (e.g., pediatric and geriatric patient populations);

- develop the appropriate requirements-driven and patient-centered research strategy and priorities for addressing the gaps with input from armed forces service members and civilian trauma patients;
- specify an integrated military–civilian strategy with short-, intermediate-, and long-term steps for ensuring that appropriate military and civilian resources are directed toward efforts to fill the identified gaps (particularly during interwar periods), designating federal and industry stakeholder responsibilities and milestones for implementing this strategy; and
- promote military–civilian research partnerships to ensure that knowledge is transferred to and from the military and that lessons learned from combat can be refined during interwar periods.

The execution of a National Trauma Research Action Plan would certainly require a significant infusion of trauma research funding. This funding should be based on a determination of need stemming from the gap analysis recommended above and a review of current investments.

The need for a robust national trauma research enterprise also creates demands on the regulatory environment, which needs to consciously foster learning and knowledge exchange, or at least not be inimical to them, even while protecting the interests of human subjects and addressing privacy concerns. A separate National Academies of Sciences, Engineering, and Medicine committee—the Committee on Federal Research Regulations and Reporting Requirements—was charged with broadly reviewing federal regulations and reporting requirements and developing a new framework for federal regulation of research institutions. That committee has released a two-part report, which recommends actions to improve the efficiency of federal regulations (NASEM, 2016). While not specifically charged with such a comprehensive evaluation of federal research regulations, many of the present committee's findings were congruent with theirs. As a result of the existing federal regulatory landscape—not just the regulations themselves but also their interpretations—military and civilian trauma systems share barriers to the effective functioning of a learning system. As a result, critical research and quality improvement activities are not being conducted.

Conclusion: *A learning trauma care system cannot function optimally in the current federal regulatory landscape. Federal regulations or their interpretations often present unnecessary barriers to quality improvement and research activities. Lack of understanding of relevant provisions of the Health Insurance Portability and Accountability Act has resulted in missed opportunities to share data across the continuum of care in both the military and civilian sectors.*

Recommendation 8: To accelerate progress toward the aim of zero preventable deaths after injury and minimizing disability, regulatory agencies should revise research regulations and reduce misinterpretation of the regulations through policy statements (i.e., guidance documents).

In the process of implementing this recommendation, the following issues are points to consider:

- Prior national committees and legislative efforts have recommended that Congress, in instances of minimal-risk research where requiring informed consent would make the research impracticable, amend the FDA's authority so as to allow the FDA to develop criteria for waiver or modification of the requirement of informed consent for minimal-risk research. The present committee supports these recommendations, which would address current impediments to the conduct of certain types of minimal-risk research in the trauma setting (e.g., diagnostic device results that would not be used to affect patient care).
- For nonexempt human subjects research that falls under either HHS or FDA human subjects protections as applicable, DoD should consider eliminating the need to also apply 10 U.S.C. § 980, "Limitation on Use of Humans as Experimental Subjects" to the research.
- HHS's Office for Civil Rights should consider providing guidance on the scope and applicability of the Health Insurance Portability and Accountability Act (HIPAA) with respect to trauma care and trauma research such that barriers to the use and disclosure (sharing) of protected health information across the spectrum of care (from the prehospital or field setting, to trauma centers and hospitals, to rehabilitation centers and long-term care facilities) will be minimized.
- The FDA, in consultation with DoD, should consider establishing an internal Military Use Panel, including clinicians with deployment experience and patient representative(s) (i.e., one or more injured soldiers), that can serve as an interagency communication and collaboration mechanism to facilitate more timely fielding of urgently needed medical therapeutic and diagnostic products for trauma care.
- In trauma settings in which there are unproven or inadequate therapeutic alternatives for life-threatening injuries, the FDA should explore the appropriate scientific and ethical balance between premarket and postmarket data collection such that potentially lifesaving products are made available more quickly (after sufficient

testing). At the same time, the FDA should consider developing innovative methods for addressing data gaps in the postmarket setting that adhere to regulatory and statutory constraints.

- Consistent with its approach to applications for rare diseases, the FDA should consider exercising flexibility in evidentiary standards for effectiveness within the constraints of applicable law when a large body of clinical evidence (albeit uncontrolled) supports a new indication for an FDA-approved product for the diagnosis or treatment of traumatic injury, and pragmatic, scientific, or ethical issues constrain the conduct of a randomized controlled trial (e.g., on the battlefield or in the prehospital setting).
- A learning trauma care system involves continuous learning through pragmatic methods (e.g., focused empiricism) and activities that have elements of both quality improvement and research. HHS, when considering revisions to the Common Rule, should consider whether the distinction it makes between quality improvement and research permits active use of these pragmatic methods within a continuous learning process. Whatever distinction is ultimately made by HHS, the committee believes that it needs to support a learning health system. Additionally, HHS, working with DoD, should consider providing detailed guidance for stakeholders on the distinctions between quality improvement and research, including discussion of appropriate governance and oversight specific to trauma care (e.g., the continuum of combat casualty care, and prehospital and mass casualty settings).

The FDA is an invaluable asset to DoD in ensuring that research aimed at developing knowledge that can improve care for service members is conducted in the most informative and valuable manner while minimizing risks to research subjects. To this end, the FDA's Emergency Preparedness and Medical Countermeasures Program within the Center for Devices and Radiological Health has made important efforts to promote greater cooperation and efficiency in its interactions with the military through early-stage discussions on medical device development projects (Kumar and Schwartz, 2015). This new paradigm featuring a more collaborative approach to the FDA's regulatory process can serve as a model for the broader partnership envisioned by the committee for the proposed Military Use Panel. This panel would have multiple purposes:

- Promotion of discussions early in the development of medical products that would include the FDA regulatory review division and other relevant FDA offices. The goal of these discussions would be identifying acceptable paths forward (e.g., scientific, regulatory, ethical, contextual) for clinical research on medical therapeutic products for battlefield trauma care. Given the urgency of the need, this interagency and cross-agency collaboration should be designed to be as efficient and seamless as possible such that lifesaving products will be accessible as quickly as possible.

- Translation of scientific, regulatory, ethical, and policy lessons learned from trauma research in the military context to the civilian context such that the design of trauma-related research and product development will benefit from deliberations and considerations in the military sector.
- Provision of the specific military context and considerations to the FDA to inform discussions of the expansion of FDA-labeled indications to include approval for a military indication (not to be conflated with military use only). Matters to be deliberated would include but not be limited to evidentiary standards compliant with FDA statutory limitations, the feasibility and ethics of conducting controlled research within the combat setting, pragmatic clinical trials versus traditional clinical trials, and alternative research designs or empiric data gathering mechanisms acceptable to the FDA when controlled clinical trials are impracticable or unethical.
- In combination with the FDA regulatory review division and other relevant FDA offices, evaluation of products that have been approved for use by NATO allies and have applications for the U.S. military to determine whether the extant associated empiric evidence would support FDA approval for the use under consideration (and if not, what additional evidence would be needed for approval and how clinical trials could be designed and conducted).

It should be emphasized that the committee does not intend that this panel would be used to work toward military-use-only indications for therapeutic and diagnostic devices. The committee sees a number of problems with military-specific approvals. For example, limiting the use of a drug, device, or biologic to the military prevents the civilian sector from benefiting from that intervention. In addition, these indications create a restricted market for manufacturers and limit military use to the deployed setting, preventing the military from training in and using the products in the United States. Rather, the intent in recommending the establishment of such a panel is to create an ongoing forum for discussion that would cut across the various centers and offices of the FDA so that discussions between the military and the FDA would not occur solely on a product-by-product basis.

Systems and Incentives for Improving Transparency and Trauma Care Quality

Elements that promote the adoption of innovations and best practices include a leadership-instilled culture of learning and improvement, incentives, and mechanisms for identifying potentially beneficial practices from other organizations and sectors (IOM, 2013). Each is critical to a national system for trauma care that would ensure the diffusion of best practices within and across the military and civilian sectors.

Reporting on performance data and practice variation can drive the adoption of evidence-based trauma care practices by providing a mechanism for comparison across centers and systems and identifying practices and design elements associated with superior performance. Although the American College of Surgeons Trauma Quality Improvement Program (TQIP) enables comparison across trauma centers, no mechanism currently exists to enable comparison across systems for prehospital care or regional trauma systems as a whole.

Conclusion: *The absence of a comprehensive, standardized process by which the military and civilian sectors engage in system-level trauma care quality improvement impedes learning, continuous improvement, and the bidirectional translation of best practices and lessons learned.*

Recommendation 9: All military and civilian trauma systems should participate in a structured trauma quality improvement process.

The following steps should be taken to enable learning and improvement in trauma care within and across systems:

- The Secretary of HHS, the Secretary of Defense, and the Secretary of the VA, along with their private-sector and professional society partners, should apply appropriate incentives to ensure that all military and civilian trauma centers and VA hospitals participate in a risk-adjusted, evidence-based quality improvement program (e.g., ACS TQIP, Vizient).
- To address the full continuum of trauma care, the American College of Surgeons should expand TQIP to encompass measures from point-of-injury/prehospital care through long-term outcomes, for its adult as well as pediatric programs.
- The Center for Medicare & Medicaid Innovation should pilot, fund, and evaluate regional, system-level models of trauma care delivery from point of injury through rehabilitation.

Widespread participation in a structured trauma quality improvement process, spanning the continuum of care,[3] would support horizontal learning (i.e., among peers) and vertical learning (i.e., from upstream and downstream collaborators). Center for Medicare and Medicaid Innovation pilots would help identify and diffuse best practices in trauma system design and care delivery that are contributing to superior outcomes at high-performing trauma systems. One group has estimated that the lives of nearly 100,000 Americans could be saved over a 5-year period if all trauma centers achieved outcomes similar to those at the highest-performing centers (Hashmi et al., 2016). The potential to save lives may be even greater if similar improvements could be made at the system level, inclusive of prehospital and post-acute care.

Learning from the military experience, the greatest opportunity to save lives is in the prehospital setting and the integration of prehospital care into the broader trauma care system is needed to ensure the delivery of optimal trauma care across the health care continuum, best understand the impact of trauma care, and recognize and address gaps and requirements to prevent deaths after injury. Because emergency medical services (EMS) is not currently a provider type designated under the Social Security Act, HHS does not link the emergent medical care delivered out of hospital to value-based payment or other current health care reform efforts. As a result, EMS continues to be a patchwork of systems across the nation with differing standards of care, few universal protocols, and perverse payment standards, yielding inconstant quality of care and variable patient outcomes. Such a system is not optimally designed to serve as a training platform for the military during interwar periods. Recognizing that a centralized model of prehospital care delivery is impracticable, national leadership is needed to define the requirements, standards, incentives, policies, and procedures that will ensure the adoption of best practices and the integration of prehospital care as a seamless component of the trauma care delivery system (see Figure 8-3). Without universal integration and structured governance, prehospital care will not become a truly functional part of the effort to prevent deaths and limit disability.

> ***Conclusion:*** *A national system-based and patient-centered approach to prehospital trauma care is needed in the civilian sector to incentivize improved care delivery, the rapid broad translation of military best practices, reduced provider and system variability, uniform data collection and performance improvement, and integration with hospital*

[3] As the VA is a major provider of rehabilitative care for veteran service members who sustained injuries during combat operations, it is important for VA hospitals to participate in trauma system quality improvement processes.

trauma systems so that comprehensive trauma care can be evaluated for quality performance. However, designation of emergency medical services as a supplier of transportation under the Social Security Act impedes the seamless integration of prehospital care into the trauma care continuum and its alignment with health care reform efforts.

Recommendation 10: Congress, in consultation with the U.S. Department of Health and Human Services, should identify, evaluate, and implement mechanisms that ensure the inclusion of prehospital care (e.g., emergency medical services) as a seamless component of health care delivery rather than merely a transport mechanism.

Possible mechanisms that might be considered in this process include, but are not limited to:

- Amendment of the Social Security Act such that emergency medical services is identified as a provider type, enabling the establishment of conditions of participation and health and safety standards.
- Modification of CMS's ambulance fee schedule to better link the quality of prehospital care to reimbursement and health care delivery reform efforts.
- Establishing responsibility, authority, and resources within HHS to ensure that prehospital care is an integral component of health care delivery, not merely a provider of patient transport. The existing Emergency Care Coordination Center could be leveraged as a locus of responsibility and authority (see Recommendation 4) but would need to be appropriately resourced and better positioned within an operational division of HHS to ensure alignment of trauma and emergency care with health delivery improvement and reform efforts.
- Supporting and appropriately resourcing an EMS needs assessment to determine the necessary EMS workforce size, location, competencies, training, and equipping needed for optimal prehospital medical care.

The changes necessary to integrate prehospital care as a seamless component of health care, including those mechanisms suggested above, would have vast implications that warrant thorough reflection. The application of existing certification standards to EMS agencies, for example, would need to be considered when amending the Social Security Act, a complex piece of legislation. Recognizing the complexities of the proposed actions, the committee strongly believes the inclusion of prehospital care within health care reform efforts through implementation of this recommendation is critical to the development of a patient-centered, comprehensive approach to the delivery of trauma care across the nation. Under the proposed consideration for change in legislation, minimum health and safety standards would be established, including the need for medical oversight, a data collection mechanism linked to hospital based care, a performance improvement system, and a patient safety program. Additionally, modifying the Social Security Act to define EMS as a provider type could prompt CMS to develop a trauma or emergency care-based shared savings model with relevant metrics that could be used to measure the value of prehospital care delivered, including patient outcomes and the appropriateness of the facilities receiving patients.

Although a national EMS assessment was released in 2011 that described the present state of EMS (FICEMS, 2011), what is needed now is a comprehensive assessment that articulates the needs of a population for EMS and how the nation should better position and deliver care in the prehospital environment.

Platforms to Create and Sustain an Expert Trauma Care Workforce

The readiness mission of the Military Health System requires that a network of military medical teams—comprising expert clinical providers (physicians, nurses, allied health professionals) and support professionals (administrators, managers, information technology personnel, data managers)—be readily available to deploy on short notice in support of military operations. The nation's service members deserve the same high standard of care and specialty care available at any Level I trauma center in the United States. To this end, military trauma teams need to train to an expert level. Yet most military teams sent to care for injured service members during Operation Enduring Freedom and Operation Iraqi Freedom would not have been allowed to care for trauma patients at a civilian Level I trauma center. The development of an expert trauma care workforce requires a significant investment of both time and resources, necessitating in some cases more than a decade of education and specialty medical training. This investment also must extend to include the education and training of senior line and medical leaders on trauma system concepts as well as the importance of sustaining and continuously improving the military trauma system.

When the next military conflict inevitably transpires, there will be little time to reconstruct an optimal combat casualty care capability from a diminished state of readiness. DoD cannot wait until the next war to begin the process of generating a ready medical force to meet its wartime needs. However, DoD alone cannot maintain the readiness of an expert military trauma care workforce that can deliver the volume and quality of trauma care needed to support service members on the battlefield. As discussed in Chapter 5, the main problem is that the Military Health System simply does not see the clinical volume of trauma cases during interwar periods necessary for trauma teams to acquire and maintain expertise in trauma care. No credible plan appears to be in place to address this problem, which virtually ensures that wounded combatants in a future war will, at least for a time, have worse outcomes than would have been achieved with full readiness. If the lessons from the past 15 years are not sustained and history repeats itself, the next war will see wounded military personnel lose lives and limbs that should have been saved.

> ***Conclusion:*** *To eliminate preventable mortality and morbidity at the start of and throughout future conflicts, comprehensive trauma training, education, and sustainment programs throughout DoD are needed for battlefield-critical physicians, nurses, medics, administrators, and other allied health professionals who comprise military trauma teams. This effort will ensure that a ready military medical force with expert combat casualty care skills is sustained throughout peacetime. A single military leader (general officer) needs to be accountable for generating and sustaining this education and training platform across the Military Health System to deliver trauma experts to the battlefield. In addition, line and medical leaders need to be held accountable for the results delivered by their trauma teams on the battlefield.*

The best clinical outcomes come from high-functioning trauma teams with substantial administrative commitment, experienced in all elements of trauma care, that care for trauma patients on a daily basis, and in which all team members (physicians, nurses, medics, technicians, and administrators) know what their responsibilities are. Much as military line leadership trains constantly for combat, military trauma teams need to care for trauma patients repeatedly, on a daily basis. Enabling all providers, administrators, and leaders within the Military Health System to have experience with trauma care on a daily basis would ensure the highest-quality care for combat casualties.

An expert military trauma workforce needs to be developed and sustained to achieve trauma care capabilities defined by DoD—specifically, the Joint Capabilities Integration and Development System—as necessary to the success of its wartime mission. Meeting this need will require trauma-specific career paths with defined standards for competency and increased integration of the Military Health System and civilian trauma systems.

> **Recommendation 11: To ensure readiness and to save lives through the delivery of optimal combat casualty care, the Secretary of Defense should direct the development of career paths for trauma care (e.g., foster leadership development, create joint clinical and senior leader-**

ship positions, remove any relevant career barriers, and attract and retain a cadre of military trauma experts with financial incentives for trauma-relevant specialties). Furthermore, the Secretary of Defense should direct the Military Health System to pursue the development of integrated, permanent joint civilian and military trauma system training platforms to create and sustain an expert trauma workforce.

Specifically, within 1 year, the Secretary of Defense should direct the following actions:

- Ensure the verification of a subset of military treatment facilities (MTFs) by the American College of Surgeons as Level I, II, or III trauma centers where permanently assigned military medical personnel deliver trauma care and accumulate relevant administrative experience every day, achieving expert-level performance. The results of a needs assessment should inform the selection of these military treatment facilities, and these new centers should participate fully in the existing civilian trauma system and in the American College of Surgeons' TQIP and National Trauma Data Bank.
- Establish and direct permanent manpower allocations for the assignment of military trauma teams representing the full spectrum of providers of prehospital, hospital, and rehabilitation-based care to civilian trauma centers. Provision should be made for these teams to obtain experience in prehospital care, burn care, pediatric trauma, emergency general surgery, and other aspects of trauma care across the system.
- Identify the optimum placement of these teams based on criteria determined by the DHA including but not limited to volume, severity, diversity, and quality-of-care outcomes of trauma patients at the civilian trauma centers, as well as the required number of teams as determined by a comprehensive DoD assessment.
- Develop and sustain a research portfolio focused on optimizing mechanisms by which all (active duty, Reserve, and National Guard) military medical personnel acquire and sustain expert-level performance in combat casualty care, to include research on evolving training modalities and technologies (e.g., simulation, telemedicine).
- Hold the DHA accountable for standardizing the curricula, skill sets, and competencies for all physicians, nurses, and allied health professionals (e.g., medics, technicians, administrators). The development of these curricula, skill sets, and competencies should be informed by data from the DoD Trauma Registry and DoD-

developed clinical practice guidelines (including tactical combat casualty care and JTS guidelines); best civilian trauma care practices, outcomes, and data; and professional organizations representing the full spectrum of the military trauma care workforce. The JTS should validate these curricula, skill sets, and competencies.

The committee notes that the development of trauma-related career pathways will necessitate the establishment of trauma-specific skills identifiers for all provider types where those identifiers do not already exist (e.g., trauma nurse coordinators).

Implications for Military Treatment Facilities

There are currently only three ACS-verified military trauma centers (Levels I through III), and only a single military hospital participates in TQIP (Haut et al., 2016). To provide additional trauma training opportunities for the military medical force, several additional MTFs could become Level I or II trauma centers, and many more could easily become Level III centers. To achieve adequate trauma patient volumes, military trauma centers need to participate fully in the existing civilian trauma system, caring for and transferring both military and civilian patients as required by regional trauma policy.[4] The San Antonio Military Medical Center (see Box 2-4 in Chapter 2) should be used as a model for the integration of MTFs into the local civilian trauma system. The benefits of learning about and actively participating in existing regional trauma systems would be realized in fewer preventable deaths on the next battlefield.

To ensure that existing civilian trauma systems would not be threatened by dilution of a finite patient pool, the results of a needs assessment should inform the selection of MTFs for verification as trauma centers. Further, the selected MTFs should submit data to the American College of Surgeons' National Trauma Data Bank (NTDB) and participate in TQIP,[5] thereby ensuring the highest quality of care for all DoD trauma patients, as well as making military trauma data more available for registry-based research in the civilian sector, including cross-sector comparisons.

Designation of additional MTFs as trauma centers would have significant resource implications, particularly in terms of personnel. Currently, medical specialty allocations in the Military Health System are based on peacetime needs for beneficiary care (Mabry, 2015). The development

[4] This would include Walter Reed National Military Medical Center.

[5] Potential security concerns have previously been resolved within DoD; the DoD Trauma Registry is a nonclassified database, and some military treatment facilities already submit data to the National Trauma Data Bank.

of sufficient trauma personnel to staff additional military trauma centers would require either additional resources or diversion of resources currently used for beneficiary care. The resource requirements for medical readiness need to be a strong consideration as Congress and DoD continue discussions on TRICARE reform. Use of financial incentives to encourage the selection of combat-relevant specialties is another promising approach to meeting personnel needs.

Implications for Civilian Academic Medical Centers and Trauma Systems

Over the past decade, civilian trauma systems have grown stronger, and there currently exists a network of highly regarded civilian Level I trauma centers housed in America's best academic medical centers and teaching hospitals. Many of these centers have served as the training sites for military surgeons pursuing fellowships in surgical subspecialties and offer resident clinical rotations for military surgical and medical trainees. These Level I centers provide vibrant learning platforms whose further development into strong partnerships with the Military Health System would greatly advance military combat trauma training and education. The aims of such partnerships would be both to bolster trauma care capacity in those centers during peacetime and to ensure that the embedded trauma teams would be fully ready to function at an expert level at the time of future deployment. To overcome the current lack of standardized training requirements, a joint readiness program could be developed to replace current service-specific training centers, placing military trauma care teams in local civilian trauma centers. These joint training centers would have a uniform approach but could include modules for service-specific training. This joint program could consolidate and build on existing agreements developed to address cost sharing, billing, malpractice, deployment-related backfilling, research opportunities, and other considerations, and would ensure needed allocations of personnel for both beneficiary care and trauma care readiness. Such a new training and readiness system would require leadership at many levels: national leadership to craft and resource the system, professional leadership to design and improve the training processes, and organizational leadership in both the Military Health System and civilian trauma care to ensure joint planning and monitoring. This greater centralized coordination would help address the potential concern that the simultaneous mobilization of multiple providers for deployment might disrupt the trauma capability of a regional civilian trauma system in which they were practicing.

The selection of civilian centers to serve as joint trauma training sites would appropriately be informed by data on patient volumes from the NTDB and quality outcome criteria from TQIP. Notably, the opportunity exists for the DHA and DoD to provide a much-needed service by placing military surgeons and trauma care teams at safety net hospitals that provide Level I trauma center care to large and needy urban populations and meet volume requirements and quality standards. The busiest and best civilian trauma centers currently care for many thousands of unfunded patients, creating an extensive financial burden on the hospitals that treat them (IOM, 2007). Having additional trained military medical personnel would help relieve this burden. Other potential benefits to host trauma centers and the populations they serve include greater efficiency in the translation of wartime lessons learned and innovations in trauma care.

It should be emphasized, however, that the utility of civilian trauma centers as military training platforms is threatened by the financially driven expansion of Level I and II trauma centers[6] in certain geographic regions across the United States beyond levels required to meet the needs of the local population (Branas et al., 2005; Eastman et al., 2013; Johnson, 2015). This has the effect of diluting patient volume at individual centers, compromising the training mission of these centers for military teams as envisioned by the committee as well as civilian trainees (Simon et al., 2009). The American College of Surgeons has issued a strong position statement emphasizing the importance of strategically placing trauma centers based on need (ACS, 2015) and is currently developing a needs-based assessment tool that can be used by those regions struggling with this issue.[7] The nation will need to further address this threat if the network of civilian Level I trauma centers is to be successful in training future generations of military trauma care providers.

Implications for Prehospital Providers

The necessary trauma focus of military medics serves service members on the battlefield well, but during interwar periods, military medics may be assigned to nonmedical duties. To maintain their trauma care skills, military medics could be integrated into civilian EMS systems; to see the patient volumes and types of trauma necessary to maintain proficiency, they would likely need to work in busy, typically urban trauma systems. Integration of military medics into civilian EMS systems would also require that they have additional medical training. Relative to the patients seen in military settings, the diverse patient population seen by civilian EMS providers requires broader knowledge and expertise in such areas as cardiology, pediatrics, geriatrics, obstetrics, chronic disease, and polypharmacy.

[6] Those that provide definitive care for severely injured patients.

[7] A preliminary draft of this tool was released in September 2015 and is available at https://www.facs.org/quality-programs/trauma/tscp/nbats#nbatstool (accessed April 28, 2016).

Additional Benefits of a Military–Civilian Trauma Training Platform

The implementation of Recommendation 11 would prepare military trauma care teams to be ready to provide expert-level trauma care for the first casualties of the next war. The vibrant exchange of personnel, information, and experience across the military and civilian systems would ensure constant readiness in both environments. This more comprehensive military–civilian network would emerge as a continuously learning health system focused on the development of strong research endeavors aimed at advancing knowledge concerning the logistics of delivering quality care and optimizing outcomes for the severely injured for the United States and its allies. A number of other problems with the current system also would be addressed through implementation of Recommendation 11:

1. Military personnel who enjoy working with trauma patients would be empowered by this approach and could advance their careers while maintaining a trauma focus. Currently, many of these personnel have limited opportunities to advance.
2. Beyond the trauma care rendered by military trauma care teams, it is vitally important that senior military medical leaders (nursing, medical, and administrative), including the service surgeons general, become expert in the application of trauma system concepts so they can better ensure the delivery of high-quality trauma care, from prevention through all aspects of prehospital and hospital-based care and rehabilitation.
3. By focusing on a trauma system approach, all military medical personnel would become knowledgeable and many would become expert in trauma systems. Applying these concepts to the battlefield would become normal rather than novel.
4. Licensing of medics, nurses, and physicians for brief trauma rotations can be difficult. Permanently assigning military medical personnel to civilian trauma centers would remove this barrier.[8]
5. Brief "just-in-time" rotations usually mean that nurses and physicians can observe clinical care but not actually perform it. This is analogous to watching someone fire a weapon, rather than actually firing it oneself. Assigning military personnel to civilian centers for 2 to 3 years at a time would allow trust to be built so that the military providers could actually care for patients.

[8] Although typical permanent assignments are generally for 3-4 years (Mundell, 2010), longer assignments of military trauma personnel to civilian training centers have been proposed and should be considered, especially given the time required to address licensing issues (Eibner, 2008).

6. Upon the onset of the next conflict, the first teams to deploy would be those from the designated civilian trauma centers and the existing military trauma centers, ensuring that the first casualty on the battlefield would receive the highest-quality care. These teams could be reconstituted from the active duty or reserve force as needed, creating an extensive repository of expertise prepared for repeated deployments.
7. During interwar periods, the civilian trauma system is the repository of trauma knowledge, expertise, research, and advancement that could be freely exchanged by having military teams embedded at multiple civilian centers, thereby ensuring the highest-quality care at the onset of hostilities.
8. During wartime, the military leads in trauma innovation. Having trauma care teams deploy and return to multiple civilian centers would ensure the rapid exchange of those innovations, enriching and improving the civilian system.

CONCLUDING THOUGHTS

In studying the performance of the military trauma care system and its learning capacity, the committee found a cup far more than half-full. Indeed, other sectors of care, military and civilian alike, would do well to take lessons from the extraordinary history of progress in combat casualty care—but also its failures. It is time for the nation to improve its approach to trauma care. If the current course of trauma care continues, the consequences will be dire for tens of thousands of trauma patients who deserve, and could have, better outcomes (Hashmi et al., 2016; Kwon et al, 2014).

In its work on learning health systems (IOM, 2013), the IOM has provided a useful template for redesign that can enable a much better trauma care system. In its albeit-isolated examples of success in the field, the Military Health System has shown not only what is possible, but also how. The next steps recommended by the committee would replace these isolated examples with a comprehensive learning system. The key requirements for doing so are known: stronger and more consolidated leadership; clearer, bolder aims; much more comprehensive and more usable data and information systems; support for innovation through increased research investment; continuing emphasis on local knowledge and capacity; and much higher and more consistent levels of cooperation within the military, between the military and civilian sectors, and across the nation. Of key importance to the military's readiness mission, progress will require a paradigm shift that entails seeing military and civilian trauma care as tightly interconnected—not two systems, but one.

The problem is of such magnitude and the current systems are so fragmented that the committee believes action and leadership are needed at the highest levels of the White House, as well as across HHS, DoD, the VA, DOT, and DHS. History has shown that anything less will fail to realize the goal—ambitious but achievable—articulated by the committee during the course of this study: zero preventable deaths after injury and minimal trauma-related disability for those the nation sends into harm's way in combat and, indeed, for every American.

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Appendixes

A

Case Studies

As an aid to understanding the military trauma care learning health system and its translation to the civilian sector, and in accordance with the committee's statement of task, this appendix presents case studies that illustrate a broad spectrum of battlefield injuries relevant also to the civilian sector: extremity hemorrhage, blunt trauma with vascular injury, pediatric burn, dismounted complex blast injury, and severe traumatic brain injury. Collectively, the cases provide information on the following topics specified in the committee's statement of task:

- Levels of evidence used to develop military and civilian (as applicable) clinical guidelines for the spectrum of trauma care in each case.
- Pertinent innovative changes (devices, medications, equipment, methods) that have been incorporated into the spectrum of trauma care for each case as a result of the U.S. Department of Defense's (DoD's) evidence-based improvement process.
- Processes by which patient and injury information was collected, stored, reviewed and analyzed by the Joint Trauma System (JTS), including how this information was used for the JTS's evidence-based improvement process and made available for clinical and epidemiologic research.
- How collection, storage, review and analysis of patient injury and management information differed for those killed in action versus those wounded in action (i.e., different system for those who die prior to arrival at a medical center, thus eliminating ability to study ways to improve survival).

- Impact that evidence-supported changes in military trauma care and the JTS's evidence-supported process improvement may have had on survivability.
- How the results of the military's Defense Health Program (DHP) research investment and elements of focused empiricism have been integrated into the JTS, its clinical practice guidelines, and usual military practice.
- Evidence of how these changes may be effectively integrated into military training and doctrine (e.g., special units such as the Army Rangers) and how these lessons learned can be applied in the civilian sector.
- Time elapsed between the compilation/publication of evidence and development and implementation of clinical guidelines.

For each case, the DoD authors listed below provided information related to interventions, outcomes, levels of evidence for clinical guidelines, and relevant learning health system context:

- LTC (P) Andrew P. Cap, M.D., Ph.D., U.S. Army Institute of Surgical Research, FT Sam Houston, Texas
- LTC Matthew A. Borgman, M.D., San Antonio Military Medical Center, FT Sam Houston, Texas
- Dr. (COL ret) John F. Kragh, M.D., U.S. Army Institute of Surgical Research, FT Sam Houston, Texas
- COL Kirby R. Gross, M.D., Joint Trauma System, U.S. Army Institute of Surgical Research, FT Sam Houston, Texas

Dr. Leon Dent, a Robert Wood Johnson Fellow and Associate Professor and Chair of Surgery at Meharry Medical College, Nashville, Tennessee, provided additional assistance in crafting the case studies.

The committee is grateful for their efforts in support of this study.

The cases were reviewed for

- medical description of case (care provided, errors, factors that influenced outcome);
- military learning process (data management; description of military clinical performance improvement processes, including clinical guideline development and education and training initiatives; and impact of DoD trauma research investment); and
- knowledge transfer between the military and civilian sectors regarding best practices and lessons learned.

EXTREMITY HEMORRHAGE CASES

Case Description

Case 1

In 2006, a male American soldier suffered blast injuries isolated to both lower limbs. The right limb had soft tissue loss, including a length of a major artery, and the left limb injury was a mid-thigh traumatic amputation. In a "scoop-and-run strategy," he was flown to the emergency room of a nearby combat support hospital ("Baghdad ER"), arriving 6 minutes after injury. Neither in the field nor in the aircraft was an attempt made to control bleeding from his extremity wounds. Upon arrival at the hospital, the first attempt to control bleeding was made when he was found to be pulseless, in hemorrhagic shock. Emergency providers placed a field tourniquet on each lower limb and resuscitation was attempted, but the patient was soon declared dead from the prior exsanguination.

Case 2

In a separate incident in 2006, a male American soldier was wounded when an explosion resulted in traumatic amputation of both lower limbs. One limb was amputated above the knee and the other below the knee; he had no other injuries. A fellow soldier, who was not a medic, placed tourniquets on both of the patient's extremities. Bleeding was controlled promptly, and the casualty was flown to the "Baghdad ER." Upon arrival at the hospital, he was in shock and received a massive transfusion of blood. He was taken to the operating room, where his leg wounds were debrided, and he survived.

Case Discussion

These two cases highlight how application of tourniquets in the prehospital setting has a significant impact on outcomes for this injury pattern. In Case 2, the tourniquet was applied at the point of injury by a nonmedic, indicating that the soldiers had been trained to use tourniquets and had tourniquets available. Prompt control of hemorrhage led to the patient's survival despite traumatic amputation of both lower limbs. Case 1 had a similar injury pattern but did not survive because the tourniquets were not applied until the patient reached the hospital. The key point is that tourniquet application in Case 2 was prehospital, illustrating the importance of timely intervention focused on preventing blood loss and death.

Tourniquets were distributed to deployed service personnel in 2005, so it is possible that the device was available and could have been applied to Case 1 in the field, although this was not documented explicitly in the after-action review. Early in the war, poor outcomes resulted from a lack of knowledge regarding the proper use of tourniquets and their consequential application as a tool of last resort. The culture of the military as a whole and of this unit in particular had not yet incorporated practices of tactical combat casualty care (TCCC), which called for the use of tourniquets. Subsequent on-the-ground feedback to Case 1's unit commanding officer resulted in immediate training in tourniquet use and equipping of the unit with tourniquets. In the years that followed this preventable fatality, TCCC guidelines for tourniquets were adopted widely. This case was used as an impetus for incremental improvements in the trauma care system, which in turn improved survival rates. From 2005 to 2011, an estimated 1,000 to 2,000 lives were saved by widespread tourniquet distribution to deploying U.S. military service members (Andersen et al., 2012). During this time period, the annual rate of deployed U.S. military service members dying from limb exsanguination decreased sixfold (Eastridge et al., 2012). Tourniquets are the most important lifesaving intervention during the war.

The Military Learning Process

Data Management

Important efforts in data collection regarding tourniquet use included debriefs of personnel from Special Operations Forces after they had redeployed, evaluations of data on preventable deaths through the office of the Armed Forces Medical Examiner (AFME), and several surveys of caregiver performance at the Baghdad combat support hospital. These data were used to refine best tourniquet practices. Intellectual aspects of decision making on whether to use a tourniquet were studied empirically to provide useful evidence. Under an institutional review board (IRB)-approved protocol and via the registry process, the in-theater research teams helped collect data, enabling rapid analysis and dissemination of information on the safety of tourniquets and the requirement for their prehospital application. Separate analyses conducted in 2005 and 2006 showed a transition to more frequent tourniquet use and improved outcomes (Beekley et al., 2008; Kragh et al., 2008). These findings were shared within the Joint Trauma System (JTS) communication network, leading to changes in care.

AFME data have been studied to determine whether fatally injured service members—such as the soldier described in Case 1—could potentially have survived in order to inform performance improvement efforts and identify medical capability gaps for further research and development. The

U.S. Army Institute for Surgical Research (USAISR) worked with AFME to conduct a preventable death analysis in 2004 (Kragh et al., 2013a). This analysis yielded reports (Holcomb et al., 2007; Kelly et al., 2008) noting that significant numbers of preventable deaths were due to extremity hemorrhage from tourniquet-amenable injuries. These findings spurred efforts to improve tourniquet distribution and use. Such studies have shown the importance of capturing data on dead (killed in action [KIA] and died of wounds [DOW]) and wounded casualties (including rehabilitation) and integrating these data into one registry to enable examination of the entire wounding continuum for new knowledge that can improve outcomes. However, these data are currently fragmented across multiple systems.

All patients admitted to Role 3 facilities (e.g., combat support hospitals) are captured in the Department of Defense Trauma Registry (DoDTR), and the Pre-Hospital Trauma Registry (PHTR) now captures data from the point of injury to support performance improvement initiatives. Kotwal and colleagues (2011) demonstrated the importance and effectiveness of a PHTR in the 75th Ranger Regiment. Although impeded initially by information assurance concerns, JTS efforts to develop a U.S. Department of Defense (DoD)-wide PHTR were eventually successful, and the PHTR was fielded in summer 2013. As of November 2015, the care records of approximately 770 patients had been entered in the PHTR. Prior to the creation of the PHTR, data on patients deemed KIA (i.e., died before reaching a treatment facility) and casualties who died at Role 2 military treatment facilities (MTFs) were not captured for inclusion in a DoD trauma registry other than the AFME system.[1] Given the sensitive nature of KIA information, these data are housed separately from the medical records and the trauma registries.

All combat deaths undergo postmortem examination. However, case-specific results are not immediately available to individual providers, and preventable death analyses are not routinely performed. Currently, an effort is under way to provide definitions and a framework for preventable death analyses. Eastridge and colleagues (2012) report that nearly 1,000 servicemembers killed in action between 2001 and 2011 died of wounds that were potentially survivable). However, their objective was merely to review deaths from an anatomic perspective. A true preventable death analysis requires consideration of additional features, such as the tactical situation at the time of the casualty's injury. The capability to conduct such analyses is difficult to develop, but is essential for a complete understanding of where resources need to be applied.

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[1] Trauma registries are designed to capture data relating to the quality of care provided by a trauma system. Patients who are KIA may or may not have received any care, depending on the mechanism and timing of their fatal injury.

Performance Improvement

The need for tourniquets was recognized in the very first papers on TCCC dating back to 1996 (Butler et al., 1996), and tourniquet use was taught at the military's joint trauma training center at Ben Taub Trauma Center in 2001 (Kragh et al., 2013b). However, tourniquets were not widely issued to troops until a *Baltimore Sun* article in 2005 prompted multiple congressional inquiries (Kragh et al., 2013b). It was difficult to overcome inertia and conventional wisdom regarding tourniquets, and they were often used incorrectly as a last resort. After limb exsanguination deaths were recognized to be both common and preventable, the services changed their practice to the use of tourniquets as a means of first aid. Surveys of tourniquet use in Baghdad, including Case 2 above, were published to broadcast the findings to the widest possible audience. The importance of bleeding control was made clear, and by 2009, when the *Combat Lifesaver Course* book was revised, almost all soldiers had been trained in tourniquet use. This common experience soon helped change the culture of caregiving.

Widespread implementation of tourniquet use has been achieved through such efforts as improvement of clinical performance, refinement of logistic supply management, improvement of leadership in key organizations, improvement in training of all persons at risk, amendment of doctrinal practices, advancement of laboratory research, development of both medical devices and best practices, and use of intermittent surveys to measure progress in caregiving. Connections among medical, logistics, and training stakeholders were instrumental in ensuring the eventual inclusion of tourniquets in first-aid kits issued to all deploying soldiers and the eventual training of all soldiers in using tourniquets effectively. Implementation was initially uneven as Special Operations Forces implemented tourniquet use much earlier, more rapidly, and more thoroughly relative to the conventional military services. Knowledge was disseminated via consultant visits in theater, in-theater trauma conferences, JTS and TCCC guidelines, predeployment training sites, e-mail, presentations at military and civilian meetings, and journal publications.

Impact of DoD Trauma Research Investment

USAISR funded an early (2003) tourniquet distribution effort and, more important, a testing program for tourniquets. Laboratory studies showed that four out of seven tested tourniquets approved by the U.S. Food and Drug Administration (FDA) were not adequately effective at stopping bleeding (Walters et al., 2005). As a result of this effort, the combat application tourniquet (CAT) was selected as the TCCC tourniquet of choice, with subsequent widespread distribution. This capability to test approved devices in military laboratories and identify a single recommended device is crucial, as no other independent laboratories have this capability. Initial experience with tourniquet testing prepared USAISR for later efforts in evaluating junctional tourniquets designed to control bleeding from vascular injuries in the groin and axilla. This work is discussed in the case study on dismounted complex brain injury later in this appendix.

Transfer of Knowledge Between Military and Civilian Sectors

The civilian sector's implementation of best practices in tourniquet use has lagged behind that of the military. A majority of civilian trauma centers (55.1 percent) responding to a recent survey reported that fewer than 20 percent of patients who could have benefited from a tourniquet arrived with one in place (Haider et al., 2015). This lag in civilian use of tourniquets is due in part to the lack of reliable integrated prehospital, hospital, and medical examiner data that collectively describe the problem of preventable deaths from limb wound exsanguination. In addition, very few traumatic amputations or massive tissue disruption injuries resulting from high-velocity gunshots or artillery shell fragments occur in the civilian sector, making it difficult to promote tourniquet use among civilians. Only in the last few years have papers been published regarding civilian tourniquet use; an evidence-based clinical care guideline for external hemorrhage control was released by the American College of Surgeons in 2014 (Bulger et al., 2014).

Despite the lag, the success of tourniquet use on the battlefield has translated to successful use in civilian prehospital care, seen most clearly following the Boston Marathon bombings, where "without a doubt, tourniquets were a difference-maker and saved lives" (Elster et al., 2013). Recently, the Hartford Consensus Committee—a joint committee convened by the American College of Surgeons—developed recommendations for improving the outcomes from exsanguinating limb hemorrhage due to active shooter and other mass casualty events. The group recommends that a continuum of care be implemented that incorporates not only emergency medical services (EMS) response but also initiation of care by law enforcement officers and potentially lay bystanders as well. The foundation for this new paradigm is the body of guidelines issued by the U.S. Military's Committee on Tactical Combat Casualty Care and its civilian counterpart, the Committee on Tactical Emergency Casualty Care. In October 2015, the White House launched a "Stop the Bleed" campaign to empower American civilians to stop life-threatening hemorrhage. Beyond raising awareness, the campaign is working to expand personal and public access to bleeding control kits that contain, among other items, tourniquets. The timeline for the development of greater tourniquet use in military and civilian sectors is summarized in Box A-1.

Box A-1 TIMELINE FOR GREATER TOURNIQUET USE

- 1996—Need for tourniquets recognized in first tactical combat casualty care (TCCC) papers.
- 1999—TCCC guidelines published in prehospital trauma life support manual, recommending use of tourniquets for care under fire.
- 2001—Joint trauma training center begins teaching tourniquet use.
- 2001—Special Operations Forces begin deploying to Afghanistan carrying tourniquets.
- March 6, 2005—*Baltimore Sun* article decries lack of tourniquet availability (Little, 2005).
- March 11, 2005—Senators Levin and Durbin write to Defense Secretary Rumsfeld about inadequate fielding of tourniquets.
- March 18, 2005—Initiation of efforts to widely distribute tourniquets to deploying U.S. military service members.
- 2006—The above-detailed cases occur (one unit uses best practice; the other does not).
- 2009—Tourniquet training provided for almost all soldiers, not just medics.
- 2013—American College of Surgeons' Hartford Consensus recommends an improved approach to civilian prehospital hemorrhage control.
- 2014—American College of Surgeons Committee on Trauma proposes an evidence-based guideline for external hemorrhage control in the prehospital setting.
- 2015—White House launches the "Stop the Bleed" campaign to improve bystander awareness of how to control bleeding.

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BLUNT TRAUMA WITH VASCULAR INJURY CASE

Case Description

A 27-year-old male soldier was ejected from the turret at the top of his vehicle when it rolled over. He sustained multiple blunt injuries, including complex vascular, nerve, and soft tissue damage to the right upper extremity. He also sustained bilateral humeral fractures. The medic at the scene noted no loss of consciousness, but the patient was observed to have deformities of both upper extremities. Initial vital signs were systolic blood pressure (SBP) 90 mmHg (no diastolic blood pressure could be measured), heart rate (HR) 90 beats per minute (bpm), respiratory rate (RR) 20 breaths per minute (rpm), Glasgow coma score (GCS) 15. Upon the patient's arrival at the receiving Role 3 MTF, the right upper extremity was pulseless, and no motor function or sensation was observed. The right upper extremity had suffered a laceration and soft tissue loss in the axilla and exhibited minimal bleeding. A computed tomography (CT) scan with contrast (see Figure A-1) revealed no flow in the right axillary artery, a left pneumothorax, a left

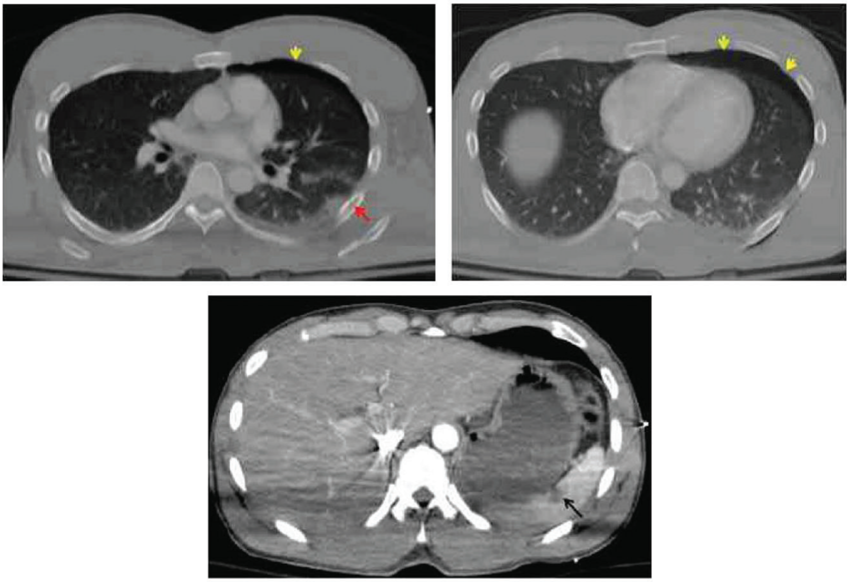

FIGURE A-1 The top figures show left pneumothorax (yellow), lung contusion, and nondisplaced sixth rib fracture (red). The bottom figure shows splenic injury (black); femoral line contrast injection results in beam-hardening artifact from density of contrast in the interior vena cava.

lung contusion, and a nondisplaced left sixth rib fracture. Abdominal CT images revealed a grade I hilar splenic injury and a nondisplaced L5 pars interarticularis fracture. There was no hemoperitoneum. Bilateral humeral fractures were present (see Figure A-2). A transected right axillary artery and vein were identified at the time of injury (see Figure A-3), in addition to anatomic disruption of the ulnar nerve.

Role of Care

In the field, bulky dressings were applied to a right upper extremity open fracture, and a cervical collar was placed. The patient was rapidly

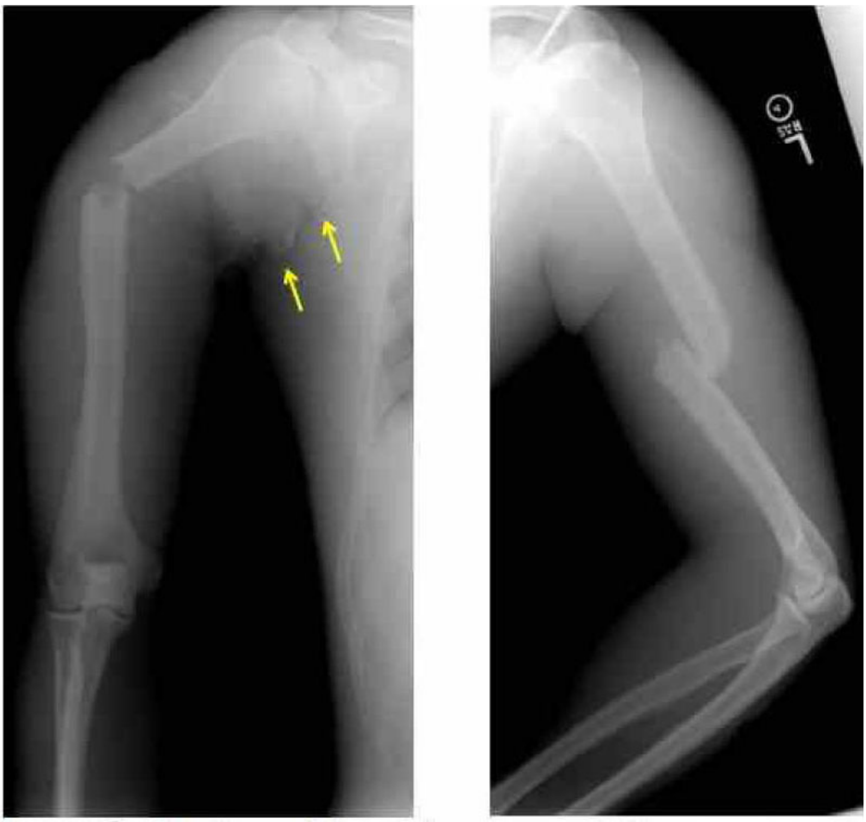

FIGURE A-2 The image on the left shows right humerus fracture and axillary soft tissue injury. The image on the right shows left humerus fracture.

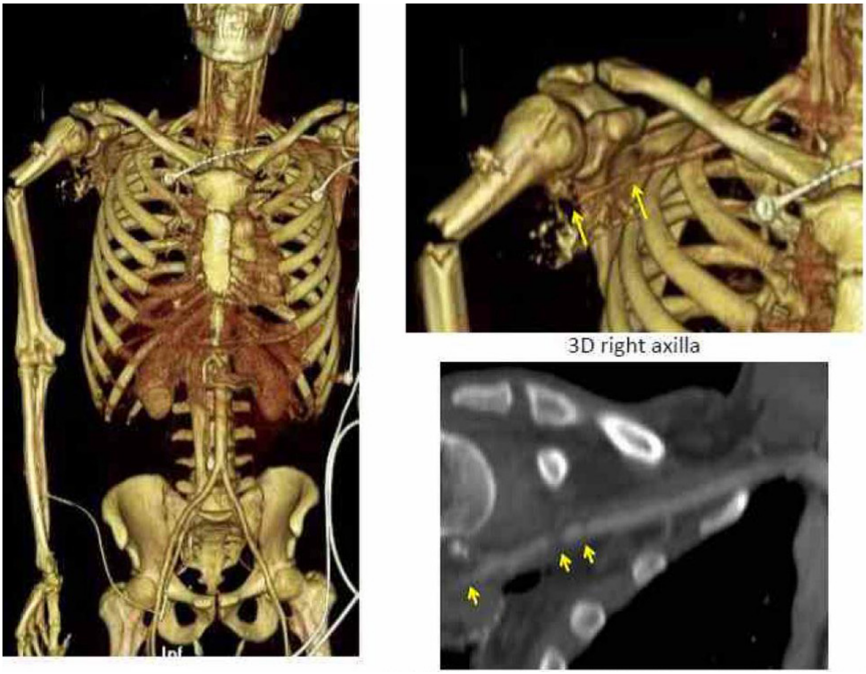

FIGURE A-3 Imaging shows transected right axillary artery.

evacuated in a 5-minute flight to a Role 3 MTF capable of providing subspecialty surgical care.

Role 3 Care

In the MTF operating room (OR), a left chest tube was placed, the left upper extremity was reduced and splinted, and a vascular shunt was placed from the axillary to the brachial artery. An external fixator was applied to the right humerus. Subsequently, the patient underwent arterial reconstruction, venous interposition, and fasciotomy (incomplete) of the right forearm. He was transfused 7 units of red blood cells, 6 units of fresh frozen plasma, and 1 apheresis unit of platelets. On post-injury day 1, he was transferred to the Role 3 strategic evacuation (STRATEVAC) hub. Repeat CT scanning at the STRATEVAC hub demonstrated a pneumothorax with the chest tube incorrectly placed in the extrapleural space. No bleeding from the spleen was noted. The patient was taken to the OR, where the right arm vascular repair was reassessed; the axillary artery had good flow, but the vein was thrombosed. The right forearm fasciotomy was completed, and a latissimus dorsi muscle flap was mobilized to repair the axillary soft tissue defect and cover the vascular repair. Wounds were covered with negative-pressure dressings, and the patient was extubated prior to transfer to Germany on post-injury day 3.

Case Discussion

The overall good outcome of this patient was due to rapid evacuation (5 minutes) from the point of injury to the combat support hospital and prompt resuscitation from hemorrhagic shock. Prompt revascularization resulted in limb salvage. The use of a vascular shunt to delay definitive vascular repair was appropriate in this case given the nature of the polytrauma, the complex vascular injury, and the patient's compromised hemodynamic status. A lengthy vascular repair performed in an austere environment by a surgeon who may perform vascular surgery infrequently is suboptimal. However, several errors in patient management were noted. The error in chest tube placement, resulting in a persistent pneumothorax, was potentially dangerous because of the possibility of the patient's developing a life-threatening tension pneumothorax, particularly during air transport. The importance of obtaining a confirmatory chest x-ray following insertion of a chest tube is a long-held tenet of trauma surgery. The omission of a follow-up chest x-ray was most likely an oversight but may point to inadequate training. The incomplete fasciotomy probably contributed to the loss of the venous graft. Further opening of the forearm fascial compartments was performed on the patient in this case at the Role 3 air hub. This patient's rehabilitation would have been aided by targeted nerve implantation of the axillary nerve roots into the pectoralis muscle. Targeted nerve implantation into muscle has been demonstrated to reduce the formation of painful neuromas, which occur in 13-32 percent of amputees (Pet et al., 2014), limiting or preventing the use of prosthetic devices. This procedure has been used in advanced civilian trauma centers since 2005, but has not been widely adopted.

The Military Learning Process

Data Management

The acquisition and storage of patient data have evolved within the military in recent years. To mitigate the problem of lost patient data and to assist with performance improvement efforts, patient information is now captured and stored in an electronic medical record (EMR), the Theater Medical Data Store. This system was built over the course of Operation Iraqi Freedom/Operation New Dawn and Operation Enduring Freedom as the need for an EMR was recognized. In addition, JTS abstractors gathered data for inclusion in the DoDTR to support performance improvement.

Patients such as the case presented herein undergo several transfers in care before returning to the United States. These transfers often entail loss of pertinent clinical information from one level of care to the next. Patient information from the point of injury to the initial MTF is transmitted primarily by verbal report from the flight medic to the receiving providers. For only 7 percent of casualties can a TCCC card be identified in the medical chart. Records from the Role 2 MTF are copied and transferred physically with the casualty to the Role 3 MTF. After the theater of operations became mature, nearly all Role 2 facilities had computers that could link to the Theater Medical Data Store to upload patient records. However, because of bandwidth limitations and periods during which the Internet was blocked as a result of operational security concerns, the most reliable means of ensuring that care provided at a Role 2 MTF was relayed to a Role 3 MTF was by hard copy. Entries made into the Theater Medical Data Store by the Role 2 MTF would eventually be available to the Role 3 MTF, where information technology support was much more robust. Before transfer out of theater, however, the entire medical record was copied and then moved physically with the patient. Hard-copy records could be useful to the critical care air transport teams during the 8- to 10-hour transport period out of theater. To further assist successive medical teams along the continuum of care by ensuring efficient transfer of patient data, clinical information sheets were created and transported with the patient. To indicate whether patients with a blunt mechanism of injury had met criteria for clearance of the cervical spine, for example, a spine clearance documentation sheet was included in accordance with the JTS Cervical Spine Evaluation Clinical Practice Guideline. This sheet (see Figure A-4) was completed for each casualty with a blunt injury mechanism and accompanied the patient during movement out of theater.

Performance Improvement

During the early experience of Operation Iraqi Freedom, colleagues at Landstuhl Regional Medical Center (Role 4) identified a higher-than-expected rate of incomplete fasciotomies. Many general surgeons lacked training in or experience with extremity injuries, as their orthopedic or vascular colleagues frequently manage these wounds. In the deployed environment, orthopedic surgeons may not be present at all MTFs. To provide feedback to downrange providers and correct deficiencies such as incomplete fasciotomy, a weekly Thursday Combat Casualty Care teleconference connecting in-theater MTFs with Landstuhl and U.S. MTFs was established in 2006. This teleconference provides near-real-time feedback to downrange

Joint Theater Trauma System Clinical Practice Guideline

APPENDIX C JOINT THEATER TRAUMA SYSTEM CERVICAL SPINE CLEARANCE STATUS

JOINT THEATER TRAUMA SYSTEM - CERVICAL SPINE CLEARANCE STATUS

Mechanism: ☐ Explosive ☐ MVC ☐ Fall ☐ Other

Notes:____

Collar placed: ☐ Pre-hospital ☐ Hospital ☐ No Collar

Patient RELIABLE? ☐ Yes ☐ No Reason Unreliable: ☐ Altered Mental Status (GCS<15) ☐ Significant Distracting Injury

Notes:____

Patient Complaints ☐ None ☐ Neck Pain (where:____________________) ☐ Paresthesia

Notes:____

Physical Findings

Inspection: ☐ Normal ☐ Abnormal:____________________________

Palpation: ☐ Normal ☐ Point Tenderness ☐ Deformity

Notes:____

Active Range of Motion: ☐ Full ☐ Limited:____________________________

Notes:____

Imaging Studies [CT is Standard. Films acceptable only when CT is unavailable]

CT SCAN: ☐ Normal ☐ Abnormal:____________________________

Notes:____

Lateral ☐ Normal ☐ Abnormal:____________________

AP ☐ Normal ☐ Abnormal:____________________

Odontoid ☐ Normal ☐ Abnormal:____________________

C L E A R A N C E

The Cervical Spine is:

☐ CLEAR of significant injury and instability on the basis of the following:

- ☐ Normal exam in completely reliable patient with no need for imaging.
- ☐ Normal imaging of full C-Spine and normal exam.

☐ NOT CLEAR on the basis of the following:

- ☐ Neurological complaint or abnormal physical exam finding
- ☐ Abnormal imaging
- ☐ Unreliable patient at time of evacuation /final disposition

Physician________________/________________ MTF:____________ Date/Time:____________

Print Name Signature

PATIENT'S IDENTIFICATION: (For typed or written entries give: Name – last, first, middle; ID No or SSN; Sex; Date of Birth; Rank/Grade)

JTTS Cervical Spine Clearance Note

Medical Record (Rev. May 2009)

FIGURE A-4 Cervical spine clearance documentation sheet.

providers. Early in the conflicts, 15 to 20 cases per week were discussed in this forum, which afforded a chance to provide feedback regarding outcomes as well as opportunities for improvement.

The weekly Thursday Combat Casualty Care teleconference also serves to facilitate recognition of system-wide issues that may need to be addressed through the development of clinical practice guidelines (CPGs) and other performance improvement methods (e.g., educational campaigns). The process by which new CPGs are generated and existing CPGs are updated is described on the JTS CPG webpage (http:www.usaisr.amedd.army.mil/cpgs.html). Topics under consideration are presented to a theater trauma leader or the JTS director. An initial draft of the CPG is generated and reviewed by theater trauma leadership; theater trauma subject matter experts; and, subsequently, military trauma subject-matter experts (from each service) who are not currently deployed. Trauma directors at the stateside facilities that receive combat casualties also are asked to provide input. Input from these subject matter experts is collated by the chief of performance improvement at the JTS. Ideally, the JTS director, the chief performance improvement officer of the JTS, and theater trauma leadership reach consensus. The JTS director is the final clinical approval authority; however, the director may convene subject matter experts in an effort to achieve consensus. Current CPGs relevant to blunt trauma with vascular injury are listed in Box A-2.

The compartment syndrome and fasciotomy CPG, which prescribes

Box A-2 JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINES RELEVANT TO BLUNT TRAUMA WITH VASCULAR INJURY

- Battle/Non-Battle Injury Documentation Resuscitation Record
- Blunt Abdominal Trauma
- Cervical Spine Evaluation
- Compartment Syndrome and Fasciotomy
- Damage Control Resuscitation
- Hypothermia Prevention
- Infection Control
- Intratheater Transfer and Transport
- Management of Pain, Anxiety, and Delirium
- Management of War Wounds
- Prehospital Care (Tactical Combat Casualty Care guidelines)
- Prevention of Deep Venous Thrombosis
- Trauma Anesthesia
- Wartime Vascular Injury

SOURCE: http://www.usaisr.amedd.army.mil/cpgs.html (accessed August 10, 2016).

complete release of all compartments through full skin and fascial incisions when indicated in patients with ischemic extremities, was developed in June 2009, even though the problem of incomplete fasciotomies was identified as early as 2004. Measurement of the effectiveness of JTS performance improvement initiatives and compliance with CPGs is facilitated by core performance/adherence measures written into a performance improvement monitoring section of each CPG. For example, the core measures for compartment syndrome and fasciotomy CPG are that (1) when fasciotomy is performed, there is complete release of all compartments through full skin and fascial incisions, and (2) when indicated in patients with ischemic extremities, fasciotomy is performed at the time of revascularization. In an October 2012 audit filter review of core measure (1) only 2 of 144 patients undergoing revascularization were found to have required further fasciotomy. For core measure (2) fasciotomy was performed in 69 percent of cases of revascularization. Reviews of data on compliance with core measures during the weekly Thursday Combat Casualty Care teleconference proved to be an effective way of providing feedback on compliance with the CPGs.

The weekly Thursday Combat Casualty Care teleconference, now called the Combat Casualty Care Curriculum, has evolved from a strictly performance improvement focus to an educational forum. Each week a continuing medical education (CME) topic relevant to deployed care is selected, and one or two appropriate cases are presented.

General surgery residents completing their research year at San Antonio Military Medical Center have been directed by their general surgery program director to attend the weekly teleconferences so they can benefit from the lessons learned over the past decade of combat medicine. No other military physicians in training have been directed by leadership to participate in these teleconferences, even though they are an ideal way to meet military-specific education requirements for physicians in training and introduce them to the trauma system in which they will likely be participating. Topics chosen for CME presentations during the Thursday teleconferences are specific to combat casualty care. The topics are sequenced to coincide with the graduate medical education academic year, and all major topics of relevance to combat casualty care are discussed. Trauma system topics are covered early in the academic year. The curriculum also incorporates presentations by military medical historians and military medical research leaders.

The teleconferences will be continued indefinitely to ensure that the technical infrastructure for cross-theater communications is maintained, to reinforce the importance of the trauma system, and to provide combat casualty care education. Based on its demonstrated value in the U.S. Central Command (CENTCOM) area of operations, U.S. Pacific Command (PACOM) has established a similar teleconference, which reviews trauma cases, addresses trauma system issues, and serves as an educational forum.

Ideally, all U.S. combatant commands will establish a similar teleconference in their areas of responsibility.

Transfer of Knowledge Between Military and Civilian Sectors

Techniques to restore blood flow through injured vessels to prevent ischemic injury and limb loss have evolved through a continuous transfer of knowledge between military and civilian sectors. Despite evidence during World Wars I and II of the potential value of intravascular tubular devices for bridging arterial injuries and maintaining perfusion, interest in such devices waned during the Korean and Vietnam Wars as focus shifted to vascular repair approaches (Hancock et al., 2010). During this period, commercially available vascular shunts were developed in the civilian sector to permit flow during open, elective vascular procedures but there remained little investigation into the use of shunts for trauma applications until a significant burden of vascular injury during the wars in Afghanistan and Iraq generated the necessity. Vascular shunts were incorporated into damage control strategies at forward surgical sites (Role 2) early during the war in Iraq and were shown to be effective at restoring extremity perfusion until the patient could be evacuated to higher levels of care for definitive reconstructive vascular surgery (Hancock et al., 2010). Having shown that the use of vascular shunts extends the window of opportunity for limb salvage, efforts are under way to develop vascular shunts with specific application to military trauma management. The features useful in vascular shunts for trauma care would be a side port for blood pressure monitoring, anticoagulant administration, and contrast injection. Local anticoagulant administration would ensure that therapeutic dosage could be administered directly to a compromised extremity. Also, since combat trauma commonly involves multilevel injury, the distal vascular structures may benefit from radiographic imaging for identification of multilevel vascular injury prior to definitive vascular repair.

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PEDIATRIC BURN CASE

Case Description

In fall 2004, a 2-year-old male presented to the 31st Combat Support Hospital emergency room ("Baghdad ER") after a vehicle explosion. He had been seated in the back seat of a vehicle stopped at a checkpoint that exploded after being struck from behind by another vehicle. He suffered approximately 30 percent total body surface area flame burn (partial to full thickness) to the face, anterior torso, abdomen, bilateral hands, bilateral legs (left leg circumferentially), and lower back. His past medical history, surgical history, medications, and allergies were all unknown. His social history also was unknown, other than that his mother and brother had perished in the fire. The time of injury to presentation was not documented, but was presumed to be less than 2 hours. Upon arrival at the hospital, he was awake and crying, Glascow coma score (GCS) was 15. Initial vital signs were blood pressure 156/67, heart rate 124, respiratory rate 34, saturation 100 percent on supplemental oxygen delivered by nonrebreather mask. His estimated weight was 10 kg. He was breathing comfortably but had soot noted in the airway; his lungs were clear to auscultation. A venous blood gas measurement revealed acidosis and hypoxia: pH 7.12, pO_2 62 mmHg, pCO_2 31 mmHg, bicarbonate 20 mEq/L, base excess 9 mEq/L.

The patient was intubated and brought immediately to the operating room for debridement and dressing of burns. Lateral escharatomies were performed on the left leg and the dorsum of each foot. He received a total of 700 mL of crystalloid and had minimal blood loss. He was transferred to the intensive care unit (ICU) for continued care, with good pulmonary compliance noted. The child developed significant capillary leak and fluid overload in the initial 72 hours. Additional extremity escharatomies were performed on days 1 and 2 for compartment syndrome. A peritoneal drain was placed on day 3 for abdominal compartment syndrome. The child also developed severe acute respiratory distress syndrome. No advanced forms of invasive ventilation were available to treat his worsening pulmonary compliance, and he required peak inspiratory pressures of 90 mm Hg and positive-end expiratory pressure of 20 mmHg, as well as prone positioning, to maintain oxygen saturations greater than 85 percent and pH greater than 7.2. He required a total of approximately 25 days on the ventilator. Ultimately, he was successfully weaned to room air and was discharged to home on hospital day 40. He was able to receive limited physical therapy and rehabilitation while admitted.

Case Discussion

This case highlights several challenges in the care of burn patients, and pediatric patients in general. U.S. and Coalition military patients with severe burns are quickly evacuated out of theater by critical care air transport teams, and patients with the most severe burns are transported by a specialized burn team from the U.S. Army Institute of Surgical Research in San Antonio, Texas. In contrast, this patient, like other host nation citizens with significant burns, could not be evacuated to an alternative hospital with a specialized burn team and long-term rehabilitation capabilities (including nutritional and psychosocial resources).

This patient benefited from the care of a pediatric intensivist who happened to be deployed to Baghdad at the time. This kind of specialty care is not commonly available in a war zone. Although a good outcome was achieved, several deficiencies hampered the care of this child. No advanced forms of invasive ventilation, such as high-frequency oscillatory ventilation or inhaled nitric oxide support, were available to treat his worsening pulmonary compliance and edema. Devices for accurately measuring intra-abdominal pressure also were not available. Innovative use of bedside ultrasound in the hospital made it possible to determine that the patient was hypervolemic based on superior vena cava diameter and atrial size. This determination assisted in the diagnosis of abdominal compartment syndrome as the cause of the child's anuria and renal failure. Overall, this patient was overresuscitated, as evidenced by his abdominal compartment syndrome. Where in the chain of care this occurred is unclear, but it was probably in the hospital stage. Documentation of prehospital care for this patient was not available.

Burn injury accounted for 14 percent of all pediatric patients seen at DoD Role 3 or 2b MTFs in Afghanistan and Iraq from 2003 through 2011. The average hospital length of stay was 10 days (range 0 to 171 days). Because of longer lengths of stay, children accounted for 11 percent of all bed days during this period, although representing only 5.8 percent of admissions. Their overall mortality was 13.3 percent (Borgman et al., 2015).

Despite the substantial numbers of pediatric patients cared for at expeditionary military hospitals, resources are inadequate for the acute and long-term care of critically ill children (and adult host nation burn patients). Early in the conflicts, clinicians had to improvise pediatric-sized medical equipment. In 2006, with input from pediatricians, the U.S. Army Medical Materiel Agency made available a set of pediatric supplies, which ultimately resulted in the assembly of the current pediatric humanitarian assistance augmentation medical equipment set. Even after 2006, however, when complete sets of pediatric equipment and medication had been developed, lack of communication about the existence of these kits impaired the implementation of their use, as the kits had to be specially requested.

Although optimal supplies and personnel may not have been available to treat a pediatric casualty in a combat environment, the care the child in this case report received far exceeded that which was (and is) available in Baghdad. This was just one of many cases indicating the need to deploy a set of pediatric equipment and physicians trained in pediatric critical care to combat support hospitals in theater. Military doctrine still has not evolved to ensure the availability of critical care for pediatric combat casualties.

The Military's Learning Process

Data Management

Although the DoDTR was initially envisaged as a means of tracking and informing the care of U.S. casualties, it is also a robust repository of data on severely injured children. Pediatric cases admitted to Role 3 MTFs are entered into the DoDTR; otherwise, data collection on these patients is extremely limited (case reports). DoDTR data enabled an in-depth epidemiological study of pediatric burn injuries in combat, which identified factors associated with mortality based on burn severity (Borgman et al., 2015). However, entry of pediatric data into the DoDTR has not been a priority, and as a result, there generally has been a considerable lag between the occurrence of pediatric cases and their entry into the system for analysis. Armed Forces Medical Examiner (AFME) data are not available to inform preventable death analyses for pediatric patients since the AFME performs autopsies on U.S. service members killed in action, not on host country nationals.

Performance Improvement

Resources for deployed physicians treating burn and pediatric patients were developed by the JTS primarily by expert consensus, but also informed by ongoing analysis of clinical data from the DoDTR. When this case occurred, no definitive guidance on the care of pediatric burns was available. The JTS Burn Care CPG (JTS, 2013) has evolved since this case occurred to include issues useful in the management of children with burns. However, there are no CPGs specific to pediatric burn care. The recommendations added to the burn care CPG with regard to children are more like rules of thumb and are not based on a rigorous analysis of CENTCOM outcomes in these patients (which would be hard to perform for long-term outcomes since host national patients are eventually discharged out of the military system). Very few clinical trials have been conducted in these areas, so guidelines are frequently based on Level 3 evidence.

While capabilities to care for these complex pediatric patients generally have improved since the start of the wars, pediatric host national cases are not rigorously analyzed for performance improvement purposes, and there are no published studies on improvement in these patients over time nor is there any pediatric-specific monitoring of CPG compliance. Even when performance improvement processes such as mortality and morbidity reviews were carried out at combat support hospitals, transmission of the resultant lessons learned to the next group of physicians was a challenge. Lessons learned were often distributed by word of mouth and in a textbook that was published years later (Fuenfer and Creamer, 2010). To address potential knowledge and training deficits, the U.S. Army Medical Department Center and School developed a 5-day course—the Joint Forces Combat Trauma Management Course—that addresses burns, pediatric patients, and other topics relevant specifically to those providers deploying to Role 2 or 3 MTFs. Specialty-specific e-mail listservs (including separate teleconsultation groups for burn trauma and pediatrics) also were created so that deployed providers could rapidly contact specialists in the United States should complex clinical questions arise.

Impact of DoD Trauma Research Investment

The recent experience in Afghanistan and Iraq has led to significant improvements in the U.S. military's ability to provide advanced care to adult burn patients in the deployed setting. For example, the recurrent problems encountered with fluid overload in burn management led to the development of the Burn Resuscitation Decision Support System (BRDSS) by the U.S. Combat Casualty Care Research Program. The BRDSS can enable providers to accurately resuscitate burn patients from the point of injury to definitive care using an algorithm that automatically generates patient-specific fluid rate recommendations for resuscitation. This medical device, available for use in hospitals and the field (mobile format deployed in 2014), started as a research project within the U.S. Army Medical Research and Materiel Command and was the first device to undergo advanced development and go from FDA approval to the field. Its success represents a development model that is also enabling progress in closing other combat casualty care capability gaps (DoD, 2015). However, the BRDSS is not currently indicated for pediatric patients (under 18 years of age), although future versions may include a pediatric module. Research on optimal clinician training and configuration of equipment sets and systems-level integration of host national pediatric and burn care into the overall DoD trauma system represent opportunities for further refinement of expeditionary medicine.

Transfer of Knowledge Between Military and Civilian Sectors

Care for pediatric burn patients provides a rich opportunity for military and civilian knowledge transfer and collaboration to fill gaps in both sectors. Several civilian pediatric burn centers have established protocols for care for pediatric burn patients that include timing of surgery, wound care management, sedation and analgesia, nutrition, pharmacology, and psychosocial care. These protocols could be adapted to resources available for pediatric burn care in an austere environment. As these protocols are not published, the process for knowledge transfer could involve subject matter experts teaming with military providers to create a best practices protocol.

Civilian pediatric trauma centers rarely encounter blast-related penetrating injuries, but this type of injury is commonplace in a war zone, enabling military researchers to conduct research that would be difficult or even infeasible in the civilian sector. For example, Borgman and colleagues (2011) used the DoDTR to develop the pediatric "BIG" trauma score for predicting mortality on admission in pediatric trauma patients. This method was later validated with data from German pediatric civilians as well as Canadian blunt trauma patients (Borgman et al., 2011; Davis et al., 2015), and may have use in a variety of civilian trauma and research centers.

Military experience with adult burn patients also has informed burn care in the civilian sector. For example, military data from burned soldiers were used to develop a revised fluid resuscitation formula (Modified Brooke) that has been widely applied to avoid fluid overload at civilian burn centers. In addition, the computerized decision support tool developed at the U.S. Army Institute of Surgical Research Burn Center to help guide fluid management has supported care for both civilian burned casualties and service members being evacuated out of theater.

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DISMOUNTED COMPLEX BLAST INJURY CASE

Case Description

A 29-year-old male service member sustained injuries in 2009 from an improvised explosive device while on patrol. His injuries included traumatic amputation of his left lower extremity and a compound right lower extremity fracture (see Figure A-5). There was extensive soft tissue injury to both lower extremities. The field medic noted that the patient had a palpable radial pulse, heart rate 110, respiratory rate 15, Glasgow coma score 15, and severe pain. Further evaluation during tactical evacuation revealed a large perineal wound that later was shown to extend from the right groin through the perineum to the perirectal area (see Figure A-6). A computed tomography (CT) scan showed widening and misalignment of the patient's symphysis pubis (see Figure A-7).

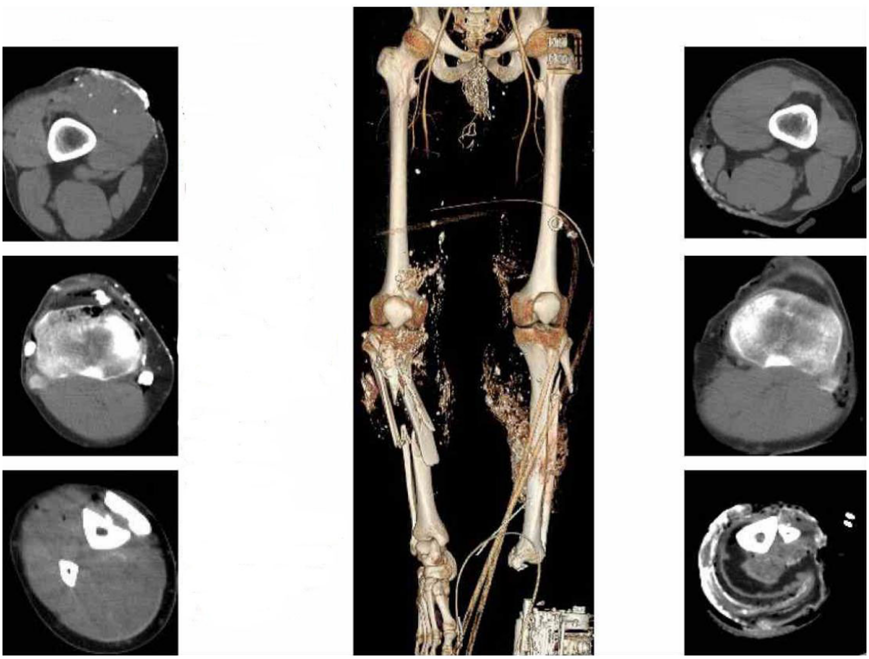

FIGURE A-5 This 3-D CT image with representative axial images shows bilateral lower-extremity below-the-knee amputations (incomplete on the right lower extremity) with extensive soft tissue injury with debris, fragments, and lower extremity fractures. Bilateral pneumatic tourniquets at the thigh cause loss of vascular opacification.

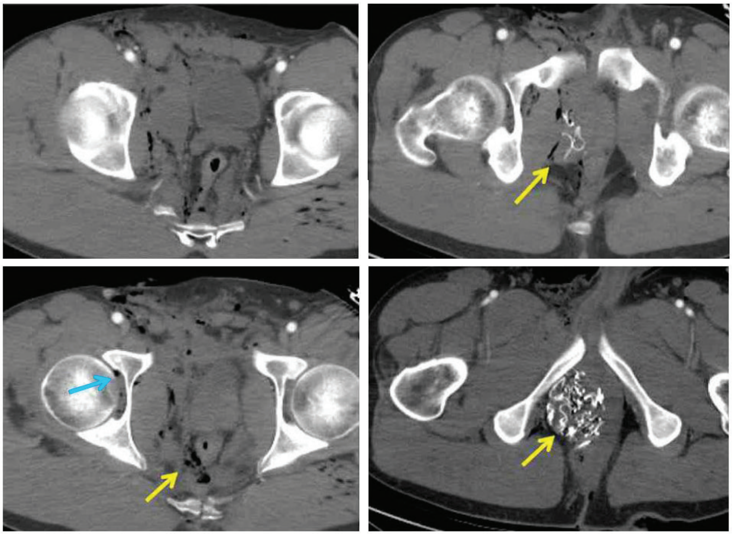

FIGURE A-6 Axial CT images demonstrate a soft tissue injury tract along the right groin extending to the perirectal region (yellow) with adjacent surgical packing. Soft tissue gas and pelvic hematoma are found along the tract. Note small amount of air in right hip joint (blue).

Role 1 Care

At the point of injury, the field medic applied the following interventions: two SOF-T tourniquets to the left lower extremity, makeshift splinting of the right lower extremity, pressure dressing application to the right lower extremity and right groin, a pelvic binder, saline lock placement, ketamine 50 mg intravenous for pain, and a hypothermia prevention and management kit. The patient exhibited signs of hemorrhagic shock (a thready pulse) and subsequently was given 300 ml saline.

Tactical Evacuation

During tactical evacuation, intraosseous vascular access was established, and further bleeding control measures were taken (packing and pressure on the perineal wound, and transfusion with 1 unit each of red blood cells and fresh frozen plasma). Additional ketamine was administered in an effort to manage pain.

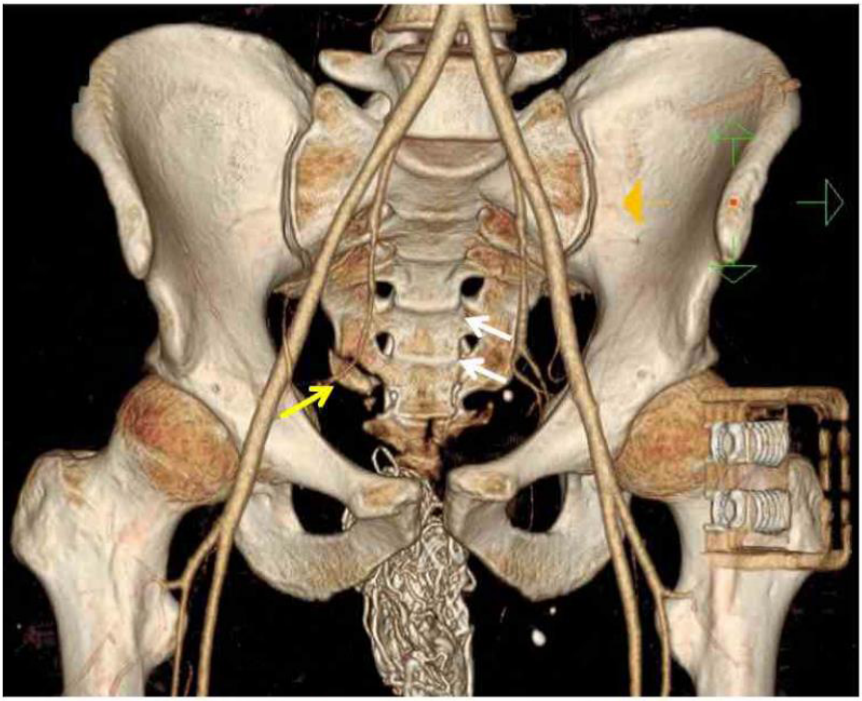

FIGURE A-7 3-D image of the pelvis demonstrates subtle widening and misalignment of the symphysis pubis. There is a displaced fracture of the right sacrum as well as a nondisplaced left sacral alar fracture involving the neuroforamina (arrow). Overlying pelvic binder and surgical packing are present.

Role 3 Care

At the receiving Role 3 MTF, pneumatic tourniquets were applied, and the patient received further resuscitation with whole blood and tranexamic acid (TXA). In the operating room, the colon was divided at the rectosigmoid junction and left in discontinuity. A temporary abdominal closure was applied. During the same operative intervention, a pelvic external fixator was placed, and both lower extremities were amputated through the knees. On the day following the injury, the patient was transported by a critical care air transport team to a Role 3 strategic evacuation (STRATEVAC) hub, where washouts of the lower extremity wounds were performed and negative pressure dressings applied, the pelvic external fixator was adjusted, and an end colostomy was fashioned. Nasoenteral feeding access was placed during an exploratory laparotomy by advancing a tube into the proximal jejunum. Subsequently, the fascia was closed.

Evacuation Out of Theater

The patient was transported out of theater on day 2 post-injury by a critical care air transport team. During the 8.5-hour flight, the patient received another transfusion with 4 units of red blood cells and 3 units of fresh frozen plasma to counter ongoing blood loss.

Role 4 Care

Upon arrival at Landstuhl Regional Medical Center in Germany, the patient's wounds were washed out, and he was extubated. An oblique fracture of the third metacarpal bone and a ruptured tympanic membrane were identified. The patient remained in Germany for 3 days before being moved to the United States.

Role 5 Care

During the patient's treatment at a U.S. MTF, both lower extremity amputations were revised to above the knee, and the sacroiliac joint was transfixed.

Case Discussion

This case typifies the dismounted complex blast injury (DCBI) pattern, caused by exposure of warfighters on foot patrol to blast and high-velocity fragments generated by the detonation of buried or concealed ground-level explosive devices. The injury pattern includes a traumatic amputation of at least one leg, a severe injury to another extremity, and pelvic, abdominal, or urogenital wounding. This pattern of injury was formally described as DCBI in 2010.

In this case, the medic's actions to control blood loss (prompt application of tourniquets and packing of the groin wound) and prevent hypothermia in the field were consistent with TCCC guidelines and were key to this patient's survival. According to TCCC guidelines, the patient might also have benefited from administration of TXA, antibiotics, and blood products for resuscitation (whole blood or red blood cells and plasma) in the field, as well as application of a junctional tourniquet. Currently, however, DoD has fielded junctional tourniquets on a very limited basis. Whole blood and freeze-dried plasma are available only in Special Operations units, and red blood cells and plasma are available only on a limited basis for medical evacuation (MEDEVAC), not for field care.

The Military Learning Process

Data Management

The patient described in this case received prehospital and hospital-based care. Data from his medical records for these two phases of care are currently entered into separate DoD databases. Point-of-injury care is abstracted into the Pre-Hospital Trauma Registry (PHTR), and data from Role 3, Role 4, and Role 5 MTFs are captured in the DoDTR. Patient data collected during tactical evacuation (intratheater) are abstracted into a separate TACEVAC (formerly called MEDEVAC) database developed by the JTS. Data capture for care provided at the point of injury and during transport between theater MTFs has been reliable since 2009. Because DoDTR inclusion criteria prior to 2013 required an admission to a Role 3 MTF, data on casualties who received care at a Role 2 facility were not abstracted into the DoDTR if (1) they did not require evacuation to a Role 3 facility or (2) they died at the Role 2 facility. Care provided to patients in these two categories was abstracted into a Role 2 database by Role 2 clinical staff. The separate databases for the different levels of care represent a suboptimal system design. Ideally, an integrated registry would be developed that is oriented less to the role of care and more to the casualty. Despite these limitations, however, the DoDTR was a critical resource in the identification of the DCBI injury pattern and subsequent efforts to improve care for service members sustaining these devastating injuries. In its absence, the ability to detect distinct and evolving wounding patterns may have been significantly delayed.

Performance Improvement

DoDTR data were analyzed in 2010 in response to concerns from deployed line and medical communities regarding an apparent increase in multiple limb amputations concomitant with severe genitourinary injury. This analysis revealed a clear increase in the frequency of the injury pattern described as DCBI. These data and the severe nature of the injuries prompted the Army Surgeon General to appoint a task force charged with studying the causation, prevention, protection, treatment, and long-term care options for this injury pattern. The task force's report was released in June 2011.

Many of the best practices identified by the task force and applied to the care of DCBI patients represented advances made in the earlier years of conflicts in Afghanistan and Iraq. For example, the task force echoed TCCC recommendations to use tourniquets at the point of injury for hemorrhaging extremity injuries and to avoid large-volume crystalloid resuscitation.

CPGs—introduced initially in December 2004 as the deployed trauma system's means of avoiding variation in care—had already been developed for the topics of resuscitation, management of war wounds, hypothermia prevention, and intratheater transport and were well accepted by the time of the dramatic increase in the DCBI wounding pattern. Recognition of DCBI prompted renewed attention to CPG implementation, education, and performance improvement measures. (CPGs relevant to DCBI are listed in Box A-3.)

A new CPG—the Invasive Fungal Infection CPG—was developed by the JTS in direct response to complications seen with this pattern of injury. The development of invasive fungal infections associated with DCBI was noted among marines injured during dismounted patrol in Helmand Province returning for treatment to the National Naval Medical Center (now the Walter Reed National Military Medical Center[2]). Trauma leadership at the National Naval Medical Center informed the JTS of these fungal infections, and infectious disease colleagues at Landstuhl Regional Medical Center and the Trauma Infectious Disease Outcomes Study Group at the Uniformed Services University of the Health Sciences undertook the development of the Invasive Fungal Infection in War Wounds CPG. The CPG, which was distributed in 2012, identified casualties at risk for invasive fungal infections and directed that these patients have Dakin's solution applied to wounds as a countermeasure effective at low concentrations against fungus (Rodriguez et al., 2014). Evidence supporting this CPG is Level 3 and is based on retrospective review of a prospectively gathered database.

Other changes in the deployed trauma system were made in response to recommendations from the DCBI task force's report. For example, the report prompted the deployment of urologists to Role 3 MTFs to improve care of genitourinary injuries in the DCBI context and the equipping of MEDEVAC helicopters with supplies to enable blood-product-based resuscitation (specifically plasma and red blood cell units delivered in a 1:1 ratio) for certain missions. To facilitate early blood-based resuscitation, the task force also called for a major effort to deliver a freeze-dried plasma product to the battlefield. Freeze-dried plasma lacks FDA approval, but freeze-dried plasma produced by the French Army was procured under an Expanded Access Investigational New Drug protocol for U.S. Special Operations Forces. No FDA-approved product is widely available to deployed troops.

Collectively, the changes in JTS guidance and care practices likely led to improvement in survivability. However, no data exist with which to determine impacts on outcomes associated with specific changes in practice, and quality-of-life metrics for survivors remain a significant gap in report-

[2] Walter Reed Army Medical Center and the National Naval Medical Center came under one roof as a joint facility in Bethesda, Maryland, in August 2011.

Box A-3 JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINES RELEVANT TO DISMOUNTED COMPLEX BLAST INJURY

- Acoustic Trauma and Hearing Loss
- Amputation
- Battle/Non-Battle Injury Documentation Resuscitation Record
- Damage Control Resuscitation
- Fresh Whole Blood Transfusion
- Hypothermia Prevention
- Infection Control
- Intratheater Transfer and Transport
- Management of Pain, Anxiety, and Delirium
- Management of War Wounds
- Nutrition
- Pelvic Fracture Care
- Pre-Hospital Care (Tactical Combat Casualty Care guidelines)
- Prevention of Deep Venous Thrombosis
- Trauma Anesthesia

SOURCE: http://www.usaisr.amedd.army.mil/cpgs.html (accessed August 10, 2016).

ing as the focus has been on mortality. The JTS does not currently have the resources to obtain long-term functional recovery and quality-of-life data on combat casualties.

Impact of DoD Research Investment

The DCBI task force and related research efforts expanded on TCCC methods to incorporate use of junctional tourniquets to aid in the control of groin bleeding. Service members on foot patrol suffering improvised explosive device blasts may have very proximal traumatic amputations precluding effective application of extremity tourniquets. Dr. John Kragh at the U.S. Army Institute of Surgical Research demonstrated effective techniques for a junctional tourniquet (the combat-ready clamp) as early as 2012. To date, DoD's Combat Casualty Care Research Program has yielded several junctional tourniquet models that have been approved by the FDA and fielded on a limited basis.

DCBI, which is associated with significant soft tissue injury and hemorrhage leading to the coagulopathy of trauma, also prompted a particular focus on evaluation of the use of TXA, an antifibrinolytic agent, to improve combat trauma mortality, based on the findings of the CRASH-2 (Clinical Randomization of an Antifibrinolytic in Significant Haemorrhage) trial, published in 2010 (Shakur et al., 2010). Initially, the JTS decided not to add TXA to resuscitation guidelines because of questions about the applicability of the CRASH-2 study results to combat injuries. However, the Military Application of Tranexamic Acid for Trauma Emergency Resuscitation (MATTERs) study, a retrospective observational cohort study, demonstrated an association between TXA use and improved mortality outcomes in patients treated in deployed U.K.–U.S. MTFs (Morrison et al., 2012). Based on these research data, TXA was added to the Central Command (CENTCOM) formulary, and a recommendation for its use was added to the JTS Damage Control Resuscitation CPG in 2011, even though it has not been approved by the FDA for the treatment of hemorrhage.[3] Because of continued concerns regarding potential adverse effects of TXA (e.g., thromboembolic events), its use and the associated risk of complications remain closely monitored through JTS performance improvement processes. DoD has funded several prospective randomized controlled trials of TXA that are currently under way at civilian trauma centers across the United States.

Overall, the recognition of DCBI, the work of the DCBI task force, and related research and development efforts have had a major impact on DoD medical doctrine, training, and materiel. Similar research, development, and education efforts were undertaken by the U.K. military, deepening already significant collaboration between the U.S. and U.K. military medical communities.

Transfer of Knowledge Between Military and Civilian Sectors

Although injury patterns like those associated with DCBI are rare in the civilian sector, valuable concepts from the battlefield warrant transfer to nonmilitary settings. For example, lessons learned related to massive hemorrhage control, including hemorrhage control and transfusion practices, have applicability to other types of injuries more commonly encountered in the United States.

As described above, bidirectional translation of knowledge between the military and civilian sectors and collaborative clinical investigations have been paramount in ongoing efforts to determine the safety and efficacy of TXA for treatment of hemorrhage. Damage control resuscitation more generally represents a notable example of successful translation of military experience to the civilian sector. Early in the wars, the military approach to resuscitation was based on civilian Advanced Trauma Life Support practices for care of acute trauma, but the opportunity to observe a high number of severe traumatic injuries requiring massive transfusion over a

[3] TXA is FDA-approved for prevention or reduction of bleeding during dental procedures for patients with hemophilia and for control of heavy menstrual cyclic bleeding.

short period of time quickly led to the development and adoption of an alternative approach. In response to observations of worsening acidosis and coagulopathy attributed in part to dilution of hemostatic factors following administration of crystalloid and colloid, DoD resuscitative measures evolved to include early resuscitation with blood products (plasma and red blood cells) at a 1:1 or 1:2 ratio (Holcomb et al., 2007). A retrospective study using data from the Joint Theater Trauma Registry showed improved survival associated with use of a 1:1 plasma to red blood cell ratio during massive transfusion (Borgman et al., 2007). Subsequently, inclusion of platelets in massive transfusion was shown to be associated with improved survival, prompting adoption of the 1:1:1 red blood cells:plasma:platelets ratio (Perkins et al., 2009). Massive transfusion practices developed empirically in theater were later validated in large-scale clinical trials conducted in collaboration with the civilian sector. The 2013 PRospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) prospective cohort study (Holcomb et al., 2013) and the 2015 Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) randomized controlled trial (Holcomb et al., 2015) provided strong, high-quality evidence for early, balanced massive transfusion ratios.

Military damage control resuscitation practices have since been widely adopted in the civilian sector. In a national survey of trauma medical directors, 67 percent of respondents reported use of a 1:1:1 ratio of red blood cells:plasma:platelets in massive transfusions (Haider et al., 2015). Additional survey data led researchers to conclude that exposure to providers previously affiliated with the military and demonstrated benefits reported in the civilian literature contributed to civilian uptake of the military damage control resuscitation practices.

DCBI results in massive wounds and hemorrhage in the groin and perineum that are difficult to manage with pressure alone. Hemostatic gauze dressings impregnated with kaolin, chitosan, or zeolite have been used successfully on the battlefield to help control bleeding. These hemostatic adjuncts have proven effective and safe in civilian environments as well.

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SEVERE TRAUMATIC BRAIN INJURY CASE

Case Description

A 29-year-old male service member suffered a gunshot wound to the head while on patrol. In the field, he was noted to have strong carotid pulses, a heart rate (HR) of 130 beats per minute (bpm), and a respiratory rate (RR) of 75 breaths per minute. He was unresponsive and exhibited decorticate posturing.

Role 1 Care

In the field, a cricothyroidotomy was performed, and a surgical airway was placed. The patient was also wrapped in a hypothermia prevention blanket.

Tactical Evacuation

The patient was evacuated within 5 minutes of the request for evacuation. Transport to a Role 3 MTF required an hour, and on arrival the flight medics noted the following vital signs: blood pressure (BP) 80 mmHg (systolic only), HR 135 bpm, RR 30, Glasgow coma score (GCS) 3, oxygen saturation (SpO_2) 95 percent. Both pupils were reactive; the right pupil measured 3 mm and the left pupil 4 mm. The patient had significant bleeding from his head wound, leading to concern about hypovolemia and shock. Hypertonic saline was administered, and he was transfused 2 units of red blood cells en route. He continued to exhibit decorticate posturing. Ventilation was maintained by bag-valve-mask, and SpO_2 was sustained at 100 percent.

Role 3 Care

Upon the patient's arrival at the Role 3 MTF, a CT scan revealed the gunshot wound to the vertex of the skull with displacement of multiple bone fragments (see Figures A-8 and A-9). The patient showed diffuse cerebral edema, intraparenchymal hematoma, subarachnoid hemorrhage, subdural hemorrhage, and epidural hemorrhage at the vertex in association with disruption of the middle third of the superior sagittal sinus. He was urgently taken to the operating room for decompressive hemicraniectomy, evacuation of subdural hematoma, and placement of a right-sided external ventricular drain (EVD). The 7.5F field cricothyroidotomy tube was replaced by an 8.0F tracheostomy. The patient was administered thyroxin on a standard T4 protocol, as well as 3 percent sodium chloride (NaCl).

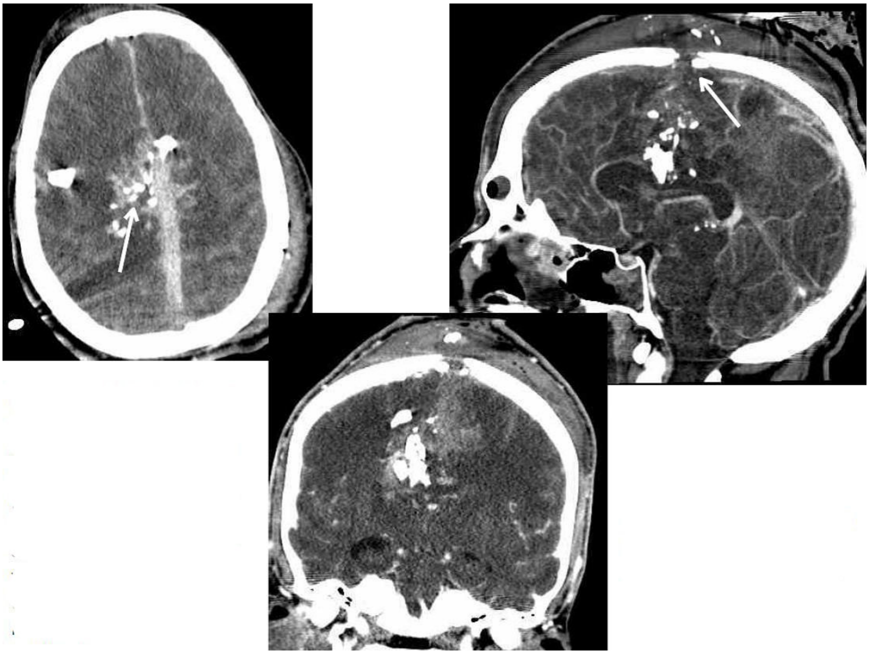

FIGURE A-8 Axial (left) and coronal (center) images demonstrate the displaced skull fragments within the brain parenchyma and adjacent hemorrhage. Low attenuation (R>L) is consistent with edema. Adjacent extraparenchymal hemorrhage is present as well. A post-contrast sagittal image (right) demonstrates a defect in the superior sagittal sinus (arrow) consistent with laceration adjacent to the skull defect with displaced fragments.

A second EVD was placed on the left side to control increased intracranial pressure measurement of 23 cm H_2O resulting from bifrontal cerebral hemorrhaging. Following this intervention, intracranial pressure improved to 8-10 cm H_2O, and the patient had a cerebral perfusion pressure of 60 mmHg. Tranexamic acid (TXA) was also infused in an effort to control bleeding. Ultimately, the patient's GCS improved to 7T, with a motor score of 4. He underwent bronchoscopy to evaluate the effects of the surgical airway procedures and was found to have no evidence of tracheal injury.

Evacuation Out of Theater

The patient was transferred out of theater on post-injury day 1 via the critical care air transport team. Cerebral protective strategies were maintained throughout transport. Sedation was increased prior to transport,

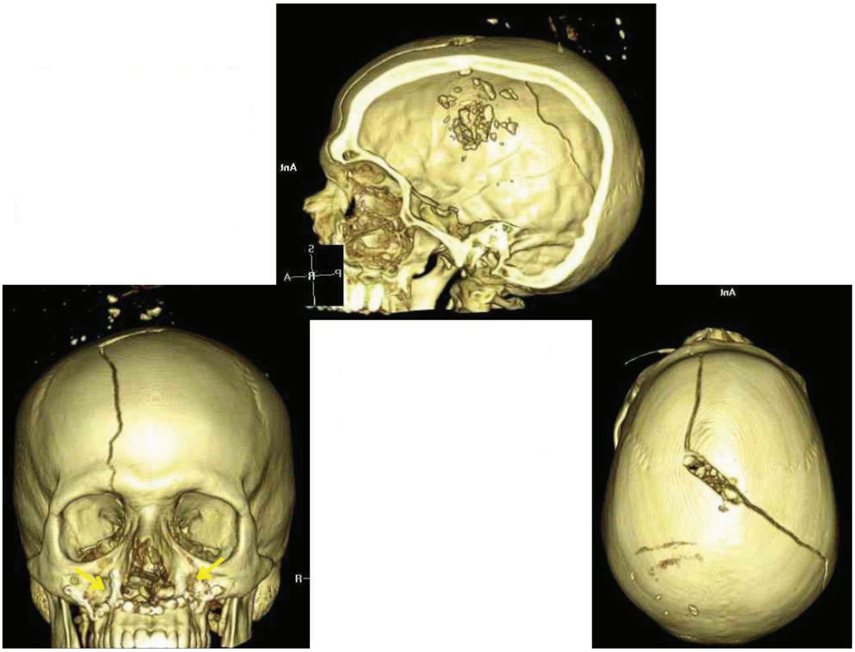

FIGURE A-9 3-D image (left) frontal view shows extension of fracture anteriorly to right orbit. Note metallic hardware from prior jaw surgery at maxilla (arrow). 3-D image cut-away view (center) shows intracranial calvarial fragments and 3-D image looking down (right) shows tangential nature of impact. No intracranial metal fragments were seen.

resulting in a drop in GCS from 6T to 3T. In flight, cerebral perfusion pressure was maintained at greater than 60 mmHg with low-dose vasopressors, and intracranial pressure was maintained at less than 20 mmHg. The patient was transfused 2 units of red blood cells and a 300-mL bolus of normal saline. His hemoglobin increased from 8.2 to 9.2 g/dL. Upon arrival at Landstuhl Regional Medical Center in Germany, his GCS returned to 6T.

Role 4 Care

Upon arrival at Landstuhl, the patient was rapidly weaned off vasopressors and was evaluated by a neurosurgeon. His GCS was initially 5T, with intracranial pressure less than 20 cm H_2O, and his brain stem reflexes were intact. A repeat CT scan revealed intraventricular and large intraparenchymal hemorrhages (see Figure A-10). His intracranial pressure gradually increased to greater than 20 mmHg, and he was taken back to the operating room for evacuation of hematomas and drain placement.

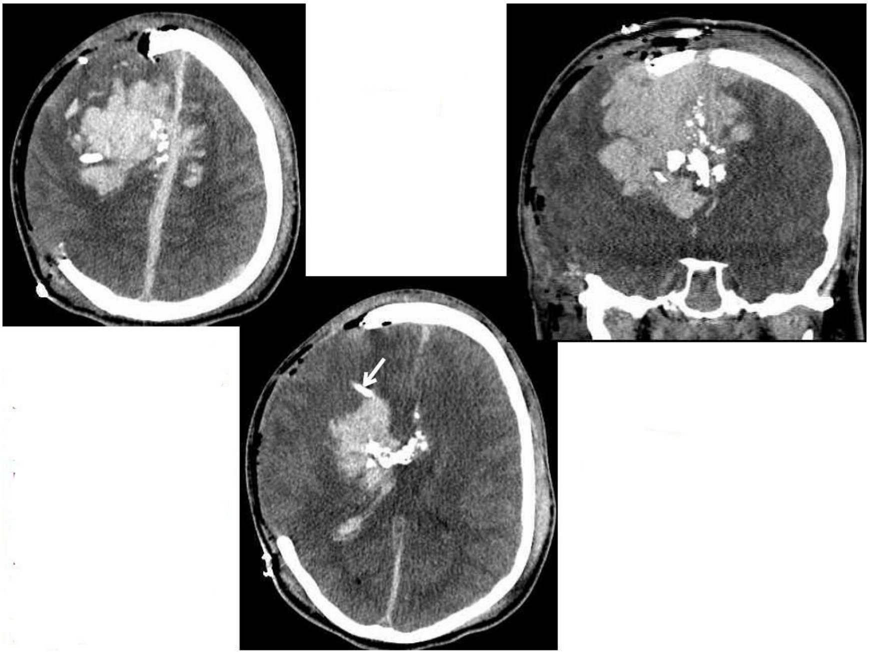

FIGURE A-10 Post-decompressive craniectomy changes are depicted. Axial CT images left and center demonstrate the skull defect and increased intraparenchymal hematoma (R>>L). Note ventriculostomy catheter (arrow) with adjacent blood in the lateral ventricle. There is also a subdural hematoma along the falx. Coronal image (right) demonstrates similar findings. Numerous calvarial fragments remain.

Following surgery, his intracranial pressure improved, and enteral feeding and prophylaxis for deep venous thrombosis were initiated. He was evacuated to the United States with a GCS of 4T.

Role 5 Care

On arrival in the United States, the patient was hemodynamically stable but febrile. The infectious diseases service was consulted and confirmed a diagnosis of right lower lobe pneumonia. The patient was administered antibiotics and antifungals, resulting in resolution of the pneumonia. His brain edema gradually resolved, and his GCS increased to 5T with a normal intracranial pressure. He was transitioned to Emerging Consciousness Rehabilitation after the ventriculostomies were removed on post-injury day 35. There, early rehabilitation was initiated with a multidisciplinary team specializing in this type of care. Long-term follow-up demonstrated the patient's dramatically improved mental status. He can communicate reliably and is fully oriented. However, he does exhibit several cognitive deficits, such as reduced attention span, reduced visual-spatial skills, and left-sided neglect, as well as some memory impairment. His physical status also has improved; he is able to use his right upper extremity and has modest antigravity strength in his right lower extremity. He has severe impairment of his left upper and lower extremities due to the site of his brain injury. He tolerates sitting for greater than 4 hours per day and can stand for 40 minutes at a time. His tracheostomy was removed, and he can eat a regular diet.

Case Discussion

Care for severe traumatic brain injury (TBI) fundamentally involves maintaining perfusion of the brain with oxygenated blood. This treatment applies whether the patient is injured on a highway in the United States or on a dismounted patrol in Afghanistan. In this case, the actions taken by the medic in the field to prevent hypoxia and secondary brain injury, prompt evacuation of the patient to a Role 3 MTF, rapid resuscitation to restore cerebral perfusion and ensure oxygenation, damage control resuscitation, aggressive neurosurgical interventions, and early multidisciplinary rehabilitation (Nakase-Richardson et al., 2013) all contributed to the successful outcome for this patient despite the challenges of caring for severe TBI cases in a remote, austere environment.

This case demonstrates how providing a more advanced resuscitative capability closer to the point of injury might improve outcomes in severe TBI. Hypoxia has been shown to be associated with poor outcomes for TBI in both the military and civilian literature (Badjatia et al., 2008). This patient immediately received measures to control his airway to ensure oxygenation. The cricothyroidotomy was an essential prehospital task performed by the field medic, especially in light of the anticipated transport, and indicates a high level of medic training. Administration of 3 percent saline by pre-MTF providers was introduced to the TCCC guidelines at the start of the recent conflicts; however, neuroprotective measures were not mentioned in the original TCCC article in 1996. Another example of increased capability for pre-MTF providers in the updated TCCC guidelines is the guidance to administer TXA.

This case also illustrates the military's highly aggressive approach to managing service members with severe TBI. Cerebral resuscitation began during the tactical evacuation. The patient presented with hypotension, a neurologic emergency in the context of severe TBI (Badjatia et al., 2008). Administering blood products and hyperosmolar therapy and ensuring adequate oxygenation were essential in anticipation of the 1-hour transport time to surgical intervention (Brain Trauma Foundation et al., 2007). In the Role 3 MTF, the patient underwent prompt surgery for hematoma evacuation, decompressive craniectomy, and EVD placement to control intracranial pressure. These interventions accord with the JTS Management of Severe Brain Trauma CPG (JTS, 2014) and Brain Trauma Foundation guidelines (Brain Trauma Foundation et al., 2007).

The Military Learning Process

Retrospective studies using DoDTR data have informed changes in military trauma care practices, codified through the JTS CPGs. DoD clinical investigators may submit queries to the JTS Data Analysis Branch if they wish to receive information from the DoDTR. A clinical investigator's proposal is reviewed by his or her local regulatory group to determine whether the investigation is research or a performance improvement effort. If the clinical investigation is deemed research, a formal institutional review board review must be conducted.

While initially drawing heavily on civilian sector best practice guidelines for care of brain trauma (e.g., Brain Trauma Foundation guidelines), the JTS CPGs evolved as data showing the benefit of aggressive neurosurgical intervention and critical care management accumulated (DuBose et al., 2011). For example, a large retrospective analysis of Joint Theater Trauma Registry (JTTR)[4] data for patients with severe TBI led to recommendations for early hemicraniectomy as part of damage control in anticipation of overseas transport (Bell et al., 2010). (The JTS CPGs relevant to severe TBI are listed in Box A-4.)

Another important intervention discussed in this case—the use of a hypothermia prevention blanket—represents an intervention implemented after review of JTTR data indicated worse outcomes in hypothermic TBI patients (Arthurs et al., 2006). Hypothermia is a major concern in the management of trauma patients, largely because of the impact of hypothermia on traumatic coagulopathy (Morrison et al., 2013). In 2006, the JTS released a CPG on hypothermia prevention, monitoring, and management, resulting in a significant reduction in hypothermia incidence (Nesbitt et al., 2010; Palm et al., 2012).

Transfer of Knowledge Between Military and Civilian Sectors

In contrast to previous conflicts, in which patients with severe TBI would have been treated as expectant, deployed medical providers in Afghanistan and Iraq adopted a highly aggressive posture in managing service

[4] The JTTR was the precursor of the DoDTR.

Box A-4 JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINES RELEVANT TO SEVERE TRAUMATIC BRAIN INJURY

- Acoustic Trauma and Hearing Loss
- Battle/Non-Battle Injury Documentation Resuscitation Record
- Damage Control Resuscitation
- Hypothermia Prevention
- Infection Control
- Intratheater Transfer and Transport
- Management of Pain, Anxiety, and Delirium
- Management of Severe Head Injury
- Neurosurgical Management
- Management of War Wounds
- Nutrition
- Prehospital Care (Tactical Combat Casualty Care guidelines)
- Prevention of Deep Venous Thrombosis
- Trauma Airway Management
- Trauma Anesthesia

SOURCE: http://www.usaisr.amedd.army.mil/cpgs.html (accessed August 10, 2016).

members with these injuries (Bell et al., 2010). This approach has been supported by patient outcome data. With respect to short-term outcomes, 32 percent of casualties with an admission GCS of 3 to 5 progressed to functional independence (Weisbrod et al., 2012). Colleagues at Department of Veterans Affairs rehabilitation centers reported that most patients (64 percent) enrolled in a disorders-of-consciousness program emerged to regain consciousness during rehabilitation (Nakase-Richardson et al., 2013). Despite these encouraging outcome data, however, neurosurgical interventions for severe TBI are controversial in the civilian sector.

A study of severe TBI published in 2011 revealed that mortality outcomes in military patients compared favorably with those in the civilian population (DuBose et al., 2011). In this study, military TBI patients in the DoDTR meeting inclusion criteria were propensity matched to similar patients from the National Trauma Data Bank (DuBose et al., 2011). Military patients were much more likely to undergo any operative intervention (21.5 percent versus 7.2 percent in the civilian population) such as invasive intracranial pressure monitoring, craniectomy, or craniotomy. The overall mortality rate was approximately 3 times lower for military patients relative to their civilian counterparts (7.7 percent versus 21.0 percent). The difference in mortality outcomes was even more striking when the analysis was restricted to penetrating brain injury (5.6 percent and 47.9 percent for military and civilian patients, respectively). This differential is surprising in light of the complex patient movements required for care of combat casualties with these severe injuries, and indicates that the civilian sector may benefit from evaluating and, as appropriate, adopting military approaches to the care of severe TBI. Currently, it is impossible to identify any one factor that may account for this differential, and there are significant differences in military and civilian settings (e.g., destructive force of weaponry, personal protective gear) that need to be considered. Prospective studies are needed to validate the application of aggressive TBI management practices in the civilian population and inform changes to civilian guidelines, such as those of the Brain Trauma Foundation and the Trauma Quality Improvement Program.

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B

Committee Collective Analysis of Case Studies

As highlighted throughout this report, analysis of the cases presented in Appendix A assisted the committee in identifying those factors that have supported and gaps that have impeded learning and continuous improvement in the military trauma care system. The incremental improvements in patient care and outcomes observed over the course of the conflicts in Afghanistan and Iraq were the result of a multitude of practices—many of which align with the components of a learning trauma care system (see Table B-1)—that include the implementation of lessons learned from previous conflicts and high-performing civilian trauma systems, digital data capture, performance improvement, requirements-driven research, and the dissemination of best practices.

One cross-cutting theme evident throughout the case studies is the extent to which the military's trauma care system adapted to the difficult conditions, austere environments, and high burden of injury that characterized U.S. engagement in the Middle East. This adaptation is exemplified by the military's use of focused empiricism as a nimble approach to evidence generation, particularly in those instances in which high-quality data were not available to inform clinical practice changes, including the development and refinement of clinical practice guidelines (CPGs). This approach is highlighted by the dismounted complex blast injury (DCBI) case. These devastating injuries—rarely seen in the civilian trauma experience—required innovation in the field and spurred the appointment of a task force to study the injury pattern's causation, prevention, protection, treatment, and long-term care options. The task force emphasized the importance and implementation of existing guidelines, including the prompt application of

TABLE B-1 Strengths and Gaps Demonstrated by the Case Studies, by Learning Trauma Care System Component

	CASE	
Learning Trauma Care System Component	**Extremity Hemorrhage**	**Blunt Trauma with Vascular Injury**
Digital Capture of the Trauma Patient Care Experience	Strength(s): Data captured in the Mortality Trauma Registry enabled preventable death studies. Gap(s): Patient data are fragmented across multiple systems.	Strength(s): The electronic medical record Theater Medical Data Store was developed. Gap(s): Bandwidth limitations impaired communication of patient data along the continuum of care.
Coordinated Performance Improvement and Research to Support Evidence-Based Trauma Care	Strength(s): Analyses confirmed improved outcomes with tourniquet use. Gap(s): N/A	Strength(s): Military research on vascular shunts has improved methods for treatment of vascular injuries on the battlefield. Gap(s): N/A
Processes and Tools for Timely Dissemination of Trauma Knowledge	Strength(s): Implementation of tourniquet use was encouraged via in-theater conferences, guidelines, training, e-mail, presentations, and publications. Gap(s): Translation to the civilian sector is lagging.	Strength(s): The CPG for complete fasciotomy was developed. Near-real-time feedback to field providers reduced incomplete fasciotomies. Gap(s): N/A

CASE		
Pediatric Burn	**Dismounted Complex Blast Injury**	**Severe Traumatic Brain Injury**
Strength(s): The Department of Defense Trauma Registry (DoDTR) is now a major resource for analysis of pediatric trauma during wartime and could be used to inform planning for future conflicts. Gap(s): Entry of pediatric data into the DoDTR was delayed.	Strength(s): Prehospital care data are captured in the Pre-Hospital Trauma Registry. Gap(s): Separate databases exist for prehospital and hospital care. There are no long-term functional recovery and quality-of-life data.	Strength(s): DoDTR data enabled comparison of outcomes with matched cases in the civilian National Trauma Data Bank (NTDB) to identify opportunities for knowledge translation. Gap(s): N/A
Strength(s): The Burn Resuscitation Decision Support System (BRDSS) was developed. Burn clinical practice guidelines (CPGs) were refined to include issues useful in management of pediatric burns. Gap(s): There has been very little research to provide high-quality evidence.	Strength(s): Registry analysis confirmed provider reports of an increase in injury frequency. The U.S. Food and Drug Administration (FDA) approved the junctional tourniquet. Research led to the addition of tranexamic acid to the Joint Trauma System (JTS) CPGs, and the JTS continuously monitors data for signs of adverse events. Gap(s): N/A	Strength(s): DoDTR data indicated poor outcomes with hypothermia. Traumatic brain injury (TBI) CPGs were refined as accumulated data and retrospective analysis showed benefit of an aggressive approach. Gap(s): Prospective research is needed to validate application to the civilian sector.
Strength(s): The BRDSS was approved by the FDA. Care was enhanced by the use of teleconsultation programs and a burn phone line. Gap(s): Communication about the existence of pediatric equipment and medication kit was lacking.	Strength(s): A new CPG on invasive fungal infection was developed. The CPG on damage control resuscitation was refined. Gap(s): N/A	Strength(s): Use of the JTS severe head injury guideline improved care for these injuries. Gap(s): N/A

continued

TABLE B-1 Continued

	CASE	
Learning Trauma Care System Component	**Extremity Hemorrhage**	**Blunt Trauma with Vascular Injury**
Systems for Ensuring an Expert Trauma Care Workforce	Strength(s): N/A Gap(s): Failure to train military personnel on tactical combat casualty care (TCCC) across DoD contributed to preventable deaths due to extremity hemorrhage.	Strength(s): N/A Gap(s): Training on extremity injuries was inadequate.
Patient-Centered Trauma Care	Strength(s): N/A Gap(s): N/A	Strength(s): N/A Gap(s): N/A
Transparency and Aligned Incentives for Quality Trauma Care	Strength(s): Feedback to Case 1's unit resulted in immediate training and equipping of unit with tourniquets. Gap(s): N/A	Strength(s): The weekly peer review teleconference provides for the exchange of knowledge and information. CPG compliance is reported. Gap(s): N/A
Leadership and a Culture of Learning[a]	Strength(s): N/A Gap(s): Line and medical leadership are not accountable for TCCC training and implementation.	Strength(s): N/A Gap(s): N/A

[a] One theme across the case studies is that leadership support and engagement are not necessarily featured as a critical aspect. The case studies demonstrate creative adaptation to challenging circumstances, but it appears that in general, leadership engagement to inculcate good practices and avoid bad practices is not evident.

tourniquets and packing to control blood loss, prevention of hypothermia, and prevention of coagulopathy by tranexamic acid administration and whole blood transfusion. A Joint Trauma System (JTS) CPG on invasive fungal infections (a complication associated with DCBI) was subsequently developed, with supporting evidence based on retrospective analysis of registry data. Similarly, JTS CPGs on burn care and severe traumatic brain injury (TBI) are based on registry data and retrospective analyses and, in the case of pediatric burn care, even "rules of thumb."

A crucial feature of focused empiricism is the continuous refinement and improvement of CPGs until high-quality data can be generated. Through

CASE

Pediatric Burn	Dismounted Complex Blast Injury	Severe Traumatic Brain Injury
Strength(s): The Joint Forces Combat Trauma Management Course was developed. Gap(s): Training does not provide expertise in burn or pediatric care.	Strength(s): N/A Gap(s): N/A	Strength(s): N/A Gap(s): N/A
Strength(s): N/A Gap(s): The military is unprepared for the pediatric patient population.	Strength(s): The DCBI Task Force report emphasizes patient-centered, holistic care that included spiritual and psychosocial aspects. Gap(s): N/A	Strength(s): Early multidisciplinary rehabilitation is provided to maximize functional recovery. Gap(s): N/A
Strength(s): N/A Gap(s): N/A	Strength(s): N/A Gap(s): N/A	Strength(s): N/A Gap(s): N/A
Strength(s): N/A Gap(s): N/A	Strength(s): N/A Gap(s): N/A	Strength(s): N/A Gap(s): N/A

its performance improvement program, the JTS collects data on and monitors the effects of focused empiricism-based interventions. As discussed in Chapter 4, however, a balanced approach to focused empiricism is essential. Hypothesis-driven research is a necessary complement to and check on evidence generated through experiential learning. The damage control resuscitation approach utilized in the DCBI case, for example, was continuously refined over time and later validated through prospective research undertaken with civilian collaborators. Similarly, although the use of tranexamic acid is included in military prehospital guidelines, the U.S. Department of Defense has funded several randomized controlled trials to study its role, efficacy, and safety given continued concern regarding its potential adverse effects. Other cases reveal gaps in knowledge and demonstrate the need for further research. The military's aggressive approach to severe TBI, for example, while developed through focused empiricism and associated with improved outcomes, requires prospective research to validate the application of military practices in the civilian sector.

Throughout these case studies, it is apparent that the military, building from its excellent systems for developing and refining CPGs, has utilized a variety of mechanisms to provide near-real-time access to knowledge of best trauma care practices. The weekly video teleconference, an e-mail-based teleconsultation program, and the Burn Resuscitation Decision Support System highlighted in the cases all facilitate learning and represent efforts to ensure that providers have the information needed to deliver the best care possible, particularly in circumstances in which predeployment training has failed to provide the necessary expertise (e.g., fasciotomy, pediatrics, burn care). At the same time, however, the committee notes limitations in training, equipment, and infrastructure necessary to support the timely dissemination of knowledge and widespread adoption of best practices. For example, the military currently has no system that enables trauma care providers to access data on their performance (e.g., CPG compliance) relative to that of their peers in near real time.

A lack of accountability contributed to many of the suboptimal outcomes presented in the case studies. The first soldier's death in the extremity hemorrhage case due to lack of tourniquet application was a seminal event and led to the recognition that deaths due to limb exsanguination were common, preventable, and unacceptable. At the time of this incident, however, tactical combat casualty care (TCCC) guidelines had already indicated that the use of tourniquets should be a priority, and the Pentagon had initiated efforts to equip every soldier with a tourniquet. Unfortunately, military line and medical leadership—particularly in the early years of the wars—did not embrace, incorporate, and hold its members accountable for TCCC practices. In an effort to provide some level of accountability, the military has developed the capacity to monitor compliance with many CPGs. The JTS weekly teleconference discussed in the blunt trauma with vascular injury case proved to be a highly effective way to provide feedback on CPG compliance. This represents progress; however, broader accountability and transparency are required.

The committee has identified patient-centered trauma care as one of the critical components of a learning trauma care system. The coordinated and comprehensive care received by the soldier in the DCBI case, including efforts to provide early pain control, reflects positively on the military and its progress in improving communication, patient transfers, and holistic care that includes psychological and spiritual support. Yet while ensuring seamless care across the trauma continuum is an important aspect of patient-centered trauma care, there are other areas in which the military has made less progress, such as consideration of special populations. This latter gap is particularly evident in the pediatric burn case. Despite a foreseeable need to provide pediatric care in wartime, the military was largely unprepared (in training and equipment) to care for injured children, who accounted for more than 10 percent of all bed days. Even after more than a decade of war, "military doctrine has still not evolved to ensure critical care availability for pediatric combat casualties."

Apparent in many of the cases is the critical importance of knowledge translation, both to and from the civilian sector. The Department of Defense Trauma Registry (DoDTR), modeled after the civilian-sector National Trauma Data Bank, has allowed the military to rapidly detect, analyze, and mitigate devastating injury patterns (e.g., DCBI). Data captured in the DoDTR support performance improvement initiatives, including the development of CPGs, and help identify priorities for clinical research (e.g., the development of a junctional tourniquet). The cases also highlight the extent to which trauma care in the civilian sector has advanced as a result of the translation of best practices and lessons learned from the military. A notable example is the civilian sector's widespread adoption of a 1:1:1 transfusion ratio, which mimics the military whole blood transfusion paradigm and has been shown to decrease trauma-induced coagulopathy, total blood use, and exsanguination. While the civilian sector's implementation of best practices regarding tourniquet use has lagged behind that of the military, the successful use of tourniquets on the battlefield has translated to their incorporation into civilian prehospital care. This was clearly evident in the aftermath of the Boston Marathon bombings, when tourniquets were applied to prevent deaths from isolated extremity hemorrhage.

In summary, the case studies offer insight as to how the military has dealt with the many challenges to trauma care faced on the battlefield, highlight opportunities for improvement, and support the committee's conclusion that the military and civilian trauma systems are symbiotic.

C

Military–Civilian Exchange of Knowledge and Practices in Trauma Care[1]

The exchange of knowledge and practices between the military and civilian sectors was seamless through World War II—civilian surgeons were activated for combat deployment and then returned to civilian practice with their lessons learned. Significant changes in military medical staffing over subsequent decades have led to an all-volunteer medical force with little trauma experience practicing largely in nontrauma hospitals. Because most deploying surgeons, allied medical specialists (e.g., in anesthesia, radiology, and emergency medicine), allied support specialists (e.g., blood bank, pharmacy, and administration personnel), nurses, and medics are not experts in trauma care and do not regularly practice in that field, brief predeployment training courses have minimal impact on their expertise. Postdeployment, they then return to the military sector, relatively isolated from the civilian trauma community. Furthermore, the episodic nature of military trauma care, with periods of intense action separated by many years, results in a "peacetime effect" in which the process of combat casualty care must be recreated almost from scratch every time combat operations escalate.

Because the civilian and military health systems are now largely segregated, scientific meetings and medical journals have become important

[1] This appendix is excerpted from a paper commissioned by the National Academies of Sciences, Engineering, and Medicine Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector, written by Jeremy W. Cannon, Perelman School of Medicine, University of Pennsylvania. The paper in its entirety is available on the study website at nationalacademies.org/TraumaCare.

venues for the exchange of knowledge and practices. However, it may be argued that although these exchanges are important and necessary, they are not sufficient. Attendance of civilian experts at military conferences is quite limited, and military members' attendance at civilian conferences is routinely threatened by various contingencies. Furthermore, dissemination of knowledge through the medical literature is notoriously slow, taking on average up to 17 years (IOM, 2001).

More optimal exchange of knowledge and practices occurs in select military treatment facility (MTF) trauma centers and integrated military–civilian training sites where regular interaction with civilian counterparts takes place. Over the past decade, first-hand interactions between military surgeons and civilian trauma and vascular experts through the Senior Visiting Surgeon (SVS) Program also demonstrated significant value for both the military and civilian communities, although the future of this program or its replacement remains unclear.

At present, the challenges to maintaining consistent practice in combat casualty care, gaining knowledge on the quality of care, and exchanging that knowledge with the civilian sector and vice versa are myriad. The vast complexity of the Military Health System (Schwab, 2015), along with frequent turnover at all levels, creates an inherently unstable system. This reality makes consistency in routine matters difficult, much less the preservation of lessons learned across decades of practice and multiple generations of military physicians. Furthermore, an artificial division exists in who is responsible for the care of patients prehospital and once they reach medical care. The military "line" (i.e., nonmedical forces) rather than the medical corps controls all aspects of the prehospital environment. The result has been significant barriers to collecting prehospital data and understanding the causes of prehospital deaths (i.e., killed in action). Finally, significant legal and policy limitations hinder the involvement of combat-experienced civilian physicians as trainers, educators, and advisors to the military (e.g., the Committee on Tactical Combat Casualty Care). All of these factors result in a highly volatile, internally fragmented system that is stovepiped from external influences and input. It is no wonder that the same mistakes are repeated and the case fatality rate rises significantly at the beginning of each war.

The infrastructure of the Joint Trauma System (JTS) (Bailey et al., 2012; Butler et al., 2015) and the pledge of partnership and collaboration between the American College of Surgeons and the Military Health System (ACS, 2014) represent ideal starting points for addressing the weaknesses identified above. These changes will doubtless benefit both combat casualties and injured civilians. Table C-1 details a number of recommended courses of action for addressing the weaknesses of the current system. The underlying premise behind these recommendations is that military–civilian exchange needs to begin at the earliest stages of medical education. Then in residency and during active practice, although civilian trauma care may be an imperfect training platform for military deployment (Smith and Hazen, 1991), immersion in this environment is far superior to no or very limited trauma care training and experience (Livingston et al., 2014; Sambasivan et al., 2010; Schreiber et al., 2008). This same conclusion was reached years ago by many U.S. allies, which routinely house deployment-eligible military medical units entirely in the reserves or on active duty embedded within high-volume civilian trauma centers (DuBose et al., 2012; Soffer and Klausner, 2012). The first step in this direction is to delineate the critical wartime specialties and the numbers needed in each specialty, and then to ensure that combat-designated military physicians, nurses, and medics are immersed in full-time trauma care either in an MTF trauma center or a high-volume, high-acuity civilian center (Schwab, 2015). Ideally, these personnel would work together as a unit and would also deploy as a unit for optimal effectiveness (Kellicut et al., 2014; Thorson et al., 2012). These units would then contribute lessons learned to the learning health system, which could be modeled after the Center for Army Lessons Learned (Dixon, 2011; USACAC, 2016). Review of these lessons learned and implementation of actionable change could then be effected through the JTS or a newly established military think tank under the auspices of Uniformed Services University of the Health Sciences or the Defense Health Agency (Eiseman and Chandler, 2005; Schwab, 2015).

TABLE C-1 Military–Civilian Exchange of Knowledge and Practices: Strengths, Weaknesses, and Opportunities

	STRENGTHS	WEAKNESSES
Undergraduate medical education—Uniformed Services University of the Health Sciences (USUHS)	• Early exposure to military medical history	• Limited exposure to civilian experts, which continues into residency (most USUHS graduates are obligated to undergo military residency)
Undergraduate medical education—Health Professions Scholarship Program (HPSP)	• Potential for exposure to national and international experts in multiple fields	• Students may attend any medical school regardless of the quality • Little to no exposure to military medical history • Required military rotations are not required to have readiness relevance
Undergraduate nursing education	• Exposure to civilian thought leaders and potential mentors	• No military medical curriculum
Military medic education and training	• Heavy emphasis on prehospital trauma stabilization	• Disconnect between scope of practice during deployment and in garrison • Little exposure to civilians in comparable positions • No requirement for patient contact prior to deployment
Residency/fellowship—military	• Exposure to staff with deployment experience • Education in readiness-relevant topics and Joint Trauma System (JTS) clinical practice guidelines (CPGs)	• No opportunity to deploy even for an elective rotation (some residents have completed Landstuhl Regional Medical Center [LRMC] rotations) • Low-volume/low-acuity training with some exceptions (e.g., San Antonio Military Medical Center [SAMMC] in Trauma+Surgical Critical Care) • Military regulations now limit meeting attendance
Residency/fellowship—civilian (sponsored or deferred)	• Potential for exposure to national and international experts • Trauma+Surgical Critical Care: exposure to critical clinical and systems-based practice concepts	• Little to no exposure to military physicians or military-specific topics

RECOMMENDATIONS
• Require a minimum of one civilian rotation for USUHS students in an approved specialty at approved locations
• Utilize the same standards as for the Yellow Ribbon undergraduate program (medical schools should actively compete for military scholarship students)[a] • HPSP students should learn military medical history (e.g., USUHS course) and should perform at least one deployment-relevant clinical rotation
• Develop a basic military nursing curriculum for the Reserve Officers' Training Corps (ROTC) and those seeking loan repayment
• Seek special training exemptions that allow medics to prepare in skills that are within their deployment scope of practice • Establish more civilian training sites for military medics • Require that medics perform and maintain hands-on patient skills
• Residents in combat-designated specialties should perform at least one rotation as a senior resident (scheduled during an elective block) in a forward location (Level III or IV facility) or military trauma center • Critically evaluate the case mix and volume in nontrauma military treatment facility (MTF) residency programs • Repeal the current restrictive policy to encourage military–civilian exchange at the resident-fellow level
• Residents in combat-designated specialties should perform at least one rotation as a senior resident (scheduled during an elective block) in a trauma MTF and another rotation in a forward location (Level III or IV facility)

continued

TABLE C-1 Continued

	STRENGTHS	WEAKNESSES
Military physicians in practice—nontrauma MTF		• Stovepiped from civilian physicians if at an MTF (except through off-duty employment [ODE]) • Little overlap between regular and deployed practice • Low-volume/low-acuity practice with little exposure to trauma • Lessons learned in combat are not disseminated to civilians • Military regulations now limit meeting attendance • Nursing readiness/trauma skills only episodically maintained
Military physicians in practice—trauma MTF	• Diverse exposure to high-acuity military and civilian trauma patients (SAMMC) • SAMMC: Co-located with the JTS and U.S. Army Institute of Surgical Research (USAISR) • Walter Reed National Military Medical Center (WRNMMC): Collocated with USUHS and Walter Reed Army Institute of Research (WRAIR) • Interaction with members of the American College of Surgeons Committee on Trauma (ACS COT) • Diverse research opportunities • Frequent civilian visiting professors • Emergency War Surgery Course (EWSC) and ACS-endorsed courses taught frequently	• Some do not permit care of civilian patients (WRNMC, LRMC) • Military regulations now limit meeting attendance • No incentive for combat-essential specialists to remain current in trauma
Military physicians in practice—civilian training center cadre	• Immersion in high-volume, high-acuity trauma practice with civilian experts • Robust experience for multiple specialties, nurses, and medics	• Cadre typically does not deploy • One site does not fully credential cadre (Army Trauma Training Center [ATTC]) • No external validation of training consistency and quality

RECOMMENDATIONS
• Combat-designated physicians, nurses, and medics should be assigned to trauma MTFs or to selected high-volume, high-acuity civilian trauma centers • Utilize the Center for Army Lessons Learned (CALL) (or comparable system) to capture and disseminate lessons learned to other military members and to the civilian sector • Repeal the current restrictive policy to encourage military–civilian exchange at the staff level
• Expand the Secretary of Army/Navy/Air Force programs to permit care of civilian trauma patients • Consider designating additional Army, Navy, and Air Force MTFs as trauma centers • Repeal the current restrictive policy to encourage military–civilian exchange at the staff level • Consider a "combat-designated" pay incentive
• Provide additional staffing to permit cadre to deploy • All sites should fully credential qualified staff surgeons • Institute reporting requirements and JTS verification reviews of training sites • Consider a "combat-designated" pay incentive

continued

TABLE C-1 Continued

	STRENGTHS	WEAKNESSES
National Guard/ Reserves	• Immersed in civilian practice which generally affords a robust and diverse clinical experience • Immediate translation of lessons learned back to the civilian sector • Deployment experience valuable for civilian disaster response	• Clinical practice experience can be variable and may not be combat-relevant
Predeployment training—civilian training sites	• High-quality educational offerings at all five sites • Deployment-experienced cadre	• Students are expected to be experts in trauma care at the end of 2–4 weeks • Very few deploying teams and physicians pass through any of these sites despite in-place requirements
ACS sponsored courses	• Many with readiness relevance • Military members have contributed modules	• Some are prohibitively expensive • Combat-relevant modules needed in some courses
Pre-deployment training—EWSC	• Most frequently taken predeployment course • Compact, high-yield course • Includes ACS-endorsed course material • Operational modules add relevance • Nurse education track in parallel	• Challenging to maintain standardized material with multiple sites offering and little administrative support • Students are expected to be experts in trauma care at the end of 3 days • Little to no civilian input aside from ACS-endorsed content
Senior Visiting Surgeon Program	• 192 trauma and vascular surgeons spent 2–4 weeks providing expert consultation and clinical coverage at LRMC or downrange • Many gave expert grand rounds lectures • Research mentorship for military surgeons	• Only selected trauma surgeons able to participate • No clear plan or directive for continuing this program
Professional societies and conferences—civilian	• Many have provided robust military support • Some have military committees • New ACS–Military Health System (MHS) partnership promising for sustained military–civilian exchange	• Attendance has been curtailed by military regulations • Few have dedicated military sessions

RECOMMENDATIONS
• The JTS should validate the practice of the Guard and Reserve combat-designated specialists • Consider a "combat-designated" pay incentive
• Rotators should come through for refresher training with significant prior experience and expertise in trauma • In the reorganization, only combat-designated teams should pass through for a final "check ride"
• Liberalize staff:student ratio for experienced students (i.e., attending surgeons)—Advanced Trauma Operative Management (ATOM) • Encourage military members to develop modules
• Require that EWSC be kept current and that all sites use this version; provide additional administrative support • Students should come through for refresher training with significant prior experience and expertise in trauma • Seek civilian consultants to contribute to EWSC content
• Make participation in this program a competitive application reviewed by the JTS, ACS, American Association for the Surgery of Trauma (AAST), and Society for Vascular Surgery • Continue the program in some form negotiated among all stakeholders
• Repeal the current restrictive policy to encourage military–civilian exchange at the staff level • Advocate for dedicated military sessions • Include military members in society leadership and governance

continued

TABLE C-1 Continued

	STRENGTHS	WEAKNESSES
Professional societies and conferences—military	• Important forum for dissemination of military research results to other military centers	• Few civilian attendees • Research quality is variable • The Association of Military Surgeons of the United States (AMSUS) currently places little emphasis on deployment medicine
Professional journals	• Military supplements in *Journal of Trauma and Acute Care Surgery* and *Shock* • These are high-impact articles • New technology makes these references readily available	• No military editors in top journals • Historically difficult to access or ignored • Difficult to determine which recommendations represent standard practice
Research funding and protocols	• Military funds significant numbers of trauma-specific research protocols (gap-driven) • USAISR and WRAIR have both military and civilian research personnel	• Intramural protocols typically have mostly or only military investigators • Extramural protocols typically have mostly or only civilian investigators • Imbalance between burden of disease and available funds in both the National Institutes of Health (NIH) and U.S. Department of Defense (DoD) research budgets
JTS CPGs	• Repository of most current best practices in military trauma care • Housed and updated by the JTS	• Some relevant topics not covered • CPG development does not adhere to systematic review standards • Little to no external validation or civilian review/input
Recently separated or retired military physicians, nurses, and medics	• Wealth of knowledge and experience • Many go on to serve as civilians in MTFs or U.S. Department of Veterans Affairs Medical Centers (VAMCs)	• No mechanism for formally interfacing with military personnel who are facing deployment

[a] Information on the Yellow Ribbon Program is available from http://www.benefits.va.gov/gibill/yellow_ribbon/yellow_ribbon_info_schools.asp (accessed May 23, 2016).

RECOMMENDATIONS
• Improve conference quality to attract civilian attendees • Include civilians in society leadership and governance • Be more selective in abstract acceptance • Add a readiness element to AMSUS
• Encourage military associate editorial positions • Look to CPGs for clarification
• Require military and civilian investigators on all DoD-funded grants • Promote increased federal and private funding for injury-related research
• Conduct regular CPG reviews using the Delphi method involving both military and civilian experts • Consider adding systematic review experts to the JTS staff • Require that each CPG have at least one civilian reviewer
• Establish a formal mechanism for physicians, nurses, and medics who have valuable wartime skills and experience to interface with the next generation of deploying medical professionals • Create means for deployed team members to seek advice or consultation from combat-experienced individuals who are no longer in the military

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D

Military and Civilian Trauma Care in the Context of a Continuously Learning Health System[1]

The Institute of Medicine (IOM) has categorized the characteristics of a continuously learning health system into four major groups: (1) science and informatics (real-time access to knowledge, digital capture of the care experience); (2) patient–clinician partnerships (engaged, empowered patients); (3) incentives (incentives aligned for value, full transparency); and (4) continuous learning culture (leadership-instilled culture of learning, supportive system competencies) (IOM, 2013). Benefits resulting from these characteristics include improvement of clinical decision making, improvement of health care safety and quality, real-time generation and application of knowledge for health care improvement, health care anchored in patient needs, teamwork and collaboration in support of continuous learning as a core aim, systems analysis and information development, and the creation of feedback loops for system and performance improvement. Table D-1 denotes to what degree these characteristics have been integrated into current trauma care systems, with specific comparison of the military versus civilian systems. Although pockets of excellence can be identified,

[1] The analysis in this appendix was excerpted from a report commissioned by the National Academies of Sciences, Engineering, and Medicine Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector, written by Elliott R. Haut, Johns Hopkins University School of Medicine and the Johns Hopkins Bloomberg School of Public Health; N. Clay Mann, University of Utah School of Medicine; and COL (ret) Russ S. Kotwal, Uniformed Services University of the Health Sciences and Texas A&M Health Science Center. The paper in its entirety is available on the study website at nationalacademies.org/TraumaCare.

TABLE D-1 Characteristics of a Continuously Learning Health System: Military Versus Civilian Trauma Systems

STATUS **1** Functional **2** Progressing **3** No Progress

BARRIERS TO IMPLEMENTATION

A Absent (No Barriers) **B** Budgetary (Lack of Priority and/or Financial Restraints) **C** Confidentiality (Policy, Regulations, and Concerns for Patient Privacy, and/or Operational Security) **D** Decision Making (Lack of Leadership, Decision Making, Mandate, Policy, and/or Culture)

			Science and Informatics			
			Real-time access to knowledge		Digital capture of the care experience	
	MILITARY	CIVILIAN	MIL	CIV	MIL	CIV
Prehospital	Role 1, nonmedic first responder, medic	Layperson	2BCD	3CD	3BCD	3BCD
En Route 1	PH-Hosp, CASEVAC, MEDEVAC, medic	First responder EMT, paramedic	2BCD	2CD	3BCD	1D
Hospital (Initial)	Role 2, FST, small	Lower level, nontrauma center	2BD	2BCD	3BCD	2BD
En Route 2	Hosp-Hosp, Intratheater (medic and nurse)	N/A	2BD	N/A	3BCD	N/A
Hospital (Intermediate)	Role 3, area support, large	N/A	1D	N/A	2D	N/A
En Route 3 and En Route 4	Hosp-Hosp, Role 3 to 4, Role 4 to 4, Intertheater, AE, CCATT (ICU physician, ICU nurse, respiratory therapist)	Hosp-Hosp (paramedic and/or nurse)	1D	1BD	2D	2D
Hospital (Final)	Role 4, regional, large, referral center	Trauma referral center	1D	1BD	1D	2D
Postdischarge	VA, rehab. facility (inpatient, outpatient)	Inpatient and outpatient rehab.	2CD	2D	3CD	2BD

NOTES: Notable for both military and civilian systems is that on each characteristic of a learning health system, no entity of care is currently functional and without barriers ("1A"), 100 percent have a decision making barrier ("D"), 56 percent have a confidentiality barrier ("C"), and 55 percent have a budgetary barrier ("B").

Patient–Clinician Partnerships		Incentives				Continuous Learning Culture			
Engaged, empowered patients		Incentives aligned for value		Full transparency		Leadership-instilled culture of learning		Supportive system competencies	
MIL	CIV	MIL	CIV	MIL	CIV	MIL	CIV	MIL	CIV
3BD	3D	2CD	3D	3BCD	3CD	2BCD	3BCD	3BCD	2BD
3BCD	2D	2CD	1D	3BCD	2CD	2BCD	2BCD	3BCD	2BD
3CD	2D	2CD	2BD	3BCD	1BD	2BCD	2BCD	3BCD	2BD
2BD	NA	2CD	NA	3BCD	NA	2BCD	NA	3BCD	NA
1CD	NA	1D	NA	3BCD	NA	2BD	NA	2BCD	NA
1CD	2D	1D	1D	3BCD	2BD	2BD	2BCD	2BCD	2BD
1CD	2D	1D	1D	3BCD	2BD	2BD	1CD	2BCD	2D
2CD	2D	3CD	2CD	3BCD	2CD	3BCD	2BCD	3BCD	2BD

AE = aeromedical evacuation; CASEVAC = casualty evacuation; CCATT = critical care air transport team; CIV = civilian; EMT = emergency medical technician; FST = forward surgical team; ICU = intensive care unit; MEDEVAC = medical evacuation; MIL = military; N/A = not applicable; VA = U.S. Department of Veterans Affairs.

both systems have characteristics that can be improved and barriers to be removed, particularly in the realm of decision making and leadership. Notable for both systems is that on each characteristic of a learning health system, no entity of care is currently functional and without barriers ("1A"); all have a decision-making barrier ("D"); 56 percent have a confidentiality barrier ("C"); and 55 percent have a budgetary barrier ("B").

In the area of **science and informatics,** the barrier is not technology. The advanced interconnectivity of computers and mobile devices (e.g., iPhones) is remarkable. In fact, many people have better, more seamless transitions (i.e., cloud-based sharing of files, contacts, photos, etc.) in their personal lives than in the health care information technology world. Robust systems exist for both real-time data access and digital capture of health care, which have been implemented successfully by some. However, the use of technology has yet to be maximized and globally integrated into trauma system practices.

Specifically, on the civilian side, the National Emergency Medical Services Information System project ensures the standardization and exportability of out-of-hospital patient care information among all health care systems in U.S. states. Nevertheless, existing health information exchanges have few federal or state incentives to integrate emergency medical services (EMS) data into electronic health records. Some EMS agencies have Global Positioning System (GPS)-enabled tablet computers in the back of ambulances capturing time-stamped vital signs and procedures. However, when EMS providers arrive at a trauma center, they cannot download the computer-generated documentation directly into the hospital electronic medical record or trauma registry. They may need to print their data to be scanned into a nonsearchable medical record days later, only to be reabstracted by hand by a trauma registrar, losing data fidelity and not giving the trauma team immediate access to the information. Similarly, the nearly ubiquitous use of the National Trauma Data Standard in acute care hospital-based trauma registries and adoption of Trauma Quality Improvement Program performance measures and monitoring greatly enhance standardization of care decisions and benchmarking of performance metrics. However, the interoperability of these products with other phases of care and health care exchanges remains limited.

Some electronic medical records allow storage of images (i.e., photographs of traumatic wounds, operative procedures). Yet many have not been enabled because of lack of leadership understanding of the importance of these visual data and greater priority of concerns about possible regulatory and Health Insurance Portability and Accountability Act violations. Privacy concerns have been raised, especially as leaked photos of high-profile cases have appeared on social media sites. Yet the informal workarounds used (e.g., residents taking photos and text messaging or e-mailing attending physicians) likely put confidentiality more at risk than if leaders would acknowledge that this occurs and enable a more controlled approach to optimizing image sharing. Some studies of specific integrated computerized clinical decision support tools have shown that they dramatically improve care, but they have been used only sporadically.

On the military side, there are real concerns about operational security as technology can provide friendly force location, troop composition, and other detailed information to enemy forces or others who would do harm. Although secure systems have been developed and are in use, interfacing classified and unclassified data systems requires leaders who realize that performance improvement must be accomplished regardless of the classification and where data reside. Unclassified data residing on classified systems can be transferred to unclassified systems if appropriate measures and approval are obtained. Although classified data residing on classified systems cannot be transferred to unclassified systems, unclassified data on unclassified systems can be transferred to classified systems for integrated analysis with classified data. Although active mission details and information on trauma training programs and personal protective equipment must be safeguarded so as not to provide enemy forces with friendly force vulnerabilities, these data can still be analyzed and published on classified systems in near real time for performance improvement and to inform leaders. Additionally, when some unclassified data are being aggregated, these data can become classified and should then be transferred to classified systems.

Patient–clinician partnerships are critical to ensure that care remains focused on the factors that patients value. The concept of patient-centered care is not new, but it is receiving more attention, especially with the creation of the Patient-Centered Outcomes Research Institute. In some areas of trauma care, patients are routinely and heavily engaged and drive decision making. For example, patient advocacy groups have been instrumental in improving long-term care for trauma patients with spinal cord injury, traumatic brain injury, and amputations. These groups, many of which focus on military injuries, raise awareness and funds while helping give patients a voice to let their preferences be known. Collaborative projects between researchers and patient stakeholders provide usable data, allowing patients to make informed decisions about their medical care. For example, amputation decisions may be informed by prospective observational studies that have shown differences in long-term functional outcomes when comparing amputation versus limb salvage for patients with severe lower extremity trauma in both the civilian (Bosse et al., 2002) and military (Doukas et al., 2013) settings. Yet in other areas, patients are less empowered to change trauma care delivery, and decisions are made with little to no patient input.

The major barrier to improved patient-centered care falls under the category of decision making. The issue is not one of mandate or policy; it is primarily a lack of leadership from medical professionals, who are often hesitant to change culture. Newer ideas, such as including family members in multidisciplinary rounds and engaging them to help with care (e.g., range-of-motion exercises, bathing) of intensive care unit (ICU) patients, are still uncomfortable for some physicians and nurses. However, early feedback suggests that families and patients end up with a better experience overall as a result of these practices and may have improved outcomes (Wyskiel et al., 2015a,b).

Incentives, especially those that are financial, are often not aligned to encourage continuous improvement within a learning health system. Although some changes in the forms of value-based purchasing and pay for performance are slowly occurring, the classic fee-for-service model is still the norm in much of the private sector. A major difference between trauma care in the civilian and military sectors is that the military basically has a single-payer system, covering all aspects of care for its covered population. This should, in theory, help align financial incentives across the continuum of care. However, an extremely large budget coupled with little financial accountability may also drive military health care spending, rather than pushing it to reduce waste and reward high-value care. Accordingly, barriers to progress in this area are somewhat financial, but are also driven by culture and lack of leadership. The aim of the Choosing Wisely campaign is to cut back on unnecessary medical testing and procedures (Morden et al., 2014), but the campaign's reception has been somewhat lukewarm as individual physicians often do not want their practice of the art of medicine to be dictated to them from external sources.

In a **continuous learning culture,** active monitoring of the quality and safety of health care is a major focus. The importance of data use in quality improvement work is discussed later, but must be mentioned here as there are numerous barriers to allowing this to occur in a useful manner. From a budgetary standpoint, financial incentives in this regard have been sorely lacking. Most hospitals expend considerably more resources on and have many more data analysts assigned to financial issues (e.g., supply chain, staffing) versus quality-of-care improvement initiatives, indicating their true prioritization. Some issues of confidentiality exist, especially when attempting to learn from individual patient harm. On the civilian side, hospital lawyers and risk management departments frequently fear financial and/or reputational losses and therefore do not allow examples of harm to be shared so others can learn and prevent errors from occurring again. To some degree, the military has been effective in overcoming this barrier by establishing and maintaining a Joint Trauma System weekly worldwide trauma teleconference that connects the entire continuum of the trauma system in order to critically review trauma care delivery for best practices as well as for performance improvement opportunities.

The most critical and ubiquitous barrier to a learning health system in both the military and civilian sectors relates to decision making. The trauma systems of both sectors lack the leadership necessary to promote and maximize learning from failures and mistakes, and push for changes in practice in order to prevent recurrences of errors. In the military, leaders are often comfortable promoting good news stories such as "highest combat casualty survival rate in history"; however, these same leaders are often reluctant to take it to the next level and be relentlessly dissatisfied with any degree of preventable morbidity and mortality. Additionally, as medical leaders do not own prehospital assets, and as nonmedical leaders who own prehospital assets are not held accountable for medical efforts, there is no true ownership of prehospital preventable morbidity and mortality, which is where most combat deaths occur (Butler et al., 2015; Eastridge et al., 2012; Kotwal et al., 2013; Mabry, 2015). There remains a pervasive cultural barrier to learning from mistakes in civilian medicine. In particular, a clearly defined hierarchy both within physician ranks (student, intern, resident, fellow, attending) and among professionals (medics, nurses, physician assistants, physicians) limits safety improvement in real time, as not all health care professionals feel comfortable speaking up, even when egregious errors are about to be made. The military hierarchy of rank exacerbates and complicates this concern.

Although the military and civilian levels of care do not always have direct analogues, the overall general structure of prehospital, in-hospital, and postdischarge care is similar. The nuances remain different at every level, but where similarities exist, there can be opportunities to share best practices and learn from one another. One major difference is the proportion of patients who undergo interhospital transfer. In combat theaters, the vast majority of injured military patients do not remain at the initial treating facility. Most undergo at least one and, more frequently, two interhospital transfers, often across thousands of miles and multiple continents. To achieve this medical transportation, the military has multiple modes of transport as well as various types of medical providers, depending on where the evacuation is occurring. In the prehospital realm of a combat zone, where personnel and transportation assets are subject to hazardous conditions, medical capabilities for casualty evacuation and medical evacuation have traditionally been more limited. However, recent data from the Afghanistan conflict have shown that increased medical capabilities on prehospital transport platforms, similar to the practice in the civilian sector, can improve morbidity and mortality on the battlefield (Kotwal et al., 2016; Mabry et al., 2012; Morrison et al., 2013). Rapid interfacility aeromedical transport out of a combat zone, with robust critical care air transport team en route capability (ICU physician, ICU nurse, and respiratory therapist), has proven effective (Ingalls et al., 2014). Additionally, interfacility transport between Role 4 hospitals (Outside Contiguous United States [OCONUS] to Contiguous United States [CONUS] or CONUS to CONUS) has proven beneficial from the standpoint of patient–clinician partnerships as family members have been afforded the opportunity to travel as attendants with their injured family members. Annex 4-1 at the end of Chapter 4 provides an example case of an injured military service member to illustrate the multiple transports as well as highlight the opportunity for better data use along the continuum of care.

In the civilian sector, the majority of injured patients remain at the first hospital to which they arrive. Some patients are transferred from the initial treating center for medical necessity (i.e., higher level of care and/or specialized services) or for social reasons to be closer to home/family if they were injured in a different state or region.

Differences also exist between the military and civilian trauma care systems in most other categories. One key difference is in the immediate first response to an injured patient. In the military setting, all personnel have received some degree of basic trauma training and tools (e.g., tourniquets, pressure dressings) to begin self- or buddy care. In the civilian sector, only a minority of the public truly understand initial trauma care, and rarely are they provided such tools. Emerging from the military's tactical combat casualty care guidelines, the 2015 "Stop the Bleed" campaign (http://www.dhs.gov/stopthebleed) recently began to address this concern. For trained prehospital providers, the military education system is focused primarily on traumatic injury care, environmental injury prevention and care, and care for common minor illnesses. In the civilian realm, emergency medical technicians and paramedics receive broader training that encompasses all aspects of care (e.g., cardiac arrest, obstetrical emergencies). While the equipment, personnel, staffing, and medical care available at the final destination hospital are comparable, there are likely dramatic differences in resources between military and civilian initial hospital care. A basic non-trauma center emergency department may likely have more physical capabilities (e.g., x-ray, computerized tomography (CT) scan) than a forward surgical team (FST) operating in a tent; however, it may lack immediate surgical response training as provided by the military. Arriving at an FST in a combat zone versus a small rural nontrauma hospital may prove advantageous for a casualty if the FST has been seeing patients routinely; however, this may not be the case if it has been a while since the FST has seen and treated a casualty.

While Table D-1 illustrates barriers with respect to characteristics of a continuously learning health system for both the military and civilian trauma systems, Box D-1 highlights specific military trauma system gaps or barriers in data collection, distribution, and use whose resolution could improve trauma care and patient outcomes.

Box D-1 SPECIFIC MILITARY TRAUMA SYSTEM GAPS OR BARRIERS IN DATA COLLECTION, DISTRIBUTION, AND USE

- Global mission with challenges including "tyranny of distance" results in limited or isolated facilities, long transports, and trauma care delivery and data collection in austere, hostile, and underresourced environments.
- U.S. Department of Defense (DoD) and theater trauma system and registry is not institutionalized. There is no permanent requirement and/or authorization document (table of distribution and allowances, modified table of organization and equipment, joint manning document). There are no permanent personnel and/or resources.
- Clinical practice guidelines must be tailored to mission; enemy actions and tactics; as well as multiple environments at sea, on land, and in the air.
- Data collection is suboptimal at prehospital Role 1: battalion aid stations, tactical combat casualty care (TCCC) (care under fire, tactical field care, tactical evacuation).
- Data collection is suboptimal at Role 2: forward surgical teams and intratheater interfacility transport.
- Combat prehospital structure is suboptimal. There is no overarching ownership or commander for prehospital medicine. There is a lack of prehospital experts and emergency medical services directors trained and assigned to tactical (prehospital) combat units; thus TCCC is inconsistently implemented as concepts are outside of their comfort zone, and training is provided through civilian-based residency programs.
- "Responsibility for battlefield care delivery is distributed to the point where seemingly no one 'owns' it. Unity of command is not established and thus no single senior military medical leader, directorate, division or command is uniquely focused on battlefield care, the quintessential mission of military medicine" (Mabry, 2015). Example of the adage: "When everyone is responsible, no one is responsible."
- Funding to study military trauma care is limited. Non-defense-related medical research has received more funding in DoD over the past decade than defense-related medical research. Among defense-related medical research, research and development efforts are focused primarily on materiel advances. Additionally, medical combat development efforts are focused on rearranging existing paradigms for doctrine, manpower, and equipment; this is in spite of the fact that training, leadership, and organization efforts have made the most significant documented improvements in survival (Kotwal et al., 2013; Mabry, 2015).
- Interwar mission and relevance of trauma care remain underappreciated. Trauma is the leading cause of death, even during times of relative peace. Trauma continues to occur from military aircraft and vehicle crashes, training for combat, and static-line and free-fall parachute incidents.
- Data integration and access are lacking among the Joint Trauma System, Joint Trauma Analysis and Prevention of Injuries in Combat, Armed Forces Medical Examiner System, safety center, and U.S. Department of Veterans Affairs.
- "Military Medicine" needs to be further developed and refined as a specialty or fellowship, with associated education and training goals and metrics.

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E

Public Committee Meeting Agendas

Held by the Committee on
Military Trauma Care's Learning Health System
and Its Translation to the Civilian Sector
(May 2015-February 2016)

MEETING ONE: May 18, 2015
National Academy of Sciences Building
2101 Constitution Ave. NW, Washington, DC 20418

Agenda

SESSION I: SPONSOR BRIEFING: DISCUSSION OF THE COMMITTEE'S CHARGE

10:15 a.m. Welcome and Introductions

DON BERWICK, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

10:30 a.m. Federal Perspectives on Charge to the Committee

COL TODD RASMUSSEN
Director, Combat Casualty Care Research Program
U.S. Army Medical Research and Materiel Command
U.S. Department of Defense

ARTHUR KELLERMAN
Dean, F. Edward Hébert School of Medicine
Uniformed Services University of the Health Sciences

KATHRYN BRINSFIELD
Assistant Secretary for Health Affairs and Chief Medical Officer
U.S. Department of Homeland Security

DREW DAWSON
Director of the Office of Emergency Medical Services
National Highway Traffic Safety Administration
U.S. Department of Transportation

11:30 a.m. Discussion with Committee

12:00 p.m. Professional Organization Perspectives on Charge to the Committee

DAVID HOYT (*by Teleconference*)
Executive Director
American College of Surgeons

M. MARGARET KNUDSON (*by Teleconference*)
Medical Director
American College of Surgeons Military Health System Strategic Partnership

CRAIG MANIFOLD
American College of Emergency Physicians

JULIO LAIRET
Government Services Chapter
American College of Emergency Physicians

ALLEN YEE
National Association of EMS Physicians

STEVEN MERCER
National Association of Emergency Medical Technicians

JOHN OSBORN
Trauma Center Association of America

12:50 p.m. Discussion with Committee

1:15 p.m. Lunch

SESSION II: ADDITIONAL CONTEXT FOR THE STUDY

2:00 p.m. White House Initiative on Bystander Interventions for Life-Threatening Traumatic Hemorrhage

RICHARD HUNT
Director for Medical Preparedness Policy
National Security Council Staff
The White House

2:15 p.m. Discussion with Committee

2:30 p.m. Overview of the U.S. Department of Defense Trauma System Elements

COL KIRBY GROSS
Director, Joint Trauma System
U.S. Department of Defense

DAVID BAER
Deputy Director
Combat Casualty Care Research Program
U.S. Army Medical Research and Materiel Command
U.S. Department of Defense

LTC ANDREW CAP
Chief, Blood Research
U.S. Army Institute of Surgical Research
U.S. Department of Defense

3:15 p.m.	Discussion with Committee
3:45 p.m.	Public Comment Period
4:00 p.m.	ADJOURN OPEN SESSION

MEETING TWO: July 23-24, 2015
National Academy of Sciences Building
2101 Constitution Ave. NW, Washington, DC 20418

Agenda

July 23, 2015

10:00 a.m. Welcome and Meeting Objectives

Don Berwick, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

SESSION I:
LEADERSHIP AND ACCOUNTABILITY

10:10 a.m. Military Sector Panel

RADM (ret) David Smith
Deputy Assistant Secretary of Defense for Health
Readiness Policy and Oversight
U.S. Department of Defense

Lt Gen Doug Robb
Director, Defense Health Agency
U.S. Department of Defense

10:30 a.m. Discussion with the Committee

11:15 a.m. Civilian Sector Panel

David Hoyt
Executive Director
American College of Surgeons

Paul Patrick
President, National Association of State EMS Officials
Deputy Division Director, Utah Department of Health
Division of Family Health and Preparedness

	LENWORTH JACOBS Director of Trauma and Emergency Medicine Vice President of Academic Affairs and Chief Academic Officer Hartford Hospital
	BRENDAN CARR Director, Emergency Care Coordination Center U.S. Department of Health and Human Services
12:00 p.m.	Discussion with the Committee
12:45 p.m.	Lunch

SESSION II:
TRAUMA DATA AND INFORMATION SYSTEMS

1:30 p.m.	Military Sector Panel
	MARY ANN SPOTT Deputy Director, Joint Trauma System U.S. Department of Defense
	COL (RET) BRIAN EASTRIDGE Professor of Surgery, Jocelyn and Joe Straus Endowed Chair in Trauma Research University of Texas Health Science Center
1:45 p.m.	Civilian Sector Panel
	AVERY NATHENS Director, Trauma Quality Improvement Program American College of Surgeons Chief of Surgery, Sunnybrook Health Sciences Centre
	MARK BARNES Partner Ropes and Gray, LLP
2:00 p.m.	Discussion with the Committee

SESSION III: CLINICAL GUIDELINE DEVELOPMENT

2:45 p.m. Military Sector Panel

CAPT Zsolt Stockinger
Director of Performance Improvement
Joint Trauma System
U.S. Department of Defense

CAPT (ret) Frank Butler
Chair, Committee on Tactical Combat Casualty Care
Director of Pre-Hospital Trauma Care
Joint Trauma System
U.S. Department of Defense

3:00 p.m. Civilian Sector Panel

Carolyn Clancy
Chief Medical Officer
U.S. Department of Veterans Affairs

Susan Kirsh
National Director
Clinic Practice Management for Clinical Operations and Access
U.S. Department of Veterans Affairs

Peter Taillac
Clinical Professor, Division of Emergency Medicine
University of Utah School of Medicine
Medical Director, Bureau of EMS and Preparedness,
Utah Department of Health
Colonel, Medical Corps
State Surgeon, Utah Army National Guard

David Callaway
Co-Director
Committee on Tactical Emergency Casualty Care
Associate Professor of Emergency Medicine
Carolinas Medical Center

3:30 p.m. Discussion with the Committee

4:15 p.m. Break

SESSION IV:
EDUCATION AND TRAINING FOR READINESS

4:30 p.m. Military Sector Panel

CHARLES RICE
President
Uniformed Services University of the Health Sciences
U.S. Department of Defense

BRIG GEN ROBERT MILLER
Director, Defense Health Agency Education and Training Directorate
Commandant, Medical Education and Training Campus
U.S. Department of Defense

COL RAYMOND FANG
Director, U.S. Air Force Center for Sustainment of Trauma and Readiness Skills (C-STARS)-Baltimore
U.S. Department of Defense

LTC JASON SEERY
Director, U.S. Army Trauma Training Center
U.S. Department of Defense

CAPT (RET) PETER RHEE
Professor of Surgery and Chief, Division of Trauma, Critical Care, Burn and Emergency Surgery
University of Arizona

ALEC BEEKLEY
Associate Professor
Thomas Jefferson University Hospitals

5:15 p.m. Discussion with the Committee

6:00 p.m. Public Comment Period

6:15 p.m. ADJOURN OPEN SESSION

July 24, 2015

8:00 a.m. Discussion of Draft Case Studies with Committee

LTC Andrew Cap
Chief, Blood Research
U.S. Army Institute of Surgical Research
U.S. Department of Defense

Kathryn Brinsfield
Assistant Secretary for Health Affairs and Chief Medical Officer
U.S. Department of Homeland Security

Drew Dawson
Director of the Office of Emergency Medical Services
National Highway Traffic Safety Administration
U.S. Department of Transportation

David Hoyt (*by Teleconference*)
Executive Director
American College of Surgeons

Allen Yee
National Association of EMS Physicians

Steven Mercer (*by Teleconference*)
National Association of Emergency Medical Technicians

John Osborn
Trauma Center Association of America

10:00 a.m. Closing Keynote Address

GEN (ret) Peter Chiarelli
Chief Executive Officer
One Mind

10:45 a.m. ADJOURN OPEN SESSION

MEETING THREE: September 16-17, 2015
National Academy of Sciences Keck Building
500 Fifth Street NW, Washington, DC 20001

Agenda

September 16, 2015

8:30 a.m. Welcome and Meeting Objectives

DON BERWICK, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

SESSION I:
ETHICAL AND REGULATORY ISSUES

8:40 a.m. Facilitated Panel Discussion on Ethical and Regulatory Issues

Regulatory Perspective

LAURA BROSCH
Director, Office of Research Protections
U.S. Army Medical Research and Materiel Command
U.S. Department of Defense

LUCIANA BORIO
Acting Chief Scientist
U.S. Food and Drug Administration
U.S. Department of Health and Human Services

JERRY MENIKOFF
Director, Office for Human Research Protections
U.S. Department of Health and Human Services

Field Practitioner Perspective

NEAL DICKERT (*by Teleconference*)
Assistant Professor of Medicine
Division of Cardiology
Emory University School of Medicine

CHUCK CAIRNS
Interim Dean, College of Medicine
Professor of Emergency Medicine
Vice President, Clinical Research
University of Arizona Health Sciences Center

CHARLES BRANAS (*by Teleconference*)
Professor of Epidemiology
University of Pennsylvania

Christina Heide
Senior Advisor for HIPAA Policy
Office for Civil Rights
U.S. Department of Health
and Human Services

SESSION II: TRAUMA RESEARCH INVESTMENT

11:00 a.m. Panel Discussion on Trauma Research Investment

Jeremy Brown
Director, Office of Emergency Care Research
National Institutes of Health
U.S. Department of Health and Human Services

Col Todd Rasmussen
Director, Combat Casualty Care Research Program
U.S. Army Medical Research and Materiel Command
U.S. Department of Defense

Nicole Di Resta
Senior Vice President
Cassidy and Associates

Andrew Pollak
The James Lawrence Kernan Professor and Chair
Department of Orthopaedics
University of Maryland School of Medicine
Chief of Orthopaedics
University of Maryland Medical System

Mary Woolley
President
Research!America

12:15 p.m. Lunch

SESSION III: COMMISSIONED PAPERS

1:00 p.m. Discussion of Commissioned Papers with Committee

ELLIOTT HAUT
Associate Professor of Surgery and Anesthesiology & Critical Care Medicine, Department of Surgery
Johns Hopkins Medicine

COL (RET) RUSS KOTWAL (*by Teleconference*)
Independent Medical Consultant

CLAY MANN (*by Teleconference*)
Professor, Department of Pediatrics
University of Utah School of Medicine

JEREMY CANNON
Associate Professor of Surgery
Perelman School of Medicine
University of Pennsylvania

2:00 p.m. Public Comment Period

2:15 p.m. ADJOURN OPEN SESSION

September 17, 2015

8:00 a.m. Joint Trauma System Video Teleconference

9:00 a.m. ADJOURN OPEN SESSION

MEETING FOUR: October 26, 2015
WebEx (Teleconference) Meeting

Agenda

12:00 p.m. Welcome and Introductions

DON BERWICK, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

12:10 p.m. EMS in the Context of a Learning Health System

SCOTT BOURN
Senior Vice President of Quality Measurement and Improvement
Evolution Health

DIA GAINOR
Executive Director
National Association of State EMS Officials

DAVID PAGE
Director, Prehospital Care Research Forum
University of California, Los Angeles

SEVERO RODRIGUEZ
Executive Director
National Registry of Emergency Medical Technicians

1:00 p.m. Discussion with Committee

2:00 p.m. ADJOURN OPEN SESSION

MEETING FIVE: December 2, 2015
WebEx (Teleconference) Meeting

Agenda

9:00 a.m. Welcome and Meeting Objectives

DON BERWICK, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

9:10 a.m. The Role of Leadership in a Learning Trauma Care System

ADM (RET) MICHAEL MULLEN
President/CEO, MGM Consulting, LLC
17th Chairman, Joint Chiefs of Staff

10:00 a.m. ADJOURN OPEN SESSION

MEETING SIX: January 5, 2016
WebEx (Teleconference) Meeting

Agenda

3:00 p.m. Welcome and Introductions

Don Berwick, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

3:10 p.m. Nursing in the Context of a Learning Health System

Col (ret) Elizabeth Bridges
U.S. Air Force Nurse Corps (Retired)
Associate Professor
University of Washington School of Nursing

Lt Col Jennifer Hatzfeld
En Route Care Portfolio Manager
Combat Casualty Care Research Program
U.S. Air Force Nurse Corps

Kate Fitzpatrick
Senior Vice President and Chief Nursing Officer
University of Vermont Medical Center

Therese Richmond
Andrea B. Laporte Endowed Professor of Nursing and
Associate Dean for Research and Innovation
University of Pennsylvania

MG Margaret Wilmoth
Deputy Surgeon General for Mobilization, Readiness and
Army Reserve Affairs
Office of the Surgeon General, U.S. Army
U.S. Department of Defense

4:00 p.m. Discussion with Committee

5:00 p.m. ADJOURN OPEN SESSION

MEETING SEVEN: February 5, 2016
WebEx (Teleconference) Meeting

Agenda

3:00 p.m. Welcome and Introductions

DON BERWICK, *Committee Chair*
President Emeritus and Senior Fellow
Institute for Healthcare Improvement

3:10 p.m. Military Health System Leadership in a Learning Trauma Care System

LT GEN MARK EDIGER
Surgeon General for the U.S. Air Force
U.S. Department of Defense

MICHAEL MALANOSKI
Executive Director
U.S. Navy Bureau of Medicine and Surgery
U.S. Department of Defense

3:30 p.m. Discussion with Committee

4:00 p.m. ADJOURN OPEN SESSION

F Committee Biosketches

Donald M. Berwick, M.D., M.P.P., FRCP (*Chair*), is president emeritus and senior fellow, Institute for Healthcare Improvement, and is also former Administrator of the Centers for Medicare & Medicaid Services. A pediatrician by background, Dr. Berwick has served on the faculty of the Harvard Medical School and Harvard School of Public Health, and on the staffs of Boston's Children's Hospital Medical Center, Massachusetts General Hospital, and the Brigham and Women's Hospital. He has also served as vice chair of the U.S. Preventive Services Task Force, the first "Independent Member" of the American Hospital Association Board of Trustees, and chair of the National Advisory Council of the Agency for Healthcare Research and Quality. He served two terms on the Institute of Medicine's (IOM's) Governing Council, was a member of the IOM's Global Health Board, and served on President Clinton's Advisory Commission on Consumer Protection and Quality in the Healthcare Industry. Recognized as a leading authority on health care quality and improvement, Dr. Berwick has received numerous awards for his contributions. In 2005, he was appointed Honorary Knight Commander of the British Empire by Her Majesty Queen Elizabeth II in recognition of his work with the British National Health Service. Dr. Berwick is the author or co-author of more than 160 scientific articles and 6 books.

Ellen P. Embrey, is managing partner of Stratitia, Inc., and 2c4 Technologies, Inc. Stratitia is a strategy and management consulting firm specializing in supporting clients that serve the health care, national security, and information technology sectors, and 2c4 Technologies specializes in providing health sector information technology (IT) solutions and services. Ms. Embrey also is a counselor in The Cohen Group, a firm that provides global business consulting services and advice on tactical and strategic opportunities in virtually every market. She has extensive executive and program leadership experience in the executive branch of the federal government. In her last federal role, she served as the Assistant Secretary of Defense (Health Affairs) and the director, TRICARE Management Activity, during the presidential transition period in 2009-2010. In that capacity, she led and managed the Military Health System, a $47 billion/year defense health program employing more than 200,000 health professionals serving more than 9.6 million service members, retirees, and their families in more than 70 hospitals and 500 clinics and laboratories around the globe. As Deputy Assistant Secretary of Defense (Force Health Protection and Readiness) from 2002 to 2009, Ms. Embrey orchestrated significant improvements in U.S. Department of Defense (DoD) policies and programs, affecting deployment and combat casualty medicine, health promotion and preventive medicine, medical readiness, and public health emergency preparedness and response. As DoD's "line of action" lead for addressing traumatic brain injury (TBI) and/or post-traumatic stress disorder (PTSD), she led collaborative efforts to identify gaps and prioritize investments in TBI and PTSD research, align clinical best practices of DoD and the U.S. Department of Veterans Affairs (VA), and establish new U.S. *International Classification of Diseases, Ninth Edition* (ICD-9) codes for TBI diagnoses and treatment based on DoD/VA experience. At the Secretary of Defense's request, Ms. Embrey led a landmark study of sexual assault in the military, making recommendations that led to widespread reforms across the department. Throughout 2001, during the presidential transition period, Ms. Embrey served as the Assistant Secretary of Defense for Reserve Affairs, shaping policies affecting the readiness and use of the National Guard and Reserve in both federal and state status. From 2000 to 2001, she served as Chief of Staff of that office, and from 1998 to 2001, as Deputy Assistant Secretary of Defense for Military Assistance to Civil Authorities, developing policies that shaped the role of the National Guard and Reserve components in supporting homeland security, disaster preparedness, and national disaster response capabilities, including advising the President on such matters in the days and weeks following September 11, 2001. Over her distinguished 35-year federal career, Ms. Embrey received many awards, the highest of which include two Secretary of Defense Distinguished Civilian Service Awards and two Presidential Meritorious Executive Rank Awards.

Sara Goldkind, M.D., M.A., is currently an independent research and clinical bioethics consultant with Goldkind Consulting, LLC. In this capacity, her work includes consulting on novel therapies, innovative clinical trial designs and product development in special settings (e.g., research involving pregnant women, pediatric populations, decisionally impaired subjects, rare diseases, international research, emergency research); advising on and developing human research protections programs and institutional review boards; and regulatory compliance. Since leaving the U.S. Food and Drug Administration (FDA), she serves as a special government expert for the FDA, a member of Walter Reed National Military Medical Center Ethics Committee, as well as a member of various data monitoring committees at the National Institutes of Health. Dr. Goldkind is a nationally recognized expert on clinical research ethics, and is the former senior bioethicist at the FDA within the Office of the Commissioner. In this position, she served as an agency expert for medical ethics and participated in the planning, management, and implementation of bioethics activities and policies across the FDA. These activities included ethics consultations both within the U.S. Department of Health and Human Services and for industry; guidance and policy development; educational programming; and evaluation of the ethical aspects of research involving human subjects, including clinical trial oversight. Dr. Goldkind came to the FDA in 2003. Previously, she was involved in clinical consultative ethics, policy development, and education in both the clinical setting and academia. She is a board-certified internist. Dr. Goldkind completed a fellowship in clinical medical ethics and obtained a master's degree in religious studies focusing on comparative religious ethics and public policy at the University of South Florida School of Medicine, where she was on the faculty in the Department of Medicine.

Adil H. Haider, M.D., M.P.H., FACS, is a clinically active trauma surgeon; widely published researcher; and the Kessler Director for the Center for Surgery and Public Health, a joint initiative of Brigham and Women's Hospital (BWH), Harvard Medical School, and Harvard T.H. Chan School of Public Health. Dr. Haider's research focuses on long-term clinical and functional outcomes after trauma, race and gender disparities in health care, optimal treatment of trauma/critically ill patients in resource-poor settings, and advanced analytics for outcomes research using large databases. Crucial to this report, in 2013 he led a team of researchers that conducted a nationwide survey on the impact of contemporary military practices on civilian trauma care, identifying successes and barriers in translating the military's experience to the civilian setting. As an internationally renowned trauma outcomes researcher he has been the lead author of multiple research methods publications including best practices for using National Trauma Data Bank data. He is also the principal investigator (PI) of a joint project with the Uniformed Services University of Health Sciences (USUHS) that uses military TRICARE claims data from more than 8 million patients to study comparative effectiveness of various interventions, epidemiology and practice patterns, potential health care disparities, wounded warrior care, and health policy issues important to our military health system. In 2015, Dr. Haider served as the Organizing Secretary for the first-ever summit on the science of surgical disparities, hosted by the National Institutes of Health's (NIH's) National Institute on Minority Health and Health Disparities (NIMHD) and the American College of Surgeons (ACS) that has led to the recently announced National Agenda for Surgical Disparities Research. He is also the PI for the groundbreaking EQUALITY (Emergency Department QUery for Patient-Centered Approaches to Sexual Orientation and Gender Identity) Study, which is focused on developing patient-centered approaches to collect sexual orientation and gender identity information in emergency departments. Dr. Haider's work has been recognized with more than two dozen major awards, including the prestigious Joan and Julius Promising Investigator Award from the ACS. His leadership positions include deputy editor of *JAMA Surgery*, recorder and program committee chair for the Association for Academic Surgery, vice chair for the ACS Committee on Health Care Disparities, and several committee membership positions in both the American Association for the Surgery of Trauma and the Eastern Association for the Surgery of Trauma. Dr. Haider has formally mentored more than 100 research trainees, published more than 175 peer-reviewed papers, and currently serves as PI on extramural grants worth more than $7 million. Dr. Haider believes that equality is the cornerstone of medicine, and his professional goal is to ensure that all patients receive the highest-quality patient-centered care.

COL (ret) John Bradley Holcomb, M.D., FACS, has been a leader in trauma surgery and related research at the University of Texas Health Science Center in Houston since his 2008 retirement from the Army. He serves as director of the Center for Translational Injury Research, professor and vice chair of the Department of Surgery, and as the Jack H. Mayfield, M.D., Chair in Surgery. In 1993, MAJ Holcomb was deployed with U.S. Special Operations Forces to Somalia, where he cared for soldiers who had been severely wounded on the battlefield of Mogadishu in the violent Black Hawk Down episode. The experience had a profound impact, spurring his decision to dedicate his career to trauma surgery and research aimed at improving outcomes for the injured. In 1997, Dr. Holcomb became chief of the Military Trauma Research Branch of the U.S. Army Institute of Surgical Research. In 1999, LTC Holcomb established the U.S. Department of Defense's (DoD's) first Joint Trauma Training Center in Houston, Texas, focused on preparing physicians, nurses, and medics to deploy into a combat zone and optimally care for combat casualties. In 2001, he completed a surgical critical care fellowship at the University of Texas at Houston while serving as trauma advisor to the U.S. Special Operations Command. From 2002 until his retirement from the military in 2008, he served as both commander of the U.S. Army Institute of Surgical Research and trauma consultant to the Army Surgeon General. Because of his leadership, the military began issuing life-saving tourniquets to every member of the U.S. Armed Forces deployed in combat zones. Dr. Holcomb initiated the use of hemostatic dressings in place of gauze dressings to stem bleeding more effectively and introduced major advances in resuscitation (damage control resuscitation). For these initiatives, he was the recipient of three Army Greatest Invention awards. Most importantly, COL Holcomb led the efforts to establish the Joint Theater Trauma System and the first DoD Trauma Registry. His achievements and dedication to servicemen and -women earned him numerous military honors, including the Honorary Medal for Combat Surgical Care, the Army's Development Achievement Award for Leadership and Excellence, and the U.S. Special Forces Command Medal. In 2008, Dr. Holcomb received the American Heart Association's Lifetime Achievement Award in Trauma Resuscitation Science and the American College of Surgeons Committee on Trauma Service Award for outstanding scientific contributions to the surgery of trauma and dedication to the care of wounded warriors.

Brent C. James, M.D., M.Stat., is the chief quality officer and executive director, Institute for Health Care Delivery Research, at Intermountain Healthcare. Intermountain is an integrated system of 22 hospitals, more than 185 freestanding clinics, a 1,300+ member physician group, and an HMO/PPO insurance plan jointly responsible for more than 850,000 covered lives serving patients in Utah, Idaho, and, at a tertiary level, seven surrounding states. Dr. James is known internationally for his work in clinical quality improvement; patient safety; and the infrastructure that underlies successful improvement efforts, such as culture change, data systems, payment methods, and management roles. He is a member of the National Academy of Medicine (and participated in many of that organization's seminal works on quality and patient safety). He was recently recognized for his pioneering work in applying quality improvement techniques originally developed by W. Edwards Deming and others and awarded the 2011 Deming Cup. The award is given annually to an individual who has made outstanding contributions in the area of operations and has established a culture of continuous improvement within his or her respective organization. Dr. James was instrumental in helping to create and implement a "system" model at Intermountain in which physicians study process and outcomes data to determine the types of care that are most effective. He holds faculty appointments at the Stanford University School of Medicine (Department of Medicine), the University of Utah School of Medicine (Family Medicine and Biomedical Informatics), Harvard School of Public Health

(Health Policy and Management), and the University of Sydney, Australia, School of Public Health. Through the Intermountain Advanced Training Program in Clinical Practice Improvement, he has trained more than 5,000 senior physician, nursing, and administrative executives from around the world in clinical management methods, with proven improvement results (and more than 50 "daughter" training programs in 10 countries). Before coming to Intermountain, he was an assistant professor in the Department of Biostatistics at the Harvard School of Public Health, providing statistical support for the Eastern Cooperative Oncology Group; and staffed the American College of Surgeons' Commission on Cancer. He holds B.S. degrees in computer science (electrical engineering) and medical biology; an M.D. degree (with residency training in general surgery and oncology); and a master of statistics degree. Dr. James serves on several nonprofit boards of trustees dedicated to clinical improvement.

Jorie Klein, R.N., is the director of nursing at the Rees-Jones Trauma Center at Parkland. She is the current chair of Texas Governor's EMS, Trauma Advisory Council's Trauma System Committee. In addition, she is the vice chair of the North Central Texas Trauma Regional Advisory Council. She is the board chair for the Texas EMS, Trauma and Acute Care Foundation and a past president of the Society of Trauma Nurses (STN) and is a current member of the STN Trauma Outcomes Performance Improvement Course (TOPIC) committee and Advanced Trauma Course for Nurses (ATCN) committee. She is an instructor for the TOPIC Course and the ATCN course as well as the Region VI chair for STN. In addition, she is an instructor for the Disaster Management Emergency Preparedness Course sponsored by the American College of Surgeons. Ms. Klein is an appointed STN liaison to the ACS Performance Improvement Patient Safety Committee. She is an emeritus board member for the Trauma Center Association of American and the course coordinator for the Trauma Center Leadership Course and the Trauma System Leadership Course. She is a founding member of the Texas Trauma Coordinators Forum.

Douglas Kupas, M.D., serves as the associate chief academic officer for Simulation and Medical Education for Geisinger Health System, where he also practices as an emergency physician. He is board certified in emergency medicine and the subspecialty of emergency medical services (EMS). He is also assistant dean for Student Affairs at the Geisinger campus for Temple University School of Medicine. Dr. Kupas completed his emergency medicine residency program at Geisinger Medical Center, his graduate degree at Jefferson Medical College of Thomas Jefferson University, and his undergraduate degree at Indiana University of Pennsylvania. He is a member of numerous local, state, and national organizations and has many honors, awards, and publications to his credit. He remains active in his field of research. Dr. Kupas is a paramedic and has been an active field EMS provider since 1980. He also serves as the Commonwealth EMS Director for the Bureau of Emergency Medical Services for the Pennsylvania Department of Health, and is former chair of the Medical Directors Council of the National Association of EMS Officials, the Mobile Integrated Healthcare/Community Paramedicine Committee of the National Association of EMS Physicians (NAEMSP), the Standards and Practices Committee of NAEMSP, and the Rural EMS Committee of NAEMSP. His clinical and research interests include EMS medical direction, EMS provider and patient safety, field trauma triage, emergency airway management, therapeutic hypothermia, wilderness EMS, and simulation in medical education. Dr. Kupas directs the ARCTIC (Advanced Resuscitation Cooling Therapies in Cardiac Arrest) program at Geisinger Health System, and partnered with the HeartRescue project to advance statewide out-of-hospital cardiac arrest care in Pennsylvania. Additionally, he was involved in writing a national position statement on patient restraint that guided the development of protocols for EMS operations nationwide. He also participated in evidence-based reviews for the International Liaison Committee on Resuscitation that drafts the guidelines used by the American Heart Association and other resuscitation groups around the world and for the Centers for Disease Control and Prevention/American College of Surgeons field trauma triage guidelines. Dr. Kupas has served as state EMS medical director for Pennsylvania since 2000, and during that time he led the process of developing statewide EMS protocols. He also participated in projects to develop and implement national evidence-based guidelines for EMS.

Cato T. Laurencin, M.D., Ph.D., is the Albert and Wilda Van Dusen Distinguished Professor of Orthopaedic Surgery, Professor of Chemical and Biomolecular Engineering, Professor of Materials Science and Engineering, and Professor of Biomedical Engineering at the University of Connecticut (UConn). Dr. Laurencin is the founder and director of both the Institute for Regenerative Engineering and the Raymond and Beverly Sackler Center for Biomedical, Biological, Physical and Engineering Sciences at UConn. He also serves as Chief Executive Officer of the Connecticut Institute for Clinical and Translational Science at UConn. For his outstanding achievements in medicine, engineering, and science, and for his distinguished service to the university, UConn named him a University Professor. He is the 8th in UConn's 130-year history. Dr. Laurencin earned his B.S.E. in chemical engineering from Princeton University and his M.D., Magna Cum Laude, from the Harvard Medical School. He simultaneously earned his Ph.D. in biochemical engineering/biotechnology from the Massachusetts Institute of Technology where he was a Hugh Hampton Young Fellow. Dr. Laurencin's work in science focuses on biomaterials, nanotechnology, drug delivery, stem cell science, and a new field he has pioneered—regenerative engineering. In 2012, his work was highlighted by *National Geographic Magazine* in its edition, "100 Scientific Discoveries That Changed the World." Dr. Laurencin's work is funded by the National Science Foundation, the U.S. Department of Defense, and the National Institutes of Health (NIH), where he is a recipient of a 2014 NIH Pioneer Award for his work in regenerative engineering. A practicing shoulder and knee surgeon, Dr. Laurencin is a Fellow of the American College of Surgeons, a Fellow of the American Surgical Association, and a Fellow of the American Academy of Orthopaedic Surgeons. He won the Nicolas Andry Award from the Association of Bone and Joint Surgeons. He has been listed in America's Top Doctors™ continuously for the past decade. A Fellow of the American Chemical Society, the American Institute of Chemical Engineers, the Materials Research Society, and the American Association for the Advancement of Science, Dr. Laurencin is a Fellow of the American Institute for Medical and Biological Engineering and served as the Chair of the College of Fellows. He is an International Fellow in Biomaterials Science and Engineering and served on the Council of the Society for Biomaterials. He is a Fellow of the Biomedical Engineering Society and has been a member of the Board of Directors. Dr. Laurencin received the Presidential Faculty Fellowship Award from President Clinton in recognition of his research work bridging medicine and engineering. In 2009, the American Institute of Chemical Engineers named him 1 of the 100 Engineers of the Modern Era at its centennial celebration. In 2014, he received the Percy Julian Medal from the National Organization of Black Chemists and Chemical Engineers at its annual meeting. Dr. Laurencin has been active in service to our nation. He has served on the National Science Advisory Board of the U.S. Food and Drug Administration (FDA), the National Science Foundation's Engineering Advisory Committee (ADCOM), the NIH Advisory Council for Biomedical Imaging and Bioengineering, and the NIH Advisory Council for Arthritis, Musculoskeletal and Skin Diseases. At the National Academies of Sciences, Engineering, and Medicine he has served as co-chair of the Clinical Effectiveness Research Innovation Collaborative as a member of the Academies Roundtable on Value & Science-Driven Health Care. Dr. Laurencin is an outstanding mentor. He has received the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring from President Barack Obama in ceremonies at the White House, the Elizabeth Hurlock Beckman Award for Mentoring, the Alvin H. Crawford Mentoring Award from the J. Robert Gladden Orthopaedic Society, and the American Association for the Advancement of Science's Mentor Award. Dr. Laurencin is an elected member of the National Academy of Medicine and the National Academy of Engineering. Internationally, he is an elected Fellow of the African Academy of Sciences and an elected Fellow of the World Academy of Sciences. Dr. Laurencin is a recipient of the National Medal of Technology and Innovation in ceremonies at the White House.

Ellen MacKenzie, Ph.D., is the Fred and Julie Soper Professor and Chair of the Department of Health Policy and Management at the Johns Hopkins Bloomberg School of Public Health and director of the Major Extremity Trauma Research Consortium, dedicated to advancing limb trauma care and outcomes through research. She is a graduate of the School of Public Health, where she earned M.S. and Ph.D. degrees in biostatistics. She joined the Hopkins faculty in 1980 and holds joint appointments in the school's Department of Biostatistics and the departments of Emergency Medicine and Physical Medicine and Rehabilitation at the Johns Hopkins University School of Medicine. In addition to her faculty appointments, Dr. MacKenzie served as senior associate dean at the school from 1996 to 2000 and director of the Center for Injury Research and Policy from 1995 to 2005. Dr. MacKenzie completed a term as chair of the National Advisory Committee for Injury Prevention and Control and was past president of the American Trauma Society. Her research focuses on the impact of health services and policies on the short- and long-term consequences of traumatic injury, with special emphasis on orthopaedic trauma outcomes. She has contributed to the development and evaluation of tools for measuring both the severity and outcomes of injury, and her research has advanced understanding of both the clinical and nonclinical factors that influence recovery post-injury. Dr. MacKenzie was co-principal investigator on the Lower Extremity Assessment Project (LEAP) study and the METALS study. She was also principal investigator on the National Study on the Costs and Outcomes of Trauma Care (NSCOT). Some of her more recent efforts include the development and evaluation of self-management programs for survivors of serious trauma. Her awards include the A.J. Mirkin Service Award from the Association for the Advancement of Automotive Medicine, the Kappa Delta Award from the American Academy of Orthopaedic Surgeons (for the LEAP Study), Distinguished Career Awards from the American Public Health Association and the American Trauma Society, and the Trauma Leadership Award from the Society of Trauma Nurses. She is also an honorary fellow of the American Association for the Surgery of Trauma and in 2012, she was named by the Centers for Disease Control and Prevention (CDC) as 1 of 20 leaders and visionaries who have had a transformative effect on the field of violence and injury prevention over the past 20 years.

David Marcozzi, M.D., MHS-CL, FACEP, is an associate professor and the director of Population Health in the Department of Emergency Medicine at the University of Maryland School of Medicine. Prior to this academic role, he served in the federal government as a senior leader and subject matter expert on health delivery, emergency care, and emergency preparedness. During his federal tenure, Dr. Marcozzi held positions in the U.S. Department of Health and Human Services (HHS) and the White House. As the senior advisor for emergency preparedness and acute care in the Centers for Medicare & Medicaid Services, Dr. Marcozzi was involved with health delivery reform efforts and clinical quality standards and measures development. Before being asked to assume this role, he served as director of the National Healthcare Preparedness Programs within the Office of the Assistant Secretary for Preparedness and Response (ASPR). Dr. Marcozzi returned to HHS in September 2011 after completing a 3-year detail to the White House National Security Council, where he served as director of All-Hazards Medical Preparedness Policy. During his time at the White House, he led multiple sub-interagency policy committees and assisted in responding to several events of national significance. Before his detail to the White House in 2008, he created and directed the Emergency Care Coordination Center, an office within HHS established to improve prehospital and hospital-based emergency care. Prior to his federal positions, Dr. Marcozzi completed a congressional fellowship at the U.S. Senate. Serving on the Bioterrorism and Public Health Preparedness Subcommittee, he assisted in drafting the Pandemic and All-Hazards Preparedness Act that became law in 2006. A lieutenant colonel in the U.S. Army Reserves, Dr. Marcozzi has been mobilized four times since 2001 and is now assigned to the U.S. Army Special Operations Command as a deputy surgeon. As a member of the National Disaster Medical System, he responded to multiple disasters, including the September 11, 2001, attack on the World Trade Center. The author of several articles and scientific manuscripts, he is also the recipient of numerous military and civilian awards including the National Security Council Outstanding Achievement Award, a Certificate of Appreciation from the Assistant to the President for Homeland Security and Counterterrorism, the Army Commendation Medal, the National Disaster Medical System Distinguished Member Award, and the Duke Emergency Medicine Distinguished Faculty Award.

C. Joseph McCannon, is co-founder and CEO of the Billions Institute. Previously, he was an appointee in the Obama administration, serving as senior advisor to the administrator at the Centers for Medicare & Medicaid Services (CMS) in the U.S. Department of Health and Human Services (HHS). There he rolled out major pieces of the Affordable Care Act and was part of the founding leadership team at the Center for Medicare & Medicaid Innovation (CMMI), directing its Learning and Diffusion Group. Prior to joining CMS, he was vice president and faculty in large-scale improvement at the Institute for Healthcare Improvement (IHI), leading the organization's major domestic initiative to improve patient safety, the 100,000 Lives Campaign, and initiating its work in Africa. Mr. McCannon has supported large-scale transformation in several nations, including Canada, Denmark, England, Japan, and South Africa, and consulted on the topic for a number of organizations, including the Bill & Melinda Gates Foundation, the World Health Organization, and Community Solutions (100,000 Homes Campaign). He started his career in the publishing industry with roles at *Fast Company*, *The Atlantic Monthly*, and *Outside* magazine. He is a graduate of Harvard University and was a Reuters fellow at Stanford University.

Norman E. McSwain, Jr., M.D., FACS, was professor of surgery and trauma director, Interim Louisiana State University Public Hospital and police surgeon for the New Orleans Police Department. Dr. McSwain attended college at the University of the South in Sewanee, Tennessee, and medical school at the University of Alabama. He then joined the Air Force and later went into private practice before joining the clinical and academic faculty at the University of Kansas in Kansas City, where he assumed responsibility for emergency medical services (EMS) education and system development for the state of Kansas. When he was recruited 4 years later to Tulane University School of Medicine, Department of Surgery, and Charity Hospital, 90 percent of the population of Kansas was covered by paramedic quality care within 10 minutes, and 1 of every 500 Kansans (including the entire Kansas Highway Patrol) were trained as an emergency medical technician (EMT)-basic. Dr. McSwain joined the academic and clinical faculty at Tulane, but his main interest was in Charity Hospital, prehospital patient care, and trauma and general surgery patients. He was recruited by the city of New Orleans to develop an EMS system for the city. He initiated both EMT-Basic and EMT-Paramedic training within the New Orleans Police Department and a city-wide EMS system. During this time, he was recruited to the American College of Surgeons Committee on Trauma (ACS COT) to assist in the development of the Advanced Trauma Life Support program, and worked with the ACS COT and the National Association of EMTs to develop the Pre-Hospital Trauma Life Support (PHTLS) program. Today, PHTLS has trained more than 1 million people in 67 countries and is considered the world standard for prehospital trauma care. Dr. McSwain also worked with the military and the U.S. Department of Defense to develop the tactical combat casualty care program for military medics. For 30 years, he provided care to severely injured police officers and other patients at the Spirit of Charity Center. Dr. McSwain wrote or revised more than 25 textbooks, published more than 360 articles, and traveled throughout the world giving more than 800 presentations. He is the only person in the history of the ACS to receive all five major trauma awards.

John A. Parrish, M.D., is chief executive officer and founder of the Consortia for Improving Medicine with Innovation and Technology (CIMIT), a consortium of academic and engineering research laboratories, universities, and more than 40 private-sector companies. Through CIMIT, clinical investigators work to advance the standards of care for all patients through the development and the adoption of targeted medical devices and technologies. Trained in internal medicine, dermatology, and clinical research, Dr. Parrish has been recognized as a visionary and innovator whose accomplishments include the development of therapies to treat skin disease, including the now-common use of ultraviolet light. For two decades, he served as chief of the Department of Dermatology at Massachusetts General Hospital, founding the Wellman Center for Photomedicine, the first—and now the world's largest—multidisciplinary research group to study the effects of lasers on tissue. A graduate of Duke University and Yale University School of Medicine, Dr. Parrish is the author or co-author of more than 300 publications, including 6 books. Dr. Parrish has earned the Discovery Award from the National Dermatology Foundation; the Bowditch Prize from Massachusetts General Hospital for enhancing the quality of patient care while reducing the cost of that care; the U.S. Army's Thurman Award, honoring the late GEN Maxwell Reid Thurman, who championed the advancement of life-saving medical technologies within the U.S. Army; and the 2011 Humanitarian Award, for his wide-ranging lifetime professional contributions to the field of dermatology. Dr. Parrish proudly served in the United States Marine Corps and was a battlefield doctor in Vietnam. As a result, he is acutely aware of the needs of soldiers and their supportive medical units. He is the founding director of the Boston Red Sox Foundation–Massachusetts General Hospital Home Base Program, a novel public–private partnership aimed at helping veterans of the wars in Afghanistan and Iraq who are affected by posttraumatic stress disorder and traumatic brain injury. Dr. Parrish is a member of the National Academy of Medicine and the American Academy of Arts and Sciences.

Rita Redberg, M.D., FACC, M.Sc., has been a cardiologist and professor of medicine at the University of California, San Francisco since 1990. She is currently the chief editor of *JAMA Internal Medicine* (formerly *Archives of Internal Medicine*). Her research interests are in the area of health policy and technology assessment; her work includes comparative effectiveness research and focuses on how evidence relates to U.S. Food and Drug Administration (FDA) approval, insurance coverage, and medical guidelines and practice. Dr. Redberg is a member of the Medicare Payment Advisory Commission that advises Congress on Medicare payment policy. She has chaired the Medicare Evidence, Development and Coverage Advisory Commission since 2012 and also served as a member from 2003 to 2006.

Dr. Redberg was recently appointed to the Clinical Advisory Panel for the California Coronary Artery Bypass Graft (CABG) Outcomes Reporting Program where she joins several other Institute for Health Policy Studies (IHPS) faculty. She currently is a member of the California Technology Assessment Forum, the Medical Policy Technology and Advisory Committee, and the FDA Cardiovascular Devices Expert Panel. She also is a consultant to the Center for Medical Technology Policy. She and Sanket Dhruva recently completed an extensive review of the FDA Cardiovascular Device pre-market approval process including issues related to gender bias and has ongoing work looking at post-market surveillance of medical devices, including collaborations with the Pew Charitable Trusts and the FDA. In addition, Dr. Redberg is a member of the American College of Cardiology's (ACC's) Clinical Quality Committee, serves on the ACC Quality in Technology Work Group, is a member of the ACC Comparative Effectiveness Work Group, represents the ACC on the Institute of Clinical and Economic Review Advisory Board, and serves on other ACC committees, including several on appropriate use of cardiac imaging and radiation safety. She was a member of the Institute of Medicine's Learning Health Care Committee and has chaired the American Heart Association (AHA)/ACC Writing Group on Primary Prevention Performance Measures. Dr. Redberg graduated from Cornell University and holds an M.S. in health policy and administration from the London School of Economics. She earned her medical degree from the University of Pennsylvania School of Medicine.

Uwe E. Reinhardt, Ph.D., is professor of economics and public affairs, Woodrow Wilson School of Public and International Affairs, Princeton University. Recognized as one of the nation's leading authorities on health care economics, he has been a member of the National Academy of Medicine since 1978 and is past president of the Association of Health Services Research. From 1986 to 1995, he served as a commissioner on the Physician Payment Review Committee, established in 1986 by Congress to advise it on issues related to the payment of physicians. He is a senior associate of the Judge Institute for Management of Cambridge University, and a trustee of Duke University and the Duke University Health System. Dr. Reinhardt is or was a member of numerous editorial boards, among them the *Journal of Health Economics*, the *Milbank Memorial Quarterly*, *Health Affairs*, the *New England Journal of Medicine*, and the *Journal of the American Medical Association*. Dr. Reinhardt is a prominent scholar in health care economics and a frequent speaker and author on subjects ranging from the war in Iraq to the future of Medicare. His most recent research has focused on hospital pricing, systems of health care around the world, Medicare reform, and health care spending. His work has appeared in *Health Affairs*, the *New England Journal of Medicine*, *JAMA*, and the *British*

Medical Journal. His previous work on hospitals examined the tax and cost of equity capital advantages of not-for-profit hospitals over for-profit hospitals. Dr. Reinhardt's scholarship has often analyzed the U.S. health care industry in relation to systems around the world. In 2003, he and 14 other prominent health policy experts and private health care industry leaders signed an open letter arguing that Medicare should lead the U.S. health care industry in paying for performance by tying financial reimbursement to quality measures. In addition to his university duties, Dr. Reinhardt has been active as an advisor for government, nonprofit organizations, and private industry and has held directorships in various for-profit companies in the health industry. He served on the Governing Council of the Institute of Medicine between 1979 and 1982, following election to the Institute in 1978, where he has served on a number of study panels, including the Committee on the Implications of For-Profit Medicine, the Committee on Technical Innovation in Medicine, the Committee on the Implications of a Physicians Surplus, and the Committee on the U.S. Physician Supply. In 1996, he was appointed to the Board of Health Care Services of the Institute. From 1986 to 1995, he served three consecutive terms as a commissioner on the Physician Payment Review Commission. Dr. Reinhardt also serves as a commissioner for the Kaiser Family Foundation Commission on Medicaid and the Uninsured.

James Robinson, MA(C), EMT-P, currently serves as assistant chief for Denver Health EMS. He is the immediate past president and a founding member of the International Association of EMS Chiefs, and a director at large for the National EMS Memorial Foundation. Chief Robinson began his emergency medical services (EMS) career as a volunteer emergency medical technician (EMT) in 1989, and in 1993 went on to a professional career with the city and county of Denver as a field paramedic. Since then, he has been involved in every facet of the Denver Health Paramedic Division's operations, and has been an assistant chief since 2005. Chief Robinson is involved in numerous local-, regional-, state-, and national-level EMS, public health, and emergency management initiatives, serving as chairman of the Denver Urban Area Security Initiative (UASI)/Colorado North Central All-Hazards Region's EMS subcommittee, as an EMS representative to the State of Colorado All-Hazards Advisory Committee, and member of the State of Colorado's Public Health and Medical Advisory Committee. He has served as the Denver Metro Region 3 Board of Directors' representative to the Emergency Medical Services Association of Colorado, as a member of the George Washington University National EMS Preparedness Initiative summits, as a member of the Systems Subcommittee of the National EMS Advisory Council, and as a member of the Department of Homeland Security Interagency Board Active Shooter Working Group. Chief Robinson holds a B.S., magna cum laude, in human services from Metropolitan State University of Denver and is a graduate of Cohort 6 of the Harvard Kennedy School of Government and the Harvard School of Public Health's National Preparedness Leadership Initiative. He is currently a master's degree candidate in the Naval Postgraduate School's Center for Homeland Defense and Security Master's Degree Program.

Thomas M. Scalea, M.D., began his career at the Kings County Hospital/Downstate Medical Center, where he became chief of Trauma and Critical Care and rose to the rank of professor. He also founded the Department of Emergency Medicine at Downstate. In 1997, Dr. Scalea became the physician-in-chief at the R Adams Cowley Shock Trauma Center at the University of Maryland, the nation's only freestanding trauma hospital. He later became the first medical school endowed professor of trauma, the Honorable Senator Francis X. Kelly Distinguished Professor in Trauma Surgery. Dr. Scalea is also the system chief for Critical Care Services at the University of Maryland Medical System. His faculty cares for all acute care surgery patients at the University of Maryland Medical Center and he is administratively in charge of many nontrauma intensive care units (ICUs). He is currently creating a critical care network linking ICUs across the state. Shock Trauma also houses the nation's largest Accreditation Council for Graduate Medical Education (ACGME) surgical critical care training program, as well as the largest American Association for the Surgery of Trauma (AAST)-approved acute care surgery fellowships. In 2001, Dr. Scalea established the U.S. Air Force C-STARS (Center for Sustainment of Trauma and Readiness Skills) program, which has trained approximately 4,000 Air Force men and women prior to deployment to Afghanistan or Iraq. In 2008 and 2011, Dr. Scalea traveled to Afghanistan and Iraq, respectively, to observe the wounded warrior care system in the field, provide unbiased recommendations for improving the system, and determine how to continually refine trauma training. He also served as a senior visiting surgeon at Landstuhl Regional Medical Center, providing care for injured soldiers as they were evacuated from Iraq. He is the immediate past president of the AAST and the Western Trauma Association.

C. William Schwab, M.D., FACS, FRCS, is currently professor of surgery at the University of Pennsylvania. In 1987, Dr. Schwab established a Level I Regional Resource Trauma Center, a Surgical Critical Care Service, the PennSTAR Flight Program, and the Communications Center at the University of Pennsylvania Medical Center. Today, his surgical practice focuses on caring for the severely injured patient and developing regional trauma and emergency care systems. He is one of the first traumatologists to study the effects of trauma in the elderly patient. In addition, Dr. Schwab is active in the field of violence prevention and continues to teach trauma surgeons how to become leaders in the public health effort to reduce firearm-related injuries. He also directs the University of Pennsylvania Trauma Network, administrating and coordinating several centers throughout eastern Pennsylvania with Penn's Level I trauma center to enhance the quality of trauma and emergency care. In addition, he directs the fellowship program in trauma surgery and critical care at the Hospital of the University of Pennsylvania, a program with 10 trainees annually and more than 70 graduates located throughout the world. Dr. Schwab received his medical degree from the State University of New York. During medical school, he joined the U.S. Navy and he performed his residency during the Vietnam War at the Naval Regional Medical Center in Portsmouth, Virginia.

Phillip Spinella, M.D., is an associate professor and the director of the Critical Care Translational Research program at Washington University School of Medicine in St. Louis. He has authored approximately 100 manuscripts/chapters and has been an invited speaker at more than 100 institutions globally on the topic of traumatic hemorrhagic shock. A well-established investigator, having been awarded ~$20 million from the U.S. Department of Defense (DoD) and the National Institutes of Health (NIH), he is primary investigator for two randomized controlled trials: Age of Blood in Children in Pediatric Intensive Care Units (ABC-PICU), examining effects of red blood cell storage age on outcomes in critically ill children, and Tranexamic Acid Mechanisms and Pharmacokinetics in Traumatic Injury (TAMPITI), examining immunologic effects of tranexamic acid in adults with severe traumatic injuries. Dr. Spinella served 15 years in the U.S. Army, separating as lieutenant colonel. As a veteran of the Iraq war, he received a Bronze Star, Combat Medic Badge and the U.S. Army's Best Invention Award for the concept of "damage control resuscitation." He has previously served as consultant to the U.S. Army Blood Research Program at the U.S. Army Institute of Surgical Research, the U.S. Department of Homeland Security, the Public Health Service–Northeast Region, and the Norwegian Navy Blood Research Program. He is co-founder and chair of the Pediatric Critical Care Blood Research Network and the Trauma Hemostasis and Oxygenation Research Network, international multidisciplinary networks focused on improving outcomes for patients with shock or coagulopathy.