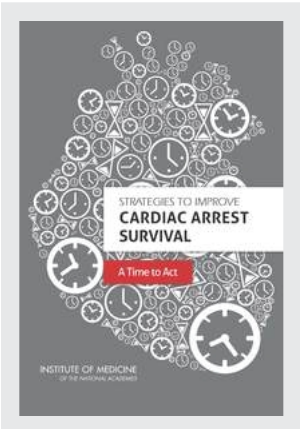

Strategies to Improve Cardiac Arrest Survival: A Time to Act

DETAILS

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AUTHORS

Robert Graham, Margaret A. McCoy, and Andrea M. Schultz, Editors; Committee on the Treatment of Cardiac Arrest: Current Status and Future Directions; Board on Health Sciences Policy; Institute of Medicine

STRATEGIES TO IMPROVE CARDIAC ARREST SURVIVAL

A Time to Act

Committee on the Treatment of Cardiac Arrest:
Current Status and Future Directions

Board on Health Sciences Policy

Robert Graham, Margaret A. McCoy,
and Andrea M. Schultz, *Editors*

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"Knowing is not enough; we must apply.
Willing is not enough; we must do."
—Goethe

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Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. 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:

ROBERT A. BERG, Children's Hospital of Philadelphia, PA
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MYRON L. WEISFELDT, Fund for Johns Hopkins Medicine and Business Development, Baltimore, MD
JAMES O. WOOLLISCROFT, University of Michigan Medical School, Ann Arbor

Although the reviewers listed above have provided many constructive comments and suggestions, they did not see the final draft of the report before its release. The review of this report was overseen by **HUGH H. TILSON,** Adjunct Professor of Public Health Leadership, University of North Carolina, and **CHARLES E. PHELPS,** Provost Emeritus, University of Rochester. Appointed by the Institute of Medicine, 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

As a medical emergency there is nothing more dramatic than sudden cardiac arrest. It is only in the past 50 years that medical therapy and procedures have made it possible for successful resuscitation. When cardiopulmonary resuscitation (CPR) and defibrillation are provided quickly, and there is an effective system of care, the chance of successful restoration of life with full neurological recovery is possible.

Emergency medical services (EMS) personnel, often with the assistance of citizen bystanders, comprise the front line in resuscitation in the out-of-hospital setting. In hospital settings, health care professionals are often faced with the challenge of responding to a cardiac arrest in pediatric and adult patients who suffer from other serious medical conditions. Although breakthroughs in understanding and treatment are impressive, the ability to consistently deliver timely interventions and high-quality care is less than impressive. The result is too many people dying from cardiac arrest. Based on recent estimates, more than 1,600 people suffer a cardiac arrest every day in the United States, defining an immense and sustained public health problem.

Equally unacceptable are the disparate survival rates within our population. Minorities and those in the lower economic strata fare worse compared to others. And where one resides is determinant of survival. There is wide diversity in survival rates among communities and hospitals in America. In some communities more than 60 percent of persons with out-of-hospital cardiac arrest (due to bystander-witnessed ventricular fibrillation) survive and are discharged from the hospital. In far more communities, the survival rate is 10 percent or less. Why is this, and what can be done?

This report examines the complex challenges and barriers to successfully treat cardiac arrest, both in the community and in the hospital, and offers concrete suggestions to improve, what the committee believes to be, an unacceptably low survival rate. Observing high-performing EMS and health care systems allows best practices to be identified and, in turn, offers strategies for other communities to adopt. Recommendations are made that the committee believes will lead to higher survival rates and give everyone, everyplace, a better chance of survival.

The primary goal in treating cardiac arrest, whether in the community or in hospitals, is to provide high-quality care quickly. For out-of-hospital cardiac arrest this is no easy feat considering the challenges of bystanders recognizing the event and calling 911; emergency telecommunicators identifying the problem, providing guidance to the rescuer, and dispatching emergency responders; and emergency medical technicians (EMTs) and paramedics responding to the call, arriving at the scene, and beginning CPR (if not already started), providing a defibrillatory shock (if required), achieving airway control, inserting an intravenous line, and delivering medications. Different yet similar challenges exist for cardiac arrest occurring within hospitals.

This report represents the collective conclusions and recommendations of a diverse group of experts, each of whom brought their expertise and perspectives. The charge to the committee was clear. How can we improve survival and quality of life following cardiac arrest both in the community and in the hospital? This report emphasizes the following strategies:

1. Establish a national registry of cardiac arrest in order to monitor performance in terms of both success and failure, identify problems, and track progress.
2. Enhance performance of EMS systems with emphasis on dispatcher-assisted CPR and high-performance CPR.
3. Develop strategies to improve systems of care within hospital settings and special resuscitation circumstances.
4. Expand basic, clinical, translational, and health services research in cardiac arrest resuscitation and promote innovative technologies and treatments.
5. Educate and train the public in CPR, use of automated external defibrillators, and EMS-system activation.

6. Create a national cardiac arrest collaborative to unify the field and identify common goals to improve survival.

This report benefited immensely from the skilled work and dedication of the Institute of Medicine staff, led by Margaret McCoy, and assisted by Catharyn Liverman, Sarah Domnitz, Ashna Kibria, and R. Brian Woodbury. We also wish to thank our colleagues on the committee for their passion, expertise, contributions, and unflagging patience as we considered, debated, and reached consensus on the complex issues.

The committee's work was enhanced by testimony and presentations by dozens of individuals from a host of federal and community agencies. Throughout the United States, the response to community cardiac arrest is provided by emergency medical services. Hundreds of thousands of dispatchers, telecommunicators, EMTs, first responders, and paramedics work together to provide the highest level of care directly at the scene of the cardiac arrest. Similarly, we extend our appreciation in equal measure to hospital professionals who provide care for patients who arrest in the hospital and who continue the intensive and complex care after the transfer of care for patients who respond to treatment in the field. We thank all of these individuals for their dedication and professionalism. We applaud the citizen bystanders, patient and family advocates, and community leaders who have the courage and compassion to step forward and provide CPR and defibrillation and who promote cultures of action within their communities. Finally, we acknowledge those individuals and families who have been affected by cardiac arrest and encourage them to continue to share their experiences with others as important examples of what is at stake and what is possible.

Robert Graham, *Chair*
Mickey Eisenberg, *Vice Chair*
Committee on the Treatment of Cardiac Arrest:
Current Status and Future Directions

Acknowledgments

The Institute of Medicine (IOM) Committee on the Treatment of Cardiac Arrest: Current Status and Future Directions would like to express its sincere gratitude to everyone who made this report possible. This report was informed by the contributions of many individuals who provided expertise, personal insights and perspectives, data, and analysis. This report was generously supported by the American College of Cardiology, the American Heart Association, the American Red Cross, the Centers for Disease Control and Prevention, the National Institutes of Health (NIH), and the U.S. Department of Veterans Affairs.

The committee held two public workshops in May and July 2013 and gained valuable insights from the substantive presentations provided by the following speakers:

Mark Alberts, University of Texas Southwestern Medical Center
Amer Aldeen, Chicago Cardiac Arrest Resuscitation Education Service
Robert Berg, University of Pennsylvania
Scott Berry, Berry Consultants
Robin Boineau, National Heart, Lung and Blood Institute
Bernd Böttiger, University Hospital of Cologne, Germany
Steven Bradley, Veterans Affairs Eastern Colorado Health Care System
Jeremy Brown, NIH Office of Emergency Care Research
Paul Chan, St. Luke's Health System
Allison Crouch, Emory University
Gregory Dean, Washington, DC, Fire Department
Dana Edelson, University of Chicago Medicine

Jim Fogarty, King County Emergency Medical Services System
Romer Geocadin, Johns Hopkins University
Louis Gonzales, Office of the Medical Director at Austin-Travis County EMS System
Stephen Grant, Division of Cardiovascular and Renal Products, Food and Drug Administration
Amy Burnett Heldman, Centers for Disease Control and Prevention
Ahamed Idris, University of Texas Southwestern Medical Center
David Jacobs, Durham Fire Department
Peter Kudenchuk, University of Washington
Jonathan Larsen, Captain, City of Seattle Fire Department
Bryan McNally, Emory University
Vinay Nadkarni, Children's Hospital of Philadelphia
Robert Neumar, University of Michigan
Mary Newman, Sudden Cardiac Arrest Foundation
Graham Nichol, University of Washington-Harborview Center for Pre-hospital Emergency Care
Sue Nixon, Ardent Sage
Joseph Ornato, Virginia Commonwealth University Medical Center
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Comilla Sasson, American Heart Association
Cleo Subido, King County Emergency Medical Services System
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Michele Wenhold, Parent Heart Watch
Demetris Yannopoulos, University of Minnesota Medical School
Bram Zuckerman, Center for Devices and Radiological Health, Food and Drug Administration

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We also thank the city of Seattle, Washington, and Councilman Nick Licata for hosting, and Ann Doll for helping prepare for the committee's second meeting, which provided a beautiful backdrop for the committee's information-gathering activities and deliberations.

The committee benefited from the work of the IOM study staff team: Margaret McCoy directed the study, and Sarah Domnitz, Ashna Kibria, and R. Brian Woodbury provided research support. Our thanks to Andrew Pope and Catharyn Liverman for their leadership and advice. Additionally, Judy Estep, Jeanette Gaida, and Claire Giammaria were instrumental in finalizing the report. Thanks to the IOM and the National Research Council staff members who worked behind the scenes to ensure successful production and dissemination of this report: Anton Bandy, Porter Coggeshall, Laura DeStefano, Chelsea Frakes, Molly Galvin, Greta Gorman, Linda Kilroy, Fariha Mahmud, Maureen Mellody, Abbey Meltzer, Lora Taylor, and Jennifer Walsh.

Contents

Summary

Each year, cardiac arrest strikes more than half a million people and contributes to avoidable death and disability across the United States; it affects seemingly healthy individuals of all ages, races, and genders, often without warning. Defined as a severe malfunction or cessation of the electrical and mechanical activity of the heart, cardiac arrest results in almost instantaneous loss of consciousness and collapse. Following a cardiac arrest, each minute without treatment decreases the likelihood of survival with good neurologic and functional outcomes. Thus, the consequences of delayed action can have profound and, in many cases, avoidable ramifications for individuals, families, and communities.

Conservative estimates identify cardiac arrest as the third leading cause of death in the United States, following cancer and heart disease (see Taniguchi et al., 2012). In 2013, approximately 395,000 people suffered a cardiac arrest in community settings (Daya et al., 2015).[1] In hospital settings, annual cardiac arrests incidence is approximately 200,000 (Merchant et al., 2011).[2] Of these, approximately 12,500 children experience cardiac arrest each year (Atkins et al., 2009; Morrison et al., 2013).

[1]The 2013 out-of-hospital cardiac arrest (OHCA) incidence statistic (395,000) includes patient of all ages and cardiac arrests events with both cardiac and non-cardiac (e.g., trauma, drowning, poisoning, and other related causes) etiologies. This figure is an approximation based on analysis of data from the Resuscitation Outcomes Consortium-Epistry, the limitations of which are described in Chapter 2. The calculation of incidence is available in the committee's commissioned paper (Daya et al., 2015).

[2]The reported statistics for in-hospital cardiac arrest (IHCA) are based a 2011 analysis, using the most recent available data (years 2003 through 2007) from the Get with the Guidelines-Resuscitation Registry (Chan, 2015). The study used three separate approaches to calculate the estimated ranges of annual in-hospital cardiac arrest (IHCA) events in the United States.

Overall, cardiac arrest survival rates remain low (Daya et al., 2015; Go et al., 2013), and the cost of care and the number of productive years lost because of cardiac arrest death and disability are large relative to other conditions, such as individual cancers (Stecker et al., 2014).

Cardiac arrest survival rates vary widely between communities and hospitals (Carr et al., 2009; Chatalas and Plorde, 2014; Merchant et al., 2014; Nichol et al., 2008) and are a reflection of complex system, environmental, and social challenges. Although some communities and hospitals have improved cardiac arrest outcomes (Blom et al., 2014; Chan et al., 2014; Wong et al., 2014), pronounced variations in outcomes persist, disproportionally affecting individuals who already have greater risks for poor health status. Notable disparities may be affected by individual demographics (e.g., race, age, gender, health status), location of arrest, initial cardiac arrest rhythm, rates of bystander cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED) use, and characteristics of emergency medical services (EMS) and health care systems (e.g., response time, treatment availability, training, and care quality).

Effective treatments for specific types of cardiac arrest are widely available and could reduce deaths and disability if they were more efficiently implemented. Decreasing the time between cardiac arrest onset and the first chest compressions is critical. High-performing communities provide examples of public health infrastructures and organized system responses that facilitate timely treatments and effective transitions of care (see Chatalas and Plorde, 2014). Within systems of care, continuous quality improvement initiatives based on existing guidelines have led to more proactive and responsive care models that fit local needs and resources, contributing to higher quality care and better outcomes. Bystander-administered CPR is associated with increased survival rates and better neurologic outcomes following cardiac arrest (Bobrow et al., 2010; Kitamura et al., 2012; McNally et al., 2011; Sasson et al., 2010). Public education campaigns encourage discussions about the importance of being prepared to respond to a cardiac arrest, and advances in basic, clinical, and translational research could lead to new discoveries in cardiac arrest etiology and pathophysiology, facilitating innovative technologies, new research models, and the widespread adoption of new therapies.

However, even if all communities and hospitals maximized performance based on current knowledge and practice, better treatments and processes still are needed to improve cardiac arrest outcomes in the next decade. Fundamentally, cardiac arrest treatment is a community issue;

local resources and personnel must provide appropriate, high-quality care to save the life of a community member. But local decisions should be informed by data, analysis, and shared experience, evolving in response to emerging research and innovative therapies to improve cardiac arrest outcomes. To facilitate informed decision making and collaboration within the resuscitation field, specific barriers must be overcome.

From a social perspective, the resuscitation field has a public identity crisis, which has stymied attempts to communicate the public health threat of cardiac arrest for more than 30 years. The public often equates cardiac arrest with a heart attack, but cardiac arrests outside of hospitals (unlike heart attacks) rarely have early warning signs and require immediate intervention to avoid death and disability. Bystanders can provide basic life support treatments, by activating the EMS system, administering CPR, and applying defibrillation with an AED. Some European countries mandate first aid training, resulting in as many as 95 percent (Norway) and 80 percent (Germany) of the public trained in CPR and AED use (IFRC, 2009). However, less than 3 percent of the U.S. population receives CPR training annually (Anderson et al., 2014), rendering many bystanders unprepared to respond to cardiac arrest.

Within the resuscitation field, cardiac arrest is often characterized by location of the event (i.e., out-of-hospital cardiac arrest [OHCA] versus in-hospital cardiac arrest [IHCA]), which may be a natural reflection of the traditionally separate roles of EMS and hospital systems. However, this characterization tends to fragment the research community, limit advocacy coordination, and complicate efforts to best utilize finite resources. For example, the study and delivery of care for OHCA and IHCA are often viewed as independent and sometimes competing areas rather than complementary activities within the same system of response. Although the general risk factors and contexts for each type of cardiac arrest may differ, health outcomes depend on coordination across the systems and the alignment of quality improvement activities. Similarly, tensions related to prioritization and funding exist between the need to effectively implement interventions associated with improved outcomes and the need for basic, clinical, and translational research to generate new treatments and care paradigms.

The resuscitation field currently lacks comprehensive data and reliable measurement tools related to incidence and effective treatments, leading to broad ranging estimates and unknowns. Moreover, dedicated funding and infrastructure for resuscitation research is substantially lacking compared to diseases that account for fewer annual deaths in the

United States. For example, stroke kills approximately 130,000 people each year (CDC, 2015). However, in 2014 stroke research received seven times more support from the National Institutes of Health (NIH) than cardiac arrest research, which included studies related to cardiac arrest, sudden cardiac death, or resuscitation sciences (Lathrop, 2014; NIH, 2015). This lack of data and resources creates challenges for promoting general public and professional awareness about cardiac arrest and the need for immediate response and treatment. It also stifles the potential of resuscitation research to advance the field and improve patient outcomes.

The resuscitation field is well positioned to capitalize on an existing and substantial knowledge base and to improve health outcomes from cardiac arrest over the next decade. However, it must first overcome internal and external challenges in a cohesive and coordinated manner to maximize high-functioning survival rates for almost 600,000 individuals annually.[3]

SCOPE OF WORK

In 2013, the American College of Cardiology, the American Heart Association, the American Red Cross, the Centers for Disease Control and Prevention, NIH, and the U.S. Department of Veterans Affairs asked the Institute of Medicine (IOM) to conduct a consensus study on the factors affecting resuscitation research and outcomes in the United States. The IOM committee was charged with evaluating the public health dimensions of cardiac arrest treatment, with a focus on the following five areas: CPR and the use of AEDs, EMS and hospital systems of resuscitation care, national cardiac arrest statistics, resuscitation research, and future therapies and strategies for improving health outcomes from cardiac arrest within the next decade. The committee's charge did not include examining the role or impact of prevention. Additionally, because of the quality and availability of evidence about cardiac arrest, the committee focused its analysis on treatments up through hospital discharge and outcomes through 90-days post discharge.

To respond to its charge, the IOM convened a 19-member committee with a broad range of expertise. The committee held five meetings and two public workshops throughout its term in order to solicit input from a variety of stakeholders. In addition to input received through public

[3]This statistic is an approximation based on annual case counts of OHCA and IHCA.

workshops, the committee examined the available scientific literature and commissioned analyses of recent data on OHCA and IHCA.

A UNIFYING FRAMEWORK FOR CARDIAC ARREST

Since 1991, the chain of survival (see Figure S-1) has been the dominant operational model in the resuscitation field. The model focuses on early activation of basic and advanced life support responses for individuals with cardiac arrest, beginning in the prehospital phase and following through to post-arrest care. The likelihood of a positive outcome decreases if any link is delayed or improperly implemented. This model has been influential in strengthening the delivery of care within discrete systems, leading to increased survival rates for some pioneering communities. Strategies and interventions aimed at enhancing the recognition of cardiac arrest and increasing the timeliness and quality of care have been applied to further reinforce the chain. Although the chain of survival is useful to guide operational decisions within individual systems, a different framework is needed to identify overarching goals for the broader resuscitation field.

Promoting advances in cardiac arrest health outcomes will require coordination, cooperation, and consultation across many disciplines and actors. Fluid and formal transitions between sites of care help identify and target factors influencing patient care. To facilitate productive discussion between federal, state, local, and community representatives, a comprehensive systems-level framework is needed to guide the development of cohesive short- and long-term strategies that are necessary to reduce the public burden of cardiac arrest. Figure S-2 illustrates a systems-level framework that can be used to identify relationships between actors and organize actions between actors that affect cardiac arrest treatment and outcomes. One goal—to increase the likelihood of survival with good neurologic and functional outcomes for any person who suffers a cardiac arrest (i.e., improved patient outcomes)—provides the roof. Together, the foundation and pillars are part of an integral, comprehensive, system-level response that is necessary to revitalize the resuscitation field and improve population health and patient outcomes from cardiac arrest in the short and long term.

FIGURE S-1 Cardiac arrest chain of survival.
NOTE: ACLS = advanced cardiac life support; CPR = cardiopulmonary resuscitation.
SOURCE: Resuscitation Academy, n.d., p. 14.

Effective cardiac arrest response requires the actions of five groups (represented by the five columns in Figure S-2), who directly and indirectly affect patient outcomes. The public includes bystanders, who are at the forefront of the response and have the opportunity to report the event and initiate the response. The public also includes individuals who experience a cardiac arrest, friends and families, and individuals in industry, the workplace, schools, care facilities, and community organizations. EMS systems include 911 call takers, dispatchers, first responders, emergency medical technicians (EMTs), and paramedics, who respond to cardiac arrests and transport patients to local hospitals and emergency medical facilities after initiating resuscitation treatment. Similarly, individuals within EMS systems have the opportunity to instruct bystanders on how to administer CPR through dispatcher-assisted CPR.[4] Hospitals and broader health care systems (which may include rehabilitation services) respond to cardiac arrests, provide essential post-arrest care for patients, and facilitate critical care transitions between EMS systems and various departments within the hospitals. Basic, clinical, and translational

[4]Dispatcher-assisted CPR (also referred to as dispatcher-assisted bystander CPR, just-in-time instruction, and telecommunicator CPR) is a term that includes the identification of cardiac arrest and the provision of CPR instructions to a 911 caller prior to the arrival of EMS providers at the scene of a cardiac arrest (see Chapter 4). Because dispatchers and 911 call takers may not be the same person, especially in large 911 centers, "telecommunicator" is used as an umbrella term to refer to any individual who works in a 911 center and has responsibility for receiving calls and/or sending help. However, to remain consistent with recent Utstein core measures and with terminology generally used in emergency medicine and by the public, this report uses the term "dispatcher-assisted CPR" to mean CPR instruction provided over a phone to a rescuer by a trained individual.

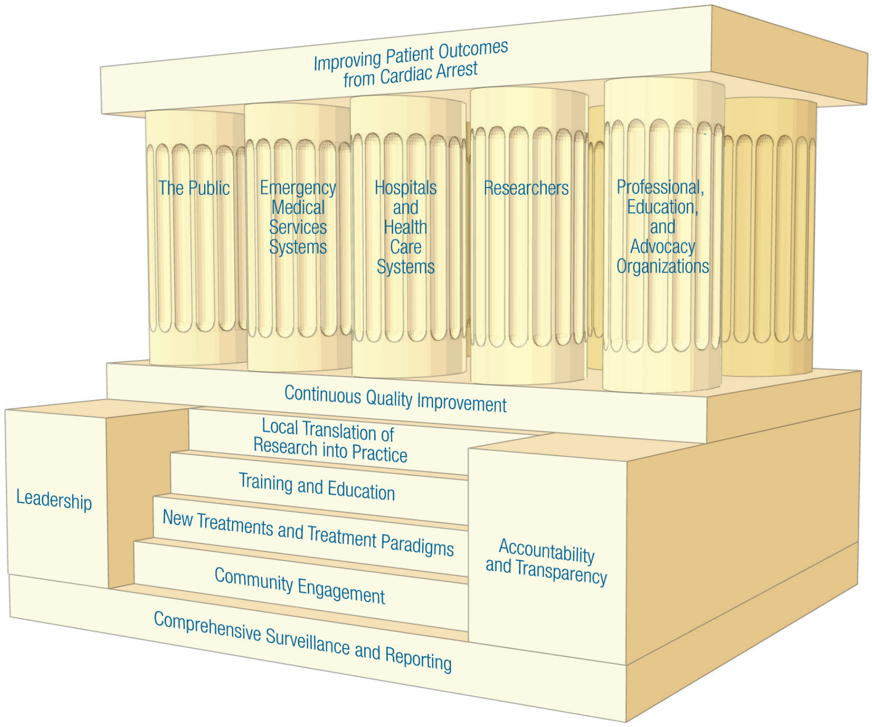

FIGURE S-2 A unifying framework for improving patient outcomes from cardiac arrest.
NOTES: This figure is based on an illustration from the Institute of Medicine's *Crisis Standards of Care* series, which proposed a framework for catastrophic disaster response to assist in crisis standards of care planning (IOM, 2013, p. 18). Although the purpose and specific elements are different, the committee found the general approach useful to frame the principles, actions, and actors relevant to an overarching system of response to cardiac arrest.

researchers generate hypotheses and new insights about the mechanisms and pathophysiology of cardiac arrest identifying novel pathways for rapid delivery of innovative treatments and treatment models. Finally, professional, training, and advocacy organizations can provide opportunities to educate and train various actors across the system, promoting valuable interdisciplinary dialogue, better informed policies, and a culture of action through increased accountability. Improved patient outcomes are more likely when these actors collaborate and coordinate their activities to strengthen the field and kindle progress.

The foundation comprises six steps, each representing fundamental key actions, including (1) comprehensive surveillance and reporting, (2) community engagement, (3) new treatments and treatment paradigms, (4) training and education, (5) local translation of research into practice, and (6) continuous quality improvement. Leadership, along with transparency and accountability, serve as the cornerstones that establish the position and direction of the entire structure.

Comprehensive Surveillance and Reporting

Given the large health burden of cardiac arrest, a national responsibility exists to facilitate dialogue about cardiac arrest that is informed by comprehensive data collection and timely reporting and dissemination of information. Reliable and accurate data are needed to empower states, local health departments, EMS systems, health care systems, and researchers to develop metrics, identify benchmarks, revise education and training materials, and implement best practices. Furthermore, increasing public awareness about disparities in care and opportunities to improve outcomes can lead to greater public engagement in education and training, larger advocacy networks, and stronger community leadership efforts related to cardiac arrest.

Community Engagement

The urgent nature of cardiac arrest and the risks of mortality and disability without immediate response imply a societal obligation of bystanders to be prepared and willing to deliver basic life support before the arrival of professional emergency responders. Communities can foster a culture of action by promoting awareness of cardiac arrest symptoms, early activation of emergency medical systems, easy access to CPR and AED training, and active engagement in response to cardiac arrest. Communities can also cultivate community engagement through public advocacy, local awareness events and campaigns, and leadership opportunities that create a platform for dialogue within the community.

New Treatments and Treatment Paradigms

Strategic investment in research will increase the understanding of disease processes that can expand the availability of new therapies and drive beneficial changes in the resuscitation field. Traditional treatments for cardiac arrest do not fully account for the complex pathophysiology of cardiac arrests. For example, although an effective treatment for some cardiac arrest rhythms (e.g., pulseless ventricular tachycardia and ventricular fibrillation), defibrillation is not effective for all cardiac arrest rhythms (e.g., those with pulseless electrical activity and asystole) nor does it address the effects of global ischemia. Treatment strategies for cardiac arrest need to evolve further based on new information generated from basic and clinical research.

Training and Education

Successful resuscitation following cardiac arrest requires a series of synchronized, exacting responses, often involving complex transitions between different actors, including bystanders, trained first responders, EMS personnel, and health care providers. Given the need for reliable competency and consistent care quality to improve health outcomes across sites of care, all actors must be educated about the burden of cardiac arrest and trained (and retrained) to provide rapid and effective treatment for cardiac arrest.

Local Translation of Research into Practice

Efficient translation of resuscitation science and research into care delivery practices is essential to optimize patient outcomes from cardiac arrest. National guidelines should be viewed as baseline standards from which regional and local practice and care delivery protocols may evolve based on emerging evidence (e.g., continuous monitoring of local data, published literature), local challenges (e.g., disparities in outcomes, low bystander response rates), state regulation and governance structure of EMS and health care systems, and available resources (e.g., trained EMS or health care personnel, funding).

Continuous Quality Improvement Programs

Widespread adoption of continuous quality improvement programs throughout the field of resuscitation would encourage data collection across all sites of care, enable comparisons within and between EMS and health care systems, and lead to the identification of best practices to improve population health and patient outcomes following cardiac arrest. Public policies encouraging such programs for other systems of care (e.g., learning health care systems) should serve as models for the field of resuscitation, which includes a broader range of individuals responding to cardiac arrest.

Leadership

Cardiac arrest outcomes are affected by leadership across a wide range of settings, including federal agencies, state and local government (including health departments), EMS systems, health care organizations, and community clinics and advocates. Communities that have demonstrated higher cardiac arrest survival rates and favorable neurologic outcomes typically have strong civic and health care system leaders, who establish accountability for these outcomes to their communities through increased public awareness efforts, widespread training in CPR and AED use, and sustained investment in outcome measurement, data reporting, and self-assessment. With appropriate leadership, effective treatments and strategies can be implemented in other communities to save thousands of more lives across the country each year.

Accountability and Transparency

Enhanced accountability and transparency can increase operational effectiveness and efficiency by building trust among stakeholders, engaging individuals and organizations in continuous quality activities, and fostering innovation. Currently, the resuscitation field lacks appropriate transparency and accountability for cardiac arrest incidence and outcomes. As more comprehensive data become available, new opportunities will emerge to increase public awareness, enhance training across different sectors, and modify local system treatment protocols and service delivery models related to cardiac arrest. These opportunities will require explicit responsibility to collect and disseminate data to the public in order to establish accountability for system performance through various social and policy mechanisms.

ESTABLISH ROBUST DATA COLLECTION AND DISSEMINATION

Currently, national surveillance data on the incidence and factors associated with cardiac arrest do not exist. Databases that do exist are voluntary, limiting their scope and generalizability. Moreover, issues related to data harmonization, standardized metrics and measures, common data infrastructures, and varying degrees of oversight across databases contribute to a lack of interoperability and hinder evidence-based decision making related to research support and intervention adoption and evaluation. As a result, significant gaps in knowledge persist related to the epidemiology, pathophysiology, and treatment of cardiac arrest. With critical funding for some of the larger cardiac arrest registries ending (see Chapter 2),[5] it becomes increasingly important to coordinate existing surveillance activities and broaden the scope of surveillance nationally. A lead organization is necessary to promote data collection, establish sustainability and continuity, and streamline data dissemination that will drive the collective public health efforts to save lives.

Recommendation 1. Establish a National Cardiac Arrest Registry
The Centers for Disease Control and Prevention (CDC)—in collaboration with state and local health departments—should expand and coordinate cardiac arrest data collection through a publicly reported and available national cardiac arrest registry, including both out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) data, to help increase federal and state accountability for current system performance and promote actions to improve cardiac arrest outcomes.

Specifically, CDC should

- establish a cardiac arrest surveillance system for the nation that includes IHCA and OHCA data in pediatric and adult populations;
- make data publicly available through appropriate mechanisms to enable comparisons across data sets in order to increase public awareness about cardiac arrest incidence and treatments, improve accountability for emergency medical services system and health care system performance, and target interventions that will reduce disparities and improve patient outcomes;
- identify and adopt standardized definitions, criteria, and metrics (such as age, gender, race and ethnicity, socioeconomic status, and primary language) for cardiac arrest identification, treatment, and outcome assessment; and

[5]Personal communication, J. Brown, NIH, May 22, 2015.

- promote and coordinate the development and implementation of unique diagnostic codes for OHCA and IHCA in *International Classification of Diseases* (ICD) coding models through its North American Collaborating Center, working with the Centers for Medicare & Medicaid Services and the World Health Organization.

Specifically, state, territorial, and local health departments should

- mandate tracking and reporting of all cardiac arrest events; and
- publicly report the incidence and outcomes of IHCA and OHCA within and across various areas within states and territories, taking appropriate steps to protect patient privacy and confidentiality.

Establishing standard definitions and data elements across local, state, national, and international stakeholders would enhance data harmonization and interoperability. These enhancements would allow for more reliable and accurate data aggregation, enable benchmarking and continuous quality improvement initiatives, and reduce unnecessary confusion in an already complex field of study.

EDUCATE AND TRAIN THE PUBLIC

Although evidence indicates that bystander CPR and AED use can significantly improve survival and outcomes from cardiac arrest, rates of bystander training in CPR and AED use remain less than 3 percent annually in the United States (Anderson et al., 2014). The public's current inability to recognize cardiac arrest, initiate CPR, and apply AEDs presents a call for action. An informed, coordinated, and effective campaign to promote public education and training opportunities and reduce barriers to the provision of bystander CPR and defibrillation would provide immense value to the overall health of the nation.

Recommendation 2. Foster a Culture of Action Through Public Awareness and Training
State and local departments of health and education, and leading organizations in cardiac arrest response and treatment, should partner with training organizations, professional organizations, public advocacy groups, community and neighborhood organizations and service providers, and local employers to promote public awareness of the signs, symptoms, and treatment of cardiac arrest. These efforts require public cardiopulmonary resuscitation (CPR) and automated external defibrillators (AED) training across the lifespan, creating a culture of action that prepares and motivates bystanders to respond immediately upon witnessing a cardiac arrest. Specifically,

- State and local education departments should partner with training organizations and public advocacy groups to promote and facilitate CPR and AED training as a graduation requirement for middle and high school students;
- Employers (e.g., federal agencies, private business owners, and schools) should be encouraged to maintain easy-to-locate and clearly marked AEDs, provide CPR and AED training to their employees, and specifically include cardiac arrest in formal emergency response plans; and
- Local health departments should engage with community and neighborhood organizations and service providers to expand the types and locations of available CPR and AED training to populations over age 65 and caregivers for this population.

IMPROVE DELIVERY OF HIGH-QUALITY RESUSCITATION AND POST-ARREST CARE

Although it is possible to conduct broad assessments of the quality of care provided by EMS or hospital systems that are based on overall survival rates and positive neurologic and functional outcomes, it is more difficult to distinguish which specific care elements, or combination of elements, directly influence patient outcomes. Despite these challenges, a number of EMS and hospital actions related to cardiac arrest care have been associated with higher survival rates in some communities, offering promising strategies that could be more widely adopted in order to reduce the public health burden of cardiac arrest. Standardized training and performance evaluation measures for care processes and protocols would promote a more rapid and uniform adoption and assessment of cardiac-arrest quality of care on a national scale.

Recommendation 3. Enhance the Capabilities and Performance of Emergency Medical Services (EMS) Systems
As the informal agency for EMS, the National Highway Traffic Safety Administration should coordinate with other federal agencies and representatives from private industry, states, professional organizations, first responders, EMS systems, and nonprofit organizations to promote uniformly high-quality emergency medical systems by

- convening interested stakeholders to develop standardized dispatcher-assisted cardiopulmonary resuscitation (CPR) protocols and national educational standards for use by all public safety answering points; and
- establishing a standardized definition and training curriculum for high-performance CPR to be used in basic emergency medical technician training and certification.

Recommendation 4. Set National Accreditation Standards Related to Cardiac Arrest for Hospitals and Health Care Systems
The Joint Commission—in collaboration with the American Red Cross, the American Heart Association, hospital systems, hospitals, professional organizations, and patient advocacy groups—should develop and implement an accreditation standard for health care facilities specific to cardiac arrest care for adult and pediatric populations.

Recommendation 5. Adopt Continuous Quality Improvement Programs
Emergency Medical Services (EMS) systems, health care systems, and hospitals should adopt formal, continuous quality improvement programs for cardiac arrest response that

- assign responsibility, authority, and accountability within each organization or agency for specific cardiac arrest measures;

- implement core technical and nontechnical training, simulation, and debriefing protocols to ensure that EMS and hospital personnel can respond competently to both adult and pediatric cardiac arrests; and
- actively collaborate and share data to facilitate national, state, and local benchmarking for quality improvement.

INCREASE THE IMPACT OF CARDIAC ARREST RESEARCH AND THERAPIES

Resuscitation science should be a major force in advancing patient outcomes. New research findings and emerging discoveries related to pharmaceuticals, devices, and biosensors provide compelling promise for boosting survival and positive outcomes and for reshaping approaches to the cardiac arrest treatments and care delivery models. However, federal agency support for resuscitation research is less than diseases and conditions with similar incidence. Large knowledge gaps about the etiology, epidemiology, pathophysiology, and even the effectiveness of current therapies for cardiac arrest persist. Future research must include a focus on basic, clinical, and translational science that leads to newer therapies. These, in turn, require clinical studies to develop sound evidence for, and the wide adoption of, best practices and interventions, as well as the evaluation of existing and new therapy effectiveness.

Recommendation 6. Accelerate Research on Pathophysiology, New Therapies, and Translation of Science for Cardiac Arrest
In order to identify new, effective treatments for cardiac arrest, the National Institutes of Health (NIH), the American Heart Association, and the U.S. Department of Veterans Affairs should lead a collaborative effort with other federal agencies and private industry to build the nation's research infrastructure that will support and accelerate innovative research on the causal mechanisms of onset, pathophysiology, treatment, and outcomes of cardiac arrest. These actions should

- strengthen laboratory, clinical, and translational resuscitation research support to levels commensurate with the public health burden of cardiac arrest for adult and pediatric populations across federal agencies, including NIH institutes; and

- establish a balanced and comprehensive portfolio of grants across the full spectrum of science translation to encourage the development and application of novel and efficient research strategies and innovative trial designs in preclinical, clinical (e.g., exploratory and hypothesis-generating studies), and population-based resuscitation research.

Recommendation 7. Accelerate Research on the Evaluation and Adoption of Cardiac Arrest Therapies
The National Institutes of Health should lead a collaborative effort with the U.S. Department of Veterans Affairs, the Agency for Healthcare Research and Quality, and the Patient-Centered Outcomes Research Institute to prioritize health services research related to the identification, evaluation, and adoption of best practices; the use of innovative technologies (e.g., mobile and social media strategies to increase bystander cardiopulmonary resuscitation or automated external defibrillator use); and the development of new implementation strategies for cardiac arrest treatments.

STRENGTHEN STAKEHOLDER COLLABORATION

Numerous organizations and institutions have supported valuable activities to advance the science and implementation of resuscitation. These efforts have led to critical progress within the field over the years. These efforts, however, have not established a united advocacy presence to heighten the visibility of cardiac arrest as a treatable public health threat that warrants the attention and support of policy makers and the public. To develop shared strategies, identify and support new leaders and advocates, and maximize the impact of limited resources within a field, formal and sustained collaboration is essential.

Recommendation 8. Create a National Cardiac Arrest Collaborative
The American Heart Association and the American Red Cross—with the U.S. Department of Health and Human Services and other federal agencies, national and international resuscitation councils, professional organizations, private industry, and patient advocates—should establish a National Cardiac Arrest Collaborative to unify the cardiac arrest field, identify common

goals, and build momentum within the field to ultimately improve survival from cardiac arrest with good neurologic and functional outcomes. The Collaborative should

- provide a platform for information exchange about key successes and failures in different systems and settings and for stakeholder communication about new research findings and initiatives;
- convene working groups on short- and long-term national research priorities for cardiac resuscitation and post-arrest care, which focus on critical knowledge gaps (such as the impact of care transitions; the organization, composition, and training of resuscitation teams; optimal timing of initial neurological evaluation; and appropriate withdrawal-of-care protocols);
- develop action strategies related to health policy, research funding and translation, continuous quality improvement, and public awareness and training;
- produce and update toolkits for different stakeholders (e.g., emergency medical services [EMS] systems, hospitals, local health departments, and local health care providers) in order to facilitate effective system and individual responses to cardiac arrest;
- hold an annual collaborative meeting in conjunction with a regularly scheduled health professional conference to discuss short- and long-term goals and progress; and
- encourage public–private partnerships to support activities that focus on reducing the time to defibrillation for cardiac arrest, including the development of technologies to facilitate automated external defibrillator registries for use by the public, EMS systems, and other stakeholders.

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1

Introduction

Cardiac arrest can strike seemingly healthy individuals of any age, race, ethnicity, or gender at any time in any location, often without warning. The person who experiences a cardiac arrest may be a co-worker at the office; a child on a soccer field; a friend in a hospital; a stranger on the sidewalk; or a parent, grandparent, or spouse in a home. In an instant, a person's pulse or blood pressure disappears, leading to a loss of consciousness and collapse, which is followed by death if treatment is not provided quickly. The risk of irreversible brain and organ injury and major disability increases the longer the delay in restoring a heart rhythm and blood flow. However, if the heart can be restarted shortly after arrest, then it is possible for individuals to make a complete recovery without any long-term effects.

Death and disability from cardiac arrest are prominent public health threats. Using conservative estimates, cardiac arrest is the third leading cause of death in the United States, following cancer and heart diseases (see Taniguchi et al., 2012). In 2013, the estimated incidence of total cardiac arrests in the United States occurring outside the hospital (i.e., out-of-hospital cardiac arrests [OHCAs]) was approximately 395,000 (Daya et al., 2015).[1] The most recent estimates document an additional 200,000 cardiac arrests occurring in hospitals (i.e., in-hospital cardiac

[1]The 2013 OHCA incidence statistic (395,000) includes patient of all ages and cardiac arrests events with both cardiac and noncardiac (e.g., trauma, drowning, and poisoning) etiologies (Daya et al., 2015). This figure is an approximation based on analysis of data from the Resuscitation Outcomes Consortium-Epistry, the limitations of which are described in Chapter 2. The calculation of incidence is available in the commissioned paper by Daya and colleagues (2015).

arrests [IHCAs]) (Merchant et al., 2011).[2] Pediatric OHCAs are less common, and make up between 2 to 3 percent of all cardiac arrests in the country (Daya et al., 2015).

Despite nearly 50 years of advocacy to improve cardiac arrest treatment, overall survival rates remain low, and disability with poor neurologic and functional outcome affect communities throughout the United States. Nationally, less than 6 percent of people who experience an OHCA and 24 percent of patients who experience an IHCA survive to hospital discharge (Chan, 2015; Daya et al., 2015). One notable study found that overall survival-to-discharge rates for adults suffering OHCA in the United States had not increased during the past 30 years (Sasson et al., 2010), although emergency medical services (EMS) systems and hospitals enrolled in specific cardiac arrest registries have found positive survival trends in more recent years (Chan, 2015; Daya et al., 2015). Relative to other conditions, the cost of care and the number of productive years of lives lost due to cardiac arrest death and disability are also large (Stecker et al., 2014).

Wide disparities in cardiac arrest outcomes have also been documented. Many of these disparities may be a result of variation in local response to cardiac arrest (e.g., bystander cardiopulmonary resuscitation [CPR] rates) and variation in care processes and protocols—factors that can be modified. For example, a study by Nichols and colleagues (2008) found that survival rates from OHCA ranged from 7.7 percent to 39.9 percent across 10 North American sites. Seattle and King County, Washington, have demonstrated survival rates for OHCA of 62 percent, among patients who had witnessed cardiac arrest, caused by a specific cardiac rhythm, compared to single-digit survival rates in other urban areas in the United States (Chatalas and Plorde, 2014). Risk-adjusted survival rates for IHCA also vary by 10.3 percent between bottom- and top-decile hospitals (Merchant et al., 2014). Similar variation exists for children who experience an IHCA (Jayaram et al., 2014). A wide range of factors may contribute to documented variations, including differences in patient demographics and health status, geographic chacteristics, and system-level factors affecting the quality and availability of care.

Effective treatments for specific types of cardiac arrest are known and, if more efficiently implemented on a broader basis, could avoid

[2] The reported statistics are based on a 2011 analysis, using the most recently available data (years 2003 through 2007) from the Get With The Guidelines-Resuscitation (GWTG-R) registry. The study used three separate approaches to calculate the estimated range of annual IHCA events in the United States.

needless deaths and disability each year. Decreasing the time between the onset of cardiac arrest and the first compression is essential. Similarly, timely delivery of electrical shocks (i.e., defibrillation) can revive heart muscles for specific types of cardiac arrest and significantly increase the likelihood of survival to hospital discharge (Caffrey et al., 2002; Chan et al., 2008; Field et al., 2010). Bystander-administered CPR is associated with substantial increases in survival rates and with better neurologic outcomes after cardiac arrest (Bobrow et al., 2010; Kitamura et al., 2012; McNally et al., 2011; Sasson et al., 2010). Unfortunately, only a small fraction of the public receives CPR training in the United States annually (Anderson et al., 2014). Recent public awareness campaigns are engaging more bystanders in discussions about the importance of being prepared to respond to a cardiac arrest (see Heart Rhythm Society, 2015), and new technologies offer promising advancements in training to reduce that time to first compression and improve the quality of delivered care.

High-performing communities provide examples of how functional public health infrastructures and well-organized health system responses can facilitate timely treatments and formal transitions of care across informally defined teams (including bystanders, first responders, emergency medical technicians, paramedics, and hospital-based health care providers) to significantly improve survival and neurologic function following cardiac arrest. Within systems of care, continuous quality improvement initiatives that are based on process evaluation and observed outcomes can serve as a foundation for the development of more proactive and responsive care models, thus benefiting patients.

The solution to improving outcomes from cardiac arrest, however, does not end with better implementation of known treatments and therapies. Even if all communities and hospitals were to maximize performance based on current evidence and clinical practice guidelines, sustained support for continuing basic, clinical, and translational research is necessary to generate more effective treatments and care paradigms, and a more nimble system is needed to update care processes and treatment protocols based on evidence. Approximately 8 out of 10 cardiac arrests occur in a home setting (Vellano et al., 2015), and only 46 percent of OHCAs are witnessed by another person (Daya et al., 2015), requiring new thinking about how technologies could be used to alert possible responders to a cardiac arrest. Because approximately 70 percent of OHCAs are caused by rhythms that do not typically respond to electrical shock (Daya et al., 2015; Vellano et al., 2015), it is also important to support and translate basic and clinical research discoveries that can provide new insights about etiology, pathophysiology, causation, and therapies. Recent advancements in available cardiac treatments (e.g., percutaneous coronary interventions, emergency cardiopulmonary bypass, cardiac revascularization, and post-resuscitation care algorithms) have also demonstrated favorable impacts on cardiac arrest outcomes. New drug combinations that target reperfusion injury may prevent cardiovascular and neurologic decline that occurs in many patients after resuscitation. Efforts to personalize medicine and improve prognostication are also leading to new models of care and reshaping discussions with patients and their families (Chan et al., 2012; Melville, 2015).

Generating the necessary momentum to foster meaningful change in cardiac arrest practice, policy, and prioritization is possible, despite many social, political, and practical challenges. Throughout the report, the committee emphasizes the need to consider the overarching system of response to cardiac arrest, which is affected by and influences other factors, including data collection, research infrastructure, public and professional training and education, program evaluation, accountability, and civic and community leadership. Leveraging existing and developing capabilities could strengthen the system of response to cardiac arrest throughout the United States, raising public awareness and stimulating action that is needed to advance the resuscitation field as a whole and preserve the length and quality of life for individuals who experience a cardiac arrest.

COMMITTEE SCOPE OF WORK

In 2013, the American College of Cardiology, the American Heart Association, the American Red Cross, the Centers for Disease Control and Prevention, the National Institutes of Health, and the U.S. Department of Veterans Affairs asked the Institute of Medicine (IOM) to conduct a consensus study on the factors currently affecting cardiac arrest treatment and outcomes in the United States. Specifically, the IOM's Committee on the Treatment of Cardiac Arrest: Current Status and Future Directions was charged with evaluating the following five areas: CPR and use of automated external defibrillators (AEDs), EMS and hospital systems of resuscitation care, national cardiac arrest statistics, resuscitation research, and future therapies and strategies for improving health outcomes from cardiac arrest within the next decade. Box 1-1 provides the committee's complete statement of task.

BOX 1-1
Statement of Task

Treatment of Cardiac Arrest:
Current Status and Future Directions

The Institute of Medicine will conduct a study on the current status of, and future opportunities to improve, cardiac arrest outcomes in the United States. The study will examine current statistics and variability regarding survival rates from cardiac arrest in the United States and will assess the state of scientific evidence on existing lifesaving therapies and public health strategies that could improve survival rates. Additionally, the study will include a focus on promising areas of research and next steps to improve the quality of care for cardiac arrest.

The study will focus on the following topics and questions:

- *Cardiopulmonary resuscitation (CPR) and use of automated external defibrillators (AEDs).* What are the data on the effectiveness and use of CPR and AEDs? What is hindering use of these methods by the general public? What efforts have been conducted to improve the implementation of CPR and AEDs by the general public? What training efforts should be explored in schools or through other public initiatives?
- *EMS and hospital resuscitation systems of care*. What is the quality and performance level of out-of-hospital EMS providers and in-hospital resuscitation care teams? What is known about whether each patient is getting the care that they need? What challenges and barriers exist for teams and systems to more quickly implement best practices?
- *Resuscitation research*. What is the state of resuscitation research in the United States, including research on therapeutic hypothermia, emergency cardiopulmonary bypass resuscitation, and aggressive post-resuscitation critical care for cardiac arrest patients? Where are the research, technology transfer and innovation, and implementation gaps?
- *Next steps*. What are the new therapies and strategies on the "near horizon" (next 5 to 10 years) that hold the most promise to significantly enhance survival rates or to be the next paradigm in resuscitation care? How can resuscitation science discoveries be optimized for the rapid implementation of new therapies?

To respond to this charge, the IOM convened a committee of 19 experts with backgrounds in clinical medicine, health care services and delivery, epidemiology, statistics, research methods, health disparities, public education and outreach, cardiac electrophysiology, and ethics (see Appendix C). The committee held five meetings and two public workshops during the course of its work (see Appendix B) to solicit input from a variety of stakeholders and experts. In addition to input received through public workshops, the committee examined the available scientific literature, and also commissioned analyses of the most recently available data from the following registries: the Cardiac Arrest Registry to Enhance Survival, the Resuscitation Outcomes Consortium Epistry, and the Get With The Guidelines-Resuscitation registry.

Although both prevention and treatment of cardiac arrest are important to reduce the impact of cardiac arrest in the United States, the committee's scope of work was explicitly limited to an analysis of how to improve outcomes following cardiac arrest. Additionally, because of concerns about the quality and availability of evidence about cardiac arrest, in general, the committee limited its analysis of treatments up through hospital discharge and outcomes through 90-days post discharge, which excluded a detailed analysis of rehabilitation. The committee acknowledges the important roles that prevention and rehabilitation play and notes that both topics merit separate and dedicated analyses. With this in mind, elements related to prevention and rehabilitation are mentioned throughout this report. Some of the committee's recommendations related to cardiac arrest treatment will also affect cardiac arrest prevention, as well as rehabilitation.

The lack of data and currently available resources to study cardiac arrest etiology, causation, and treatment presented substantial barriers to the committee when trying to determine the effectiveness of either new or existing therapies. Moreover, the committee did not want to duplicate the work of guideline-issuing organizations that are currently conducting large-scale and comprehensive literature reviews for all existing cardiac arrest treatment and care protocols. As such, this report focuses more heavily on identifying short- and long-term strategies to propel the overall field of resuscitation. This includes discussions about strategies to encourage the development of new therapies and treatments, increase public awareness and willingness to intervene, as well as catalyze immediate system-level responses and quality improvement activities related to cardiac arrest in communities.

DEFINING CARDIAC ARREST

Cardiac arrest is a severe malfunction or cessation of the electrical and mechanical activity of the heart.[3,4] Under normal circumstances, the sinoatrial node initiates and sends an electrical signal to the right and left atria, causing the atria to contract and pump blood into the ventricles (see Figure 1-1). The electrical signal then travels from the atrioventricular node to the right and left ventricles, causing them to contract in a coordinated sequence and pump blood out of the heart to the lungs and the rest of the body. When the signal dissipates, the ventricles relax, and the process begins again after a normal delay.

Although the terms are often used interchangeably in the media and casual conversation, cardiac arrest is different and medically distinct from a heart attack (i.e., a myocardial infarction). Cardiac arrest results in almost instantaneous loss of consciousness and collapse, which will uniformly lead to death if not promptly reversed. Other symptoms may include absent or abnormal breathing (e.g., gasping or agonal breaths). Cardiac arrest may be due to a primary loss of cardiac pumping function, a variety of blood vessel-related factors (e.g., mechanical obstruction to arrest, usually as a consequence of a disturbance in the electrical activity of the heart that results in loss of mechanical function [commonly referred to as "sudden cardiac arrest"]), and to a lesser extent on causes that are primarily vascular or respiratory.

Compare this to a heart attack, a condition in which blood flow to an area of the heart is blocked by a narrowed or completely obstructed coronary artery. This causes inadequate oxygenation and subsequent injury or death to a portion of the heart. Acute symptoms of a heart attack include chest pain, shortness of breath, sweatiness, and dizziness, but do not necessarily include the pattern of immediate loss of consciousness that characterizes a cardiac arrest. A heart attack, large or small, can affect the electrical signaling and *cause* a cardiac arrest. However,

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[3]In its broadest definition, the term "cardiac arrest" refers to the loss of blood flow needed to maintain organ function and ultimate viability.

[4]Sudden cardiac death is defined as death due to a cardiac etiology or cardiac involvement in a noncardiac disorder, in a person with or without a known preexisting disease, and in whom the time and mode of death are unexpected (Myerburg and Castellanos, 2015). The committee selected to use the term "cardiac arrest" rather than "sudden cardiac death" to emphasize the broad range of factors that affect treatment of a clinical event as well as health outcomes beyond survival or death.

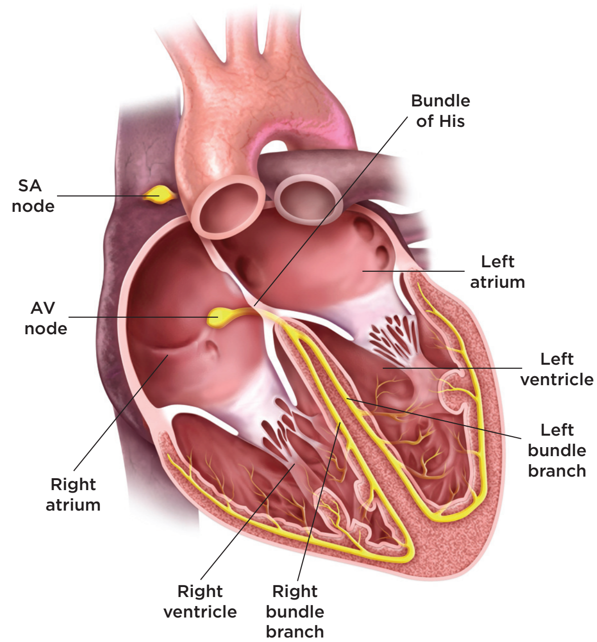

FIGURE 1-1 Anatomy of the heart's electrical system.
NOTE: AV = atrioventricular; SA = sinoatrial. The bundle of His is "the specialized tissue in the heart that transmits the electrical impulses and helps synchronize contraction" (Roquin, 2006, p. 480).
SOURCE: Adapted illustration reprinted by the IOM, with permission from Medmovie Copyright 2015.

a cardiac arrest does not cause a heart attack. Table 1-1 provides an overview of the differences between cardiac arrest and heart attack.

The distinction between cardiac arrest and heart attack is important because the goals and timing of treatment and the individuals qualified to perform specific treatments for these conditions are very different. The primary goals of cardiac arrest treatment are to facilitate return of spontaneous circulation (ROSC) and to avoid death and any physical or neurological damage.[5] This requires reestablishing circulation (either manual or spontaneous) as quickly as possible, because survival decreases by approximately 10 percent per minute following arrest (Boineau, 2014).

[5]Chapter 5 provides a more comprehensive explanation of possible outcomes from cardiac arrest.

TABLE 1-1 Differences Between Cardiac Arrest and Heart Attack

Characteristics	Cardiac Arrest	Heart Attack
Average age	63 (OHCA)[a]:65 (IHCA)[b]	65 (men): 72 (women)[c]
Male:female incidence ratio	3:2[a,b]; occurs in all ages, although frequency increases with increasing age	2:1[c]; less likely to occur in people younger than 35 years of age
Immediate cause	Cessation of mechanical activity of the heart, caused by a malfunction in the heart's electrical system	Blockage or significant narrowing of a coronary artery, causing tissue damage to an area of heart muscle due to lack of oxygen
Early warning symptoms	Some patients may experience palpitations, dizziness, chest pain, or shortness of breath momentarily before loss of consciousness and collapse	Patients may experience chest pain or upper body discomfort, unusual fatigue, weakness, nausea, shortness of breath; symptoms may occur days or weeks before
Loss of pulse, blood pressure, consciousness	Yes—in all cases	Heart attack may lead to cardiac arrest
Breathing	No, although gasping and agonal breaths may be mistaken for normal breathing	Yes
Cardiac rhythm	Characterized by complete lack of a heart rhythm or one incapable of generating a mechanical heart beat	May be accompanied by arrhythmias that do not cause loss of mechanical heart beats
Risk factors/ medical history	Cardiac risk factors include coronary artery disease, cardiomyopathy, myocardial infarction, valvular heart disease, congenital heart disease, and genetic syndromes	Coronary artery disease, congenital abnormalities in vasculature of the myocardium

continued

Characteristics	Cardiac Arrest	Heart Attack
Risk factors/ medical history	Noncardiac causes include electrolyte imbalance, severe blood loss, drug use, and drowning	
Treatment	• Cardiopulmonary resuscitation • Defibrillation • Advanced cardiac life support • Post-arrest care	• Medication to dissolve blood clot, dilate coronary blood vessels, and provide chest pain relief • Coronary angioplasty and stent to open blocked artery • Post-infarct care

NOTE: IHCA = in-hospital cardiac arrest; OHCA = out-of-hospital cardiac arrest.
SOURCES: [a]Vellano et al., 2015; [b]Chan, 2015; [c]Mozaffarian et al., 2015.

The likelihood of irreversible brain injury resulting in brain death, coma, vegetative state, or significant neurologic disability increases with delay in ROSC. Alternatively, neurologic and organ ischemia are less likely with a heart attack unless blood pressure is severely decreased. The primary goals of treatment for a heart attack are to reopen blocked arteries and restore blood flow to the heart before irreversible death of the heart muscle is present—usually 20 to 40 minutes after onset of inadequate oxygenation (Pierard, 2003).

Unlike with a heart attack, bystanders can perform CPR to treat cardiac arrest. CPR mechanically restores blood circulation and traditionally includes "integrated chest compressions and rescue breathing [i.e., mouth-to-mouth resuscitation]" to optimize circulation and oxygenation until ROSC is achieved (Travers et al., 2010, p. s677). The exact CPR performance specifications depend on the rescuer (e.g., some training courses now teach compression-only CPR, whereas courses for health professionals still emphasize ventilation and chest compression). Regardless of method, the basic actions can be performed by most adolescents and adults and should be delivered as soon as possible after recognition of a cardiac arrest. Although CPR can provide sufficient blood flow to protect the heart and the brain for some minutes—and can be effective in attaining ROSC—CPR typically is used to buy critical time until more effective treatments can be initiated.

A second treatment option is defibrillation, which is the provision of an electrical shock to the heart muscle, with the intent of restoring normal cardiac electrical activity and contractions (Travers et al., 2010). AEDs are devices that can be used by bystanders, as well as trained professionals. An AED analyzes heart rhythms and advises rescuers to administer a shock or resume CPR as appropriate. The devices are designed to be user friendly, provide easy-to-follow visual and auditory signs, and prevent the accidental or intentional administration of inappropriate shocks.

Not all cardiac arrests will respond to defibrillation. Four primary alterations in electrical activity of the heart may be associated with cardiac arrest: ventricular fibrillation (VF), pulseless ventricular tachycardia (pVT), pulseless electrical activity (PEA), and asystole (see Table 1-2). VF results from a faulty electrical signal in heart tissue resulting in loss of a coordination of contracting heart cells, and pVT is a failure of contraction during a very rapid heartbeat, originating in the ventricles. Cardiac arrest may also occur as a result of a primary mechanical function failure, in which the electrical signal fails to initiate a mechanical response (PEA) or when there is complete loss of an electrical signal so that no mechanical response can occur (asystole). “Shockable” arrhythmias (i.e., pVT and VF) may respond to defibrillation or electrical cardioversion, whereas “nonshockable” arrhythmias (i.e., PEA and asystole) usually do not. In addition to mechanism, cardiac arrest is also generally categorized by location of the arrest—OHCA and IHCA). The majority of both OHCAs and IHCAs are attributed to nonshockable rhythms, which may require development of new treatments and therapies to significantly improve outcomes, as discussed in Chapter 6.

In the context of OHCA, emergency medical systems professionals and/or bystanders may perform basic life support (BLS), which includes recognition of cardiac arrest, activation of the emergency response system, and performance of CPR and defibrillation. Advanced cardiac life support (ACLS) is used to complement BLS interventions, usually during transport to medical facilities by treating the cardiac arrest and stabilizing patients who achieve ROSC (Neumar et al., 2010). ACLS can be performed in the field or in hospital settings by trained professionals and often includes CPR, intravenous medications, advanced airway management, and physiological monitoring (Neumar et al., 2010). The effectiveness of specific ACLS interventions is debated, as described in greater detail in Chapter 4.

TABLE 1-2 The Types and Characteristics of Primary Cardiac Arrest Arrhythmias

	Ventricular Fibrillation	Pulseless Ventricular Tachycardia	Pulseless Electrical Activity*	Asystole
Definition	Uncoordinated electrical activation of heart, resulting in loss of organized contraction of the ventricles[a]	Organized electrical activation of heart, with absent or ineffective contraction of the ventricles, due to rate or extent of disease[a]	The heart's electrical activity is present, often slow and/or irregular, but the signal fails to initiate a mechanical response in the cells, resulting in no ventricle contraction[a]	Absence of electrical activity of the heart; no signal to initiate contraction of the ventricles[a]
ECG appearance	Grossly irregular electrical pattern on ECG, without identifiable QRS complexes[a]	Regular QRS complexes, usually wide and fast[a]	Usually wide QRS complexes, often slow and irregular;[a] sometimes narrow QRS complexes	No electrical activity—flat line[a]
Electrical activity	Yes	Yes	Yes	No
Palpable pulse	No	Usually not; occasionally present but weak	No	No
Responds to shock	Yes (usually)	Yes (usually)	No	No
Total CA in adults by first documented CA rhythm (%)**	OHCA 22.0[b] IHCA 10.0[c]	OHCA Included with VF IHCA 7.4[c]	OHCA 23.5[b] IHCA 54.6[c]	OHCA 46.9[b] IHCA 28.0[c]

	Ventricular Fibrillation	Pulseless Ventricular Tachycardia	Pulseless Electrical Activity*	Asystole
Total CA in children by first documented CA rhythm (%)	OHCA 4.9[b]	OHCA Included in VF	OHCA 12.9[b]	OHCA 68.9[b]
	IHCA 14.0[d]	IHCA Included in VF	IHCA 24.0[d]	IHCA 40.0[d]
Adult patients with first documented CA rhythm who survive to hospital discharge (%)	OHCA 28.7[b]	OHCA Included in VF	OHCA 8.7[b]	OHCA 2.0[b]
	IHCA 46.2[c]	IHCA 44.9[c]	IHCA 19.8[c]	IHCA 20.2[c]

* This term was previously "electrical-mechanical dissociation."
** This table does not present a small percent of unknown OHCA rhythms.
NOTE: CA = cardiac arrest; ECG = electrocardiogram; IHCA = in-hospital cardiac arrest; OHCA = out-of-hospital cardiac arrest; QRS complexes = "the series of deflections in an electrocardiogram that represent electrical activity generated by ventricular depolarization prior to contraction of the ventricles" (Merriam-Webster.com, 2015); VF = ventricular fibrillation.
SOURCES: [a]Mann et al., 2014; [b]Daya et al., 2015; [c]Chan, 2015; [d]Nadkarni et al., 2006.

Upon ROSC, post-arrest care is administered to reduce the risks of post-cardiac arrest syndrome, which includes cerebral and cardiac damage and dysfunction (Morrison et al., 2013; Neumar et al., 2008; Stub et al., 2011). Early post-arrest care includes prognosis assessments and integrated treatments designed to "optimize cardiopulmonary function and vital organ perfusion," transport a patient to an appropriate care facility (either hospital or unit within a hospital), and "identify and treat the precipitating causes of arrest and prevent recurrent arrest" (Peberdy et al., 2010, p. s768). Treatments and therapies may include oxygenation and ventilation, targeted temperature management (e.g., hypothermia), cardiovascular management, cardiac catheterization, hemodynamic support, vasopressor therapies, extracorporeal membrane oxygenation, anticonvulsants, and metabolic management. Post-arrest care protocols also differ for OHCA and IHCA. For example, in post-arrest care, targeted temperature management is rarely used after IHCA, which may be due to concerns of additional acute illnesses in these patients that may have unpredictable systemic responses to widespread temperature changes (Mikkelsen et al., 2013). Although the majority of post–cardiac arrest care is delivered in the hospital setting, EMS personnel may also provide some elements of post-arrest care, such as targeted temperature management and administration of specific pharmaceuticals and intravenous saline (Pinchalk, 2010). These treatment and therapies, which are described in greater detail in Chapters 5 and 6, have varying degrees of effectiveness.

THE CARDIAC ARREST CHAIN OF SURVIVAL

In 1991, the American Heart Association introduced the "chain of survival" model (Cummins et al., 1991) (see Figure 1-2), which has served as the dominant operational model for the resuscitation field since its publication and has been influential in affecting the delivery of efficient and effective care within discrete systems of some pioneering communities.

The chain, which originally evolved in the resuscitation field for use by EMS systems, includes five key, time-sensitive, and interdependent links: early access, early CPR, early defibrillation, early ACLS, and early post-resuscitative care (see Box 1-2). All of these links must rapidly and efficiently occur, sometimes sequentially or in parallel, to maximize the likelihood of survival and favorable neurologic and functional outcomes from cardiac arrest. The likelihood of successful resuscitation decreases if any link is delayed or improperly performed. Moreover, "separate specialized programs are necessary to develop strength in each link" (Cummins et al., 1991, p. 1832). In recent decades, many organizations,

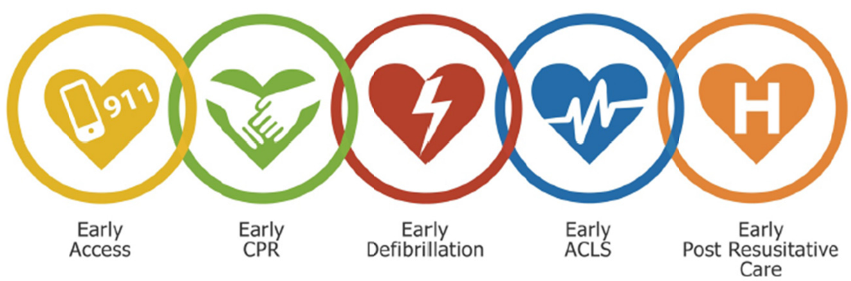

FIGURE 1-2 The cardiac arrest chain of survival.
NOTE: ACLS = advanced cardiac life support; CPR = cardiopulmonary resuscitation.
SOURCE: Resuscitation Academy, 2014.

BOX 1-2
Definitions of the Five Links in the OHCA Chain of Survival

Early Access: Early access to care comprises all events that are initiated after the patient's collapse until the arrival of EMS providers. Access includes recognition of the event, activation of the emergency medical system (i.e., calling 9-1-1), discussion with a dispatcher, and the decision to send an emergency response vehicle (Cummins et al., 1991).

Early Advanced Cardiac Life Support: Beyond CPR and defibrillation, paramedics may need to deliver early advanced care life support (e.g., drug therapies, airway management, and other intravenous treatment and monitoring) to achieve spontaneous resuscitation (Cummins et al., 1991).

Early CPR: Early CPR includes the initiation of basic CPR immediately after recognition of the event. It may overlap with efforts to activate the EMS system (Cummins et al., 1991).

Early Defibrillation: Early defibrillation includes the provision of electrical shock to the heart to reestablish a normal, spontaneous heart rhythm (Cummins et al., 1991). Several options for rapid defibrillation exist, including automated external, semi-automated external, or manual defibrillators (AHA, 2000).

Early Post-Resuscitative Care: Early and effective post-arrest care following resuscitation has the potential to restore and preserve the cognitive and functional health status of cardiac arrest patients. It may include more advanced treatments, such as prognosis assessments, oxygenation and ventilation, targeted temperature management (e.g., hypothermia), cardiovascular management, cardiac catheterization, hemodynamic support, vasopressor therapies, extracorporeal membrane oxygenation, and metabolic management (Neumar et al., 2010).

departments, and individuals have developed myriad strategies and interventions to strengthen the chain, specifically aimed at improving recognition of cardiac arrest and increasing the timeliness and quality of care. For example, some communities have implemented dispatcher-assisted CPR training to improve rates of bystander CPR performance. Other communities have implemented programs designed to promote high-quality CPR by EMS personnel and have demonstrated significant improvement in patient outcomes.

The principles of early recognition and early treatment are relevant to both OHCA and IHCA. Although the basic concepts involved in response to OHCA and IHCA are similar, there are specific differences between the events—both in terms of the health of the patient population and the treatment protocols—and these differences can affect the links within the chain and the provision of care at each stage. Patients who have an arrest in a hospital, particularly those in critical care units, are sicker than the average person who has an arrest in a community setting, and the arrest is frequently due to the heart's response to severe systemic illness rather than being the primary event. Thus, IHCA may be marked by observable deterioration of a patient in the hours leading up to the arrest, allowing for earlier and different interventions (Chan, 2015; Morrison et al., 2013). Response times are shorter and medical personnel can provide advanced screenings and immediate and simultaneous treatments in team environments in response to IHCA.

Because the chain is an operational model, it has a limited ability to identify objectives for the broader resuscitation field or strategies to synchronize interrelated components within the field. Furthermore, the current chain of survival model does not explicitly emphasize the importance of proactive leadership; transparency of, and accountability for, care quality and outcomes; or mechanisms to promote continual evaluation of existing treatments and systems of response. For example, the positive trends of cardiac arrest survival in selected communities may be a result of better feedback to EMS personnel, particularly in regard to meeting performance standards of care (Chan et al., 2014; McNally et al., 2011). Although the chain of survival does not exclude these actions, it also does not explicitly identify specific key actions to encourage efforts to enhance cardiac arrest outcomes.

A SYSTEMS FRAMEWORK

Effective care for cardiac arrest requires a proactive and coordinated system of response. Across this system, various actors may deliver care in succession or simultaneously. These actors may include the general public; local emergency services organizations; health care facilities; federal, state, and local health, education, and emergency services agencies; national nonprofit organizations; schools; and employers. Regardless of the order of care provided, high-quality performance and treatments must be maintained across all actors and settings to ensure patient survival and good neurologic and functional outcomes following cardiac arrest.

To facilitate productive discussion between federal, state, local, and community representatives, a comprehensive systems-level framework is needed to guide the development of cohesive short- and long-term strategies, which are necessary to reduce the public burden of cardiac arrest. Figure 1-3 illustrates a systems-level framework that can be used to identify and describe the relationships between critical components (i.e., actions and actors) that affect treatment of cardiac arrest. One goal—to increase the likelihood of survival with good neurologic function for any person who suffers a cardiac arrest (i.e., improved patient outcomes)—provides the roof. Together, the foundation and pillars are part of an integral, comprehensive system-level response that is necessary to revitalize the resuscitation field and improve population health and patient outcomes from cardiac arrest in the short and long terms.

Effective cardiac arrest response requires the actions of five groups (represented by the five columns in the figure) that directly and indirectly affect patient outcomes. The public includes bystanders, who are at the forefront of the response and have the opportunity to report the event and initiate the response. The public also includes individuals who experience a cardiac arrest, friends, and families, along with individuals in industry, the workplace, schools, care facilities, and community organizations. EMS systems include 911 call takers, dispatchers, first responders, emergency medical technicians, and paramedics, who respond to cardiac arrests and transport patients to local hospitals and emergency medical facilities after initiating resuscitation treatment. Similarly, individuals within EMS systems have the opportunity to instruct bystanders on how to administer CPR through dispatcher-assisted CPR.[6] Hospitals and broader health care systems (which

[6]Dispatcher-assisted CPR (also referred to as dispatcher-assisted bystander CPR, just-in-time instruction, and telecommunicator CPR) is a term that includes the identification of cardiac arrest and the provision of CPR instructions to a 911 caller prior to the arrival of EMS providers at the scene of a cardiac arrest (see Chapter 4). Because dispatchers and 911 call takers may not be the same person, especially in large 911 centers, "telecommunicator" is used as an umbrella term to refer to any individual who works in a 911 center and has responsibility for receiving calls and/or sending help. To remain consistent with recent Utstein core measures and with terminology generally used in emergency medicine and by the public, this report uses the term "dispatcher-assisted CPR" to mean CPR instruction provided over a phone to a rescuer by a trained individual.

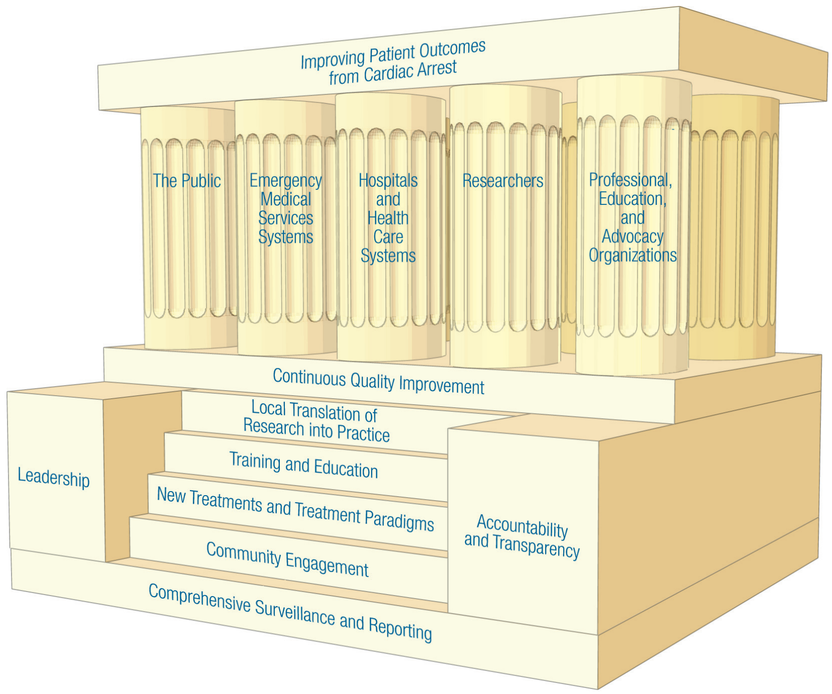

FIGURE 1-3 A unifying framework for improving patient outcomes from cardiac arrest.
NOTES: This figure is based on a figure from the Institute of Medicine's *Crisis Standards of Care* series, which proposed a framework for catastrophic disaster response to assist in crisis standards of care planning (IOM, 2013, p. 18). Although the purpose and specific elements are different, the committee found the general approach useful in framing the principles, actions, and actors relevant to improved cardiac arrest response.

may include rehabilitation services) respond to cardiac arrests, provide essential post-arrest care for patients, and facilitate critical care transitions between EMS systems and various departments within the hospitals. Basic, clinical, and translational researchers generate hypotheses and new insights about the mechanisms and pathophysiology of cardiac arrest, identifying novel pathways that can lead to the delivery of innovative treatments and treatment models. Finally, professional, training, and advocacy organizations can provide opportunities to educate and train various actors across the system, promoting valuable interdisciplinary dialogue, better informed policies, and a culture of action through increased accountability. Improved patient outcomes are more likely when these actors come together to collaborate and coordinate their activities to strengthen the field and kindle progress.

The foundation of the figure comprises six steps, each representing fundamental key actions: (1) comprehensive surveillance and reporting, (2) community engagement, (3) new treatments and treatment paradigms, (4) training and education, (5) local translation of research into practice, and (6) continuous quality improvement programs. Leadership, along with accountability and transparency, serve as the cornerstones that establish the position and direction of the entire structure.

Comprehensive Surveillance and Reporting

Given the large health burden of cardiac arrest, a national responsibility exists to facilitate dialogue about cardiac arrest that is informed by comprehensive data collection and timely reporting and dissemination of information. Reliable and accurate data are needed to empower states, local health departments, EMS systems, health care systems, and researchers to develop metrics, identify benchmarks, revise education and training materials, and implement best practices. Furthermore, increasing public awareness about disparities in care and opportunities to improve outcomes can lead to greater public engagement in education and training, larger advocacy networks, and stronger community leadership efforts related to cardiac arrest.

Community Engagement

The urgent nature of cardiac arrest and the risks of mortality and disability without immediate response imply a societal obligation of bystanders to be prepared and willing to deliver basic life support before the arrival of professional emergency responders. Communities can foster a culture of action by promoting easy access to CPR and AED training and active engagement in response to cardiac arrest. Communities can also cultivate community engagement through public advocacy, local awareness events and campaigns, and leadership opportunities that create a platform for dialogue within the community.

New Treatments and Treatment Paradigms

Strategic investment in research will increase the understanding of disease processes that can expand the availability of new therapies and drive beneficial changes in the resuscitation field. Traditional treatments for cardiac arrest do not fully account for the complex pathophysiology of cardiac arrests. For example, although an effective treatment for some cardiac arrest rhythms (e.g., pVT and VF), defibrillation is not effective for all cardiac arrest rhythms (e.g., those with PEA and asystole) nor does it address the effects of global ischemia. Treatment strategies for cardiac arrest need to evolve further based on new information generated from basic and clinical research.

Training and Education

Successful resuscitation following cardiac arrest requires a series of synchronized, exacting responses, often involving complex transitions between different caregivers, including bystanders, trained first responders, EMS personnel, and health care providers. Given the need for reliable competency and consistent care quality to improve health outcomes across sites of care, all caregivers must be educated about the burden of cardiac arrest and trained (and retrained) to provide rapid and effective treatment for cardiac arrest.

Local Translation of Research into Practice

Efficient translation of resuscitation science and research into care delivery practices is essential to optimize patient outcomes from cardiac arrest. National guidelines should be viewed as baseline standards from which regional and local practice and care delivery protocols may evolve based on emerging evidence (e.g., continuous monitoring of local data and published literature), local challenges (e.g., disparities in outcomes and low bystander response rates), state regulation and governance structure of EMS and health care systems, and available resources (e.g., trained EMS or health care personnel, and funding).

Continuous Quality Improvement Programs

Widespread adoption of continuous quality improvement programs throughout the field of resuscitation would encourage data collection across all sites of care, enable comparisons within and between EMS and health care systems, and lead to the identification of best practices to improve population health and patient outcomes following cardiac arrest. Public policies encouraging such programs for other systems of care (e.g., learning health care systems) should serve as models for the field of resuscitation, which includes a broader range of individuals responding to cardiac arrest.

Leadership

Cardiac arrest outcomes are affected by leadership across a wide range of settings, including federal agencies, state and local government (including health departments), EMS systems, health care organizations, and community clinics and advocacy organizations. Communities that have demonstrated higher cardiac arrest survival rates and favorable neurologic outcomes typically have strong civic, EMS, and health care system leaders, who establish accountability for these outcomes to their communities through increased public awareness efforts, widespread training in CPR and AED use, and sustained investment in outcome measurement, data reporting, and self-assessment. With appropriate leadership, effective treatments and strategies can be adopted in other communities to save thousands more lives across the country each year.

Accountability and Transparency

Enhanced accountability and transparency can increase operational effectiveness and efficiency by building trust among stakeholders, engaging individuals and organizations in continuous quality activities, and fostering innovation. Currently, the resuscitation field lacks appropriate transparency and accountability for cardiac arrest incidence and outcomes. As more detailed and larger data sets become available, new opportunities will emerge to increase public awareness, enhance training across different sectors, and modify local system treatment protocols and service delivery models related to cardiac arrest. These opportunities will require explicit responsibility to collect and disseminate data to the public in order to establish accountability for system performance through various social and policy mechanisms.

OVERVIEW OF THE REPORT

This report examines the complete system of response to cardiac arrest in the United States and identifies opportunities through existing and new treatments, strategies, and research to improve survival and recovery of patients. This chapter provides an overview of issues that are discussed throughout the report, highlights important overarching themes, and suggests a more explicit systems framework to help guide discussions and strategies to advance the field of resuscitation and to improve cardiac arrest outcomes. Chapter 2 discusses the public health burden of cardiac arrest, summarizes available data registries for the evaluation of cardiac arrest, and suggests opportunities to improve cardiac arrest surveillance in the United States. Chapter 3 explores barriers to public engagement and education and training opportunities that encourage active response to cardiac arrest in the community. Chapter 4 examines current EMS system responses to improve outcomes from OHCA. Challenges to providing high-quality resuscitation for IHCA and post-arrest care and high-quality resuscitation for IHCA are discussed in Chapter 5. Chapter 6 considers current research infrastructure and highlights innovative research methods, design, and technology to advance the science of resuscitation. Finally, Chapter 7 highlights the key messages within this report, and concludes with recommendations and priorities, aimed at individual citizens, government agencies, professional organizations, and private industry, to improve health outcomes from sudden cardiac arrest across the United States.

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2

Understanding the Public Health Burden of Cardiac Arrest: The Need for National Surveillance

Cardiac arrest is a complex and lethal condition that poses a substantial public health burden, with high nationwide mortality rates and the potential for profound and irreversible neurologic injury and functional disability. In addition to the number of lives lost, cardiac arrest has a considerable economic impact; measured in terms of productive years of life lost due to premature death or avoidable neurologic disability, it constitutes a societal burden equal to or greater than that of other leading causes of death in the nation (Stecker et al., 2014). Numerous factors can affect reported incidence and outcomes of out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA). Understanding how to best measure and influence these factors is important to inform policy decisions that can advance the resuscitation field and improve patient outcomes following cardiac arrest through appropriate resource allocation and evidence-based service provision. This requires reliable and valid data.

Current limitations make accurate measurement of cardiac arrest incidence and outcomes challenging. A paucity of evidence is available about important non-mortality-related quality measures such as neurologic outcomes, functional status, and the long-term survival potential of cardiac arrest survivors, making it difficult to measure the burden of neurologic injury that can result from cardiac arrest. Long-standing efforts to improve nationwide survival rates and patient outcomes have resulted in limited success, although surveillance systems that combine data collection with some element of continuous quality improvement have demonstrated the ability to improve cardiac arrest outcomes in a number of communities, as described in Chapter 6.

This chapter provides an overview of the current understanding of the public health burden of OHCA and IHCA in the United States. As part of its information-gathering process, the committee commissioned data analyses from the two largest OHCA registries in the United States, the Cardiac Arrest Registry to Enhance Survival (CARES) and the Resuscitation Outcomes Consortium (ROC) Epistry, as well as the Get With The Guidelines-Resuscitation (GWTG-R) registry for IHCA (see Appendix D for selected results). This chapter describes epidemiological trends in incidence and outcomes, and discusses relevant predictors of outcomes, based on the commissioned analyses and a review of published literature. It provides an overview of the existing surveillance efforts, describes primary registries, and assesses their strengths and limitations. After discussing challenges associated with measuring the burden of cardiac arrest, this chapter makes a case for a national surveillance system for cardiac arrest, highlighting some of the shortcomings of existing systems and presenting options for overcoming these barriers.

CARDIAC ARREST INCIDENCE AND OUTCOMES IN THE UNITED STATES

Recent estimates suggest that approximately 395,000 cases of OHCA occur in the United States every year among patients of all ages, in which only 5.5 percent of all patients survive to hospital discharge (Daya et al., 2015a).[1] An estimated 200,000 IHCAs of presumed cardiac origin also occur annually, with national survival rates of approximately 24 percent (Chan, 2015; Go et al., 2014; Merchant et al., 2011). Incidence also varies between adults and children. The analysis of the ROC Epistry indicates that pediatric cardiac arrests are less common and make up only about 2 to 3 percent of all OHCAs in the country (Daya et al., 2015a; Vellano et al., 2015). As this section explains, however, there is tremendous variability in these estimates resulting from different definitions of cardiac arrest used within the resuscitation field. Therefore, in the absence of a national surveillance system to capture the true incidence of cardiac arrest, any statistics should be interpreted with some degree of uncertainty, as described throughout this chapter.

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[1]The 2013 incidence statistic includes patients of all ages and cardiac arrest events with both cardiac and noncardiac (e.g., trauma, drowning, and poisoning) etiologies. This figure is an approximation based on analysis of data from the Resuscitation Outcomes Consortium Epistry, the limitations of which are described in this chapter.

Out-of-Hospital Cardiac Arrest

Overall OHCA incidence in the United States varies widely in the literature, primarily because of differences in the underlying sources of data and populations included, and in the types of cardiac arrest incidence being described (Chugh et al., 2004; Kong et al., 2011; Zheng et al., 2001). CARES, designed to help emergency medical services (EMS) agencies evaluate and improve their performance in cardiac arrest response, monitors and reports data on patients who received EMS treatment (CPR and/or defibrillation) (CDC, 2015b). The ROC Epistry is a clinical trials research database that captures incidence of both treated and untreated cases of OHCA. As a result, total incidence reported by each database ranges from approximately 180,000 to 395,000 cases (Daya et al., 2015a; Vellano et al., 2015). Table 2-1 presents additional points of comparison for reported incidence rates based on CARES and ROC data. Still other studies identify cardiac arrest using other inclusion and exclusion criteria. For example, some studies report all-cause cardiac arrest while others only report cardiac arrests that are of presumed cardiac etiology only (excluding arrests due to traumatic causes such as drowning, poisoning, or drug overdose).

According to a 2010 systematic review of 79 studies, the overall survival rates for adults in the United States have remained stable at 7.6 percent for nearly 30 years (Sasson et al., 2010). In the committee's commissioned analyses of 2013 data from CARES and the ROC Epistry, however, survival rates for EMS-treated patients who experienced an OHCA of presumed cardiac etiology is approximately 11 percent for adults (Daya et al., 2015a; Vellano et al., 2015) and 7.9 percent for children (Daya et al., 2015a). The committee's commissioned analyses also found incremental increases in cardiac arrest survival rates over time (Chan, 2015; Daya et al., 2015a,b). This increase could be due to multiple factors, including a Hawthorne effect in communities that participate in registries and therefore regularly monitor and improve the quality of care (Kellum et al., 2006).

Wide regional variation in both incidence and survival across the United States has been documented, suggesting opportunities to enhance quality of care and improve outcomes. One study by Nichol and colleagues (2008) found that survival from ventricular fibrillation (VF)-related OHCA ranged from 7.7 to 39.9 percent across 10 North American sites. Another publication that compared cardiac arrest outcomes across

TABLE 2-1 Types of Reported OHCA Incidence Among Adults in 2013

Database/Patient Population	Incidence Rate per 100,000 Person-Years	Total Incidence per Year[a]
CARES		
EMS treated	57.0	179,877
ROC-Epistry		
EMS "treated, all cause"	63.8	201,690
EMS "treated, all cause" + "untreated, all cause"[b]	124.8	394,529

[a]See commissioned reports for calculation of total annual incidence (column 3).
[b]Untreated refers to cases that did not receive resuscitation treatment because patients were either dead upon EMS arrival or had existing do-not-resuscitate orders.
NOTE: The ROC Epistry incidence includes all cardiac arrests (with cardiac and noncardiac etiology), whereas the CARES incidence counts include cardiac arrest of presumed cardiac origin only.
SOURCES: Daya et al., 2015a; Vellano et al., 2015.

35 communities in the United States found survival rates ranged from less than 3.3 percent in Chicago to 40.5 percent in Rochester, Minnesota (Rea et al., 2004). Observed geographic variation in incidence and survival between and within different communities may reflect important demographic risk factors for cardiac arrest (Carr et al., 2009; Nichol et al., 2008a). EMS- and hospital-system-level factors also contribute to variation. For example, differences in the proportion of patients treated or transported by EMS, as well as differences in prehospital drug therapies provided to patients, account for some of the variation (Glover et al., 2012; Zive et al., 2011).

Incidence is defined as the number of new cases of a given disease or condition (e.g., cardiac arrest) in any given population during a specified period of time. Different studies use different definitions (i.e., numerators and denominators) to identify OHCA incidence, which results in discrepancies in the calculation of the disease burden (Berdowski et al., 2010; Kong et al., 2011). The numerator may include, for example, all patients who die suddenly, all cases with presumed cardiac etiology, all cases where EMS responded, cases where EMS responded and resuscitation treatment was provided, or all cases of EMS-treated patients with ventricular fibrillation. Possible denominators may include total population in a neighborhood, state, or country or all adults in a given geographic area. Many registries in the United States also differ in how they collect and report certain cardiac arrest variables. For example, researchers may pull data from EMS or hospital medical records, whereas others data may be from death certificates. Furthermore, studies may use different metrics to assess specific outcomes (e.g., Glasgow Coma Scale, Cerebral Performance Category [CPC] score, and Modified Rankin Score [mRS] for neurologic status).

The State of OHCA in the United States in Comparison to Trends in Europe and Asia

Understanding the population health burden of cardiac arrest in the United States, in comparison to that in similarly developed nations in Europe and Asia, allows researchers to identify potential strategies for improvement. A large meta-analysis of 67 studies comparing the global burden of cardiac arrest found statistically significant differences in incidence of treated OHCA (Berdowski et al., 2010). This study found that North America had the highest all-rhythm OHCA incidence (54.6) per 100,000 person-years when compared to Asia (28.3), Europe (35), and Australia (44) and that rates of VF-related OHCA and the survival-to-discharge rates, respectively, for those patients varied across continents: Asia (11 percent VF-related OHCA and 2 percent survival-to-discharge rate), North America (28 percent and 6 percent), and Europe (35 percent and 9 percent) (Berdowski et al., 2010). As expected, there is also considerable variability among individual countries in each continent. The aggregate statistics in the meta-analysis should be interpreted with a degree of uncertainty, because the heterogeneity of data-collection methods and definitions in the source studies makes comparisons difficult. Consistent with recent temporal trends in U.S. registries (Chan, 2015; Daya et al., 2015b), survival rates in many European countries have also improved in recent years. For example, there was a substantial increase in nationwide 30-day and 1-year OHCA survival rates reported by the Danish Cardiac Arrest Registry between 2001 and 2010 (Wissenberg et al., 2013). The same study reports finding improvements in the rate of return of spontaneous circulation (ROSC) for OHCA in Denmark over a period of 5 years, with an increase from 21 to 61 percent. Some studies have also found decreasing incidence of VF-related cardiac arrest over time, possibly as a reflection of improving population health (Cobb et al., 2002). A recently released Australian study reported a decrease in the adjusted OHCA incidence rate from 75.7 to 65.9 per 100,000 person-years between 1997 and 2002 (Bray et al., 2014). However, the rates of survival to discharge in this study did not change over time.

In-Hospital Cardiac Arrest

Fewer studies and data sources are available to measure IHCA incidence and outcomes compared to OHCA. One of the more recent studies estimates that approximately 200,000 annual IHCA cases, ranging between 192,000 and 211,000 cases,[2] occur among adults in U.S. hospitals (Merchant et al., 2011). A 2013 American Heart Association (AHA) consensus report extrapolated incidence rates and hospital admissions data from separate studies and determined that approximately 6,000 cases of IHCA occur annually among pediatric populations (Chan et al., 2010; Morrison et al., 2013; Nadkarni et al., 2006). Like OHCA, the literature on IHCA offers a large range of data points for incidence because of differences in collected metrics, study populations, and variations in the models used to extrapolate from study cohorts to the larger population. There is also substantial variability in IHCA survival rates in the United States (Merchant et al., 2014). For instance, pediatric survival rates can range from 27 to 48.7 percent (Lopez-Herce et al., 2013; Meert et al., 2009; Nadkarni et al., 2006). However, a large majority (59 to 75 percent of adults and 53 to 63 percent of children) of IHCA survivors leave the hospital with good neurologic outcomes (Nadkarni et al., 2006).

In the absence of a specific *International Classification of Diseases* (ICD) diagnostic code differentiating IHCA from OHCA, discussed later in this chapter, researchers have historically used multiple approaches to define and identify IHCA incidence.[3] Similar to OHCA, published literature uses various proxy measures for the numerator (number of times CPR or defibrillation was initiated for patients, number of activations of an in-hospital resuscitation team, etc.). Defined denominator populations

[2]The reported statistics are based on a 2011 analysis, which used the most recent available data (years 2003-2007) from the Get With The Guidelines-Resuscitation registry. The study used three separate approaches to calculate the estimated range of annual IHCA events in the United States.

[3]Multiple diagnosis codes in the ICD-10 system can be used as a proxy measure for cardiac arrest and can lead to inaccurate and discretionary coding depending on the provider. For example, although the code for "cardiac arrest" is 427.5, a number of other ICD codes could be entered as a proxy diagnosis by the provider—including ventricular fibrillation (427.41), ventricular flutter (427.42), atrial fibrillation (427.31), and other irregular cardiac rhythms. The ICD code for cardiac arrest has been further expanded in the 10th revision and now differentiates between cardiac and noncardiac etiology of arrest (Moczygemba and Fenton, 2012).

also differ; while some studies may include all patients who experience a cardiac arrest after being admitted to a hospital, other studies may exclude patients who experience an arrest in the emergency department or in outpatient clinics or patients who have existing do-not-attempt-resuscitation (DNAR) orders. The 2013 consensus statement from the AHA proposed a standard definition for IHCA incidence, but this has not yet been uniformly applied in current research (Morrison et al., 2013).

As for OHCA, IHCA outcomes are slowly improving over time. The committee's commissioned analysis of GWTG-R data found a steady increase in survival rates for patients with both shockable and nonshockable rhythm between 2000 (16.2 percent) to 2013 (24.4 percent) (Chan, 2015). Another study documented a decrease in overall rates of neurologic damage over 10 years, because the proportion of patients who experienced poor neurologic outcomes (clinically significant neurologic disability defined as CPC score greater than 1) dropped from 32.9 to 28.1 percent (Girotra et al., 2012). These improvements may be due to changes in the hospital environment and/or the patient population. For example, Girotra and colleagues (2014) also found a significant decrease in age, prevalence of heart failure and myocardial infarction, and cardiac arrests due to shockable rhythms, among IHCA patients, all of which are known to influence outcomes following cardiac arrest. Improvements in IHCA outcomes and best practices depend on having an accurate and representative data to measure IHCA incidence in the United States. This will require a reliable system of data collection, analysis, and reporting for use by health care systems.

FACTORS INFLUENCING INCIDENCE AND SURVIVAL

Survival and neurologic recovery following cardiac arrest are influenced by multiple interdependent factors that include individual patient characteristics, EMS or hospital system characteristics, and circumstantial factors specific to the event. Risk factors also vary in the extent to which they affect incidence and outcomes of OHCA and IHCA. According to a systematic review of OHCA literature, key predictors of survival may include whether the arrest was witnessed by a bystander or EMS, availability of bystander CPR, and having a shockable, initial cardiac rhythm (e.g., ventricular fibrillation) (Sasson et al., 2010). This review also reported an association between a patient experiencing pre-hospital ROSC in the field and their likelihood of survival. More likely, the stronger predictor of neurologically favorable survival is not the location of ROSC but rather the length of time between collapse to ROSC, which would presumably be shorter for OHCA when ROSC occurs in the field versus after arrival at a hospital (Komatsu et al., 2013; Nagao et al., 2013).

Some risk factors that affect patient outcomes are modifiable and include the elements related to health care delivery and system performance. Modifiable factors, within the context of the EMS system, include factors such as whether the 911 call center dispatcher recognizes the presence of cardiac arrest and provides dispatcher-assisted CPR instructions over the telephone, EMS response times, the time interval between collapse to treatment, and quality of resuscitation care (Bobrow et al., 2014; McNally et al., 2009). Within hospitals, quality of response to IHCAs (e.g., time to defibrillation and CPR duration, activation of code teams, etc.) and availability of post-resuscitative care (e.g., availability and access to therapeutic hypothermia) affects patient outcomes. Additionally, medical leadership, ongoing quality improvement, training, cultures of excellence, and mechanisms for accountability also influence care provision. Studying the process and performance of systems of care can serve as equally important tools in understanding the state of cardiac arrest care in the nation. EMS and health care system responses to cardiac arrest are discussed in Chapters 4 and 5, respectively.

Other risk factors, such as individual patient characteristics (e.g., age, race, and ethnicity) or circumstances of an arrest (e.g., location or cardiac etiology) are nonmodifiable but can be used to help identify areas of need and target resources or specific interventions. Studies on individual patient characteristics have highlighted differences in incidence and survival across demographic factors that persist after adjusting for potential confounders, such as initial cardiac rhythm, hospital and health care system factors, and severity of illness (Moon et al., 2014; Noheria et al., 2013; Safdar et al., 2014; Shippee et al., 2011). These disparities can result from complex interactions between socioeconomic variables, health status, comorbidities, and genetics (Friedlander et al., 1998; Nehme et al., 2014a). Circumstantial factors, such as the initial cardiac rhythm and whether the arrest was witnessed and location of arrest (e.g., public versus private setting and community versus hospital settings), are associated with different patient outcomes (McNally et al., 2009, 2011; Nichol et al., 2008a). Factors associated with the public response to cardiac arrest, including provision of CPR and defibrillation, are discussed in Chapter 3.

Although successful efforts to improve cardiac arrest survival often target modifiable factors (e.g., increasing access to, or availability of, appropriate treatments and reducing EMS response time), improving research on nonmodifiable factors (e.g., patient age or race) can also influence outcomes by helping to identify high-risk populations and disparities in care. Furthermore, data and research findings on nonmodifiable factors can be used to better tailor public health interventions and allocate resources to meet identified needs and gaps throughout the health care response. The next section focuses on describing trends in cardiac arrest incidence and outcomes, depending on location of arrest, as well as patient demographic factors such as age, gender, and race and ethnicity.

Location of Arrest

Survival rates greatly depend on where the cardiac arrest occurs. This may be, in part, due to the fact that witnessed arrests tend to have shorter collapse-to-treatment times, and, as noted throughout the report, every minute counts when it comes to responding to a cardiac arrest. Thus, survival rates for IHCA are comparatively higher than for OHCA. Within hospitals, patients who arrest in nonmonitored units and the intensive care unit (ICU) are often the least likely to survive to discharge (Chan, 2015). While the nonmonitored unit results are to be expected because of a lack of possible witnesses, factors such as severity of illness could explain the ICU findings. It should be noted that location of arrest typically has a more direct impact on outcomes for OHCA patients than it does for IHCA patients.

Public Versus Private Settings

Location of arrest is an important determinant of OHCA survival with good neurologic outcomes. The committee's commissioned analysis of 2013 CARES data determined that a majority of OHCAs (70.1 percent) occur in private homes, where fewer than 1 in 10 patients survive to discharge (see Table 2-2). International studies have similar findings. In Japan, two-thirds of OHCAs occur in private homes (Moriwaki et al., 2014). However, better survival and favorable neurologic outcomes (defined as CPC 1 or 2) are reported among cases that occur in public places when compared with those that occur in private homes. In New Zealand,

TABLE 2-2 The Influence of OHCA Location on Survival

Location of Arrest	Proportion of Total OHCAs (%)	Survival Rate (%)
Private home	70.0	9.0
Nursing home/assisted living facility	10.4	4.8
Public building	7.1	23.5
Street/highway	4.5	18.1
Health care facility	4.6	16.0
Place of recreation	1.7	29.5
Industrial place	0.5	26.1
Public transportation center	0.3	42.1
Other	0.8	20.0

SOURCE: Vellano et al., 2015.

survival from arrests that occurred in public was nearly twice as common as arrests in residential locations (Fake et al., 2013). One study found that pediatric OHCAs are more likely to occur in private settings, with 88 percent of cases reported in a residential location (Brown, 2005; De Maio et al., 2004).

The lower survival rates associated with private, residential settings may be due to the relative absence of witnesses (Weisfeldt et al., 2011). Arrests that occur in public places benefit from the improved chances of a witnessed arrest and, subsequently, higher rates of CPR and earlier defibrillation by EMS or bystanders. Patients are more likely to have shockable rhythm upon EMS arrival when the time interval between the initial collapse and 911 call is shorter (McNally et al., 2011). These supportive circumstances, in turn, result in higher rates of favorable neurologic status and 30-day survival (Mitani et al., 2014; Moriwaki et al., 2014; Murakami et al., 2014). Potential confounding factors such as availability of bystander CPR and initial cardiac rhythm (also known as first recorded rhythm), rather than location of arrest, can also more directly influence outcomes. Additional data are needed to assess the relative impact of these predictors on survival.

The type of public location in which an OHCA occurs also affects survival (Brooks et al., 2013). Murakami and colleagues (2014) reported higher rates of favorable neurologic outcomes for individuals in Japan who experienced a cardiac arrest in schools (41.9 percent) and sports facilities (51.6 percent) as compared to railway stations (28.0 percent) and public buildings (23.3 percent). There is also variation in the types of public spaces where OHCA is likely to occur. For example, 10.4 percent of OHCAs take place in nursing homes and assisted living facilities, where survival—at 4.8 percent—is even less common (Vellano et al., 2015; see Table 2-2). A demonstrated lack of overlap between public spaces where automated external defibrillators (AEDs) are placed (e.g., community pools, schools and educational facilities, and public buildings) and areas where OHCAs are most likely to occur (e.g., private homes, skilled nursing facilities, and assisted living facilities) may contribute to poor survival rates reported in some public areas (Levy et al., 2013). Differences in patient health status across settings (e.g., patients in nursing homes may have severe comorbidities compared to patients in schools), as well as availability of bystander CPR (e.g., health care facility versus public highway), may additionally account for differential survival rates between locations.

Rural Versus Urban Settings

Multiple cardiac arrest studies confirm that OHCAs that occur in rural areas are associated with relatively worse outcomes, which is likely due to a number of structural barriers. Because the majority of health care resources are located in urban centers, cardiac arrests that take place in rural areas are often subject to longer EMS response times and transport intervals (Jennings et al., 2006; Stromsoe et al., 2011). Moreover, the lower population density in rural areas decreases the likelihood of witnessed arrest, bystander CPR, and access to nearby defibrillators (Ro et al., 2013; Stromsoe et al., 2011). For example, a study of OHCA in Australia found that higher rates of ROSC, survival to hospital admission, and survival to hospital discharge were associated with more densely populated areas. The study concluded that people who experience a cardiac arrest in very-high-density areas (more than 3,000 persons/km^2) were 4.32 times more likely to survive to discharge than those who arrest in very-low-density areas ($\leq$ 10 people/km^2) (Nehme et al., 2014b).

Age

Age is an important predictor of cardiac arrest incidence and survival with positive neurologic outcomes. The committee's commissioned analysis of CARES data (see Table 2-3) indicates that OHCA incidence in the United States is highest among adults aged 35 years and older, with a steep age-related gradient extending from 35 to 65 years.

Infants and Children

Infants and children constitute a particularly vulnerable segment of the cardiac arrest patient population. The committee's commissioned analyses of CARES and ROC data found an incidence of 2 to 3 percent in patients younger than 18 years of age (Daya et al., 2015a; Vellano et al., 2015). Despite this comparatively small population, the public health burden of pediatric OHCA remains high. This is due to the greater number of lost years of productivity per individual; the survival rate in children (8 percent), compared to that for adults (11 percent), is low (Daya et al., 2015a).

The estimated incidence and survival rates of pediatric cardiac arrest vary widely across studies, because of differences in definitions of variables and methods of calculation. For example, inclusion of sudden infant death syndrome–related cases or other nontraumatic cases of noncardiac origin can inflate the incidence and falsely decrease the survival rates (Atkins et al., 2009). Reported OHCA incidence rates for infants (≤ 1 year old) range from 11.5 in Denmark to 72 per 100,000 person-years in the United States (Atkins and Berger, 2012; Rajan et al., 2014). Survival rates tend to be lower for infants (3.3 percent) than for children (9.1 percent) and adolescents (8.9 percent) (Atkins and Berger, 2012).

Survival rates from pediatric cardiac arrests are comparable, or higher in European countries. In the Netherlands, among resuscitated pediatric patients (ages below 21), the survival rate was 24 percent, with the majority of survivors reporting good neurologic outcomes (Bardai et al., 2011). A study of pediatric IHCA in Spain demonstrated improvements in survival over the past 10 years (41 percent up from 25.9 percent) (Lopez-Herce et al., 2014). By comparison, the survival rate for pediatric patients in South Korea was determined to be substantially lower (Ahn et al., 2010). Compared to the data presented from European registries, incidence and survival were, respectively, higher and lower for infants as compared to children and adolescents (Park et al., 2010). As with adult cases of OHCA, survival rates are increased for children when initial rhythm is shockable, arrests are witnessed, and bystanders provide CPR (Meyer et al., 2012; Rajan et al., 2014). Despite this fact, AEDs are less

TABLE 2-3 Correlation Among Age, Incidence of OHCA, and Survival

Age (years)	Proportion of Total OHCAs (%)	Survival Rate (%)
<1	1.4	6.0
1-12	1.1	13.3
13-17	0.4	20.8
18-34	5.4	15.3
35-49	11.9	13.6
50-64	29.4	14.0
65-79	29.5	10.0
≥80	20.8	5.2

SOURCE: Vellano et al., 2015.

commonly used in children between the ages of 1 and 8 years old than in adults (Johnson et al., 2014).

Older Adults

The committee's commissioned analyses confirmed that elderly patients, those who are older than 70, were more likely to have lower short- and long-term survival rates than younger adults (Chan, 2015; Daya et al., 2015a; Vellano et al., 2015). One study found that among OHCA patients older than 75 years old, only one-quarter survived with favorable neurologic outcomes (Grimaldi et al., 2014). Less than half of this initial group of survivors survived another 6 years post-discharge. Death was nearly 3.5 times more likely for elderly cardiac arrest survivors when compared to elderly individuals in the reference population (Grimaldi et al., 2014). Similarly, among IHCA survivors over the age of 65, approximately 65 percent survived to 6 months post discharge (Chan, 2015). However, only 33 percent survived to the 5-years post-discharge mark. More than half of all IHCA survivors in this age group had moderate to severe neurologic impairment at hospital discharge.

In the same cohort of patients, long-term survival was highest among those who initially had little to no neurologic damage following the cardiac arrest, who had a shockable initial cardiac rhythm, and were discharged home (compared to those who were discharged to hospice care or rehabilitation facilities) (Chan, 2015). For example, 72.8 percent of patients with mild or nonexistent neurocognitive deficits at discharge survived 1 year beyond the cardiac arrest, compared to 42.2 percent of those with a severe disability and only 10.2 percent of those in comas or vegetative states following the cardiac arrest. There were no significant differences in hospital readmission rates between age groups, but minority populations, women, and profoundly disabled patients were all more likely to be readmitted (Chan et al., 2013). Studies demonstrating correlation between age and long-term survival following cardiac arrest should be interpreted with a degree of caution and take into account potential confounding factors, such as the higher prevalence of DNAR orders among older patients, which may account for inflated mortality rates (Seder et al., 2014).

Gender

Women, compared to men, are less likely to experience and survive a cardiac arrest. The committee's commissioned analyses of CARES and ROC data found that approximately three in five cardiac arrests occurred in men. While the survival rate following OHCA is higher among men, survival rates following IHCA appear to be similar in both groups (see Table 2-4).

Many studies corroborate the findings from these registries (Girotra, 2012; Safdar et al., 2014). However, the nature of gender's effect on cardiac arrest survival is more contentious. Depending on the statistical adjustments made and the type of survival measured, women may be reported to be less, or equally, likely to survive cardiac arrest. Mixed results regarding the correlation between gender and survival to admission, discharge, and 30 days post discharge have been reported in many studies (Hasan, 2014; Mahapatra, 2005). Survival with positive neurologic outcomes is also more common in women, potentially because of the

TABLE 2-4 Distribution of OHCA and IHCA Incidence and Survival by Gender, 2013

	Male		Female	
	Incidence (%)	Survival (%)	Incidence (%)	Survival (%)
CARES	60.8	11.8	39.2	9.6
ROC	61.8	11.6	38.2	8.8
GWTG-R	58.8	24.5	41.2	24.4

NOTE: CARES = Cardiac Arrest Registry to Enhance Survival; GWTG-R = Get With The Guidelines-Resuscitation; ROC = Resuscitation Outcomes Consortium.
SOURCES: Chan, 2015; Daya et al., 2015a; Vellano et al., 2015.

neuroprotective effects of estrogen and progesterone (Akahane, 2011; Hasan et al., 2014; Kim et al., 2014; Topjian et al., 2010).

The correlation between gender and prehospital factors affecting survival is not clearly understood. Cardiac arrest risk factors such as severe comorbidity, chronic obstructive pulmonary disease, cancer, and nonshockable cardiac rhythm are more common in women (Safdar et al., 2014; Simmons et al., 2012; Wissenberg et al., 2014). Other risk factors, such as structural heart disease, are less common in women than in men (Simmons et al., 2012). Coronary artery disease (CAD) is present in four out of five men who experience cardiac arrest, but occurs in less than half of women who have a cardiac arrest (Simmons et al., 2012). Because implantable cardioverter defibrillators were designed to prevent recurrent cardiac arrest in patients with existing CAD and other forms of structural heart disease, women are less likely than men to benefit from this therapy (Chugh et al., 2009).

Access to available cardiac arrest treatments is also associated with gender. One study found that women are less likely to receive CPR, defibrillations, or advanced cardiac life support treatments from EMS personnel following a cardiac arrest (Ahn et al., 2012; Safdar et al., 2014). However, survival for men and women is equal when similar resuscitation treatments are provided (Israelsson et al., 2014). The comparatively low rate of cardiac arrest incidence among women may cause health care professionals and the general public to be less prepared to respond to women who experience a cardiac arrest.

Race and Ethnicity

Multiple studies of both OHCA and IHCA have noted disparities in cardiac arrest incidence and survival by race and ethnicity (Groeneveld et al., 2003; Moon et al., 2014; Shippee et al., 2011). The committee's commissioned analyses of data from CARES and the GWTG-R registry also indicated higher survival-to-discharge rates among white patients when compared with patients of other races and ethnicities (Chan, 2015; Vellano et al., 2015).

Studies of OHCA conducted in Chicago and New York found that white patients were twice as likely to survive to hospital discharge as African American patients (Becker et al., 1993; Galea et al., 2007). Galea and colleagues reported that whereas the incidence of OHCA is higher among African American and Hispanic patients (10.1 per 10,000 and 6.5 per 10,000, respectively) compared with white patients (5.8 per 10,000), age-adjusted 30-day survival after hospital discharge is much lower (Galea et al., 2007). An important contributor to this lower rate of survival is the lower frequency of a shockable initial cardiac rhythm among blacks and Hispanics compared to whites (Galea et al., 2007; Vadebonceour et al., 2008). Delays related to public recognition of cardiac arrest, limited use of the 911 emergency system, and lower rates of bystander CPR in African American and Hispanic neighborhoods are potential contributors to the lower rates of shockable rhythms and survival (McNally et al., 2011; Moon et al., 2014; Sasson et al., 2014; Skolarus et al., 2013; Watts et al., 2011). Sasson and colleagues determined that the median income and racial composition of a neighborhood both predict the likelihood of receiving bystander CPR; in particular barriers associated with the cost of CPR training and a lack of information contribute to lower CPR rates in minority communities (Sasson et al., 2012, 2013). Socioeconomic variables such as family income, education, health insurance status, and language barrier are also widely known to influence patient outcomes (Reinier, 2011; Sasson et al., 2012). However, additional research is needed to parse out the mechanism by which these factors interact with other individual patient, clinical, and health system determinants of cardiac arrest survival.

Death rates following an IHCA are significantly higher for African Americans than for individuals of other races and ethnicities. Among the 49,130 IHCA patients included in the GWTG-R registry, African Americans had a higher mortality rate than white patients (60.9 percent versus 53.4 percent) (Larkin et al., 2010). Analysis of multiyear Medicare data (years 2000-2004) for 433,985 patients who received in-hospital CPR found that the adjusted odds of survival for African American patients were 23.6 percent lower than those for white patients (Ehlenbach et al., 2009). This trend continued in 2013 when the survival-to-discharge rates remained higher in white IHCA patients compared to African American IHCA patients (25.9 percent versus 20.8 percent, respectively) (Chan, 2015). Notable disparities also have been observed in long-term survival after IHCA. One-year readmission rates are higher, and long-term survival rates are lower among African American IHCA patients.

The maldistribution of risk factors for cardiac arrest and patient health factors in vulnerable populations, such as the number of preexisting conditions and illness severity, plays a crucial role in observed cardiac arrest outcome disparities. For example, a lower proportion of shockable cardiac rhythms has been identified among African American and Hispanic IHCA patients (12 percent and 15.1 percent, respectively) compared to white patients (16.7 percent) (Galea et al., 2007). In an analysis of IHCA patients in VF or pulseless ventricular tachycardia (pVT), African American patients compared to white patients were more likely to have delayed defibrillation (22 percent and 17 percent, respectively) and less likely to survive to discharge (25.2 percent versus 37.4 percent, respectively) (Chan et al., 2009). A similar trend has been observed for Hispanic patients, although due to small sample sizes in the GWTG-R registry the differences did not achieve statistical significance. These outcome disparities remain even after adjusting for temporal trends, patient characteristics, hospital, and arrest characteristics. Although health factors contribute to variation, the inequitable access to critical pre-arrest, preventative care is also an urgent consideration when discussing disparities in hospital cardiac arrest (Shippee et al., 2011).

Moreover, the fact that the differences in outcomes described above cannot be entirely explained by health characteristics raises concerns about potential disparities in health care system factors. Differences in access to post-arrest care, such as variation in rates of cardiac catheterization and implantation of a cardioverter defibrillator during the first hospitalization, access to follow-up outpatient care, differences in discharge destination (e.g., hospice versus home), or other practice patterns, can account for potential disparities in neurologically favorable survival following cardiac arrest. As noted throughout the report, the utility of existing cardiac arrest registries is limited because of missing data on race and ethnicity and socioeconomic factors. More research is needed to determine the precise influence of these factors on cardiac arrest survival and neurologic outcomes. A better understanding of the interaction of these factors is necessary in order to eliminate these disparities and ensure that every patient receives the care she or he needs regardless of age, gender, or race and ethnicity. Box 2-1 summarizes the key conclusions regarding disparities in cardiac arrest outcomes that require further research.

ECONOMIC BURDEN OF POST-ARREST CARE

The societal impact of cardiac arrest, in terms of both the years of productive life lost due to death and disability and the economic burden of caring for cardiac arrest patients who are resuscitated and arrive at the hospital alive, is substantial. In one study, the average cost of direct care

BOX 2-1
Disparities in Cardiac Arrest Outcomes

- Compared to white patients who experience both OHCA and IHCA, African American and Hispanic populations have higher incidence and lower survival-to-hospital discharge rates.
- Compared to white patients who experience both OHCA and IHCA, racial and ethnic minorities have a higher burden of residual neurologic deficits.
- Racial and ethnic minorities have lower access to appropriate cardiac arrest treatments and therapies.
- Evidence of significant health care disparities exists in sudden cardiac arrest and merit further research and new processes of care.

to an OHCA patient with ROSC (including cost of conventional care and continued care in rehabilitation) was estimated to be $102,017[4] per person (Merchant et al., 2009). Another study estimated that the total aggregate cost of OHCA in the United States was $33 billion each year (Kida et al., 2014). Many OHCA survivors are able to return to normal functional status; approximately 40 percent of patients who present an initial cardiac rhythm of asystole and 31 percent of patients with pulseless electrical activity have poor neurologic outcomes, ranging from severe dysfunction (CPC 3) to coma (CPC 4) (Vellano et al., 2015). By contrast, 90 percent of patients with VF or pVT as the initial cardiac rhythm who survive have favorable neurologic outcomes, defined as a CPC score of 1 or 2 (Vellano et al., 2015). Costs of post-arrest care for individuals following hospital discharge can be approximately $42,000 for 30 days of rehabilitation and approximately $100,000 for 365 days of long-term facility care[5] (Merchant et al., 2009).

IHCA patients discharged following cardiac arrest have frequent rehospitalization (35 readmissions per 100,000 patients) and incur additional costs of care (Chan et al., 2014). Each patient utilized resources averaging $19,000 during the first year following an arrest. The published literature on total national expenditure due to cardiac arrest is limited, although there are studies that have assessed the cost-effectiveness of

[4]Merchant and colleagues (2009) reported a total cost of $10,201,716 for a hypothetical cohort of 100 patients. The IOM report extrapolated the per-person cost.

[5]The statistics on 30-day and 365-day cost were calculated based on data presented by Merchant and colleagues (2009). The study reported rehabilitation cost of $1,390 per day and long-term nursing home care cost of $250 per day.

specific treatments (e.g., therapeutic hypothermia and percutaneous coronary intervention) and strategies (e.g., training bystanders, EMS, and public-access defibrillation programs). However, based on available data, it is conceivable that these costs could be reduced dramatically if patient outcomes could be improved, through better response systems and post-resuscitation care and discovery of more effective treatments.

CARDIAC ARREST SURVEILLANCE

Determining the magnitude of the public health burden of cardiac arrest is vital for improving patient outcomes in all communities. As discussed previously, incidence and survival are influenced by a number of modifiable (e.g., health care service characteristics) and nonmodifiable (e.g., patient demographics or location of arrest) factors. Evidence indicates that creating a consistent and reliable cardiac arrest surveillance system that routinely monitors OHCA and IHCA, and allows for the precise measurement of the mortality and morbidity burden of cardiac arrest and its associated predictors, can improve outcomes in a number of ways (McNally et al., 2009; Nichol et al., 2008a,b). It can better guide the selection and implementation of public health interventions, help determine appropriate allocation of resources in any given community (e.g., placement of AEDs), identify at-risk or vulnerable populations, and eliminate potential care disparities through targeted interventions. Moreover, it can allow researchers to assess the impact of current and emerging treatments and provide an evidence base for high-quality care and best practices.

In spite of these advantages, the United States does not currently maintain a single comprehensive surveillance system or registry that captures all cases of cardiac arrest in the nation. There are multiple registries that monitor and report data on a subset of OHCA or IHCA populations from select communities in which EMS agencies and hospitals have voluntarily agreed to participate. This section first examines the strengths and limitations of existing registries in the United States, presents an overview of international and multinational databases, and then explores short- and long-term strategies for improving the surveillance system by creating a national registry for cardiac arrest.

Primary Cardiac Arrest Databases in the United States

In the United States, two primary OHCA registries (CARES and the ROC Epistry) and one primary IHCA registry (GWTG-R) have produced multiple publications based on data collected over many years. Data are collected from multiple sources, including patient medical records from EMS and hospital systems, as well as death certificates. There are also some additional local and regional databases, examples of which are presented in Box 2-2. New databases (such as the Dynamic AED Registry and the National Institutes of Health's [NIH's] Pediatric Cardiac Arrest database) are also being developed to supplement existing cardiac arrest surveillance efforts. The OHCA and IHCA registries described below were designed to serve different purposes and therefore have varying strengths and limitations.

BOX 2-2
Examples of Additional Cardiac Arrest Registries in the United States

HeartMap Dynamic AED Registry: Aims to assess the safety of AEDs in public locations through post-market surveillance. This is important in identifying whether any of these devices have contributed to adverse outcomes in OHCA fatalities (Nichol, 2014). AEDs are tracked using crowdsourcing methods, two-dimensional matrix codes, and data on process and outcomes from EMS agencies participating in the ROC Epistry. This registry is funded by the U.S. Food and Drug Administration, as well as all monitor-defibrillator manufacturers in the United States, including Cardiac Science Corp., Heartsine Technologies Inc., Philips Health Care Inc., Physio-Control Inc., and ZOLL Medical Corp. Before the implementation of this AED registry, there was no widely deployed method of tracking their location and use in community settings (Merchant and Asch, 2012).

International Cardiac Arrest Registry (INTCAR): In 2009, the American Neurocritical Care Society joined the European Cardiac Arrest Research Network, and the Hypothermia Network, a registry based primarily in northern Europe (containing the largest number of therapeutic hypothermia-treated cardiac arrest survivors) to form this multinational registry for post arrest care (INTCAR, 2012). The organization is governed by both American and European steering committees, and participating hospitals are from both regions (73 in Europe/Asia and 10 in North and South America). Its purpose is to understand the process and outcomes associated with OHCA, and it is now the largest registry of post-resuscitation cardiac arrest care.

Milwaukee: Since its inception in 1976, the Milwaukee County EMS System has continuously maintained a computerized database of all EMS-treated patients. Information on OHCA patients includes comprehensive EMS care and survival through hospital discharge (MCDHHS, 2014). The database provides the basis for cardiac arrest continuous quality improvement programs and implementation of best clinical practice, and it is publicly available throughout the community.

National Emergency Medical Systems Information System (NEMSIS): A voluntary registry designed to capture every EMS event in the country. According to a 2011 report, NEMSIS is able to monitor cardiac arrest EMS response in 18 states (FICEMS, 2011). Unlike CARES, NEMSIS collects data from participating EMS agencies only and therefore does not include patient outcomes and discharge data from hospitals. It is funded by the National Highway Traffic Safety Administration (NHTSA), Health Resources and Services Administration, and CDC. Its primary goals are to implement an electronic documentation system in every local- and state-level registry, as well as to create a national EMS database that allows stakeholders to assess performance and benchmark. Currently, greater than 90 percent of the states and territories have a NEMSIS-compliant data system in place (NEMSIS, 2013). However, levels of sophistication vary.

Save Hearts in Arizona Registry and Education: Collects and analyzes data from Arizona cases of adult and pediatric OHCA in which resuscitation was initiated (Vadeboncoeur et al., 2007). Information about bystander use of AEDs is also captured. Data are collected from EMS agencies that respond to OHCA and the hospitals receiving the patients. Reports with feedback on patient survival are provided to participating EMS agencies.

Seattle: Since 1970, the Seattle Fire Department has maintained a registry of OHCAs for which EMS responded. Survivors are followed through hospitalization and annually thereafter. The purpose of this registry is to assess and improve quality of care delivered, and to create a system of best practices. It also enhances community accountability, because the data are made part of the public record after review by government officials (Neumar et al., 2011).

University of Pennsylvania: The Penn Alliance for Therapeutic Hypothermia was created in 2000 as a voluntary national registry of OHCA and IHCA, for patients who received therapeutic hypothermia after initial resuscitation. The registry also allows individual institutions to evaluate its performance and benchmark against other similar institutions (Grossestreuer et al., 2011).

OHCA: The Cardiac Arrest Registry to Enhance Survival (CARES)

In 2004, the Centers for Disease Control and Prevention (CDC) established CARES in collaboration with the AHA and the Department of Emergency Medicine at the Emory University School of Medicine to help communities determine standard outcome measures for OHCA and to allow EMS systems to assess their performance and benchmark at local, regional, and national levels. Since 2012, CARES has been funded by the AHA, American Red Cross, Medtronic Foundation HeartRescue Project, and Zoll Corporation (Vellano et al., 2015).

CARES collects information on nontraumatic OHCA cases of presumed cardiac etiology by linking three sources of data across the prehospital care continuum: 911 call centers, EMS systems, and receiving hospitals. The registry only includes cases of "treated" arrests (patients received attempted CPR and/or defibrillation by EMS or bystanders); cases in which resuscitation was not attempted because of existing patient DNAR orders or patients were dead upon EMS arrival are excluded (McNally et al., 2009). The CARES data set includes a minimal number of mandatory data elements for each OHCA event and its outcome. EMS data include patient demographics, arrest-specific data (e.g., location of arrest), and resuscitation-specific data (e.g., bystander CPR or AED, ROSC achieved, etc.); supplemental information from 911 centers includes time variables (e.g., time of initial call and response times), and hospital data include patient outcomes (e.g., emergency department outcome, hypothermia use, and neurologic outcome at discharge). See the CARES group commissioned report for the complete list of CARES data elements (Vellano et al., 2015).

Providers can submit data by entering them manually through the CARES website or automatically through an EMS agency's electronic platform. The CARES system also automatically contacts receiving hospitals with a request for patient outcomes data (e.g., survival to discharge and neurologic status at discharge) whenever a new case is entered into the system by paramedics (McNally et al., 2009). The software automates data analysis, allowing participating EMS agencies to access their own data, generate reports by date range, and to benchmark their performance against a summary national report. Hospitals also have access to a facility-specific report, allowing users to view prehospital and in-hospital characteristics of their patient populations with benchmarking capability.

CARES collects OHCA-related data from communities in 35 states, including 12 state-based registries (Alaska, Delaware, Hawaii, Idaho, Illinois, Michigan, Minnesota, North Carolina, Oregon, Pennsylvania, Utah, and Washington), representing approximately 80 million people, or 25 percent of the U.S. population (Vellano et al., 2015). The population catchment within the states highlighted in the CARES map (see Appendix D) ranges from 50 to 100 percent. The platform is now used internationally, through collaboration with the Pan-Asian Resuscitation Outcomes Study (PAROS), which includes nine countries (Australia, Japan, Malaysia, Singapore, South Korea, Taiwan, Thailand, Turkey, and the United Arab Emirates) (Ong et al., 2011).

CARES participation is voluntary, and EMS agencies and hospitals that contribute information are not compensated. Therefore, participating sites must be willing to invest the time and resources necessary for data entry, progress review and evaluation, and implementation of changes based on feedback. CARES outcome data are limited by potential selection bias, because higher-performing EMS systems may be more likely to voluntarily report outcomes.

OHCA: Resuscitation Outcomes Consortium (ROC) Epistry

ROC, a national network of research institutions, was established in 2004 to conduct randomized clinical trials that evaluate promising treatments and therapies for patients with OHCA and life-threatening trauma. It is a collaboration of 10 regional sites in the United States and Canada managed through a single data coordinating center. ROC is funded by the National Heart, Lung, and Blood Institute (NHLBI) in partnership with the U.S. Army Medical Research and Materiel Command, the Canadian Institutes of Health Research's Institute of Circulatory and Respiratory Health, Defence Research and Development Canada, the Heart and Stroke Foundation of Canada, and the AHA (Daya et al., 2015a). There are 120 EMS agencies enrolled in the ROC Epistry (67 from the United States and 53 from Canada), representing a population of 18 million. Case identification occurs at each ROC site through manual sorting of EMS records or automated capture from electronic records.

In order to facilitate the planning and conduct of clinical trials and to assess trends, investigators developed the ROC Epistry in 2005, a population-based prospective registry capturing incidence of all OHCA cases for which an EMS response is requested. Unlike CARES, this includes both EMS "treated" and "untreated" cardiac arrest cases. Patients who received chest compressions by EMS personnel, or any external defibrillation by either EMS personnel or lay responders, are categorized as "treated" (Morrison et al., 2008). Minimal data are also recorded for patients who did not receive any resuscitation treatment (due to DNAR order or death upon EMS arrival). An interdisciplinary ROC committee developed the original data set by using existing EMS reporting structures, OHCA templates, and mandatory and optional variables (Daya et al., 2015a). Relative to CARES, the annual cost of maintaining the ROC Epistry is considerably greater, but it contains more granular information on EMS process and outcomes per OHCA case allowing for more complex analysis. However, the research findings based on this data set may not be representative of other nonparticipating EMS and hospital systems; analyses of ROC sites should consider the potential for selection bias, because initial enrollment in ROC occurred through a competitive process, with only the most successful programs meeting participation criteria (Daya et al., 2015a; Nichol et al., 2008b). See the ROC group commissioned report for the complete list of data elements (Daya et al., 2015a).

The NIH recently announced plans for establishing a cross-collaborative clinical trials network for emergency care, titled Strategies to Innovate EmeRgeNcy Care Clinical Coordinating Center (SIREN).[6] The new network will continue the work of ROC and the NIH-supported Neurological Emergencies Treatment Trials, with the goal of designing clinical trials for patients with cardiac, neurologic, pulmonary, hematologic, and traumatic medical and surgical emergencies. These multidisciplinary research networks have the potential to improve research on cardiac arrest resuscitation and post-arrest care, by lowering the overall cost of conducting clinical trials research and creating a richer data source for assessing the complex treatments needed to improve rates of neurologically intact survival following cardiac arrest. Box 2-2 provides examples of additional national- and regional-level databases for OHCA.

IHCA: Get With The Guidelines-Resuscitation (GWTG-R) Registry

The AHA's GWTG-R registry, formerly known as the National Registry for Cardiopulmonary Resuscitation (NRCPR), was launched in 2000 to help hospitals assess their performance against national bench-

[6]Personal communication with J. Brown, NIH, May 26, 2015. SIREN is supported by the National Institute for Neurological Disorders and Stroke (NINDS), the National Heart, Lung, and Blood Institute (NHLBI), the National Center for Advancing Translational Sciences (NCATS), the Office of Emergency Care Research (OECR) in the National Institute of General Medical Sciences (NIGMS), and the Defense Medical Research and Development Program for Combat Casualty Care (DMRDP) (NIH, 2015).

marks, track patient outcomes, and improve the quality of in-hospital resuscitation care, with the overall goal of translating guidelines into clinical practice. The prospective registry includes cardiac arrest patients of all ages, and it reports a comprehensive range of data elements that cover patient demographics, in-hospital resuscitation and IHCA or OHCA hospital-based post-arrest care event data (e.g., hypothermia use, door-to-cath lab times, etc.), as well as facility-specific data (e.g., teaching status, bed size, and geographic region) (Chan, 2015).

GWTG-R provides unique resources for participating hospitals. In addition to Web-based patient management, clinical decision support, and related educational tools, it allows individual providers and hospitals to compare their own performance against other hospitals in real time (Ellrodt et al., 2013). Hospitals are rewarded with public recognition for improvement and for meeting defined goals and benchmarks. The information collected in the database is also used to inform the development and update of resuscitation care guidelines.

Although the GWTG-R registry is the largest IHCA registry in the United States, only 317 hospitals of the more than 6,000 nationwide are currently enrolled in the program (see Appendix D; Ellrodt et al., 2013). As shown in the GWTG-R map in Appendix D, hospitals are primarily located in urban and suburban sites, are not spread evenly across the United States, and do not completely represent the demographics of the country (Nichol et al., 2008b). Moreover, hospitals are required to pay an annual fee for participation, which means that resource-strained facilities may not be represented. The registry may therefore include a biased sample of hospitals, and it likely does not accurately capture the true incidence of IHCA in the United States. Additionally, the GWTG-R registry does not provide information related to the number of hospital admissions; as a result, incidence is difficult to calculate and researchers often rely on a combination of algorithms to provide estimate this figure. Like CARES and the ROC Epistry, the ability of the GWTG-R registry to report incidence or survival for specific patient groups (pediatrics or racial and ethnic minorities), or to examine the effects of confounding factors on outcomes, is fairly limited because of small sample sizes and missing data.

Strengths and Limitations of Current Registries for OHCA and IHCA

Cardiac arrest registries in the United States have achieved remarkable success in data collection in spite of the lack of mandatory reporting requirements for cardiac arrest, because of the voluntary participation of EMS and hospitals in select communities. Numerous publications have been produced based on the ROC, CARES, and GWTG-R registries, and each database has uniquely contributed to filling current gaps in knowledge. Relative to the ROC or GWTG-R registries, minimal data reporting requirements per cardiac arrest case have allowed CARES to create a surveillance network covering a greater portion of the U.S. population, with wider geographic reach and substantially lower cost. The ROC Epistry has created a more complex data source for cardiac arrest researchers, including more detailed data collection on event and resuscitation-specific process and outcomes per OHCA case. The GWTG-R registry, as the largest IHCA database, is a valuable source for assessing hospital-based resuscitation and post-arrest care.

However, common themes and limitations of current surveillance efforts have emerged. Existing registries capture data from a limited number of communities in the nation, from a voluntary subset of EMS and hospitals. In the absence of mandatory reporting requirements for OHCA and IHCA, many communities currently do not track any cardiac arrest outcomes at all. As a result, cardiac arrest incidence and outcomes data based on current surveillance systems may not be representative of the national state of cardiac arrest (Nichol et al., 2008b).

Second, because participation is voluntary, EMS and hospital systems that are already engaged in quality improvement, or have the resources to participate, are more likely to report cardiac arrest outcomes, thus introducing potential selection bias. For example, although geographically diverse, ROC sites may not be representative of all EMS agencies in the United States because they were initially selected through a competitive process for their ability to conduct OHCA randomized clinical trials. In fact, the baseline OHCA survival reported in the committee's commissioned analysis of ROC data was higher than the average survival rate (7.6 percent) reported in a recent 30-year systematic review (Daya et al., 2015a; Sasson et al., 2010).

Third, current registries are limited by missing or unreliable data on important predictors of outcomes, such as patient race and ethnicity, or socioeconomic factors (e.g., income, education, primary language, and insurance status), making it difficult to identify especially vulnerable populations and to adequately measure and rectify potential disparities in cardiac arrest treatment and outcomes. There is also a gap in evidence describing the long-term outcomes for patients who survive an arrest and are discharged from hospitals (Chan and Nallamothu, 2012). A comprehensive national database for cardiac arrest should provide reliable and valid measures of incidence and outcomes, as well as assessment of predictors and treatments on population health. Some characteristics of current national registries in the United States are highlighted in Table 2-5. Appendix D provides more information on each database.

Overview of International Cardiac Arrest Registries

There has been a proliferation of national population-based registries for cardiac arrest in Europe and Asia in recent years, as well as multinational registries such as the European Registry of Cardiac Arrest (EuReCa) and PAROS (Berg, 2014; McNally, 2014). Table 2-6 summarizes information on OHCA registries outside the United States. Registries that have published their survival rates report increasing rates of survival over time (Iwami et al., 2009; Kitamura et al., 2012). Research in Japan, Denmark, and more recently in the United States has attributed these increases to the Hawthorne effect; in other words, experts determined that communities that routinely monitor cardiac arrest responses and survival rates will improve their care over time, leading to better patient outcomes (Chan et al., 2014; Kellum et al., 2006).

TABLE 2-5 Characteristics of Primary Cardiac Arrest Registries in the United States

Database Elements and Functionality	CARES	ROC	GWTG-R
Captures OHCA EMS “treated” cases	X	X	
Captures OHCA EMS “untreated” cases		X	
Captures IHCA cases			X
Benchmarking with other participating sites	X		X
Performance feedback or reward system			X
Data quality audit	X[a]	X	
Free, no-cost enrollment open to all participants	X		
Post-discharge follow-up			

[a] This X was omitted from the prepublication copy of this report.

Next Steps for Cardiac Arrest Surveillance

In spite of the enormous societal impact of cardiac arrest, efforts to systematically monitor incidence and routinely assess outcomes are limited to voluntary OHCA and IHCA registries that provide limited geographic coverage and data on a population subset and are, therefore, unable to capture the true incidence. Robust and reliable data are needed in order to precisely measure the disease burden, identify factors that influence neurologically intact survival, and assess treatment and care protocols supporting continuous quality improvement efforts. This requires mandatory reporting and monitoring of all cardiac arrests in the United States, to allow for collection of data on both OHCA and IHCA.

Traditionally, CDC has served as the primary federal organization responsible for creating and maintaining national surveillance systems for infectious diseases to prevent epidemics or high-priority biological events (e.g., use of anthrax or other biological weapons) that can potentially impact public health and national security. National disease surveillance systems later expanded to include acute and chronic conditions such as cancer, autism, and certain cardiovascular diseases (IOM, 2011). In 2000, a federal mandate charged CDC with creating the Paul Coverdell National Acute Stroke Registry (PCNASR), in memory of the U.S. senator who suffered a fatal stroke while in Congress (CDC, 2015a). CDC's national disease surveillance system thus extends beyond its initial scope related to prevention of infectious diseases to registries that track treatment and care of clinical conditions (e.g., stroke) that have a substantial public health burden.

With many existing registries struggling and even competing for the scare funds required to create a robust surveillance systems, it is both logical and necessary to integrate current efforts into one cohesive national surveillance system for continuous and systematic monitoring, reporting, and analysis of cardiac arrest data. Several countries around the world have already implemented national registries for OHCA, demonstrating that such an endeavor is possible. Registries such as INTCAR (2012), described earlier, have combined aspects of prehospital and hospital care with the goal of evaluating post-arrest treatments and neurologic outcomes.

At this time, there are no successful surveillance models that have fully integrated collection of OHCA and IHCA, but there may be advantages to combining data collection. For example, it would allow detailed tracking of OHCA patients from initial arrest through hospital discharge, thus allowing for nuanced evaluation of treatments and outcomes. It would also allow researchers to determine a more reliable incidence for cardiac arrest, because separate registries for OHCA and IHCA data can lead to over-counting of events. A single registry may also be more cost efficient and eliminate duplicate efforts (e.g., EMS agencies now contribute data to multiple prehospital care databases such as NEMSIS, ROC, and CARES). The committee recognizes that few examples exist for such a model. Moreover, public health surveillance systems that are too complex, large, or pose a great burden on EMS and hospitals are less likely to succeed. The committee evaluated capacities of U.S.-based cardiac arrest registries and concluded that while current surveillance systems (e.g., CARES) provide a strong foundation for a national database, there are important limitations that need to be addressed. Further discussion with multidisciplinary surveillance experts, including organizations such as CDC, cardiac arrest investigators, state health departments, EMS and hospitals, and other relevant stakeholders, is needed to determine the framework for a national database. The next section describes some essential components for a national cardiac arrest surveillance system.

Standardize Definitions of Incidence and Survival Outcome

As discussed in previous sections, there are wide discrepancies in reported rates of cardiac arrest incidence and survival in the published literature, primarily attributable to disparate use of nomenclature and definitions of cardiac arrest. OHCA data collection and outcomes reporting is generally based on the standardized Utstein Style template.[7] The 2014 updated guidelines endorsed a summary metric for comparing system performance and recommended reporting of witnessed cardiac arrest cases that received bystander CPR and had a shockable first recorded rhythm and all EMS-treated cardiac arrests (Perkins et al., 2014). The AHA's 2013 consensus statement proposes defining the IHCA incidence rate as all patients who receive chest compressions and/or defibrillation

[7]In the 1990s, many experts recognized the importance of a resuscitation-survival EMS system performance metric. Identifying this gap led to the development of a standardized template for measuring cardiac arrest survival rates (Cummins et al., 1991). The Utstein Style was named after the location of where the conference was held—the Utstein Abbey in Norway. Since 1991, multiple "Utstein conferences" have attempted to unify nomenclature used for uniform reporting in many areas of resuscitation.

TABLE 2-6 Out-of-Hospital Cardiac Arrest (OHCA) Registries Outside of the United States

Location	Registry Name	Year Registry Established	Management and Funding	Participation	Additional Information
Multinational					
Asia[a]	Pan-Asian Resuscitation Outcomes Study (PAROS)	2009	Asian Emergency Medical Services Council	Voluntary	Data elements and reporting scheme based on the Cares Arrest Registry to Enhance Survival
Europe[b]	European Registry of Cardiac Arrest (EuReCa)	2007	Managed and funded by the European Resuscitation Council	Voluntary	Includes prospective data from 25 countries
National					
Denmark[c]	Danish Cardiac Arrest Registry	2000	Database owned by EMS Funded by TrygFonden, a private foundation	Voluntary	
Germany[d]	German Resuscitation Registry	2007	German Resuscitation Council	Voluntary	Records data on a national level, but participating centers represent only 9 percent of total population
Ireland[e]	National Out-of-Hospital Cardiac Arrest Register Project	2007	Pre-Hospital Emergency Care Council and the National Ambulance Service; administered and supported by the Discipline of General Practice at the National University of Ireland–Galway	Nonvoluntary	Monthly reporting to National Ambulance Services; national registry

Location	Registry Name	Year Registry Established	Management and Funding	Participation	Additional Information
Korea[g]	National Emergency Department Information System for Cardiac Arrest (NEDIS-CA) registry	2005	Supported by the National Emergency Medical Center in collaboration with the Korean Association of Cardiopulmonary Resuscitation	Voluntary	Registry structure similar to CARES
Norway[h]	Norwegian Cardiovascular Diseases Registry	2012	Norwegian Institute of Public Health	Non-voluntary	Does not require consent of individual
Sweden[i]	Swedish Cardiac Arrest Register	1990	Funded by Swedish National Board of Health and Welfare since 1993	Voluntary	
Regional					
Victoria, Australia[j]	Victorian Ambulance Cardiac Arrest Registry	1999	Managed by Ambulance Victoria, the sole EMS in Victoria; funded by government of Victoria		Data collected from prehospital through 1-year post arrest (excluding children)

SOURCES: [a]Ong et al., 2011; [b]Grasner et al., 2014a; [c]Wissenberg et al., 2013; [d]Grasner et al., 2014b; [e]OHCAR, 2014; [f]Hasagewa et al., 2013; [g]Yang et al., 2015; [h]NIPH, 2014; [i]Hollenberg et al., 2008; [j]VACAR, 2012.

(numerator) out of the total number of patients admitted to the hospital, including those in the ICU and the operating and procedure rooms, along with their recovery areas (denominator) (Morrison et al., 2013). The consensus document also recommended that patients with DNAR status be removed from both the numerator and the denominator. Although these definitions exist, they are not uniformly applied. There is a need to apply standardized definitions for both OHCA and IHCA for use in a national surveillance system, to more precisely measure the public health burden of cardiac arrest in the United States.

Identify a Uniform Set of Patient and Quality-of-Care Outcome Metrics

Creating a national database of cardiac arrest and resuscitation care requires a core set of standardized outcome metrics for both OHCA and IHCA, and expansion of data collection beyond current efforts, to serve as a reasonable baseline for every EMS and health care system in the country. The 2014 Utstein guidelines recommended a common data collection template for OHCA reporting (see Appendix F). Although existing registries have identified some common measures of mortality outcomes (such as the rate of patient survival-to-hospital discharge), there is still a lack of consensus among experts regarding nonmortality and quality-of-life data such as neurologic outcomes following cardiac arrest (Becker et al., 2011). Large databases such as CARES, ROC, and GWTG-R collect many common data elements, yet there are differences in how the information is analyzed and reported in studies, making it difficult to evaluate outcomes across registries.

Historically, resuscitation experts have measured patient outcomes primarily in terms of survival rates, including survival to hospital discharge, survival to hospital admission, or long-term survival (30-90 days, 1 year, or 5 years following discharge). The degree of neurologic injury following cardiac arrest, by contrast, has been presented using various scales, including the CPC, mRS, or other short- and long-term cognitive outcomes across studies. The Utstein reporting guidelines have designated CPC as a core outcome element (Jacobs et al., 2004) (see Box 2-3 for details). While the CARES registry reports neurologic outcomes using the CPC scoring system, the ROC Epistry relies on the mRS scale, contributing to a lack of harmonization. Some studies have defined “good outcome” as CPC 1 or CPC 2, recognizing that within these categories there may still be significant neurologic disability involving neurocognitive

BOX 2-3
Common Measures of Neurologic Function Following Cardiac Arrest

Cerebral Performance Categories (CPC):

CPC 1: good cerebral performance
CPC 2: moderate cerebral disability
CPC 3: severe dysfunction
CPC 4: coma
CPC 5: brain death

NOTE: In the updated Utstein reporting guidelines, CPC was designated as a core outcome element. Generally, CPC 1 or 2 is considered to be an indicator of positive neurologic outcome.
SOURCE: Jacobs, 2004.

Modified Rankin Scale (mRS):

0: no symptoms
1: no significant disability (able to carry out all usual activities, despite some symptoms)
2: slight disability (able to look after own affairs without assistance, but unable to carry out all previous activities)
3: moderate disability (requires some help, but able to walk unassisted)
4: moderately severe disability (unable to attend to own bodily needs without assistance, and unable to walk unassisted)
5: severe disability (requires constant nursing care and attention, bedridden, incontinent)
6: brain death

NOTE: Generally, mRS ≤ 3 is considered to be an indicator of positive neurologic outcome.
SOURCE: Banks and Marotta, 2007.

deficits. Although the CPC system is a useful outcome tool, it lacks the ability to more clearly distinguish levels of significant differences in neurologic outcomes. In a systematic review of clinical trials on post-arrest care, there was significant heterogeneity in the selection of outcome measures (Trzeciak et al., 2009). Two features were observed: (1) rather than survival alone, indices of functional survival were often used and (2) neurologic function was dichotomized into ordinal scales such as the CPC categories of “good” versus “bad” neurologic outcome. In order to improve patient outcomes following cardiac arrest, it is imperative that future surveillance efforts accurately monitor and report both mortality and morbidity measures of patient outcomes using a standardized template of variables.

The absence of a registry that captures high-quality and complete demographic data regarding race and ethnicity and socioeconomic factors makes it challenging to gather and evaluate evidence on disparities in cardiac arrest incidence, treatment, and outcomes. Racial and ethnic variables used in many studies are classified inconsistently; for example, the ROC Epistry does not include race and ethnicity data using federally defined categories (Sugarman et al., 2009). At this time CARES has a 26 percent missing rate for race and ethnicity data (McNally et al., 2011). Socioeconomic data (e.g., income, education, and insurance status) are routinely underreported in all existing registries. This is in part because challenges in collection of accurate and unbiased data; race and ethnicity data collection relies on visual assessment by EMS providers rather than patient self-reporting because the latter is not an option for cardiac arrest victims. Assessment of income and education also is usually based on neighborhood rather than individual factors. However, a method for checking completeness and accuracy for this type of reporting is needed. Additionally, some experts have suggested collecting information on location of arrest, which can be linked to demographic data from an area census tract.

Precise measurement of patient outcome variables that account for sources of potential confounding or bias is essential for advancing the current understanding of the effectiveness of existing treatments and therapies. The availability of data derived from these variables is also needed in order to guide future resuscitation research priorities. Standardized data on factors that influence a patient's likelihood of survival with positive neurologic outcomes (e.g., patient demographic characteristics, EMS and health system processes, location and geographic characteristics, and bystander CPR and AED use) is needed to allow for accurate statistical adjustments in measuring the outcome of interest.

EMS system– and health care system–level factors are often measured in units of time (e.g., response time between collapse and treatment). Although databases such as NEMSIS provide some oversight of national EMS data synthesis and reporting in an effort to identify high- and low-performing systems and best practices, a better understanding of these factors could be developed through the use of additional metrics (e.g., whether dispatcher-assisted CPR was available and provided). The implementation of additional metrics could also allow for benchmarking and drive improvements in systems of care.

Several national and international registries in other fields, such as epilepsy, have done important work in expanding surveillance efforts by linking patient medical records with administrative billing data from providers and payers (IOM, 2012). This enriches the data source by allowing researchers to assess the cost-effectiveness of specific treatments and therapies, by linking cost data with patient outcomes. Existing cardiac arrest registries have sparse data on cost and thus cannot be used to assess the economic impact of cardiac arrest.

Expanding data collection beyond the current minimal data template to include important variables, such as patient demographic and socioeconomic data and availability of specific post-arrest treatments can fill existing gaps in knowledge. The minimalist data points that are currently collected by CARES can be modified to enrich available information without creating substantial burden on the system. Cardiac arrest is a complex event that requires a wide continuum of care, in which the most critical data pieces come from separate data sources, including prehospital information collected from 911 call centers and local EMS providers, additional patient health information and administrative billing data from hospitals records, and death records. Expanding the number of data variables collected from EMS or hospitals will require a secure and integrated database that is able to accept multiple sources.

Create a Secure, Integrated Data Repository for Cardiac Arrest

Currently, data systems between EMS and hospitals lack interoperability because of the proprietary nature of each system, funding limitations, and concerns regarding patient privacy laws. However, a recent study in North Carolina demonstrated the utility of linking statewide EMS data with information from a state-based stroke registry, which allows researchers to follow the patient from the initial 911 emergency call through hospital discharge and, thus, evaluate effectiveness of specific treatments as well as quality of care (Mears et al., 2010). Future surveillance and research efforts can promote state-based data integration by leveraging electronic medical records from EMS and hospitals. Moreover, a database that is able to accept relevant data from medical devices could also be a valuable addition for cardiac arrest surveillance. For example, AEDs in public locations can provide data on location of arrest and whether cardiac arrest is due to a shockable rhythm (see Chapter 6 for detailed discussion). Other emerging sources of data such as wearable medical devices or mobile technologies can provide data about time of arrest, allowing for more precise calculation of collapse-to-treatment times. As data sources and collection activities expand, additional protections may be necessary, including security of the data system, quality control measures, procedures for protection of personal health information, deidentification of data as needed, and data reporting and analytic capabilities.

Engage State Support in Mandatory Reporting of Cardiac Arrest, Improving Data Integration and Outcomes Assessment

Involving state governments and health agencies, along with CDC, in activities related to a national surveillance system for cardiac arrest is necessary, because states would be responsible for providing technical assistance and training for participating hospitals, EMS agencies, and related staff, as well as for aggregating state-level data from multiple sources. State health and related government agencies are uniquely positioned to drive the success of a national registry for cardiac arrest by (1) mandating reporting of all new cardiac arrest (OHCA and IHCA) events, (2) coordinating data collection from EMS and hospitals into a standardized registry, and (3) collaborating with relevant stakeholders to produce a publicly available "report card" of patient outcomes. At this time, 12 state-based OHCA registries contribute EMS data into CARES. This model can be used as a template to expand data collection activities to other states using an expanded standardized reporting template, which allows for multifaceted data entry.

CDC's National Program of Cancer Registries (NPCR), for example, supports a national system of state-based cancer registries in 45 states and covers 96 percent of the U.S. population—allowing researchers to more accurately assess the burden of cancer, allowing policy makers to provide more targeted and localized solutions (CDC, 2013). The congressional act[8] provides CDC with funds for improving existing state-level registries, creating new registries in states where ones did not exist previously, and setting national quality standards, but states still have the authority to mandate reporting, timeliness, and data quality and take steps to ensure compliance with patient confidentiality requirements (Izquierdo and Schoenbach, 2000). Similarly, PCNASR, aimed at im-

[8]In 1992, Congress authorized the creation of NPCR through Public Law 102-515.

proving the quality of in-hospital stroke care (CDC, 2015a), requires that participating state health departments implement state-based registries and collaborate with local EMS systems and hospitals to collect data from the onset of the stroke through hospital discharge (George et al., 2009, 2011).

State health departments and government agencies also are a natural fit for providing surveillance oversight, because a majority of states already allocate resources to and regulate local EMS systems and hospitals. According to a recent report from the NHTSA, 39 states (78 percent) currently have formal regulations that require local EMS agencies to collect and report EMS data to a state-level EMS data system (FICEMS, 2011). A majority of these states report data using a standard template from the NEMSIS database. In the same report, 18 states noted the ability to monitor cardiac arrest data. Although only half of these state-level registries currently link EMS data with other health care systems (such as the trauma registry, emergency department and hospital discharge data, and motor vehicle crash data). State governments could enhance data consolidation from multiple sources by leveraging existing electronic health records to collect outcomes data. State-level registries could be used to produce a publicly available "report card" of patient outcomes to inform local and regional stakeholders, and allow benchmarking against a national standard.

Use Publicly Available Outcomes Data to Facilitate Accountability at Multiple Levels

The lack of accountability for EMS and health systems at the local level has likely contributed to variation in outcomes that exist between otherwise similar communities and comparably resourced health care systems. Currently, one-fifth of EMS systems and several hundred hospitals in the United States systematically collect and report data on OHCA and IHCA to a larger registry, and as a result these systems and hospitals can benchmark their performance against other communities. Although some EMS and health systems informally monitor patient and process outcomes to implement quality improvement strategies within their own system, patient outcomes data from EMS and hospitals are not harmonized across an integrated platform. As a result, the leadership of EMS systems are often unable to assess the quality of care provided by EMS personnel, because they do not have access to patient outcomes data after transporting a patient to a hospital. The inability to measure performance, and to benchmark against other communities, accounts for the general inattention to cardiac arrest and a lack of accountability among providers and leadership.

With the exception of CARES, outcome data from OHCA and IHCA cardiac arrest registries in the United States are not available to, or easily accessible by, the public. Subsequently, members of the general public are unaware of the performance of their local health care systems compared to other communities. This creates challenges for policy makers and other stakeholders to identify high-risk populations and communities, educate the public about cardiac arrest risks, and appropriately allocate resources. Reliable data at the local level will allow community organizations, advocates, and professional organizations to better target interventions toward vulnerable populations. A data system that generates customized output for the user at federal, regional, municipal, and local levels is needed. Making deidentified data sets available to academic institutions and investigators can also reduce the cost of research. Public reporting of data will increase transparency in care delivery and promote a national dialogue on cardiac arrest, thus generating greater accountability at each level of society.

CONCLUSION

The societal and economic burden of death and disability due to cardiac arrest is a significant public health problem in the United States. Published studies based on data collected by OHCA and IHCA registries have identified a number of factors related to characteristics of the individual patient and the EMS or health care system, as well as elements unique to the cardiac arrest event, that determine survival. However, existing surveillance systems for cardiac arrest have a number of limitations that have made it challenging to accurately measure and communicate the public health burden of cardiac arrest, and to assess the effectiveness of currently available treatments and care delivery strategies.

Valid and reliable data play an essential role in driving high-quality care, and ultimately in improving patient outcomes. Communities that continuously measure their performance and benchmark against national standards have made strides in improving population rates of survival with favorable neurologic outcomes. The cardiac arrest field would be substantially enhanced through the establishment of a national surveillance system for cardiac arrest, with mandatory data reporting for both

OHCA and IHCA to allow for accurate evaluation of incidence and outcomes, as well as effectiveness of treatments and care. The data from this national registry could be publicly available (with appropriate patient privacy and confidentiality protections in place) for use by a wide range of stakeholders. This would also allow the United States to contribute to a global data network and create multinational databases similar to the work that has been completed in Europe and Asia. It has become apparent that cardiac arrest and resuscitation systems, both in the hospital and out of the hospital, must know, measure, and understand local survival rates, and identify the factors that determine those outcomes, in order to promote system improvement. The creation of a national database, and mandatory reporting of cardiac arrest, may represent one of the most effective methods for driving improvements in nationwide survival.

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3

The Public Experience with Cardiac Arrest

As described in Chapter 1, the first three links in the chain of survival—early access, early cardiopulmonary resuscitation (CPR), and early defibrillation—are highly dependent on public engagement for a majority of cardiac arrest events. Under these circumstances, individuals may be required to provide basic life support, which includes mobilizing the delivery of emergency care (i.e., dialing 911), providing CPR, and using automated external defibrillators (AEDs), if they are available. Following a cardiac arrest and hospital discharge, family members and friends may be called on to provide support in continued care and rehabilitation for the individual recovering from the cardiac arrest.

Approximately 15 to 20 percent of EMS-treated out-of-hospital cardiac arrests (OHCAs) occur in a public place (Nichol et al., 2008; Vellano et al., 2015; Weisfeldt et al., 2010, 2011). The immediate, hands-on response of bystanders to cardiac arrest is critical to improve rates of effective resuscitation and, thereby, increase the likelihood of survival and positive neurologic outcomes for OHCA across the United States. For example, a definitive body of literature demonstrates statistically significant improvements to cardiac arrest survival rates when bystander CPR is performed (Akahane et al., 2013; Avalli et al., 2014; Campbell et al., 1997; Dowie et al., 2003; Ghose et al., 2010; Gilmore et al., 2006; Grmec et al., 2007; Herlitz et al., 2003, 2005; Kuisma et al., 2005; McNally et al., 2011; Nordberg et al., 2009; Rea et al., 2010a; Rudner et al., 2004; Vadeboncoeur et al., 2007; Vilke et al., 2005; Weiser et al., 2013; Yasunaga et al., 2010). By preventing the degradation of ventricular fibrillation (VF)—a shockable cardiac arrest rhythm—to a nonshockable cardiac arrest rhythm (as discussed in Chapter 1), CPR increases the number of patients who can be successfully resuscitated through defibrillation (Dowie et al., 2003; Gilmore et al., 2006; Nordberg et al., 2009). Bystander CPR is also associated with improved health outcomes for individuals who survive cardiac arrest. A number of studies have also found increased quality of life following cardiac arrest for individuals who receive bystander CPR compared to individuals who do not receive bystander CPR (Elliott et al., 2011; Granja et al., 2002; Mahapatra et al., 2005; Sladjana, 2011; Stiell et al., 2003; Yasunaga et al., 2010).

Various interventions and initiatives have been developed to increase public engagement in response to cardiac arrests. For example, placement of AEDs in public locations, implementation of effective emergency response plans in those locations, and use of AEDs in public locations have been shown to double a patient's odds of survival from cardiac arrest (Aufderheide et al., 2006; Caffrey et al., 2002; Hallstrom et al., 2004; Hazinski et al., 2005; Kilaru et al., 2014b; Lick et al., 2011; Page et al., 2013; Valenzuela et al., 2000; White et al., 2005). Despite these efforts, many barriers prevent optimal public engagement in resuscitation efforts, which leads to disparate rates of bystander CPR and AED use and contributes to poor survival rates and health outcomes.

This chapter examines the role of the public in responding to witnessed cardiac arrests, including activation of the emergency medical services (EMS) system (see also Chapter 5), engagement in bystander CPR, and application of AEDs. In addition to reviewing existing literature about the effectiveness of the elements of basic life support, this chapter also explores barriers and opportunities for increasing public engagement in cardiac arrest response. These opportunities for engaging the public and improving survival from cardiac arrest include linking CPR and AED training to eligibility for high school graduation, supporting employer efforts to maintain AEDs and provide AED training to their employees, and strengthening current legal protections for trained and untrained lay rescuers who provide CPR and defibrillation via AED for OHCA patients.

BYSTANDER CPR

After recognizing a medical emergency, one of the first critical actions a bystander should take is to call 911, which mobilizes EMS responders to the scene. In the case of a cardiac arrest, blood suddenly stops circulating through the body and normal breathing ceases. Once the bystander confirms that the individual is no longer breathing normally, CPR should be initiated and involves repeated chest compressions with or without rescue breathing under ideal circumstances. CPR provides oxygenated blood flow, keeping vital organs alive until the heart is able to resume pumping blood (Carpenter et al., 2003; White and Russell, 2002).

Bystander CPR makes the next link in the chain of survival, early defibrillation, more effective by increasing the proportion of individuals who are found with a shockable rhythm. In a study derived from the 1997 London Ambulance Service database that included 2,772 OHCAs, 48 percent of witnessed cardiac arrests with bystander CPR resulted in a ventricular tachycardia (VT) or VF rhythm; whereas, only 27 percent of witnessed arrests without bystander CPR were in VF/VT (Dowie et al., 2003). Among unwitnessed arrests, 31 percent of bystander CPR cases were in VF/VT compared to only 18 percent of non-bystander CPR cases (Dowie et al., 2003). Another study conducted by the Swedish Cardiac Arrest Register, which included 34,125 cases between 1992 and 2005, concluded that the provision of bystander CPR was associated with a higher likelihood of finding the individual in a shockable rhythm, and requiring fewer shocks to achieve return of spontaneous circulation (ROSC) (Nordberg et al., 2009). The relative benefit of bystander CPR also increases steadily when there are delays in the application of defibrillation and the collapse-to-defibrillation time increases. In a study of 2,193 VF arrests that occurred in a large metropolitan county between 1990 and 2004, the survival rate fell, and the association between survival and bystander CPR rose, as the collapse-to-defibrillation interval increased. Bystander CPR is especially important to the survival of patients who do not receive immediate defibrillation (Gilmore et al., 2006).

Despite the public's generally positive opinion of CPR and evidence indicating the utility of bystander CPR, the rate of bystander CPR in the United States remains low at only 26 percent (Bagai et al., 2013; Coons and Guy, 2009; Johnston et al., 2003; Lester et al., 2000; Lynch and Einspruch, 2010; Urban et al., 2013). Understanding what evidence exists and what barriers must be overcome to increase bystander provision of CPR can help develop interventions and educational material that will support greater use of bystander CPR following cardiac arrest.

Effectiveness of Bystander CPR

Many national and international registry studies indicate that bystander CPR can increase survival rates for OHCA between 50 and 500 percent (Ghose et al., 2010; Gilmore et al., 2006; Grmec et al., 2007; Herlitz et al., 2003, 2005; Rudner et al., 2004; Vadeboncoeur et al., 2007; Vilke et al., 2005; Waalewijn et al., 2001; Wissenberg et al., 2013). Two recent studies using OHCA data from the Cardiac Arrest Registry to Enhance Survival (CARES) found that patients who received bystander CPR had a higher probability of survival than those patients who do not. For example, McNally and colleagues (2011) noted that of 31,689 OHCAs with presumed cardiac etiology, patients who received bystander CPR compared to those who did not had overall survival rates of 11.3 percent and 8.7 percent, respectively. Rea and colleagues (2010a) found a similar improvement in a sample of 10,681 OHCA patients, where survival rates were 22.1 percent in shockable cases where bystander CPR was performed compared to a 7.8 percent survival rate overall. A recent Swedish study also found that the positive correlation between early CPR and cardiac arrest survival rates remained stable over a 21-year period (Hasselqvist-Ax et al., 2015). A meta-analysis of 79 studies involving 142,740 patients found that OHCA victims who received bystander CPR had a fourfold increase in survival rates (16.1 percent) compared to those who had not (3.9 percent), and the number needed to treat to save one life ranged from 24 to 36 (Sasson et al., 2010b).

Bystander CPR alone can only explain a modest proportion of the variation in cardiac arrest outcomes, but there is evidence to suggest it represents an important modifiable determinant of survival with positive neurologic outcome. In an early study of 316 consecutive patients with VF arrest in Seattle between 1975 and 1976, neurologic outcome was better if resuscitation was attempted by a bystander prior to the arrival of EMS (Thompson et al., 1979). Two other, more recent studies of cardiac arrest patients in the United States demonstrated a trend toward improved neurologic outcome for OHCA victims who received bystander CPR compared to those who did not, but the results did not achieve statistical significance (Haukoos et al., 2010; Kaji et al., 2014). Additionally, data from the Resuscitation Outcomes Consortium (ROC) registry and CARES have found that the good Cerebral Performance Category (CPC) scores described in Chapter two are substantially higher among patients who presented with an initial cardiac rhythm of VF or VT compared to pulseless electrical activity or asystole (Daya et al., 2015; Vellano et al., 2015). Based on these statistics, it is inferred that promoting bystander CPR will lead to improved neurologic outcomes, by way of an increased proportion of shockable first recorded rhythms among arresting patient (Kaji et al., 2014; Terman et al., 2014).

Stronger evidence to support the association between bystander CPR and improved neurologic function comes from several international studies. Among 95,072 bystander-witnessed cardiac arrests that occurred between 2005 and 2007 in Japan, bystander CPR increased the likelihood of favorable neurologic outcome (Yasunaga et al., 2010). In comparison with individuals who did not receive bystander CPR but did receive advanced cardiac life support (ACLS), the rates of survival with favorable neurologic outcomes were significantly higher when bystander CPR was combined with emergency medical technician ACLS and when bystander CPR was performed with physician ACLS. However, there were no significant differences in outcomes for individuals who did not receive bystander CPR but did receive physician ACLS (Yasunaga et al., 2010). The provision of bystander CPR also results in a significant improvement in both 1-month survival and favorable neurologic outcomes among pediatric patients (Akahane et al., 2013).

Moreover, provision of ACLS without bystander CPR substantially increases the number of patients who have unfavorable neurologic outcomes. Yasunaga and colleagues (2010) determined that the occurrence of vegetative status 1 month after a cardiac arrest was highest among patients who had received out-of-hospital ACLS performed by physicians but received no bystander CPR (Yasunaga et al., 2010). In another OHCA registry study from Italy, a lack of bystander CPR increased the odds of being discharged from the hospital with impaired neurologic outcomes (CPC score >2) (Avalli et al., 2014). In the Ontario Prehospital Advanced Life Support Study, the odds ratio (OR) for very good quality of life (Health Utilities Index Mark III >0.90) was 2.0 for patients who received bystander CPR compared to those who had not received bystander CPR (Stiell et al., 2003). This association between bystander CPR and good functional outcomes strongly reinforces the importance of promoting community CPR programs.

In addition to traditional CPR, which includes chest compressions and rescue breathing, there has been an increased interest in promoting the use of compression-only CPR (COCPR) in order to overcome bystander hesitation and concern with providing mouth-to-mouth rescue breathing (described later in this chapter). Minimizing interruptions in chest compressions has been associated with significant increases in survival. Even brief interruptions in chest compressions can negatively affect circulation. Therefore, minimizing interruptions during bystander care may also be associated with improved outcomes.

Multiple studies comparing compression-only bystander CPR to traditional CPR with rescue breathing for adults with OHCA have found no significant differences in survival. In one multicenter, randomized trial of dispatcher-assisted bystander CPR, 1,941 eligible OHCA cases were randomized to receive chest compressions with or without ventilations. No significant difference in survival to discharge was found between the two groups (Rea et al., 2010b). There was also no marked difference in the proportion of individuals who survived with a favorable neurologic outcome (Rea et al., 2010b). Another randomized study demonstrated that 30-day survival rates were similar for COCPR and tradition CPR (Svensson et al., 2010). The Save Hearts in Arizona Registry and Education (SHARE) program noted increased survival rates (from 3.7 to 9.8 percent over 5 years) after implementation of a statewide effort focused on increasing bystander CPR rates by training lay persons on COCPR (Bobrow et al., 2010). Three major findings were identified by the SHARE program: (1) there was a significant increase in the rate of bystander CPR (from 28.2 to 39.9 percent); (2) COCPR increased during the study period (from 19.6 to 75.9 percent); and (3) as compared with conventional CPR, COCPR had a significant independent association with survival (Bobrow et al., 2010). Resuscitation councils now promote the use of COCPR for lay bystanders in efforts to increase the overall rate of bystander CPR. Despite the studies that demonstrate the effectiveness of COCPR for adults, there are circumstances in which traditional CPR is more effective than COCPR. For example, the addition of rescue breathing to compressions for asphyxia-precipitated cardiac arrests (e.g., trauma, drowning, acute respiratory diseases and apnea [e.g., with drug overdoses], airway blockage, and pediatric arrests) has been associated with increased rates of ROSC and 24-hour survival in animal models, as compared to COCPR (Berg, 2000; Berg et al., 1999; Sayre et al., 2008). For children who have OHCAs from noncardiac causes (e.g., asphyxiation), conventional CPR that includes rescue breathing was found to significantly improve survival with favorable neurologic outcomes over COCPR (7.2 percent versus 1.6 percent) and should be the preferred method (Kitamura et al., 2010b). However, COCPR is considered to have a survival benefit over no CPR at all.

Bystander CPR Rates: Community, Neighborhood, Socioeconomic, and Individual Considerations

There is wide variation in bystander CPR rates in the United States based on community, neighborhood, and socioeconomic factors. The magnitude of effect of bystander CPR is higher in communities that have lower baseline survival rates. In a meta-analysis, which included 79 studies involving 142,740 patients, the pooled odds ratio (OR) for survival among patients who received bystander CPR compared with those who did not ranged from 1.23 in the studies with the highest baseline survival rates to 5.01 in the studies with the lowest baseline rates (Sasson et al., 2010b). Variations in cardiac arrest outcomes are correlated with differences in bystander response rates. For example, a review of 28,289 OHCAs not witnessed by EMS personnel found that survival to hospital discharge was significantly higher among those who received bystander CPR (McNally et al., 2011). Another study of 4,821 OHCAs occurring in Hispanic and non-Hispanic white neighborhoods in Arizona found that bystander CPR rates were lower in the Hispanic neighborhoods, as were survival to hospital discharge rates (Moon et al., 2014). Among EMS systems that report data to CARES, wide variations of bystander CPR rates were noted from less than 10 percent to greater than 60 percent (McNally et al., 2011, Figure 6). This variation may have contributed to similar differences in corresponding overall cumulative survival rates—from less than 5 percent to greater than 20 percent (McNally et al., 2011).

Rates of bystander CPR also vary within individual communities. In a study of 161 census tracts within Fulton County, Georgia (including Atlanta), the frequency of bystander CPR varied from zero to 100 percent (Sasson et al., 2010a). Another study of 200 census tracts in Columbus, Ohio, found that although the rough average bystander CPR rate was 23.8 percent, the interquartile range was zero to 33.3 percent (Sasson et al., 2012b). Similar findings were reported in Franklin County, Ohio, where the average bystander CPR rate was 20.6 percent, yet rates of zero percent were found in several census tracts (Semple et al., 2013). Although the average prevalence rate of bystander CPR in Denver was determined to be 19 percent, it was as low as zero percent in some census tracts (Nassel et al., 2014).

Socioeconomic factors that influence bystander CPR rates can, in part, explain neighborhood variations. Multiple studies have demonstrated that low-income neighborhoods have markedly lower rates of bystander

CPR when compared with higher-income neighborhoods. In a study in King County, Washington, among cardiac arrests that occurred in a private residence, a higher socioeconomic status (SES) was associated with increased odds of the provision of bystander CPR (Mitchell et al., 2009). A similar correlation was found in Ottawa, Canada, where there was increased likelihood of bystander CPR with higher property values of the individual who experienced the cardiac arrest (Vaillancourt et al., 2008). Likewise, in Fulton County, Georgia, people with cardiac arrests that took place in census tracts within the highest income quintile, compared to the lowest income quintile, were much more likely (OR 4.98) to receive bystander CPR (Sasson et al., 2011). Reports from CARES demonstrate similar findings with bystander CPR rates increasing with median household income. Bystander CPR was used in 22 percent of cases with household incomes of less than $22,000 compared to 37 percent of cases with households with an income of greater than $64,000 (Sasson et al., 2012a).

Race and ethnicity are also associated with differences in bystander CPR rates. People who live in neighborhoods that include primarily Hispanic, African American, or poor populations are two to three times more likely to have OHCA (Warden et al., 2012). Additionally, multiple studies have shown that African Americans with an OHCA experience lower rates of bystander CPR compared to white individuals with an OHCA (Becker et al., 1993; Brookoff et al., 1994; Cowie et al., 1993; Shah et al., 2014). Likewise, Hispanic ethnicity of individuals with OHCA is also associated with lower rates of bystander CPR compared to non-Hispanic white individuals (Berdowski et al., 2009; Vadeboncoeur et al., 2008).

The interaction between race and ethnicity and bystander CPR is often a function of SES, with disparities most apparent when comparing bystander CPR rates in minority, poor, and non-English-speaking neighborhoods to high-income, white, English-speaking neighborhoods (Sasson et al., 2012b; 2013b). However, race and ethnicity are also independent predictors of bystander CPR. For example, bystander CPR rates are 19 percent less in high-income African American neighborhoods than rates in high-income non–African American neighborhoods (Sasson et al., 2012b). Moreover, Latino individuals, regardless of the neighborhood where the cardiac arrest occurs, are approximately 30 percent less likely than white individuals to receive bystander CPR (Sasson et al., 2012b; 2015).

Traditional CPR certification courses are poorly targeted at those most likely to be nearby when a cardiac arrest strikes, as the majority of participants are white and less than 50 years of age (Brennan and Braslow, 1998; Selby et al., 1982). Recognizing and understanding the relationships among community and neighborhood characteristics, SES, race and ethnicity, language barriers, and bystander CPR can help guide the design, implementation, and evaluation of CPR and public health interventions in an effort to increase bystander CPR use and improve health outcomes. Spatial epidemiological clustering techniques can be used to identify high-risk neighborhoods for OHCA incidence and low provision of bystander CPR in order to target and allocate resources for training where it is most needed.

Barriers to Bystander Response

Despite evidence that bystander CPR can improve health outcomes from cardiac arrest, each year less than 5 percent of the American public receives formal CPR training (Anderson et al., 2014). Provision of bystander CPR involves three critical steps: (1) the bystander must recognize the cardiac arrest and understand that the individual needs immediate EMS assistance, (2) the bystander must be willing to activate EMS by calling 911, and (3) the bystander must be familiar with and willing to provide CPR. Survey and focus group studies have identified multiple theories as to why bystanders do not engage in each of these crucial steps. Major themes can be divided into four categories, which are presented in rough order of importance:

1. An inability to recognize an OHCA followed by a delayed activation of EMS,
2. A lack of adequate CPR training,
3. Concerns about possible liability, and
4. Psychological factors, rescuer confusion, and health concerns.

Initiatives designed to increase bystander CPR must overcome existing barriers, respond to misconceptions, and teach the technical skills necessary to perform CPR with confidence. Efforts to improve the rate of bystander CPR will need to take the barriers discussed in this section into account if they are to be successful.

Recognizing Cardiac Arrest and Early EMS Activation

The first link in the chain of survival for OHCA is recognition and early activation of EMS. However, the bystanders may have difficulty recognizing the symptoms of cardiac arrest. A cardiac arrest, for example, sometimes can be mistaken for fainting or a seizure (Clawson et al., 2008). As described in Chapter 1, cardiac arrest may also be confused with a heart attack or other cardiovascular events, which may not require immediate response and treatment, as is the case with cardiac arrest.

In addition to mistaking the signs of cardiac arrest for other cardiopulmonary events or medical conditions, the actual symptoms of cardiac arrest can be confusing to bystanders. Individuals suffering from a cardiac arrest can continue breathing for several minutes after the arrest. However, the breathing is not normal. In a study of 100 tape recordings to emergency medical dispatches for cardiac arrest patients, the incidence of suspected agonal breathing (gasping) was estimated to be approximately 30 percent. Bystander descriptions of the breathing were reported as "difficult breathing," "poor breathing," "gasping," "wheezing," "impaired," or "occasional breathing" (Bang et al., 2003). This agonal breathing is associated with survival, but decreases rapidly as time elapses (Bobrow et al., 2008). Importantly, agonal breathing can confuse bystanders, leading to miscommunication with dispatchers, and can delay the initiation of CPR (Berdowski et al., 2009). Another condition that can make recognizing cardiac arrest difficult is brief seizure-like activity (shaking) that occurs due to anoxic brain injury that results from the oxygen depletion that is associated with cardiac arrest (Clawson et al., 2008). These anoxic seizures can be confused with seizures that are more commonly associated with epilepsy and may further delay both bystander and dispatch action.

Bystanders may call a friend or relative before dialing 911, which can lead to delays in the identification of a cardiac arrest and early activation of EMS (Meischke et al., 2012). Barriers to early activation of 911 include distrust of law enforcement and fear of financial consequences. For many undocumented immigrants with limited English proficiency, language discordance and fear of exposing immigration status are significant concerns that may lead to delays in 911 activation (Ong et al., 2012; Sasson et al., 2013b; Seo et al., 2014; Skolarus et al., 2013; Watts et al., 2011). Understanding and overcoming these barriers can inform the development of culturally appropriate educational interventions to increase early recognition and improve outcomes.

The American College of Emergency Physicians (ACEP) supports the passage of laws that eliminate legal liability for good-faith reporting of emergencies related to drug overdoses (ACEP, 2014). Washington state amended its Good Samaritan law in 2010, and the response has been positive: 88 percent of surveyed drug users indicate that they would be more likely to call EMS in case of an overdose as a result of this amendment (Banta-Green et al., 2011). Protection from legal liability could be extended to include immigration status. So far 25 states have amended laws to encourage Good Samaritans to summon aid in the event of an overdose (Law, 2014).

Limited English proficiency in 911 callers is associated with delays in arrest recognition and implementation of telephone CPR (Bradley et al., 2011). Few studies have included data on bilingual language capabilities of dispatchers and preferred first language of limited-English-proficient callers. In one study of a call center where all call takers are monolingual speakers of English but translation services are available via an external company, requests formulated in English for a Spanish translator undermined the need for non-English and showed a low success rate in obtaining translation services (19 percent) compared to requests formulated in Spanish. Nonetheless, even the requests formulated in Spanish were successful in only 87 percent of cases (Raymond, 2014). Although public safety access points, such as 911, generally have translation services, the existence or availability of translation services is not synonymous with their accessibility or use. One way to overcome language barriers proposed in several cities and counties throughout the United States is to offer additional financial incentives for multilingual dispatchers (Jobs, 2015; Londoño, 2003; San Diego Police Department, 2015).

Lack of CPR Training

Fear of harming the unresponsive individual or performing CPR improperly are also commonly cited barriers. These concerns are frequently cited by individuals who have never received CPR training and those who have had training but fear that they have forgotten how to perform it correctly. Studies indicate that previous training increases bystanders' confidence and willingness to perform bystander CPR (Cho et al., 2010; Coons and Guy, 2009; Donohoe et al., 2006; Johnston et al., 2003; Kuramoto et al., 2008). Similarly, CPR provision is more common in CPR-trained bystanders when CPR training has occurred within the past

5 years (Sipsma et al., 2011; Swor et al., 2006). Despite evidence that indicates the importance of bystander CPR in cardiac arrest outcomes (described previously in the report), an insufficient percentage of the public is trained in CPR. In a cross-sectional study of CPR training data from the American Heart Association (AHA), the American Red Cross, and the Health & Safety Institute, the median annual CPR training rate in all counties in the United States was 2.39 percent and varied widely across communities with median rates between 0.51 and 6.8 percent in the lower and upper tertiles (Anderson et al., 2014). Of counties located in southern U.S. states, those with higher proportions of rural areas with larger African American and Hispanic populations and those with lower median household incomes had lower rates of CPR training than other areas (Sasson et al., 2013b).

Training costs and time considerations are some factors that affect people's decisions about seeking CPR training. Currently, CPR certification courses train a small fraction of the public in the United States—approximately 13 million annually out of 319 million (Anderson et al., 2014). Traditional CPR and AED certification courses may discourage would-be trainees because of time and money concerns (Roppolo et al., 2007). Traditional CPR certification takes approximately 4 hours to complete and requires a certified instructor in a classroom setting (AHA, 2011). While some of these courses are provided without charge through employers, many courses geared toward the general public require participants to pay a fee. Alternative models for delivering training to segments of the population who will not participate in classroom-based courses need to be expanded.

The cornerstone of traditional CPR training is through programs that integrate CPR training into civic, work, or school activities. Although some studies have suggested that certified instructor–led training may be superior, there is growing evidence to support alternative methods for bystander training (de Vries et al., 2010; Mancini et al., 2009; Yeung et al., 2011). Moreover, investigations of public CPR classes suggest that CPR certification courses are poorly targeted at those most likely to be nearby when a cardiac arrest strikes, because the majority of participants are younger than 50 years of age (Brennan and Braslow, 1998; Selby et al., 1982). Layperson instructors, computer and video self-instruction, and poster instruction provide similar competence at a lower cost as compared to traditional certification and have the potential to reach larger segments of the population (Castren et al., 2004; de Vries et al., 2008; Isbye et al., 2006; Meischke et al., 2001; Reder et al., 2006).

Previous trials have demonstrated that 30-minute training sessions, whether with video self-instruction or group training, can achieve equal or better post-training CPR knowledge compared to the traditional 4-hour-long AHA Heart Saver courses (Aldeen et al., 2013; Lynch et al., 2005; Todd et al., 1999). Moreover, home training by video self-instruction with peer facilitation has been shown to provide similar competence at a lower cost compared to traditional classroom-based training for lay responders expanding the reach of bystander CPR instruction (Wik et al., 1995). A more comprehensive description of alternative models for training to be used to enhance outreach, especially in traditionally disenfranchised communities can be found in the Alternative Training Strategies section in this chapter.

Concerns About Legal Liability

Good Samaritan laws are designed to protect those who choose to aid during an emergency, and are intended to reduce bystanders' hesitation to assist. Although every state has a Good Samaritan law or act, the character of these laws varies from one jurisdiction to another. Some Good Samaritan laws apply to all citizen rescuers, while others are specifically written for physicians. In Pennsylvania, the law specifically protects lay rescuers who have CPR certification from the AHA or the American Red Cross. In Washington state, protection is provided for "any person providing emergency care," regardless of prior training.[1] Good Samaritan laws in Minnesota and Vermont include language to establish and promote a minimum duty to provide reasonable assistance and alert medical personnel. These variations and complexities prevent potential bystanders from understanding the protections that these laws offer, thereby making them reluctant to act in an emergency (Law, 2014; Sasson et al., 2013a).[2]

A fear of legal consequences and a lack of familiarity with Good Samaritan laws are frequently cited as reasons for not performing bystander CPR (Coons and Guy, 2009; Sasson et al., 2013a). These fears are not without justification: although a bystander has no legal duty to rescue, there *can* be legal consequences for intervening (Hyman, 2005).

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[1]Revised Code of Washington. 4.24.300. Immunity from liability for certain types of medical care.

[2]State-by-state descriptions of Good Samaritan laws are available online through multiple sources, including the Society for Human Resource Management (Society for Human Resource Management, 2015).

Theoretically, a member of the public could be sued for providing bystander CPR; however, the committee is unaware of any successful suit of this type. To mitigate the confusion and fear of potential rescuers, CPR instructors are urged to inform trainees of the protections available for lay rescuers in their area (Abella et al., 2008). Such instruction is especially important for individuals who are not fluent in English, because language barriers can exacerbate confusion about Good Samaritan laws (Sasson et al., 2013b).

Laws that do not adequately protect bystanders from legal action create disincentives for providing assistance and immediate action in emergency medical situations such as cardiac arrest (Banta-Green et al., 2011; Law, 2014). The limitations of current Good Samaritan laws have been recognized by the ACEP, which produced a 2014 policy statement calling for the widespread passage of laws eliminating legal liability for good-faith reporting of emergencies through 911 and other official communication channels, with the aim of encouraging bystanders to provide assistance during a potential drug overdose (ACEP, 2014). Similar policy statements calling for the protection of citizen rescuers who perform CPR along with financial support for public participation, education, funding, and coordination for successful implementation of such laws should be promoted by medical societies so as to eliminate this commonly cited barrier to performing bystander CPR.

Emotional Considerations, Mental Factors, and Health Concerns

Psychological barriers to performing CPR include panic, apprehension, and feelings of inadequacy in emergency settings. Women and nonnative English speakers, populations that report generally higher stress levels, cite these barriers more frequently than others. Panic may influence readiness to act in an emergency situation irrespective of prior CPR training (Sasson et al., 2013a). This may, in part, explain why individuals who have had a cardiac arrest are more likely to receive CPR if the arrest is witnessed by strangers as compared to friends or family members (Casper et al., 2003; Hyman, 2005).

Multiple studies report confusion, lack of knowledge about CPR, and fear of performing CPR incorrectly as major barriers to bystander CPR (Carruth et al., 2010; Reder et al., 2006; Sasson et al., 2013a; Taniguchi et al., 2007). In scientific statements, the AHA has acknowledged that the complexity of CPR potentially contributes to these barriers (Abella et al., 2008; Sayre et al., 2008). For example, guidelines call for ventilations in all cases of pediatric cardiac arrest, regardless of the training of the rescuer (M. D. Berg et al., 2010; Biarent et al., 2010; Spencer et al., 2011). Compare this to adult cardiac arrest, where bystanders can provide either traditional or COCPR, while professional rescuers should provide traditional CPR in all cases (Hazinski, 2010). Although the shift to COCPR for lay rescuers is intended to simplify CPR, the existence of multiple guidelines may be a source of confusion for some bystanders. Moreover, frequent changes to the guidelines have themselves been cited as major sources of bystander confusion (Sasson et al., 2013a).

Resistance to providing rescue breathing, also known as mouth-to-mouth ventilation, is another noteworthy barrier for provision of bystander CPR (Locke et al., 1995; McCormack et al., 1989). One-fourth of people who suffer OHCA exhibit clinical signs of regurgitation at some point, and provision of rescue breathing increases the possible risk that the person will aspirate gastric contents (Virkkunen et al., 2006). Therefore, there are some legitimate medical concerns about use of rescue breathing following a cardiac arrest. However, bystander concerns typically revolve around the possibility of contracting a disease from the individual who has collapsed. Despite the paucity of documented cases of a communicable disease being transmitted to a rescuer following provision of rescue breathing, bystander reluctance is understandable and often cited as a large barrier to providing CPR (Locke et al., 1995; Ornato et al., 1990). The shift toward COCPR reduces concern for this commonly cited barrier and can increase the willingness of bystanders to perform CPR (Kanstad et al., 2011; Urban et al., 2013).

Strategies to Increase Bystander CPR Training

Although studies indicate that individuals who have previously participated in CPR training are more likely to initiate resuscitation than those who have not (Swor et al., 2006; Tanigawa et al., 2011), there are mixed results with regard to which types of training promote the highest-quality bystander CPR and longest retention of CPR skills and relevant knowledge. Since the initiation of bystander CPR training in the 1970s, efforts to increase bystander response have largely revolved around provision of traditional, certificate-based CPR courses that are employment, school, or event based, require several hours to complete, and can be costly. This approach has proven to be inefficient because CPR certification courses train only 3 percent of the public (Anderson et al., 2014). Moreover, such training approaches have proven to be especially inefficient in reaching lay people in the southern United States, and in regions with higher proportions of rural areas and of black and Hispanic residents (Anderson et al., 2014). A more effective approach would reach all segments of the population regardless of SES, race, ethnicity, or geography and would target individuals who are most likely to be present when a cardiac arrest occurs.

School-Based Training

Educating the lay public in bystander CPR is clearly an important way to increase survival in OHCA. However, it is difficult to reach the entire population without mandatory programs. School-based interventions allow for a broad reach that encompasses all segments of the population, regardless of SES or race and ethnicity, and have potential to decrease disparities in the delivery of bystander CPR and use of AEDs. Because schools provide large-scale, centrally organized settings to which all children and their families have access, school-based interventions can be used to increase awareness, boost responses to cardiac arrest, and ultimately improve survival and cardiac arrest outcomes at the community level. Importantly, research suggests that CPR training in schools has support within minority communities (Sasson et al., 2014, 2015).

One benefit of incorporating CPR and AED training during the school year is that students are already primed for learning. Studies comparing CPR training for children with similar training for adults indicate that children can score better than adults on multiple-choice questionnaires when similar CPR training methods are used (Jimenez-Fabrega et al., 2009; Rosafio et al., 2001). Furthermore, schools provide a platform for repeated training opportunities, and repeated training has been associated with better retention of resuscitation skills. Studies looking at retention between 3 to 12 months after training demonstrate an expected improvement in knowledge and skills after training, which is then followed by a deterioration of skills following the initial training (Christenson et al., 2007; Woollard et al., 2006). The optimal frequency of refresher training is unknown, but annual training compared to biannual training does not appear to provide a remarkable advantage (Bohn et al., 2012).

The widespread adoption of school-based CPR and AED training would not be expected to substantially increase bystander CPR rates throughout the country. In the near time, the training would provide a valuable skill set that could increase the likelihood for an appropriate response to an emergency throughout that student's lifetime. Moreover, school programs that promote taking CPR and AED study materials home to share with family members could multiply the number of adults trained in CPR and AED use, because students could share their new knowledge and skills with adult family members and other community members who may be more likely to witness a cardiac arrest (Isbye et al., 2007a,b; Lorem et al., 2008, 2010). For example, one study of high school students found that each high school student who took an educational manikin-DVD set home ended up training, on average, an additional 2.8 adults to perform CPR with 43 percent of newly trained adults being over the age of 50 (Lorem et al., 2010).

Training in schools is an essential component of a comprehensive approach to improve OHCA survival and outcomes across communities. In the long term, CPR and AED education in schools represents an investment in training multiple generations of people, and it could greatly multiply the number of adults willing to perform bystander CPR and use an AED in one generation. Although there are no longitudinal studies that assess the impact of school-based CPR training on the probability that students will provide CPR as adults, evidence demonstrates that training—undertaken at any point—increases the likelihood that a bystander will provide appropriate care when faced with an OHCA (Swor et al., 2006; Tanigawa et al., 2011). Moreover, the success of communities in Denmark, Minnesota, and Norway, where improved OHCA outcomes have been observed with increased rates of bystander CPR, has been attributed in part to school-based CPR and AED training (Lick et al., 2011; Lindner et al., 2011; Wissenberg et al., 2013). Reliably increasing the percentage of community members who are trained in CPR and AED use through school-based programs is an effective component to improve the overall community response to cardiac arrest, thereby reducing time to first compression.

The use of school-based CPR and AED training programs has been endorsed by the World Health Organization in a joint statement titled "Kids Save Lives," which is also supported by the European Patient Safety Foundation, the European Resuscitation Council, the International Liaison Committee on Resuscitation (ILCOR), and the World Federation of Societies of Anaesthesiologists (Böttiger and Van Aken, 2015). The joint statement recommends that school children received resuscitation training every year beginning at the age of 12 years (Böttiger and Van Aken, 2015). CPR and AED training in schools has also been endorsed by the AHA, the American Academy of Pediatrics, the American College of Emergency Physicians, the National Association of School Nurses, and the Society of State Directors of Health, Physical Education, and Recreation (Cave et al., 2011). Some schools have also been supportive of CPR training for students (Reder and Quan, 2003). Communities across the United States are recognizing the value of including resuscitation training in school curricula. Currently, there are 20 states that have mandated CPR education as a condition for graduation for high school students (AHA, 2015a) (see Appendix E).[3] Despite existing mandates, the specific recommendations for training vary from one state to another, and most states have not designated additional funds to support the training nor have they specified the age at which the mandated training should occur.

Lack of funds and limited class time for CPR and AED training remain two of the largest barriers to incorporating CPR training in schools (Reder and Quan, 2003). In an effort to ease financial constraints, a bill that was designed to establish and provide grants to facilitate CPR and AED training in public elementary and secondary schools was introduced in the U.S. House of Representatives in 2013.[4] However, the bill was never enacted. Some states, such as Colorado and North Dakota, have established programs that reimburse the purchase of CPR and AED training equipment for schools.[5] Although legislation in Massachusetts does not mandate, but rather encourages, CPR training in schools, the state offers funding for training programs when they are included as part of a health education program.[6]

A number of options aimed at overcoming financial obstacles and time constraints for training in schools have been introduced and supported in the academic literature. Shorter CPR training courses can address concerns about the limited ability of some students to attend long classes. Highly condensed CPR training can be effective at developing competency in CPR among students (Jones et al., 2007; Meissner et al., 2012). In basic life support (BLS) courses as short as 60 minutes long, middle school students can develop proficiency in COCPR and AED use (Kelley et al., 2006). Furthermore, the use of non–health care instructors, such as schoolteachers (Bohn et al., 2012; Toner et al., 2007), medical

[3]Two more states (Oregon and West Virginia) will begin requiring CPR certification for high school graduation in 2015-2016.

[4]Teaching Children to Save Lives Act of 2013, H.R. 2308, 113th Congress, 1st sess. (2013-2014).

[5]Colorado House Bill 14-1276 and North Dakota Senate Bill 2238.

[6]Massachusetts Law, Part 1, Title XII, Chapter 71, Section 1, 2015.

students, and peer tutors may reduce cost and scheduling difficulties associated with CPR courses (Breckwoldt et al., 2007; Carruth et al., 2010; Plant and Taylor, 2013). Training schoolteachers to be CPR instructors should be viewed as a long-term investment enabling teachers to train successive classes of students and incorporate CPR training into lesson plans for required courses, such as health or physical education. Another option is to move learning out of the school and into the home by giving self-instruction kits or assigning computer-based training programs as homework (Isbye et al., 2007b; Reder et al., 2006).

CPR as a Prerequisite to Other Activities

Half of the countries in the European Union have mandatory first aid and CPR training requirements in place in order to obtain a driver's license (Adelborg et al., 2011). Many of these mandates exist in conjunction with other national initiatives, such as school trainings and public awareness campaigns. These factors have contributed to the increase in bystander CPR rates in countries such as Denmark and Sweden (Stromsoe et al., 2010). Although there is no mandatory requirement for CPR training in the United States, the idea has been introduced in Ohio and Connecticut without success. Ohio's House Bill 283, which was introduced in 2011, would have required instruction in CPR and AED use as a graduation requirement.[7] Ohio House Bill 580, introduced in 2014, would have mandated that teenagers younger than 18 submit proof of completion of a first-aid and CPR course within 1 year after applying for a driver's license.[8] Connecticut's House Bill 6054, which was introduced in 2013, would have prohibited the commissioner of the state Department of Motor Vehicles from issuing or renewing a driver's license if an applicant had not received a CPR certification (Gendreau, 2013).

Laws regulating employer-based CPR and AED training are determined, in part, by state-level public access defibrillation (PAD) regulations and federal-level Occupational Safety and Health Administration regulations. Federal Aviation Administration regulations require that flight attendants receive instruction in proper CPR techniques and AED use that includes the performance drills followed by refresher training and drills at least once every 24 months (FAA, 2006). Likewise, the Healthcare Research and Quality Act of 1999 and the Public Health Service Act require the U.S. Department of Health and Human Services to

[7]Ohio House Bill 283, 129th General Assembly, 2011-2012.
[8]Ohio House Bill 580, 130th General Assembly, 2013-2014.

produce a set of guidelines for CPR and AED training in federal government facilities. The law states that, "in facilities where there are sufficient numbers of personnel to permit in-house training programs, a routine training schedule should be established"; that "formal refresher training should be conducted at least every 2 years"; and that "it is recommended that lay rescuer/responder teams engage in periodic 'scenario' practice sessions to maintain their skills and rehearse protocols" (GSA, 2001).

Preparing Family Members to Respond to Cardiac Arrest

Given that four out of five cardiac arrests occur in at home, the people most likely to be on hand to provide immediate response to CPR are family members (AHA, 2015b; Swor et al., 2003; Waalewijn et al., 2001). Members of the public who are exposed to educational materials promoting CPR, or who believe CPR should be performed prior to EMS arrival, express greater intention to, respectively, train in or perform CPR (Vaillancourt et al., 2013). The hospital setting may be an effective training location for family members of patients who are recovering from myocardial infarction, a particularly high-risk group for subsequent cardiac arrest. Emergency departments also provide an opportunity to refer high-risk patients and their families for appropriate CPR training. In a cross-sectional study of patients presenting to the emergency department with chest pain, only two in five households had prior CPR training. Yet, two out of every three households were willing to participate in CPR classes (Chu et al., 2003).

CPR training can reduce anxiety and help empower family members, friends, and caregivers of high-risk patients. One study of parents with high-risk children (i.e., those with premature birth, congenital heart defects, and history of apnea) demonstrated that the use of a take-home educational manikin-DVD set can provide sustained knowledge and confidence (Knight et al., 2013). The intent of the educational manikin-DVD set is to allow individuals to use the kits at home or in the workplace for self-instruction at a convenient time. When shared with others, the kits expand the number of trained individuals to include other family members, friends, and colleagues (Potts and Lynch, 2006). The kits were originally developed by the AHA and Laerdal Medical AS (Stavanger, Norway) and contain a small manikin and a 22-minute training video. The manikin allows individuals to practice the psychomotor skills of

CPR, but it does not provide similar simulation for AED application of pads and administration of a shock.

In another study of parents with premature infants and children with congenital heart disease, the use of a video self-instruction training kit for infant CPR increased caregiver comfort and led to training for a total 3.1 persons per kit, which was the result of parents sharing the kit with other caregivers (Pierick et al., 2012). In a study of adult family members or friends of patients who were admitted to a hospital with cardiac-related diagnoses, CPR training promoted self-confidence and increased secondary training of family members who were not captured by hospital training opportunities (Blewer et al., 2011). To improve cardiac arrest survival rates, especially for cardiac arrests that occur in homes and other private settings, policy makers and health care systems need to consider the widespread implementation of training for family members of patients who have medical conditions that place them at higher risk for cardiac arrest. These training programs could be included as part of hospital discharge instructions for parents of high-risk children, family members of survivors of myocardial infarction, and patients with other cardiovascular risk factors.

Critical Teaching Points for Bystanders

Any program designed to teach lay bystanders how to respond to an OHCA must include instruction on the first three links of the chain of survival: early recognition and activation of the emergency response system, CPR, and AED use. Studies have demonstrated that delays in bystander response to emergency situations may be due to uncertainty or any of the barriers described above. Nonresponding bystanders sometimes vacillate between two undesirable alternatives: acting when there is no emergency and not acting when there is an emergency. Because the signs and symptoms of a cardiac arrest can be confusing, early recognition is the most critical step. Some organizations who offer CPR training courses have simplified criteria for starting CPR. Training courses may no longer instruct bystanders to search for a pulse or watch and feel for breathing. Instead, bystanders are encouraged to start CPR on any person who has collapsed, is unresponsive as assessed by tapping and shouting, and has abnormal or absent breathing (R. A. Berg et al., 2010). It is unknown whether brief training modalities provide adequate instruction on cardiac arrest recognition compared to traditional instructor-led courses, because this component has not been tested in prior studies.

Studies have indicated that cardiac arrest outcomes are directly related to the quality of CPR provided, which includes chest compression depth, chest compression rate, and the duration of interruptions to compressions (Cheskes et al., 2014; Idris et al., 2015; Kramer-Johansen et al., 2006; Stiell et al., 2014). Achieving the target compression depth in adult victims of cardiac arrest requires the application of considerable force, and is difficult to achieve for children younger than 13 years old given their size and physical limitations (Aelen et al., 2013; Tomlinson et al., 2007). Therefore, it is reasonable to introduce instruction of adult CPR chest compression skills in middle school and not sooner. However, children as young as 4 or 5 years can be trained in the steps of cardiac arrest response, including recognition, activation of EMS by dialing 911, and opening the airway of a victim (Bollig et al., 2011). Moreover, the quality of bystander CPR is associated with a higher probability of survival than having no CPR. For this reason, inability to achieve chest compression depth or rate should not dissuade would-be rescuers from performing CPR.

Alternative Training Strategies

As noted previously, the necessary time and money for traditional classroom CPR and AED training certification may discourage the public from participating in these courses and obtaining requisite skills. Investigations of public CPR classes also suggest that CPR certification courses do not reach the individuals who are most likely to be present when a cardiac arrest occurs, with the majority of participants being younger than the populations that most commonly suffer from—and are witnesses to—cardiac arrest (Brennan and Braslow, 1998; Kramer-Johansen et al., 2006). Although some studies have suggested that certified instructor–led CPR training may be superior to other training approaches (de Vries et al., 2010; Mancini et al., 2009), there is growing evidence to support alternative methods for bystander training (Yeung et al., 2011). Layperson instructors (Castren et al., 2004) and computer and video self-instruction with practical skills modules (Isbye et al., 2006; Meischke et al., 2001; Reder et al., 2006) provide similar competence in CPR at a lower cost compared to traditional certification and have the potential to reach larger, more diverse segments of the population. For AEDs, self-training with a poster, a manikin, or a training AED were shown to be equally effective at maintaining competency in AED usage among students already trained in BLS (de Vries et al., 2008).

Randomized controlled trials have demonstrated that a 30-minute training module, whether provided through video self-instruction or group training, can achieve comparable or better post-training CPR knowledge and performance when compared to the traditional 4-hour AHA Heart Saver courses (Aldeen et al., 2013; Lynch et al., 2005; Todd et al., 1999; Wik et al., 1995). Home training by video self-instruction with peer facilitation has also been shown to provide similar competence at a lower cost in comparison to traditional classroom-based training. This approach can also be used to expand the reach of bystander CPR instruction (Wik et al., 1995).

Even ultrabrief, COCPR video training can teach adult bystanders basic CPR skills in just 60 seconds. These types of modules have demonstrated improved responsiveness, chest compression rate, and increased proportion of total resuscitation time spent providing chest compressions (Panchal et al., 2014). Similarly, cell phone apps for self-directed CPR training with feedback mechanisms can improve chest compression performance in simulated cardiac arrest scenarios. This new approach to training promises a boost in knowledge and confidence in CPR performance over a short period of time (Merchant et al., 2010; Semeraro et al., 2011).

Dispatcher-Assisted Training

Dispatcher-assisted training via telephone instruction, which is discussed in greater detail in Chapter 4, has demonstrated an increase in bystander CPR rates (Rea et al., 2001; Stipulante et al., 2014). Early simulation studies proposed the use of dispatcher-assisted CPR as a strategy to increase the rate of bystander CPR in communities where few people have CPR training and to improve the quality of CPR performed by bystanders who had prior training (Kellermann et al., 1989). Clinical studies have confirmed the success of this approach. One study of 7,265 EMS-attended, adult cardiac arrests between 1983 and 2000 in King County, Washington, determined a multivariate adjusted OR of survival of 1.69 for dispatcher-assisted bystander CPR compared with 1.45 for bystander CPR without dispatcher assistance (Rea et al., 2001). Another study conducted in Belgium concluded that bystander CPR increased from 9.9 to 22.5 percent after the implementation of a dispatch protocol that included CPR instructions (Stipulante et al., 2014).

Although dispatcher-assisted CPR has great potential to increase bystander CPR rates, challenges remain in populations with limited English proficiency. Non-English-speaking bystanders may have difficulty in accurately relaying information to dispatchers and then receiving instructions that are understandable to them. One study noted that it took dispatchers longer to recognize cardiac arrest when talking to callers who had limited English proficiency compared with callers who were fluent in English. The interval from call receipt to initiation of CPR was also longer for callers with limited English proficiency compared with callers who were fluent in English (Bradley and Rea, 2011). A higher level of English proficiency and a greater proportion of time spent in the United States were strong predictors of CPR training and intention to call 911 in an emergency (Meischke et al., 2012). These factors highlight the importance of focusing efforts on reaching out to and training most communities that have lower levels of English proficiency.

Models of Success: The Power of Multiple Initiatives

Denmark recognized the low frequency of bystander CPR (less than 20 percent) and low 30-day survival from cardiac arrest (less than 6 percent) and took steps by adopting several national initiatives to strengthen bystander resuscitation attempts. These initiative included (1) the implementation of mandatory resuscitation training in elementary schools, as well as when acquiring a driver's license, (2) an initiative to increase voluntary first-aid training, (3) free distribution of CPR self-instruction training kits, (4) nationwide improvement efforts in delivering dispatch-assisted CPR instruction, and (5) an increase in the number of AEDs placed in public locations. These national initiatives, combined with improved EMS performance and post–cardiac arrest survival rates, have led to an increase in the 1-year survival rates for cardiac arrest patients from 2.9 to 10.2 percent over the span of a 9-year period (Wissenberg et al., 2013).

Another similarly successful model of community-based initiatives to improve cardiac arrest survival rates is Minnesota's Take Heart America program. This initiative included widespread CPR and AED training in schools and businesses, deployment of AED in schools and public places, and updates to EMS and post–cardiac arrest care protocols. This initiative was correlated with an increase in bystander CPR rates between 2005 and 2009 from 20 to 29 percent. An increase in survival to hospital discharge for all patients following an OHCA from 8.5 to 19 percent was also documented (Lick et al., 2011). Arizona's SHARE program was the first to train lay persons in COCPR. SHARE is responsible for training more than 100,000 people using a range of methods that includes classes, video viewing, and other marketing methods such as a brief online training video. In association with this program, bystander CPR rates in Arizona have increased from 28 percent in 2005 to 40 percent in 2009 (Bobrow et al., 2010).

PUBLIC ACCESS DEFIBRILLATION (PAD) PROGRAMS

Cardiac arrests caused by shockable arrhythmias (e.g., VF, VT) are typically treated by the application of an electrical shock that is delivered by an AED, as discussed in Chapter 1. Studies indicate that most cardiac arrests that occur in public are due to VF (Nichol et al., 2008; Weisfeldt et al., 2010, 2011). While CPR can extend the window for successful defibrillation for cardiac arrest caused by VF, it is only defibrillation that can reverse VF. When CPR and AEDs are used very early for individuals with VF, survival rates are excellent—usually between 40 and 75 percent (Caffrey et al., 2002; Valenzuela et al., 2000; Weisfeldt et al., 1995a,b, 2010). Despite the significant benefit of AEDs, they are rarely immediately available or used by bystanders. In the ROC registry, which includes 11 sites in the United States and Canada, AED use by bystanders occurred in only 2.1 percent of all cardiac arrests (Daya et al., 2015; Weisfeldt et al., 2010). CARES, which includes 55 communities in 23 states, found that AED use occurred in approximately 4 percent of all cases (Vellano et al., 2015).

Although rare, cardiac arrest in children and adolescents is associated with extremely poor survival rates, ranging from 3 to 12 percent. Ventricular arrhythmias account for 4.9 to 19 percent of OHCAs in children and adolescents (Atkins et al., 2009; Daya et al., 2015; Donoghue et al., 2005; Mogayzel et al., 1995). As with adults, outcomes for children with VF-related cardiac arrest are better than for those with other cardiac arrest rhythms. VF-specific algorithms for defibrillation that were originally developed for adult populations also have been shown effective when applied to pediatric populations (Hickey et al., 1995; Mogayzel et al., 1995). It remains unclear how AED algorithms perform for other rhythms like supraventricular tachycardia and VT in pediatric patients (Rustwick and Atkins, 2014). However, the AHA does recommend the use of AEDs in children older than 1 year (Samson et al., 2003).

Considering the demonstrated effectiveness of early defibrillation, the opportunity to improve access to AEDs for bystanders and first responders led to the establishment of PAD programs across the United States (Hazinski et al., 2005). PAD programs, also known as lay rescuer AED programs, are intended to improve OHCA by increasing the likelihood that a bystander can access, apply an AED, and provide potentially lifesaving early defibrillation when needed. Several studies have aimed to identify public locations and buildings where cardiac arrests are most likely to occur (Becker et al., 1998; Engdahl and Herlitz, 2005; Fedoruk et al., 2002; Folke et al., 2009). Recommendations have been developed that describe the placement of AEDs in public locations based on specific criteria, which include any combination of the following:

- More than 250 adults over the age of 50 accessing the location more than 16 hours per day,
- The presence of high-risk individuals or a high-risk location,
- Health Clubs with more than 2,500 members, and
- A cardiac arrest event at the location at least once every few years (Aufderheide et al., 2006; Becker et al., 1998; Handley et al., 2005).

Further work on determining the optimal locations for strategically placing AEDs could help with evaluating these recommendations and developing guidelines for locations adopting PAD.

Effectiveness of PAD Programs

To date, many PAD programs have been implemented worldwide and have demonstrated improved cardiac arrest outcomes (Berdowski et al., 2011; Bertrand et al., 2004; Hallstrom et al., 2004; Hansen et al., 2013a; Kitamura et al., 2010a; Lick et al., 2011; Sasson et al., 2013b). Statistically significant improvements in rates of survival with favorable neurologic outcome have been shown in federal buildings (Kilaru et al., 2014b), airports (Caffrey et al., 2002), casinos (Valenzuela et al., 2000), fitness centers (Page et al., 2013), churches, schools, workplace environments, and other locations that have implemented a PAD program. The survival rates for locations with PAD programs can vary between 28 and 56 percent (Berger, 2014).

General PAD Programs

A 2002 study that evaluated the effectiveness of AED installation in heavily trafficked public locations found that 10 out of 18 individuals who collapsed with a VF-related cardiac arrest over a 2-year period in Chicago's O'Hare Airport were successfully resuscitated and survived with excellent neurologic outcomes a year after the arrest (Caffrey et al., 2002). In 2004, the PAD Trial, which involved trained laypersons in 24 North American regions, found a statistically significant twofold survival benefit with favorable neurologic outcome for adults who received bystander CPR plus AED compared with those who only received bystander CPR (Hallstrom et al., 2004). Data from the ROC database, which was published in 2007, showed that OHCA patients had significantly better outcomes when the first shock was applied by a bystander before EMS arrival (Weisfeldt et al., 2007). Additionally, multiple observational studies all demonstrated statistically significant improvements in odds of survival when an effective PAD program was in place (Berdowski et al., 2011; Cappato et al., 2006; Capucci et al., 2002; Culley et al., 2004; Fleischhackl et al., 2008; Iwami et al., 2012; Kitamura et al., 2010a; Kuisma et al., 2003; Mitani et al., 2013; Rea et al., 2010c; Swor et al., 2013; Weisfeldt et al., 2011, 2010). The timely use of AEDs by bystanders has been consistently and repeatedly deemed effective, making AED use one of the most definitively beneficial interventions known for cardiac arrest caused by a shockable rhythm.

The availability of AEDs through PAD program can substantially reduce the time to defibrillation in the United States where EMS response averages 9.4 and 9.2 minutes from dispatch to arrival on scene for adult and pediatric patients (NEMSIS, 2012). Survival rates for witnessed VF with and without bystander CPR decrease by 3 to 4 percent and 7 to 10 percent, respectively, with every minute that passes between collapse and defibrillation (Larsen et al., 1993; Valenzuela et al., 1997). Notably, the audible CPR instructions programmed into AEDs can provide life-sustaining support until EMS arrives even for individuals with non-shockable rhythms (Chiang et al., 2005; Williamson et al., 2005). However, to be successful, PAD programs must reduce the time to defibrillation prior to EMS arrival. Strengthening and expanding PAD programs could offer opportunities to fortify a scientifically proven and vital component of the public response to cardiac arrest.

In order to maximize utility and the likelihood of an AED being used by a bystander to provide lifesaving support, dissemination of AEDs should be coordinated so that the AEDs are strategically located in high-risk public places where cardiac arrest is most likely to occur. Data from an uncoordinated AED placement program in Copenhagen, Denmark, indicated that despite a 15-fold increase in AED coverage over 4 years (2007-2011), 94.6 percent of all AEDs were placed in low-risk areas or places without any cardiac arrests. However, the study reaffirmed the association between very early AED defibrillation and survival, demonstrating that 30-day survival for cases of bystander AED application was 87.5 percent compared to only 19.2 percent when bystander AEDs were not used (Hansen et al., 2014).

PAD programs have been shown to be cost-effective in different settings with the cost per quality-adjusted life-year (QALY) ranging from $30,000 to $100,000, which is within the acceptable range for many medical therapies (Berger et al., 2004; Cram et al., 2003; Foutz and Sayre, 2000; Nichol et al., 1998). Other studies have found that the cost per QALY can be higher (e.g., $108,700 per QALY), reducing the cost-effectiveness, when AEDs are placed in programs without a strategically informed focus that includes adequate training, maintenance, and EMS integration (Folke et al., 2009). These cost per QALY estimates are highly dependent on the inputs and assumptions made in developing the cost-effectiveness analysis models and can vary based on the costs associated with program development, maintenance, training, and patient outcomes.

Reported experiences with PAD programs and first-responder programs over the past two decades have identified specific elements that are required in order to achieve success (Hazinski et al., 2005). These elements extend beyond just installing AEDs in public locations and expecting bystanders to use them. Other elements for success include the overall organization of a PAD program, establishing a functional and practiced internal emergency response plan, offering adequate training for CPR and AED use, and integrating the program with local EMS systems (Foutz and Sayre, 2000). In this context, emergency response planning that includes all of these elements is important for realizing the full potential of PAD programs to improve OHCA outcomes.

Other countries have demonstrated the potential for bolstering PAD programs by implementing nationwide initiatives that are focused on increasing bystander CPR and AED use overall (Wissenberg et al., 2013). For example, between 2001 and 2010, Denmark implemented strategies that were designed to strengthen or initiate PAD programs. National efforts included a multifaceted approach to increasing resuscitation training (e.g., in schools, before obtaining a driver's license, and distribution of free CPR training kits), an increase in the number of publicly accessible AEDs, and the implementation of EMS dispatch instructions regarding the nearest AED (Wissenberg et al., 2013). During the study time frame, bystander use of AEDs was low (1.1 to 2.2 percent); however, when AEDs were used, there was a significant increase in survival rates (Wissenberg et al., 2013). Factors attributed to low AED use included the fact that expanded placement of public AEDs only happened near the end of the study and only one-quarter of OHCAs occurred in public locations where AEDs were located.

Data from the Amsterdam Resuscitation Study (ARREST) of North Holland indicated that when the location of publicly available AEDs was promoted (although not controlled or directed), the use of these AEDs increased almost threefold, from 21.4 to 59.3 percent, during the 6-year study period (2006-2012). The study also found that survival to hospital discharge with favorable neurologic outcome for patients with shockable rhythms also increased during the study period. These findings were attributed to a constellation of interventions that included equipping police teams with AEDs, a public campaign to increase AED knowledge and awareness, and encouraging a less than 6-minute window for the time between the 911 call and the shock (Blom et al., 2014). The ARREST work has also been expanded to include alerting volunteers via mobile phone of an OHCA event and nearby AEDs (Zijlstra et al., 2014). Data from ARREST have specifically illustrated how a text messaging system that activates local responders can increase early defibrillation for OHCA (Zijlstra et al., 2014).

The studies described throughout this section support the efficacy of PAD programs and the bystander use of AEDs. As described here and throughout this chapter, the best strategy for improving survival and outcomes through bystander CPR and AED use is to develop and implement multipronged initiatives that not only teach the skills necessary to respond, but also instill a culture of action throughout communities and the public.

Children and School-Based PAD Programs

In recent years, particular attention has been focused on AED placement and education in school settings (Berger et al., 2004; Cave et al., 2011; Drezner et al., 2009; Hart et al., 2013). As with CPR training, schools provide a valuable opportunity for widespread AED training across a large segment of the populations. School attendance in the United

States approaches 98 percent for elementary and middle school students and is similarly high (97.1 percent) for students aged 14 to 17, but lower (71.1 percent) for students aged 18 to 19 (U.S. Department of Education, 2012). Students represent an important audience for educational and training efforts related to cardiac arrest and AED use. As described previously with CPR, training school-children about AEDs could also lead to more adults learning about defibrillation (Chamberlain and Hazinski, 2003).

The AHA specifically recommends that AED training and skills practice should be included in CPR training that occurs in school settings (Cave et al., 2011). Studies of untrained third-grade students have been shown that they are able to effectively use AEDs, and sixth-grade students have demonstrated AED competence similar to EMS providers (Gundry et al., 1999; Lawson and March, 2002). Courses can successfully employ multiple training modalities, and among high school students, AED skills are retained for as long as 6 months after training (Fernandes et al., 2014; Plant and Taylor, 2013). For AEDs, cognitive skills are the primary focus for training, because the only required psychomotor skill is the ability to turn on the device and place the defibrillation pads. Furthermore, easy-to-understand visual and audible instructions are integrated into the AED devices and are provided as soon as the device is turned on, making operation simple and straightforward for most users.

School PAD programs have been shown to contribute to improved outcomes after cardiac arrest in school teachers and students (Cave et al., 2011; Drezner et al., 2009; Kovach and Berger, 2012; Swor et al., 2013). Despite differences in training and compliance and variability in willingness to respond in school settings, when resuscitation efforts occur, high rates of bystander CPR (up to 94 percent), shock with an AED (upward of 83 percent), and survival to hospital discharge (upward of 64 percent) have been reported in school settings (Drezner et al., 2009). A study from Japan also showed that AED use in schools for bystander-witnessed OHCA is increasing over time and can occur with a shortened collapse to shock by public-access AED time (Murakami et al., 2014). Importantly, schools with at least one AED on campus are more likely to implement other readiness measures, including development of an emergency action plan, establishing a system for activating the emergency response system, and ensuring early access to defibrillation (Toresdahl et al., 2013).

Prior work in the cardiac arrest field has also focused on the implementation of PAD programs in sports-related settings, because cardiac arrest can sometimes be precipitated by an exercise-related event

(Drezner et al., 2009; Mitani et al., 2014). The most common underlying etiologies of cardiac arrest in athletes are hypertrophic cardiomyopathy (26.4 percent) (Maron, 2003) and commotio cordis (19.9 percent)—a sudden nonpenetrating blow to the chest that leads to ventricular arrhythmia (Maron, 2003). The estimated incidence of cardiac arrest in athletes varies from approximately 1 in 200,000 for high school athletes to approximately 1 in 43,770 for college athletes (Harmon et al., 2011; Maron et al., 1998). However, the true incidence is unknown because of the lack of a mandatory reporting (Drezner et al., 2005; Maron et al., 1998; Van Camp et al., 1995). However, the U.S. Sudden Death in Young Athletes Registry collects some data on these occurrences (Maron et al., 2006). The death of a seemingly healthy, young athlete can be a particularly devastating event for a community. As a result, several organizations (e.g., American College of Sports Medicine, the AHA, and the National Athletic Trainers' Association) have recommended that universities make AEDs available at places where sporting events occur for the early intervention of cardiac arrest experiences by athletes and nonathletes who are attending sports events (Drezner et al., 2007). The use of AEDs has contributed to increased survival for some youth athletes (Drezner, 2009; Rothmier and Drezner, 2009).

In order to be effective, PAD programs in school settings must be well implemented (Drezner and Rogers, 2006; Drezner et al., 2005; Maron et al., 2002). Challenges that have been cited in responding to cardiac arrests in schools, including in student athletes, include "delayed rescuer recognition of [cardiac arrest], inaccurate rescuer assessment of pulse or respiration, delayed access to AEDs and delayed defibrillation, the presence of intrinsic structural cardiac abnormalities such as cardiomyopathies that may be more resistant to defibrillation with increasing delays in resuscitation, and increased catecholamine levels in athletes, which possibly increases the defibrillation threshold" (Rothmier and Drezner, 2009, p. 17).

Limitations in finances and personnel have also been cited as barriers to widespread implementation of AEDs and PAD programs in school settings. Nonetheless, many states—including North Carolina, Vermont, and Washington—are actively increasing the number of AEDs available on school campuses (Fields and Bright, 2011; Rothmier et al., 2007; Wasilko and Lisle, 2013). To use available funds in a cost-effective manner, AEDs could be placed in the places on campus where cardiac arrests are most likely to occur, and the public should then be made aware of their location (Moran et al., 2015). Overcoming funding limitations will also require identifying funding from a range of sources (e.g., school districts, foundations, and fundraising) and assigning a program coordinator (e.g., certified athletic trainer) who is responsible for implementing the program and overseeing emergency responses (Rothmier et al., 2007).

First-Responder Programs (FRPs)

Cardiac arrest FRPs designed for law enforcement officers have also proven effective under some circumstances. The underlying concept of FRPs is that compared with EMS vehicle coverage, the density of police cars in a given area is higher. Therefore, it is possible that law enforcement could arrive at the scene of a cardiac arrest before EMS in a large proportion of cases (Mosesso et al., 1998). There may also be a benefit for arrests at home where law enforcement can be alerted of an event and an individual's home address while the public would not be present and would not receive another person's home information (Husain and Eisenberg, 2013). Adoption of FRPs has been slow but gradual, and programs have been implemented in select cities in states across the United States (e.g., Florida, Indiana, Minnesota, Ohio, and Pennsylvania) and cities in Europe (e.g., Amsterdam and London). Data from a meta-analysis of FRPs indicate that equipping police cars with AEDs generally led to decreases in time to defibrillation and improvements in individual patient outcomes (Husain and Eisenberg, 2013). However, not all FRPs have been successful: one PAD study did not demonstrate a statistically significant increase in survival rates, even though call-to-scene times were slightly reduced and the AEDs that were used by police officers marginally reduced the time from collapse to defibrillation (Groh et al., 2001). Another prospective controlled clinical trial of first-responder firefighters equipped with AEDs found that although this group arrived on scene before paramedics and the AEDs were effective and reliable, survival to hospital and discharge were similar to CPR-treated controls (Kellermann et al., 1993). The authors emphasized the importance of optimizing all links in the chain of survival for improved survival and that low rates of bystander CPR or delays in activating EMS may be barriers for achieving the full potential of early AED availability and use.

PAD Programs in Hospitals

While FRPs focus on improving AED access and use by trained responders, in-hospital PAD programs focus on enhancing AED access and use for both the public and health care providers (Laws et al., 2004). An estimated 1 percent of all in-hospital cardiac arrests are experienced by hospital visitors or staff when they are in hospital gift shops, parking lots, cafeterias, visiting areas, and other spaces throughout the hospital (Adams, 2005). While rapid response teams are in place in many hospitals, some hospitals also have AEDs installed for immediate use by bystanders and health care professionals until a hospital response team can arrive (Adams et al., 2006; Destro et al., 1996; Sommers et al., 2002). A Dutch study showed a reduction in hospital costs with early defibrillation and AED use, because of fewer days spent in the intensive care unit (van Alem et al., 2004). PAD programs in hospital settings are explored further in Chapter 5.

PAD Program Challenges

Despite abundant evidence that supports the potential benefit of PAD programs, there is substantial variability in how recommendations for CPR and AED training have been adopted across the United States (Haskell et al., 2009). The possible benefits offered by the placement and bystander use of AEDs in public locations have also been incompletely realized (Atkins, 2009; Axelsson et al., 1996; Deakin et al., 2014; Folke et al., 2009; Haskell et al., 2009; Hazinski et al., 2004; Kozlowski et al., 2013; Leung et al., 2013; McCartney, 2009; Merchant and Asch, 2012; Money et al., 2011; Platz et al., 2000; Schober et al., 2011; Shibata et al., 2000). The ability to track the progress of PAD programs in the United States is limited, because data regarding public AED locations, accessibility, use, and integration with local dispatch centers and EMS systems are generally unavailable. Studies comparing AED locations to the locations of actual cardiac arrests have concluded that AED resources do not often align with arrest occurrences. For example, Folke and colleagues (2010) showed that, in Denmark, many AEDs were placed in low-risk locations. In fact, of the 104 existing AEDs, only 29 would have covered cardiac arrests during the study period. Other studies have also shown variability in placement and use of AEDs by location (Merchant et al., 2013; Sasaki et al., 2011; Weisfeldt et al., 2010). Although specific locations for publicly accessible AEDs have been proposed, a definitive strategy for AED placement in community settings throughout the United States has not been established (Chan et al., 2013; Folke et al., 2010).

To evaluate compliance with AED recommendations from the AHA, Haskell and colleagues (2009) developed a 25-point scoring scale to evaluate community PAD programs in Johnson County, Iowa (Atkins et al., 2009). The scoring system was modeled after the AHA's four primary components of a PAD site (Hazinski et al., 2005) and included elements related to

- Planned and practiced response (e.g., employee training in CPR and AED; awareness of AED locations; existence of AED policies and emergency response protocols; AED access, availability, and maintenance),
- Links to local EMS, and
- Continuous quality improvement (e.g., post-event review, AED and personnel performance).

Two years after PAD programs were established in the county, no site was able to comply with all of the program recommendations. Problems including limited access to AEDs, limited awareness of AED locations, and expired pads or batteries were frequently associated with low compliance (Haskell et al., 2009).

A number of challenges have prevented the successful implementation of PAD programs throughout the United States. Determining a suitable, clearly marked location for an AED does not always happen, and encouraging facilities to participate in PAD programs and maintain AEDs is not always easy. There is also a general reluctance when it comes to public action in the case of emergencies that continues to hinder the success of PAD programs. Concerns about the possibility of adverse events with the use of AEDs have also been cited but are seemingly unsubstantiated.

Locating AEDs in Public Settings

Use of an AED in an emergency requires first knowing where the AED is located. In some places the process of finding the AED is formulaic and predictable. For example, almost all U.S. airports of a certain size have AEDs publicly displayed throughout their terminals. However, in other locations, the AEDs are out of public view, and other locations do not have an AED at all (McCartney, 2009). Also, knowing that an

AED is available does not necessarily equate to knowing where it is located in a building. In some buildings, AEDs are located in the main entrance in a well-marked box, while in others the AED may be in a desk drawer only accessible by a security guard or on a floor only accessible by a keypad. In some cases, AEDs are attached to doors or other objects without adequate identification (Haskell et al., 2009). This lack of uniformity makes locating AEDs a challenge for both organizations that are focused on tracking AEDs and for individuals who are looking to identify AEDs in an emergency (Leung et al., 2013; Merchant and Asch, 2012).

To date, estimates suggest that more than 1 million AEDs have been purchased in the United States in the past 20 years (Merchant and Asch, 2012). However, a national AED registry does not exist, and AEDs are not systematically mapped or tracked by communities, cities, or states. Geo-tracking devices offer promise for identifying devices in time and space for newly deployed devices, but it would be challenging to implement the use of this technology for existing devices, especially if the specific locations of the devices are unknown. Federal, state, and local regulations and recommendations could help standardize the location of AEDs and promote public awareness of those locations, but to date, these efforts have not gained necessary traction or momentum. Unlike other public awareness campaigns, such as going green or energy efficiency, promoting AED use within businesses or communities has not occurred. Although some buildings display a sticker on a front entrance that indicates an AED is inside, this may not be relatively common in heavily trafficked public buildings.

Other countries have taken action to track and increase the use of publicly available AEDs; these successes could provide useful models for similar efforts in the United States. For example, in some communities in Denmark, AEDs are registered in an accessible database that allows dispatchers to alert callers reporting a cardiac arrest of nearby AEDs. They are also able to actively reach out to nearby AED owners and notify the owner of the need for the device. This approach would require widespread AED registration and mapping. In these studies AED use was not reported (Hansen et al., 2013a; Nielsen et al., 2013). Also of note, as of 2008, ILCOR has adopted an International Organization for Standardization compliant sign for AEDs that is increasing in placement in Europe (ILCOR, 2008). Similar guidelines do not exist in the United States. There have been some efforts in the United States to register AEDs in dispatch systems, but one report of dispatchers using a PAD registry found that very few OHCAs (8.4 percent) included the use of an AED (Rea et al., 2011).

Reluctance of Facilities to Implement or Maintain PAD Programs

Reluctance on the part of facilities to implement PAD programs is also a contributing factor to low adoption rates. Currently, there is an incomplete and disjointed dissemination of PAD programs nationally. Facilities that could participate in a PAD program have reported implementation barriers that include fear of litigation, difficulties associated with training personnel, developing facility-specific emergency response plans, and establishing around the clock response capability (Richardson et al., 2005). In schools, for example, prior reports cite a variety of barriers including funding, balancing time for training with additional scholastic requirements, scheduling, course content, and lack of equipment (Gundry et al., 1999). In some locations, AEDs have been donated to organizations, but the devices were not made publicly available (Haskell et al., 2009).

There is significant variability in AED regulations across states. Some states (e.g., California) “urge” schools to implement AED programs, other states (e.g., Virginia and Wisconsin) “require” AEDs in schools, while still other states (e.g., Tennessee) “encourage” placement in schools.[9] In some states, day care center employees and dentists are required to have AED proficiency (National Conference of State Legislatures, 2012). Considerable variability exists in which PAD program components (e.g., site placement, training, maintenance, EMS/medical coordination, continuous quality improvement, and immunity) are mandated by states. Good Samaritan laws, AED prescription requirements, and appropriations for AED funding for example, may be very different when crossing from one state to the next. Although it is unclear how specific policies impact OHCA outcomes the documented effectiveness of AEDs for shockable cardiac arrest rhythms supports efforts to increase access and usability of lifesaving AEDs and improve uniformity in relevant policies.

[9]For descriptions of current state legislation regarding AEDs in schools, see AHA, 2015a.

Reluctance of the Public to Act in an Emergency

Having a PAD program in place that includes AEDs installed in easily identified locations, a coordinated program, and plans for deployment and maintenance does not ensure success (Atkins, 2009). Not only do the devices have to be present, accessible, and in working order, but also individuals have to be willing to use them. Similar to CPR application, a low incidence of AED use by the public has been attributed to concerns about legal liabilities, limited knowledge, low rates of training, and limited access (Deakin et al., 2014; Hazinski et al., 2005; Kozlowski et al., 2013; Money et al., 2011; Schober et al., 2011). Further complicating the bystanders' willingness to use AEDs, many of the devices are stored in cases with labels that incorrectly indicate that the device is for "trained professional use only."

In 2013, Congress passed the Cardiac Arrest Survival Act of 2013 (Public Law 106-505), which specifically recommends that guidelines be developed for AED programs in U.S. federal government buildings. According to an AHA policy recommendation, the law also provides "limited immunity from civil liability for the emergency AED user and the AED acquirer if the state has not otherwise granted immunity for such persons under other statutes" (Aufderheide et al., 2006). Since its enactment, every state in the United States has instituted protection under the Good Samaritan laws for bystanders who use AEDs. Many states have also passed legislation that provides grants to state-level government agencies to purchase AEDs or requires (or strongly recommends) that AEDs are made available in certain locations such as fitness facilities or government buildings (Aufderheide et al., 2006). As the availability of AEDs in public locations such as transportation hubs, shopping malls, gymnasiums, schools, and federal buildings increases, so does the likelihood that a bystander will have immediate access to an AED. Therefore, CPR training should include instructions on the purpose and basic function of an AED.

AED Adverse Events

Ensuring that AEDs are safe for use as medical devices is one responsibility of the U.S. Food and Drug Administration (FDA). Adverse events related to AEDs are tracked in FDA's Manufacturer and User Device Experience (MAUDE) database. Reporting to the database is voluntary. As such, reports generated from MAUDE may reflect underreporting or over reporting. Also, FDA does not support the use of MAUDE for determining the incidence of device failure across devices that are currently in use. Prior studies from the MAUDE database that characterized more than 40,000 narratives that were available between 1993 and 2008 identified AED device failures such as devices not turning on, rhythm analysis not occurring, and devices spontaneously turning off unexpectedly (DeLuca et al., 2012). A subset analysis from data collected in the PAD study also reported adverse events with AED use (Peberdy et al., 2006). Of 649 cardiac arrest–related events, there were 27 AED-related adverse events (Peberdy et al., 2006). Those events were specifically attributed to theft of the device, AED placement in inaccessible locations, improper device maintenance, and mechanical challenges, none of which affected patient safety. Patient-specific adverse events were rarely reported from AED use in this trial, and no patient-related adverse events directly attributable to AED use were reported (Peberdy et al., 2006). In the PAD trial, no inappropriate shocks were delivered in the CPR-plus-AED group (Hallstrom et al., 2004). To date, reports in the literature of AED failures relating to direct patient harm are scarce. Future studies will be important for determining the incidence of device failures and characterizing the safety profile of these devices and their limitations.

OPPORTUNITIES

Despite challenges with adoption of PAD programs, several opportunities exist to promote the implementation of effective programs and improve outcomes from cardiac arrest in the United States. Social media, mobile media, and crowdsourcing are emerging as viable options to connect health resources and leverage citizen science—nonspecialists collaborating with scientist for research projects and initiatives (*Scientific American*, 2015). These emerging approaches also provide opportunities to enhance self-tracking and monitoring of PAD program progress to improve cardiac arrest survival and outcomes. Registries and other public data initiatives (e.g., Health Data Initiative, MyHeartMap Challenge) have the potential to make the identification of publicly available AEDs easier and could be used to link information to local dispatch centers and EMS systems (IOM, 2010; Merchant et al., 2013). Finally, achieving the full potential of AEDs may require a change in perspective: governments, health care organizations and professionals, and the public should approach AED dissemination—and the programs that promote their availability and use—as public health initiatives akin to earlier efforts to install seat belts and airbags in automobiles, or fire extinguishers and sprinkler systems in public buildings (Mell and Sayre, 2008). The success of seat belt use at reducing death and disability was only realized once they came to be viewed as necessary public health interventions and their installation and use were required by law. Framing AEDs and AED programs in a similar manner may be crucial to achieving their full potential to save lives.

AEDs and the Potential of Social Media, Mobile Media, and Crowdsourcing

Several efforts have been specifically designed in order to improve and track AED location awareness and public knowledge through mobile media, social media, and crowdsourcing (Ahn et al., 2011; Bosley et al., 2013; Chang et al., 2014; Merchant and Asch, 2012; Merchant et al., 2013; Ranney and Daya, 2013; Sakai et al., 2011; Scholten et al., 2011; You et al., 2008). The potential of these tools is held in the billions of social media users, the millions of individuals engaged in crowdsourcing initiatives, and the ubiquity of mobile phones and smartphones. The fact that these platforms can be used for training, knowledge, data exchange, surveillance, just-in-time education, and direction to resources is of particular value to possible interventions. The digital divide is also narrowing as access to these digital resources is increasing across different socioeconomic groups, geographic regions, and age groups (Duggan, 2013; Madden, 2010; Mislove et al., 2011; Ranney and Daya, 2013).

The MyHeartMap Project is an AED-specific initiative that challenged individuals to locate, tag, and report AEDs using a smartphone app, social networking, and gamificiation (Merchant et al., 2013). In just 8 weeks, 852 AEDs in 528 buildings were located in Philadelphia, where only 57 AEDs had been catalogued previously (Merchant et al., 2013). Almost all of the devices (99 percent) that were reported by the public were independently validated by the research team (Merchant et al., 2013). This initiative demonstrates the potential of social media to engage members of the public as citizen scientists and to help create and maintain databases about AED information. A follow-up project called the Defibrillator Design Challenge targeted AED visibility and accessibility by using social media, crowdsourcing, and design to create artwork around the physical location of AEDs to make them more noticeable and memorable (Kilaru et al., 2014a; Merchant et al., 2014). The project generated more than 100 virtually designed AEDs and garnered more than 50,000 votes and shares via Facebook and Twitter (Kilaru et al., 2014a; Merchant et al., 2014).

Other efforts—such as the PulsePoint Foundation in San Ramon, California—have focused on using smartphones to alert potential bystanders to cardiac arrest and AED locations in actual emergencies (PulsePoint Foundation, 2014). PulsePoint mobile apps share information about cardiac arrests in public locations with nearby bystanders. Occurring in real time, the alert system allows nearby participants to respond to the scene and use CPR and/or an AED for resuscitation. This program also uses crowdsourcing to empower bystanders to act quickly and responsibly in emergency situations.

Similar initiatives have also been tested in the Netherlands. Using text messages, an alert system notifies potential bystanders of nearby arrests and AED locations (Zijlstra et al., 2014). In 2013, a component of the ARREST study, used public campaigns and local advertising to identify bystander rescuers who were trained in CPR and AED use (Zijlstra et al., 2014). The program encouraged these trained bystanders to register their contact information (e.g., phone number and frequented addresses) in order to receive alerts about OHCA occurring within their close vicinity. AED locations were also registered and mapped throughout the community. This information was then linked with the local EMS dispatch system. The coverage area included two regions with approximately 1.2 million residents in total. After the program was initiated, an automated text messaging system was used to notify individuals within 1,000 meters of a presumed arrest. One-third of the bystanders were directed to the patient with cardiac arrest, and two-thirds of the bystanders were directed to retrieve a nearby AED. Over the course of the study, trained bystanders reduced the time to shock by 2 minutes and 39 seconds compared with EMS defibrillation, particularly in residential areas (Zijlstra et al., 2014). A recent Swedish study found that "a mobile-phone positioning system to dispatch lay volunteers who were trained in CPR was associated with significantly increased rates of bystander-initiated CPR among persons with out-of-hospital cardiac arrest" (Ringh et al., 2015, p. 2316). These findings provide a unique model for implementing AED registries, identifying individuals trained in CPR and AED use, linking this information with the EMS dispatch system, and using digital strategies for connecting responders with patients and AEDs in order to improve the public response to OHCAs.

Although not connected with digital technologies, similar efforts have been proposed for neighborhood-level PAD programs and response. Given the success of programs such as volunteer departments and neighborhood watches, neighborhood PAD programs have also been suggested as viable options for expanding the reach of AEDs (Zipes, 2001). In this context, neighbors trained in CPR and AED use could respond to nearby cardiac arrests. The call to 911 could simultaneously be routed to select neighborhood responders with the intent of decreasing the time to first chest compression or time to shock. This approach would require willing, trained, and available responders in neighborhoods with well-established cohesion and boundaries. This approach would also require further study before implementation in order to understand the necessary elements and potential impacts (Zipes, 2001).

Advocacy groups have successfully implemented PAD programs and lobbied state and federal legislatures for AEDs in schools, demonstrating the potential impact of engaging survivors, families, and advocacy groups in improving OHCA outcomes (Berger et al., 2004). The initiatives described in this section provide glimpses of the way in which social media, mobile apps, crowdsourcing, and communities can connect with available bystanders to enhance bystander response and increase AED awareness and use. Additional studies and pilot projects are needed in order to understand the opportunities, limitations, and benefits of digital tools and how these tools might complement existing infrastructure for individual and community response to cardiac arrest.

AED Registries

Registries represent one approach to overcoming the challenges associated with tracking AED locations and increasing the likelihood that an OHCA patient will receive bystander CPR and early defibrillation. Ideally, an AED registry would include not only information on AED location, but also linkages with EMS and bystander responders to capture data on structure, process, and outcomes (Bobrow, 2014; Merchant et al., 2013).

No comprehensive national AED registry exists in the United States. However, some existing cardiac arrest registries include a few desired AED variables. For example, the CARES database includes information about AED use, users, adjunct therapies (e.g., CPR, medications), and patient outcomes (McNally et al., 2011). The ROC Epistry includes data from all cardiac arrests with an EMS response and includes information on whether an AED was used, cardiac arrest treatment, and outcome (Bradley et al., 2010; Weisfeldt et al., 2010). The MyHeartMap database includes publicly available data on AEDs located primarily in one state (i.e., Pennsylvania), and the National Registry for AED Use in Sports tracks AED utilization for athletes (Drezner et al., 2013; Merchant et al., 2013). Table 3-1 includes other examples of characteristics to consider for an AED registry.

Other countries are also making strides in implementing AED registries. As of 2013, an AED registry in the Netherlands had 1,550 registered AEDs (Zijlstra et al., 2014). As mentioned above, AEDs registry in combination with alerted lay rescuers have been shown to decrease time to defibrillation (Hansen et al., 2013b). In Japan, a registry program was able to increase the number of available AEDs in communities by more

TABLE 3-1 Ideal Characteristics of an AED Registry

Feature	Description and Examples
Linkages	An ability for dispatchers to retrieve data from the registry and provide it to EMS and bystander responders
Location and structural information	• AED location (e.g., address) • Location description (e.g., on the wall next to the front desk on the first floor) • Location permanence (i.e., installed versus portable) • Accessibility (e.g., who has access to the device—employees only versus the general public) • Availability (e.g., the hours and days of operations)
Process information	• Maintenance schedule • How the AED performed in an emergency (e.g., shock appropriately advised, number of shocks delivered) • AED tracings from use • AED operator information (e.g., bystander, health care professional, first responder) • Lessons learned from use

than eightfold (Kitamura et al., 2010a). Over the study time frame, the use of AEDs by bystanders increased over time with improved favorable neurologic outcomes from 2.4 to 8.9 per 10 million individuals in the population (Kitamura et al., 2010a). Data from the Netherlands show that onsite AEDs saved 3.6 per 1 million inhabitants and doubled neurologically intact survival and were more beneficial than dispatched AEDs (Berdowski et al., 2011). Considering that 80 percent of arrests occur in the home and other nonpublic locations, further work is needed to evaluate the opportunities for optimizing AED availability, access, and use in these settings.

In-Home AEDs

To date, considerable time and energy have been focused on optimizing bystander and first-responder AED use in public locations, yet the majority of OHCAs occur at home and in private settings (Bardy et al., 2008). Studies and reviews of in-home AEDs have investigated the perceptions of having in-home AEDs available, training for high-risk patients and family members, potential impact of cost, and the possible impact on patient outcomes (Brown and Kellermann, 2000; Cagle et al., 2007; McDaniel et al., 1988; McLauchlan et al., 1992; Sigsbee and Geden, 1990). For example, the Home Automated External Defibrillator Trial evaluated the effectiveness of in-home AEDs for approximately 7,000 patients with a prior myocardial infarction who were not candidates for an implantable cardioverter defibrillator (Bardy et al., 2008). Patients were randomized to receive an in-home AED or not and were then followed for a total of 3 years. Of the 450 patients who died in the study time course, mortality rates were similar in the in-home AED group (6.4 percent) when compared with the control group (6.5 percent). The investigators concluded that access to an in-home AED did not improve outcomes when compared with the usual resuscitation response (Bardy et al., 2008). The study cited several reasons for the lack of a survival benefit, including the low number of witnessed cardiac arrests and the low proportion of AED use, even when the devices were available and the patient, spouse, partner, or other companions had been trained. Although case reports of AED use by parents for infants have been reported (Bar-Cohen et al., 2005; Divekar and Soni, 2006), randomized controlled trials for in-home AEDs have not been reported for pediatric populations.

Despite limited findings on the overall benefit of having an in-home AED available, the FDA allowed individuals to independently purchase AEDs without a prescription starting in 2004. Individuals who are interested in purchasing an in-home AED can currently buy one for personal use online via AED distributors, manufacturers, and other electronic commerce companies (e.g., Amazon). One of the notable benefits of AED devices is the easy-to-use visual and auditory instruction that is provided when the device is turned on. As noted previously, very little training or knowledge retention is necessary to successfully operate an AED regardless of its location. However, training for AED use is available through Web-based training programs, which can be used for training purposes in home settings. There are also mobile apps available that provide visual aids that detail AED use. These types of apps and Web-based training could provide just-in-time training in the home, but these approaches have not been formally tested for use in that setting or in comparison with more traditional training approaches.

CONCLUSION

The action of bystanders is pivotal to the success of the first three links in the chain of survival from cardiac arrest: early access (early recognition of cardiac arrest and calling 911), early CPR, and early defibrillation (use of AEDs). Although there is a multitude of evidence that indicates that bystander CPR can markedly improve survival, neurologic outcomes, and resulting quality of life, rates of bystander CPR in the United States remain adversely low, and less than 5 percent of the general public has been trained in CPR. Evidence also clearly supports the efficacy of placement and bystander use of AEDs in public locations. However, as little as 1 to 2 percent of EMS-treated cardiac arrests may receive early defibrillation from publicly available AEDs (Culley et al., 2014; Winkle et al., 2010). The implementation of multifaceted PAD programs throughout the nation remains adversely low, and the promise that these programs hold is incompletely realized.

The long-standing challenges of the public experience with cardiac arrest in terms of bystanders' ability to recognize the arrest, initiate CPR, and use AEDs when they are available signals a clarion call for action. This call for action is supported by clear evidence that highlights the need for an immediate response following a cardiac arrest and the possibility of positive outcomes with a timely response. Widespread implementation of effective PAD programs and a renewed focus on CPR and AED training across communities are necessary to overcome persistent barriers in public engagement. Increased efforts to reach communities and populations where disparities are prevalent will also be necessary to promote change. An informed, coordinated, and effective public response to cardiac arrests across the nation would provide immense value to the overall health of the nation.

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4

Emergency Medical Services Response to Cardiac Arrest

Overall outcomes from out-of-hospital cardiac arrest (OHCA), both in terms of survival and neurologic and functional ability, are poor: only 11 percent of patients treated by emergency medical services (EMS) personnel survive to discharge (Daya et al., 2015; Vellano et al., 2015). Although a few EMS systems have demonstrated the ability to significantly increase survival rates (Nichol et al., 2008; Sasson et al., 2010b), a fivefold difference in survival-to-discharge rates exists among communities in the United States (Nichol et al., 2008). This presents important challenges and opportunities to improve EMS system performance across the country.

As described in Chapter 1, the chain of survival includes five interconnected links: (1) immediate recognition of cardiac arrest and activation of the emergency response system, (2) early cardiopulmonary resuscitation (CPR), (3) rapid defibrillation, (4) effective advanced cardiac life support (ACLS), and (5) integrated post-resuscitative care (M. D. Berg et al., 2010; R. A. Berg et al., 2010). This conceptual model illustrates the sequence of events that can optimize care and outcomes for the approximately 395,000 individuals who experience an OHCA in the United States each year (Daya et al., 2015). Together, the first three steps comprise the fundamental actions within basic life support (BLS) strategies for cardiac arrest (R. A. Berg et al., 2010), including early recognition of a cardiac arrest by bystanders[1] and 911 call takers, as well as the delivery of initial treatments (i.e., CPR and defibrillation) by bystanders

[1]See Chapter 3 for a discussion of barriers and opportunities to improve bystander early access of the EMS system, as well as bystander education and training programs.

or trained first responders prior to the arrive of EMS providers (i.e., emergency medical technicians [EMTs] and paramedics).

Although the ability of an EMS system to respond effectively to cardiac arrest within a community depends to some extent on basic infrastructure and the training of EMS personnel, there are specific character-characteristics and capabilities of EMS systems that are correlated with higher cardiac arrest survival rates. This chapter focuses on the EMS system's response to cardiac arrest and covers the EMS role across all of the links in the chain-of-survival model. Because the overall structure, organization of services, and capabilities of EMS systems affect cardiac arrest care, the chapter begins with an overview of the EMS system, including discussion of the relevant personnel and oversight at the federal, state, and local levels. The second section covers elements of the EMS response itself, including the facilitation of bystander CPR and early defibrillation strategies. The final section of the chapter focuses on opportunities to improve the timeliness and quality of cardiac arrest care, which can lead to improved patient outcomes in communities across the United States.

OVERVIEW OF EMS

For purposes of this report, the committee defines an EMS system as a system that provides emergency medical care in response to serious illness or injury, such as a cardiac arrest, in the prehospital setting. An EMS system comprises a wide range of responders who provide critical services, such as response to 911 emergency calls, dispatch of medical personnel, triage, treatment, and rapid transport of patients by ground or air ambulances to appropriate care facilities (IOM, 2007). Emergency medical response and care involves different types of people and agencies, including those in the public health, public safety, and health care sectors (see Figure 4-1). As such, multiple regulatory and administrative bodies at local, state, and federal levels regulate different aspects of emergency medical care, leading to different resource and funding streams available for implementation and evaluation activities.

The myriad responsibilities of an EMS system make it challenging to assess its general performance, or to measure the impact of individual EMS system protocols and characteristics on overall system performance or particular health outcomes, such as cardiac arrest survival and

FIGURE 4-1 Contributing sectors of the emergency medical services system.
SOURCE: IOM, 2007, p. 40.

neurologic or functional outcomes. Nonetheless, some experts have argued that OHCA survival rates are a reliable and valid measure of an EMS system's overall effectiveness and may be the most appropriate measure for comparing performance among EMS systems (AHA, 2000; El Sayed, 2011). This is because the complex and emergent nature of cardiac resuscitation requires not only highly competent EMS personnel, but also integration and formal transitions among components of the larger EMS system and between EMS and the hospital systems with which it interacts.

EMS Personnel Involved in Cardiac Arrest Response

Within an EMS system, a number of trained professionals act in concert when responding to a cardiac arrest (see Box 4-1). For example, 911 call takers or emergency medical dispatchers[2] may help identify a cardiac arrest and dispatch the appropriate EMS providers. EMTs and paramedics

[2]For simplicity, this report uses the term "dispatcher" to generally indicate personnel responsible for 911 call taking and EMS provider dispatch (see Box 4-1). This is consistent with recent Utstein core measures and with terminology generally used in emergency medicine and by the public, although "telecommunicator" is becoming more widely used.

may assess the scene to confirm whether the patient is in cardiac arrest and initiate resuscitation. They also transport the patient to the most appropriate definitive care facility—usually the closest hospital that is best equipped to care for a cardiac arrest patient. When providing patient care, both EMTs and advanced-level providers operate under a combination of physician-approved standing orders (i.e., offline medical direction), as well as real-time medical control. The state medical director oversees the entire EMS system and evaluates performance within each link in the chain of survival, while local medical directors support EMS agencies at the local, city, or county level. The responsibilities of medical directors at any level typically include, but are not limited, to establishing medical protocols for dispatchers, EMTs and paramedics; providing medical supervision online and offline; promoting evidence-based practices; supervising ongoing medical quality improvement; supervising training and continuing education; establishing controlled substance policies; and providing medical discipline (ACEP, 2012a).

EMS staffing models for cardiac arrest response often vary, in part, because of differences in the availability and proximity of the nearest providers, resources, and call volume. In suburban and urban communities, a combination of basic EMTs (EMT-Bs) and paramedics typically provide EMS care, while rural areas often provide EMS care with EMT-B-level providers exclusively. In some communities, a single responding unit may arrive with one EMT and one paramedic who must conduct the entire resuscitation without additional medical support. In many urban communities, a tiered response system is used that consists of two or more units; the first unit dispatched to the scene is staffed with basic EMTs trained in CPR and AED use, and the second unit is staffed with one or more paramedics trained and equipped to perform advanced life support. This tiered-model has advantages in that more basic-level providers are available to provide defibrillation and to perform chest compressions, allowing providers to rotate out frequently in order to avoid fatigue and diminishing CPR quality. Other communities staff all responding units with at least one paramedic, and sometimes more. Many fire-based EMS systems employ a combination of fire department vehicles (e.g., fire engine trucks) staffed by firefighters with EMT-B training, and one or more ambulances staffed

BOX 4-1
Emergency Medical Services Personnel

Emergency medical dispatchers (also known as 911 dispatchers, 911 operators, or telecommunicators) is a general term for professionals who receive 911 calls, gather vital information concerning medical emergencies, rapidly dispatch the appropriate level of EMS providers to the scene, and render assistance via a telephone in the form of CPR and automated external defibrillator (AED) instructions to 911 callers on the scene. In small 911 centers, one individual may answer calls and dispatch EMS providers. In larger centers, the roles of answering calls and dispatching are separated. “Telecommunicator” is an umbrella term used for any individual who works in a 911 center and has responsibility for receiving calls and/or sending help.

Emergency medical technicians are emergency health care providers who are trained to respond quickly to emergency situations regarding medical situations, traumatic injuries, and accident scenes. There are several different levels of providers and variations in the exact scope of practice between different EMS systems.

- **Basic EMTs (EMT-Bs)** are trained to provide basic, noninvasive prehospital care (although some states may allow them to perform selected invasive procedures). These personnel provide the initial aspects of care, including CPR, bag valve mask ventilation, and defibrillation at the scene of a medical emergency and during transport to the hospital.
- **Advanced EMTs (EMT-As)** are mid-level providers between the EMT-Bs and paramedics. They can provide interventions beyond basic life support including techniques for supporting circulation and ensuring an open airway, sufficient oxygen, and adequate ventilation. EMT-As are also authorized to start intravenous lines and administer a basic collection of medications. Their training builds on an EMT foundation and includes additional didactic and clinical elements that differ from state to state.
- **Paramedics (EMT-Ps)** are trained to provide advanced life support. They receive 1,000 to 2,500 hours of training depending on state requirements and paramedic school. EMT-Ps may provide CPR; defibrillation; intravenous, intraosseous, and central line placement; endotracheal intubation; laryngeal mask airway; and medication administration. The specific medications they are permitted to administer vary widely, based on local standards of care, legal restrictions, and physician or medical director preferences.

continued

Advanced-level providers include flight medics and flight nurses. Flight nurses are registered nurses who have advanced critical care training and expertise. They provide prehospital emergency care to all types of patients during aeromedical evacuation aboard various types of medically equipped aircraft. Flight nurses are often paired with flight medics to serve as emergency and critical transport teams.

EMS medical directors have a multidimensional job of providing specialized medical oversight, as well as assisting in the development of EMS systems. The medical director is most commonly a board-certified emergency medicine physician who has particular interest and experience in prehospital care. The medical director acts as a liaison between public and private EMS agencies; hospitals; local, regional, state, and national EMS systems; national professional organizations; and other community stakeholders. The medical director assists in the development, implementation, and measurement protocols, and also ensures training and proficiency of EMS personnel.

by EMTs and paramedics. In these tiered systems, the fire department vehicles are deployed first, followed by ambulances that will transport the patient. The staffing model employed by any EMS system should promote the ability to rapidly provide high-quality CPR and defibrillation for each and every resuscitation attempt, whether the patient is an adult, adolescent, or child. Although uncommon, the special difficulties associated with pediatric resuscitation merit attention, and are discussed later in this chapter. Precisely how differences in staffing models affect performance, or how successful models developed for one community can be adapted to the needs of another, remains unclear and is a focus of ongoing research.

EMS System Oversight

Today's EMS systems are better equipped to respond to disasters and complex medical needs—such as cardiac arrest—than in decades past. However, the field as a whole continues to exhibit signs of fragmentation, an absence of systemwide coordination and planning, and a lack of federal, state, and local accountability. To better ensure collaboration and to minimize the negative effects of disconnected institutional authorities on cardiac arrest care, it is important to understand the roles that the federal government, states, and local communities play in the oversight and evaluation of EMS system performance and how they may better work together to improve cardiac resuscitation.

Role of the Federal Government

Federal EMS oversight does not belong to a single agency or department. Instead, numerous federal agencies play assorted roles in supporting the implementation and evaluation of local, regional, and state EMS systems (IOM, 2007). Box 4-2 includes examples of federal entities and their role in overseeing EMS systems and cardiac arrest care.

Lack of integration among the federal government programs that support and regulate EMS systems contributes to unnecessary redundancies, regulatory gaps, confusion, and wasted resources. The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) has taken the informal lead for EMS oversight through its Office of EMS, which is responsible for reducing "death and disability by providing leadership and coordination to the EMS community in assessing, planning, developing, and promoting comprehensive, evidence-based emergency medical services and 911 systems" (NHTSA, 2015a). Both NHTSA and the U.S. Department of Homeland Security (DHS) develop best practices or performance standards for EMS (see Box 4-2). In 2009, NHTSA developed a set of 35 consensus-based performance standards for EMS systems, including several that are relevant to treatment of cardiac arrest (NHTSA, 2009a). NHTSA has also collaborated on research exploring the development, implementation, and evaluation of guidelines for EMS (Wright, 2014). As a direct result of this work, guidelines specific to multiple treatments and conditions were published in 2014 (Gausche-Hill et al., 2014; Shah et al., 2014; Thomas et al., 2014). Meanwhile, DHS has helped produce literature on funding sources for EMS and on the role of state EMS medical directors (DHS, 2012). The Field EMS Bill—which Congress introduced to designate NHTSA as the lead federal agency for EMS—further confused the issue (Doyle, 2011; NAEMSP, 2011). Almost simultaneously, the International Association of EMS Chiefs and the National EMS Labor Alliance produced a white paper arguing that the jurisdiction over EMS provided to DHS by the 2002 Homeland Security Act made it the most appropriate lead agency for EMS (IAEMSC, 2011). Greater clarity in terms of federal government oversight and clear scope of authority would be useful.

BOX 4-2
Examples of Federal Responsibilities and Activities Related to EMS Oversight and Cardiac Arrest Care

The **U.S. Department of Transportation (DOT),** through NHTSA's Office of EMS, partners with public and private organizations to advance a national vision for EMS, facilitate EMS workforce data collection and analysis, and promote system performance evaluation through guideline development and benchmarking metrics, including public safety answering point (PSAP) contact to defibrillation and electrocardiogram intervals (NHTSA, 2009a). NHTSA's EMS-related activities include identification of national data elements, development of data collection protocols, maintenance of the National EMS Information System (described in Chapter 2), and development of national EMS education standards and performance standards (NHTSA, 2015a).

- The **Centers for Disease Control and Prevention's (CDC's)** Division of Heart Disease and Stroke Prevention provides public health leadership to improve cardiovascular health, reduce the burden, and eliminate disparities associated with heart disease and cardiac arrest. CDC's North American Collaborating Center promotes and coordinates the development of medical diagnostic and procedure codes, including those related to cardiac arrest. CDC collaborated on the development of Cardiac Arrest Registry to Enhance Survival (CARES), produces disaster preparedness plans for EMS, and funds EMS-related projects through the National Institute for Occupational Health and Safety.
- The **Centers for Medicare & Medicaid Services (CMS)** provides reimbursement for identified EMS system transportation costs, including ambulance services, for more than 120 million beneficiaries under the Medicare and Medicaid programs (CMS, 2013, 2015a,b).
- The **National Institutes of Health (NIH)** funds emergency and trauma-related research through several different NIH Institutes, including the National Heart, Lung, and Blood Institute, which is the lead institute for the study of cardiac arrest.

The **U.S. Department of Homeland Security (DHS)** "provides the coordinated, comprehensive federal response in the event of a terrorist attack, natural disaster, or other large-scale emergency while working with federal, state, local, and private-sector partners to ensure a swift and effective recovery effort" (NHTSA, 2015c). Within the DHS office of Health Affairs, the Workforce Health and Medical Support Division identifies first-responder best practices; provides guidance and support for the implementation of those practices; responds to gaps in first-responder disaster planning, resources, and education; and develops cross-DHS EMS protocols, credentialing, and quality assurance standards (DHS, 2013).

The **U.S. Department of Defense (DOD)** provides criteria, guidance, and instructions to inform EMS delivery through active duty and civilian EMS personnel, who respond to emergencies on military installations and in local communities worldwide as a result of mutual aid agreements with host nations (NHTSA, 2015c).

The **Federal Communications Commission (FCC),** through its Public Safety and Homeland Security Bureau (PSHSB), works to ensure that first responders, including EMS personnel, have access to reliable, interoperable equipment during emergencies (NHTSA, 2015c). "The PSHSB provides information on federal resources available to EMS personnel, assists in the development of emergency communications plans, and enrolls first-responder organizations in priority services, including the telecommunications service priority, wireless priority service, and government entity telecommunications service" (NHTSA, 2015c).

The **Federal Interagency Committee on EMS (FICEMS)** ensures coordination among federal agencies involved with state, local, tribal, and regional EMS and 911 systems. NHTSA, in cooperation with the Health Resources and Services Administration and the Assistant Secretary of Health Affairs at DHS, provide administrative support to FICEMS, which employs a technical working group consisting of interagency staff-level employees who meet monthly to provide support to several ongoing EMS projects (NHTSA, 2015c).

The **National EMS Advisory Council (NEMSAC)** is a national council of EMS representatives and consumers that provides advice and recommendations to NHTSA about EMS. NEMSAC does not have program management or regulatory development responsibilities (NHTSA, 2015c).

A lack of clear administrative oversight also perpetuates divisions among public safety, public health, and health care professionals, who must work as a cohesive unit to respond effectively to cardiac arrest. Clear designation of a lead federal agency "with primary programmatic responsibility for the full continuum of emergency medical services and care for adults and children" would contribute to a "coordinated, regionalized, and accountable emergency and trauma care system" (IOM, 2007, p. 107). This would provide the governance and infrastructure necessary to streamline EMS guideline and performance measure processes and to coordinate evaluations that could enhance EMS system performance overall and improve care delivery for cardiac arrest specifically.

In addition to the lack of formal federal oversight, the degree to which federal agencies have explicit authority to regulate and coordinate components of EMS systems directly affects the extent to which EMS-related cardiac arrest care can be monitored, evaluated, and standardized. For example, NHTSA is involved in EMS guidelines, benchmarking, and statewide evaluation of EMS systems in order to identify critical performance and information gaps (NHTSA, 2015a). This includes development of national EMS education standards, which define the minimal entry-level competencies for first responders, EMTs, advanced EMTs, and paramedics (NHTSA, 2009b). Separately, NHTSA has produced management, instructor, and trainee guides for emergency medical dispatch programs (NHTSA, 1996a).

Although 48 states voluntarily follow NHTSA's national standard curriculum for EMS Basic and Paramedic (FICEMS, 2012, p. 243),[3,4] accreditation and certification standards for emergency medical dispatchers are currently developed and managed by the private sector, including organizations such as the Association of Public-Safety Communications Officials International (APCO, 2015), the International Academies of Emergency Dispatch (IAED, 2015), and PowerPhone (PowerPhone, 2015). The curricula available through these organizations are not identical and may not adhere consistently to the NHTSA guidelines for training emergency medical dispatchers. Data on how these emergency medical dispatch protocol reference systems (EMDPRSs) are used by EMS is limited: NHTSA's EMS performance measures only assess the type of EMDPRS an EMS system employs, and whether the use of lights and sirens and the dispatch of EMTs as compared to paramedics is predicated on that EMDPRS (NHTSA, 2009a, pp. 5-7). This lack of standardization has significant implications for implementing and

[3]The 2011 National EMS Assessment was commissioned to better understand what data about EMS systems is available at state, regional, and local levels (FICEMS, 2012). This assessment used data from the National EMS Information System Technical Assistance Center and the NASEMSO 2011 EMS Industry Snapshot. The results are limited by which states responded to assessment questions and the accuracy of the data submitted. For each statistic presented, the corresponding assessment question is provided.

[4]The National Association of State EMS Officials (NASEMSO) 2011 EMS Industry Snapshot was delivered to the director of each state's EMS regulatory office. The data above is based on responses to the question: "Which of the following EMS credentialed levels in your state are based on the current federal DOT curriculum?" Subsequent references to this survey will list the related query.

assessing specific EMS dispatch protocols that have been associated with improved cardiac arrest outcomes, as discussed later in this chapter.

Role of State Governments

State EMS agencies play multiple roles in overseeing and coordinating local and regional EMS activities. In most states, state law governs the scope, authority, and operation of EMS agencies, leading to considerable variability in the size, organizational structure, and funding of EMS agencies from state to state. In the case of funding, 911 services are usually paid for by grants, modest surcharges on telephone bills, or through state and local taxes (NENA, 2015; NHTSA, 2013). Funding levels may fluctuate, and available funding may not be sufficient to develop next-generation 911 capabilities (NHTSA, 2013). Funding for EMS and ambulance services comes from a similarly diverse set of mechanisms (CMS, 2015c; FEMA, 2012).

All states have a state EMS office, and the vast majority of these offices are located within a state department or government entity (FICEMS, 2012, p. 128).[5] EMS office responsibilities typically include data collection, professional credentialing, EMS training standards, training programs for EMS professionals, credentialing for EMS training programs, and stroke system management. Forty-six states report having developed EMS data collection systems, 39 require data collection by law, and another 8 plan to begin requiring data collection in the next few years (FICEMS, 2012, pp. 288, 290).[6] However, less than half of the states that have legal requirements for data collection actually enforce collection for all EMS response incidents, and only 40 percent of responding state EMS offices report quality assurance and/or improvement activities as a frequent function (FICEMS, 2012, pp. 141, 292).[7]

State EMS offices are usually managed by state medical directors, a role that has been recognized by several professional organizations (Na-

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[5]NASEMSO Survey Question: "Where is the State EMS Office organizationally positioned within the State?"

[6]NASEMSO Survey Question: "Does your State maintain a State EMS data system?" and "Is the submission of EMS data to the State required?" At the time of the survey, although Louisiana did not have a state EMS data system, it did intend to begin requiring EMS data collection within a few years.

[7]NASEMSO Survey Question: "What percentage of the efforts of the State EMS Office are directed toward each of the following?" and "(If yes to the previous question) Based on the following EMS Agency types, what percentage of each is actively submitting data into the State EMS data system?"

tional Association of EMS Physicians [NAEMSP], American College of Emergency Physicians [ACEP], and NASEMSO) as playing an integral role in the safety and quality of prehospital medical care (ACEP, 2012a,b). Thirty-seven states report having an EMS medical director (FICEMS, 2012, p. 191); of those, 18 serve only in an advisory capacity, rather than having a more comprehensive role defined by state law (NHTSA, 2012, p. 192).[8] Furthermore, only one state EMS system reported that the medical director's roles and responsibilities included a cardiac arrest system of care, although data were not available for 14 states (FICEMS, 2012, p. 199).[9]

Local and Regional Responsibilities

EMS systems are largely local-level operations, with many counties and local municipalities playing instrumental roles, such as determining the EMS system structure; developing training programs on triage, treatment, and transport protocols; and implementing EMS interventions, based on local needs and available resources. There are an estimated 21,283 EMS agencies in the United States with approximately 86 percent of these responding to 911 events (FICEMS, 2012, p. 21).[10] Local prehospital services can be managed by fire departments, hospitals, independent government agencies (e.g., public health agency), nonprofit corporations, commercial for-profit companies, or volunteer-supported EMS programs. Most states reported multiple organizational structures for local EMS systems, with fire department, non-fire government, hospital, and private, nonhospital EMS systems being most common (FICEMS, 2012, p. 31).[11] This diversity suggests that training of EMS personnel needs to be adapted to the particular types of providers and organizational structures in a given system.

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[8]NASEMSO Survey Question: "Do you have a State EMS Medical Director?" and "Please select the appropriate response regarding the authority of the State EMS Medical Director within your State."

[9]NASEMSO Survey Question: "What are the roles and responsibilities of the State EMS Medical Director?"

[10]Not all EMS systems respond to 911 calls. Out of 20,877 EMS systems in 49 states, 14 percent provided specialty care transport by ground or air, nonemergent convalescent medical transport, or medical emergency dispatch services (FICEMS, 2012, p. 13). NASEMSO Survey question: "For each of the listed EMS Agency Types, how many EMS Agencies are currently licensed in your State?"

[11]NASEMSO Survey Question: "For each of the listed EMS Agency organizational types, how many EMS Agencies are currently licensed in your State?"

State EMS offices commonly certify and credential local EMS providers based on completion of predetermined coursework that develops cognitive and practical skillsets. These training programs are administered at the local and regional levels and may use a variety of models that utilize the resources of community colleges, fire departments, private companies, and hospitals. Although the National Registry of EMTs accredits training centers, only 21 states require this accreditation (FICEMS, 2012, p. 236).[12] Consequently, there is wide variability in the rigor of local EMS training programs. EMS providers must also complete a certain number of continuing education credits covering various aspects of EMS care (e.g., trauma, pediatrics, and cardiac) in order to recertify, which usually occurs on a biennial basis. As with the initial certification, continuing education is commonly provided and managed by individual EMS systems with varying degrees of stringency. This overall lack of consistency in training and educational standards may result in variability in EMS provider competency and skill proficiency. For example, studies have determined that national accreditation and lead instructor qualifications are associated with student success on paramedic credentialing examinations that test for competency in practical and cognitive skills (Dickison et al., 2006; Fernandez et al., 2008). Other studies have found that certificate-based paramedic programs produce students who are less confident in their ability to perform nonpatient care tasks than do programs that lead to an associate of applied science degree (Brown and Fowler, 1999). Finally, practicing EMTs with more accurate knowledge of CPR guidelines also adhere more closely to those performance standards (Brown et al., 2006). In short, less rigorously trained personnel perform less well on assessments, are less confident of their abilities, and are less competent rescuers. However, the relationship between education and performance remains incompletely understood. For example, one study found no significant relationship between the cognitive competency of EMTs, and the volume of calls they responded to each week or the continuing education they possessed (Studnek et al., 2009a). Further research about the relationship between the training and performance of EMS providers is needed.

At the local level, the size and population density of the areas served by EMS agencies vary greatly, as do the resources available to local EMS agencies to treat those populations. Local EMS agencies may be responsible for towns and municipalities, or entire counties. In terms of

[12]NASEMSO Survey Question: "Are your EMS educational institutions required to be accredited by an independent agency?"

resources, not all areas have access to enhanced 911 services (NHTSA, 2015b), and the number of local medical directors varies considerably among states (FICEMS, 2012, p. 217).[13] Differences in the regions and populations affect EMS performance. As compared to systems in urban centers, rural EMS systems are often responsible for larger and less densely populated areas, resulting in longer transport distances and response times that negatively affect patient outcomes (Yasunaga et al., 2011). Yet, areas with urban sprawl, where traffic hazards and delays are common, are also associated with longer response times (Trowbridge et al., 2009). In urban centers, EMS response times can also be delayed when patients arrest in the upper floors of high-rise buildings (Morrison et al., 2005). EMS performance is also affected by the demographics of the neighborhoods to which they respond. For example, residents of high-income neighborhoods may have faster EMS response times than those living in lower-income neighborhoods (Govindarajan and Schull, 2003). The relationship between other demographic factors, such as race and ethnicity, and the quality of EMS treatment and patient outcomes, is discussed in the following section.

THE EMS RESPONSE TO CARDIAC ARREST

The chain of survival—early access, early CPR, early defibrillation, early ACLS, and early post-resuscitative care—is an operational framework that can be used to assess the EMS response to OHCA. Actions specific to each link in the chain must be considered when identifying possible delays and opportunities to improve the quality of EMS treatments for cardiac arrest patients (see Figure 4-2). After a bystander recognizes an emergency (which may or may not be a cardiac arrest) and calls 911,[14] the 911 dispatcher works with the bystander to confirm the nature

[13]NASEMSO Survey Question: "How many local EMS Medical Directors are functioning within your State?"

[14]Communities have unequal access to 911 services. Rural areas often have fewer PSAPs and 911 call takers. Next Generation 911 (NG911), which allows PSAPs to receive and transfer call data from multiple sources (e.g., Voice over Internet Protocol, cell, text), is not universally available: more than half of states have NG911 systems that are entirely nonoperational, while only 21 percent of states have fully operational NG911 systems (NHTSA, 2015b, p. 3).

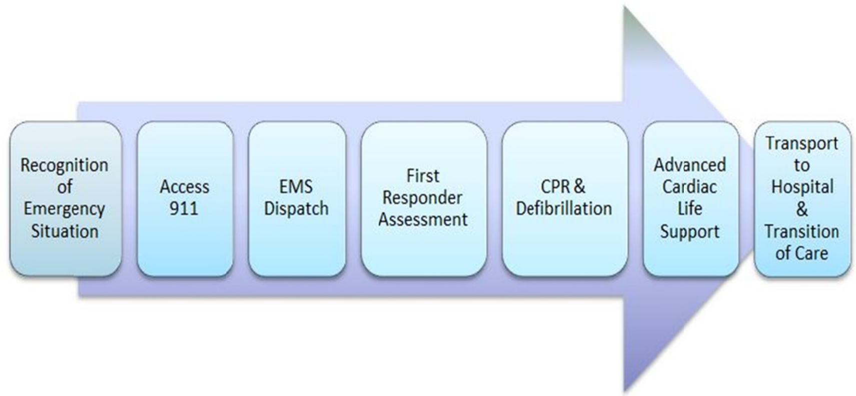

FIGURE 4-2 Actions within the overarching EMS system response to cardiac arrest.

of the emergency and may initiate the dispatch process, which alerts first responders to the type and location of the emergency. In some systems, the 911 dispatcher may instruct the bystander to perform CPR and apply defibrillation. CPR and defibrillation may be provided by a bystander, a first responder, or subsequently by EMS personnel. In the United States, ACLS in the field is typically provided by paramedics and is used to stabilize patients after return of spontaneous circulation (ROSC) during transport to a medical facility (NHTSA, 2007; NREMT, 2015). Although many post-arrest care treatments are traditionally delivered in the hospital setting, EMS personnel may also provide some elements of post-arrest care before or during transport to a hospital (Pinchalk, 2010).

EMS Activation and Dispatch

EMS activation and dispatch are similar, but not identical processes. The structure for receiving and processing 911 calls is not standardized throughout the United States. Emergency 911 dispatch centers use a variety of models and are operated by an assortment of agencies, including public safety, police, and fire departments. Box 4-3 provides additional detail about the 911 dispatch system in the United States. A common model is for 911 centers managed by law enforcement to transfer calls unrelated to law enforcement to a fire department or ambulance service for purposes of dispatching EMS.

For almost any location within the United States, personnel in one of more than 7,000 primary and secondary PSAPs are available to receive

911 calls, identify the type of emergency, determine the required EMS response, and activate local EMS (FCC, 2015b).[15] PSAPs are defined geographically within states, but where a specific call is routed may depend on how busy the applicable PSAPS are (i.e., load balancing), the operational status, the time of day, or the day of the week (GSA, 2014).

Operationally, PSAPs can be administered through any public safety organization, including fire, emergency management, EMS, or law enforcement, as well as tribal, hospital, or private organizations. While many PSAPs have emergency medical dispatchers who are trained to provide necessary medical instructions during a 911 call (e.g., dispatcher-assisted CPR), PSAPs not administered by EMS are often unable to provide such instruction due to a lack of training or restrictions on the scope of practice of call takers (NENA/APCO, 2011). Approximately 30 percent of all PSAPs do not have emergency medical dispatch capabilities; for these PSAPs, medically-related calls must be transferred before medical instruction can be provided (FICEMS, 2012, p. 407).[16] This variation suggests the need for national, standardized training and policies to ensure that all PSAP personnel are sufficiently trained to recognize and instruct callers about cardiac arrest regardless of the PSAP location and that the policies governing the PSAPs support the provision of these instructions. As discussed later in the chapter, emergency medical dispatchers can help callers correctly identify cardiac arrest and perform CPR prior to the arrival of EMS services, contributing to increased survival rates.

EMS response intervals are strongly associated with cardiac arrest survival rates, with longer response intervals linked to worse outcomes (Stiell et al., 1999). Studies indicate that the likelihood of survival with favorable neurologic outcome following a cardiac arrest increases the sooner that treatment begins, and the effect of any BLS treatment is minimal if a patient has not achieved ROSC within 10 minutes of collapse (Weisfeldt and Becker, 2002). See Chapter 6 for research into novel therapies that may extend the window of effective treatment. Given the numerous variables and actors between recognition of an emergency and

[15] "A primary PSAP is defined as a PSAP to which 911 calls are routed directly from the 911 Control Office, such as, a selective router or 911 tandem. A secondary PSAP is defined as a PSAP to which 911 calls are transferred from a primary PSAP" (FCC, 2015b).

[16] NASEMSO Survey Question: "How many of the PSAPs provide Emergency Medical Dispatch in your State?"

BOX 4-3
911 Dispatch System in the United States

The Wireless Communications and Public Safety Act of 1999 (also known as the 911 Act) aimed to enhance public safety by facilitating the deployment of a seamless national communications infrastructure for emergency services and designating 911 as the universal emergency number in the United States. Since then, the Federal Communications Commission (FCC) has taken steps to increase public safety by facilitating and organizing the development of an integrated national emergency communications system.

Approximately 70 percent of 911 calls are placed from cell phones, and that percentage is growing (NHTSA, 2015a, p. 2). More than 60 percent of states report that 75 percent and 70 percent of their geographic service areas are covered by enhanced 911 services and enhanced wireless 911 services, respectively. These enhanced services allow PSAPs to locate callers using a landline or cell phone (FICEMS, 2012, pp. 397, 403).[a] Thirty-one states report that PSAPs can determine the location of at least 90 percent of landline and wireless 911 callers (NHTSA, 2015b, p. 98).[b] EMS dispatch centers are increasingly able to capture automatic crash notification (e.g., OnStar) data, receive text message requests for assistance, receive cell phone photographs, and use social networking for monitoring purposes (FICEMS, 2012, p. 400).[c]

Some PSAPs also have the technological capabilities to determine the precise status of all rescue units available in a particular service area using a computer-aided dispatch (CAD) system. The CAD system allows a dispatcher to contact responding units via two-way radio or text message and can also be used to match EMS calls with the closest, and most appropriate, public safety resource. These technological capabilities are powerful assets for EMS systems in relationship to cardiac arrest. They can quickly and accurately identify the precise location of a cardiac arrest patient, allowing specially trained and equipped EMS providers to arrive within a few minutes of the 911 call.

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[a]NASEMSO Survey Question: "What percentage of your States Geographic Area is covered by wireless 911 (with location for cellular phones) from at least one carrier?" and "Based on the following 911 coverage types, what percentage of your States Geographic Area is covered by each?"

[b]The location of these callers can be determined within 125 meters, 67 percent of the time (NHTSA, 2015b, p. 98).

[c]NASEMSO Survey Question: "Which of the following describes the 911 access within your State?"

defibrillation or provision of CPR, there are many points at which delays might occur. For example, delays could occur if a call center was not able to track the location of a cell phone and could not immediately dispatch EMS personnel to the scene. Delays may also occur in collecting information from bystanders, routing calls between PSAPs and dispatchers, assessing a patient's medical condition, locating available nearby EMS responders, or in transitions between individuals performing BLS or ACLS and the transfer of care to hospital staff.

Although some studies have found no significant differences in EMS response times for minority patients (Becker et al., 1993; Cowie et al., 1993; David and Harrington, 2010; Sayegh et al., 1999), race and ethnicity have been associated with delays in activation of the emergency response system. Among minorities, many barriers to the immediate activation of 911 have been identified. For example, some minority groups are more likely to have negative feelings about EMS services (Finnegan et al., 2000), to believe that EMS responds slowly to emergencies taking place in neighborhoods stigmatized by a history of violence, or to feel confronted and discouraged by EMS dispatchers' questions (Skolarus et al., 2013). Among Latinos, the fear of legal action (e.g., deportation due to undocumented immigrant status) also contributes to delays in activation of emergency response systems (Sasson et al., 2014; Watts et al., 2011). Minority populations who have experience with less competent and timely prehospital care, may be deterred from calling 911 by these experiences (Watts et al., 2011). Limited proficiency in English also represents a barrier to EMS activation. Language barriers delay initiation of dispatcher-assisted CPR (Bradley et al., 2011) and are a source of frustration and anxiety for callers who are not fluent in English (Sasson et al.,2014; Watts et al., 2011). Among Cambodians, a lack of proficiency in English often causes witnesses of a cardiac arrest to call family members or friends rather than 911 (Meischke et al., 2014). Key barriers to rapid activation of the emergency response system by members of minority groups are listed in Box 4-4.

Delayed activation of the emergency response system may account for the higher rates of nonshockable arrhythmias observed among black and Hispanic patients of cardiac arrest, as compared to Caucasians (Becker et al., 1993; Moon et al., 2014). One study of 4,653 cardiac arrests in New York found that race was also associated with respectively higher and lower rates of OHCA incidence and survival to hospital discharge (see Table 4-1) (Galea et al., 2007). The primary causes for these observed disparities remain undetermined: factors such as initial cardiac rhythm, patient demographics, and event-related characteristics account for less than half of the difference in survival rates, and EMS response times were not a significant contributor (Galea et al., 2007). Further research is needed about whether and how race or ethnicity relates to EMS performance, and how EMS can improve the lower rates of survival from cardiac arrest among minority populations (David and Harrington, 2010; Galea et al., 2007). For example, more information is needed about targeted communication between EMS and the minority communities, and the implementation of strategies for improving survival from cardiac arrest among groups with limited English proficiency, such as increasing the prevalence of multilingual dispatchers.

BOX 4-4
Barriers to Early EMS Activation in Minority and Immigrant Communities

1. Resigned attitudes about delays in EMS response in stigmatized neighborhoods
2. Distrust of law enforcement, especially among immigrants who may fear deportation
3. Language barriers that delay dispatcher-assisted CPR and are a source of frustration and anxiety for non-English speakers

TABLE 4-1 Racial Disparities in Cardiac Arrest Incidence and Survival

	Initial Rhythm and Survival		
	White	Black	Hispanic
Age-adjusted OHCA incidence	5.8 of 10,000	10.1 of 10,000	6.5 of 10,000
VF/pVT (%)	16.7	12.0	15.1
Asystole (%)	62.8	68.1	66.4
Survival to discharge (%)	3.4	1.4	1.9

NOTE: OHCA = out-of-hospital cardiac arrest; pVT = pulseless ventricular tachycardia; VF = ventricular fibrillation.
SOURCE: Galea et al., 2007.

Response intervals include the time required to receive and process the initial 911 call, notify closest EMS responders, and for responders to arrive on scene with a defibrillator. These intervals vary considerably among EMS systems because of differences in geography, traffic, population density, and distribution of EMS units. Survival decreases by approximately 7 to 10 percent for every minute after witnessed cardiac arrest that passes without administration of CPR (Larsen et al., 1993). In the majority of OHCA cases where bystander CPR is not provided, cardiac arrest survival is extremely low. As discussed in Chapter 3, bystander CPR is especially important in areas where response times are often delayed.

The negative effects of transport distance and population density on EMS response times and patient outcomes can be mitigated by the use of computer-aided dispatching and coordination among ambulance crews. For example, a study of the Singapore EMS system found that by moving ambulances to locations where, and staffing them at times when, OHCAs were more likely to occur, response times decreased significantly from a monthly median of 10.1 minutes to 7.1 minutes (Ong et al., 2010). Importantly, this improvement was achieved without the addition of new ambulances, personnel, or total working hours (Ong et al., 2010). Similar efforts to decrease response times by predicting cardiac events and efficiently deploying ambulances have been successful in the United States and elsewhere (Gonzalez et al., 2009; Jermyn, 2000; Peleg and Pliskin, 2004). Response times may also be reduced by expanding access to the emergency response system. The Next Generation 911 (NG911) program seeks to enable 911 callers anywhere in the United States to connect to PSAPs via wireless and Voice over Internet Protocol (VoIP) communication devices, to locate these callers, and to allow 911 dispatchers to freely exchange call data among PSAPs (DOT, 2015). Given the increasing prevalence of smartphones in the United States, the ability to text 911 in an emergency holds promise for expanding access to 911. In 2014, the FCC adopted an order requiring all wireless carriers to develop the capability to send text messages to 911 and to deliver emergency texts to PSAPs upon request (FCC, 2015c). As a result, PSAPs began to prepare to receive emergency text messages from wireless providers; as of March 2015, more than 200 PSAPs were capable of doing so (FCC, 2015a). However, much progress remains to be made, because only 21 percent of NG911 systems are fully operational, and more than half have zero functionality (NHTSA, 2015b, p. 3).

Treatment by First Responders and EMS Personnel

First responders and EMS personnel are the vanguard of a formal EMS system; as such, they are responsible for early administration of high-quality BLS and ACLS treatments, and the initial post-arrest care of the cardiac arrest patient. Although much research has been devoted to improving prehospital care for cardiac arrest patients, many unknowns remain. As a major driver of improvements in survival from OHCA, ongoing research to develop treatment protocols and novel medical technologies is needed.

CPR and Defibrillation in the Field

BLS underpins all successful cardiac resuscitation and includes CPR and defibrillation. Unlike bystander CPR (discussed in Chapter 3), CPR provided by first responders and EMS personnel includes both compressions and ventilations. The purpose of ventilation during CPR is to ensure sufficient oxygenation and adequate removal of carbon dioxide (CO_2), while minimizing interruptions in chest compressions and not hyperventilating—two common problems that have prompted considerable research. Delivering high-quality chest compressions, minimizing interruptions, and following a protocol for minimizing hyperventilation while preparing for and delivering defibrillation is a challenging skill that requires considerable multi-provider integration, coordination, communication, training, and rehearsal.

Although optimal ventilation parameters during CPR (e.g., delivery method, rate, volume per breath, and oxygen concentration) remain undetermined (Meaney et al., 2013a), two things seem certain: oxygen delivery during CPR is essential, and hyperventilation is common and adversely affects survival (Aufderheide and Lurie, 2004; Aufderheide et al., 2004). Excessive oxygenation causes acute lung injury, and is a risk factor for aspiration. Paradoxically, hyperventilation actually decreases oxygenation of the vital organs, by lowering coronary perfusion pressure and raising intrathoracic pressure (Aufderheide and Lurie, 2004; McInnes et al., 2011; O'Neill and Deakin, 2007). The prevalence of hyperventilation during CPR is a consequence of many factors including a lack of awareness of the dangers of hyperventilation, inexperience and incompetence on the part of rescuers, and the stress and excitement of responding to a cardiac arrest (Aufderheide and Lurie, 2004; Aufderheide et al., 2004).

Research indicates that interrupting chest compressions to provide ventilation may adversely impact outcomes (Berg et al., 2001; Kern et al., 2002). In response to these findings, some EMS systems have developed protocols for minimally interrupted cardiac resuscitation, which has been associated with significant improvements in survival as compared to traditional CPR (Bobrow et al., 2008; Ewy, 2005; Ewy and Sanders, 2013; Kellum et al., 2008). In order to minimize interruptions in chest compressions, these protocols delay definitive airway management with intubation, the placement of which can cause prolonged interruptions in compressions. In one observational study, intubation-related interruptions in chest compressions averaged 109.5 seconds, with one-quarter of patients not receiving chest compressions for more than 3 minutes (Wang et al., 2009).

CPR for pediatric patients can be even more challenging for a number of reasons. First, OHCA is less common in children than in adults (Daya et al., 2015; Vellano et al., 2015), so EMS providers may be less experienced at resuscitating children. Second, CPR protocols are slightly different for pediatric populations: chest compressions are shallower and compression-to-ventilation ratio is lower when two rescuers are present (Kitamura et al., 2010). Third, the smaller size of pediatric patients can exacerbate the harm associated with hyperventilation and other instances of rescuer error or imprecision (Davis et al., 2004; Gausche et al., 2000). Finally, children require specialized resuscitation equipment (e.g., smaller bag-valve masks, airways, and defibrillator pads) that may not always be available and with which rescuers may be less familiar. These obstacles compound the challenges associated with inexperienced providers and may contribute to the lower OHCA survival rates for this population (Daya et al., 2015; Vellano et al., 2015). Further research is necessary to determine the best way to minimize rescuer error for pediatric populations. Key issues regarding treatment of pediatric cardiac arrest patients are discussed in Box 4-5.

BOX 4-5
Key Pediatric Issues

- The quality of CPR provided by EMS personnel for pediatric OHCA patients can be improved (Sutton et al., 2015).
- High-quality CPR leads to improved arterial blood pressure and outcomes among children with in-hospital cardiac arrest (Sutton et al., 2013a,b).
- Dispatcher-assisted CPR is also effective at improving outcomes in pediatric patients (Akahane et al., 2012; Goto et al., 2014; Rodriguez et al., 2014). Dispatchers may need specialized training in order to provide high-quality dispatcher-assisted CPR for pediatric patients.
- Ventricular fibrillation occurs less commonly in children, but increases with age (M. D. Berg et al., 2010). Early defibrillation improves outcomes.
- Out-of-hospital clinical trials have been infrequent because of the large multi-center trials needed to achieve adequate power. The Pediatric Emergency Care Applied Research Network administered by the Emergency Services for Children has been the most successful.[a]

[a] For more information, see http://www.pecarn.org.

Various types of defibrillators are used by emergency personnel. EMT-Bs typically use AEDs, which automatically diagnose treatable rhythms and deliver shocks (NHLBI, 2011). EMT-As may use devices that include both a manual mode that allows rescuers to interpret the heart rhythm and decide whether a shock is needed and an automated mode, which operates much like an AED where the device decides based on preset electrocardiographic parameters whether a shock is needed and the rescuer simply pushes a button as indicated (FDA, 2013; IDHS, 2015). Both types of devices deliver the same electrical shock. However, the manual mode has the advantage of allowing for more rapid interpretation of the heart rhythm by a skilled provider as opposed to waiting for the machine's diagnosis. In trials comparing the effectiveness of AEDs and manual defibrillators, AEDs were associated with longer interruptions in CPR and, consequently, with poorer outcomes (Berg et al., 2003; Kramer-Johansen et al., 2007). However, the addition of real-time audio-visual feedback to AEDs has been shown to improve CPR along a number of parameters (Fischer et al., 2011a). Paramedics (EMT-Ps) use manual defibrillators, which are capable of performing defibrillation and also of monitoring several physiological parameters such as heart rhythm, blood pressure, pulse oximetry, and end-tidal CO_2. Pulse oximetry and end-tidal CO_2, available in paramedic manual defibrillators, are particularly useful in guiding post-resuscitative care and assessing the patients' response to resuscitative efforts.

Although both CPR and defibrillation are critical components of resuscitation, one of the most important aspects of resuscitation is the interplay between CPR and defibrillation. Currently, most defibrillators require a pause in CPR while analyzing the patient's cardiac rhythm or providing shocks. Growing clinical evidence suggests that these perishock pauses are detrimental to survival (Cheskes et al., 2011b; Edelson et al., 2006; Sell et al., 2010). One study found that optimal pre- and post-shock pauses were less than 3 seconds and 6 seconds, respectively—much shorter than the average perishock pause interval (Sell et al., 2010). Another study found that, as compared to pre- and perishock pauses greater than 20 seconds and 40 seconds, respectively, those less than 10 seconds and 20 seconds, respectively, were associated with significantly higher rates of survival to hospital discharge (Cheskes et al., 2011). An American Heart Association (AHA)-recommended technique for minimizing the perishock pause is to provide compressions during the period between rhythm analysis and shock while the AED is charging, or to charge the AED prior to rhythm analysis and while compressions are ongoing. Studies have found that this technique significantly reduces perishock pause intervals and is not associated with an increase in inappropriate shocks (R. A. Berg et al., 2010; Cheskes et al., 2014, 2015).

Advances in defibrillator technology hold the promise of reducing or eliminating perishock pauses. First, the software that assesses cardiac rhythms will become more powerful, allowing AEDs to more quickly determine whether a shock is appropriate. Second, similar software advances may allow rescuers to deliver chest compression without affecting the defibrillator's ability to assess the patient's cardiac rhythm. Third, new technological capabilities may allow rescuers to continue chest compressions, eliminating the preshock pause. Defibrillators and other patient monitoring devices that provide real-time performance feedback can improve the quality of CPR or allow rescuers to adapt their interventions to meet physiological targets, such as a specific patient blood pressure. Adapting current wireless technologies for use in these devices will someday enable the automated transmittal of a patient's physiological data to the admitting emergency room, thereby allowing hospital staff to better prepare for the particular needs of a given cardiac arrest patient.

It is important to note that recommendations for treatment of cardiac arrest change with advances in medical science and technology. For example, the development of the AED allowed bystanders to defibrillate patients rather than to wait for EMS personnel to provide shocks. Available resources also affect how quickly, and by whom, lifesaving treatments are provided. Some communities provide dispatcher-assisted CPR and public access defibrillation programs, while others do not. These differences can impact survival rates. Although the evolution of treatment recommendations can complicate the training and evaluation of EMS personnel, as well as the monitoring and assessment of performance, they can also lead to improvements in patient outcomes. See Chapter 6 for a discussion of these and other facets of learning systems of response.

Advanced Cardiac Life Support

ACLS is the fourth link in the chain of survival and includes advanced airway management, drug therapies, intravenous and intraosseous access, physiological monitoring, and hemodynamic support. The scientific literature is unclear as to whether these therapies result in improved survival from OHCA. One meta-analysis found that survival was higher for OHCA patients who received ACLS compared to those who received BLS care only (Bakalos et al., 2011). Other studies have found that provision of ACLS treatment was associated with significantly higher rates of ROSC, survival to hospital admision, and survival to discharge (Ma et al., 2007; Woodall et al., 2007). Conversely, a recent Medicare database review found higher survival rates among OHCA patients treated by BLS-only EMS units than among those treated by ACLS units, an analysis of Canadian EMS systems found no improvement in survival from OHCA after ACLS capability was added to BLS units with defibrillation, and a study of 189 pediatric OHCA patients found no survival benefit associated with ACLS over BLS care (Pitetti et al., 2002; Sanghavi et al., 2015; Stiell et al., 2004).

Research also suggests that specific ACLS treatments may reduce OHCA survival rates. For example, the advanced airway management techniques used in ACLS (e.g., endotracheal intubation) have been associated with interrupted chest compressions, hyperventilation, and misplacement of the tube in the esophagus—all of which have been associated with detrimental outcomes in both adult and pediatric populations (Aufderheide and Lurie, 2004; Aufderheide et al., 2004; Morrison et al., 2010a). Similar concerns have been expressed about the efficacy of drug therapies used to treat cardiac arrest. Consider epinephrine, which increases both cerebral and coronary blood flow and pressure during CPR, and is the most commonly used medication during resuscitation (Michael et al., 1984; Morrison et al., 2010a). As will be discussed in Chapter 5, recent studies suggest that administration of epinephrine after cardiac arrest may confer no therapeutic benefit, and may even negatively affect long-term outcomes in some cases (Callaway, 2013). Other studies indicate that the time of administration is critical to the drug's efficacy (Donnino et al., 2014; Hayashi et al., 2012; Jacobs et al., 2011).

Conflicting evidence regarding ACLS effectiveness may be caused by clinically relevant variations in the characteristics of, and interactions among, patient, condition, provider, and EMS system. Cardiac arrest is a syndrome and the final outcome of many disease processes, yet many studies do not account for the effect of etiology or patient medical history on survival or the variability in EMS system capabilities and provider competencies. Additional research is needed to determine whether specific drug therapies are beneficial, harmful, or merely ineffectual, and how dosage, timing, and route of administration affect their impact on OHCA survival. Targeting a particular subset of patients that may benefit from a discrete treatment could be informative. Chapter 6 discusses such alternative approaches to resuscitation research and how they might replace standard algorithms with individualized treatment protocols.

EMS Post-Resuscitative Care

Once ROSC is achieved, the risks of post–cardiac arrest syndrome rise. Post–cardiac arrest syndrome is a distinctive, multifaceted combination of pathophysiological processes that include the possibility of post–cardiac arrest brain injury, myocardial dysfunction, and ischemia and reperfusion injuries that result from prolonged oxygen deprivation and restoration of blood circulation. A more thorough discussion of post-resuscitation phase of care is included in Chapter 5. Understanding pathophysiological processes can yield treatments, some of which can be administered by EMS providers prior to arrival at a hospital, to help improve OHCA outcomes.

Some notable therapies and factors are believed to improve survival. For example, percutaneous coronary intervention, antiarrhythmic medication, hemodynamic support, and appropriate ventilation can all increase the likelihood of positive outcomes following ROSC. Although research indicates that targeted temperature management (TTM) in a hospital setting has a beneficial effect on patient outcomes, and is recommended by the AHA for comatose patients with ROSC, no association between improved survival and the TTM use in the prehospital setting has been demonstrated (Debaty et al., 2014; Kim et al., 2014). Another important factor for EMS systems and providers is consideration of transport options to a facility where these therapies are readily available.

Two aspects of post–cardiac arrest syndrome that may require EMS monitoring and intervention during transport are fever and hemodynamic instabilities. Following cardiac arrest, fever is exceptionally harmful to the brain, which has been deprived of oxygen and nutrients throughout CPR. Health care providers can use TTM to prevent and rapidly treat elevated temperature (Nolan et al., 2003; Peberdy et al., 2010; Soar and Nolan, 2007). However, the evidence on specific protocols remain a subject of debate (Peberdy et al., 2010). Hemodynamic instability commonly occurs after OHCA and manifests as dysrhythmias, hypotension (i.e., low blood pressure), and low cardiac index. Transport intervals can vary considerably (Propp and Rosenberg, 1991; Schull et al., 2003; Spaite et al., 2009), but were determined by one meta-analysis to range from 10.77 to 17.28 minutes, depending on whether the arrest occurred in an urban or a rural setting (Carr et al., 2006). Therefore, the majority of OHCA patients only require limited hemodynamic support during transit. However, prolonged transport intervals, particularly in rural settings, may require EMS providers to be competent in managing hypotension (low blood pressure) as well as rearrest.

Termination of Resuscitation

Even prolonged and expertly performed resuscitation at the scene will not always revive an OHCA patient. In these circumstances, EMS systems and personnel must decide whether to transport the patient to the hospital while continuing resuscitation efforts, or to terminate resuscitation. Multiple studies have found that survival is rare among OHCA patients who are transported to the hospital after failing to respond to BLS and ACLS treatment in the field; patients that do survive often suffer moderate to severe neurological deficits (Kellermann et al., 1993;

Morrison et al., 2007). The documented decrease in CPR quality that occurs during patient transport almost certainly contributes to this low survival rate (Chung et al., 2010; Olasveengen et al., 2008). In fact, some experts question whether EMS systems should transport any cardiac arrest patients without ROSC, arguing that the most effective treatments for cardiac arrest—CPR and defibrillation—can be performed equally well or better in the field as compared to the hospital, and that interruptions in these treatments that occur as a result of transportation do more harm than relocating to the hospital does good (Adams and Benger, 2014).

The risks of transport extend beyond the patient to EMS personnel and the public. Rapid transport is itself associated with motor vehicle crashes and vehicle-pedestrian collisions, while performing CPR during high-speed transport poses additional risks for EMS personnel, who can sustain serious injuries in these circumstances (Maguire et al., 2002; Slattery and Silver, 2009). The multiple risks and minimal benefits of transporting OHCA patients who have not responded to resuscitation have led national organizations such as the AHA and NAEMSP to develop termination of resuscitation (TOR) protocols for adult OHCA patients (Millin et al., 2011; Morrison et al., 2010b). A recent policy statement by ACEP, NAEMSP, the American College of Surgeons, and the American Academy of Pediatrics proposed TOR protocols for traumatic pediatric OHCA, but protocols for terminating resuscitation of nontraumatic pediatric OHCA patients are not available (American College of Surgeons et al., 2014). These protocols can be highly accurate at predicting survival: one study found that TOR rules for use by BLS and ACLS providers had positive predictive values of 0.998 and 1.000, respectively (Sasson et al., 2008). Thus, there is clear practical and scientific support for TOR protocols.

Despite the accuracy of these protocols at predicting patient survival, research indicates that adherence can be less than 50 percent (O'Brien et al., 2008). This non-use of TOR protocols can be the result of a combination of factors, including legal mandates that restrict use of TOR protocols to a small subset of OHCA patients, cultural values that prohibit or discourage termination of resuscitation, EMS leaders without the authority to set or enforce such protocols, and poor communication between medical directors and EMS personnel (Sasson et al., 2009, 2010a). Nevertheless, accurate and comprehensive termination of resuscitation protocols for treating OHCA have the potential to improve the quality of BLS and ACLS care and reduce risks to the patient, EMS personnel, and the public. These protocols are grounded in ethical principles, and have the support of major professional and scientific organizations. EMS systems should review and adopt nationally endorsed TOR protocols to the greatest extent possible.

Transport and Transitions of Care

For transportation of the cardiac arrest patient to the hospital to be successful, many factors must be addressed. Transportation must be rapid, while remaining safe and limiting interruptions in treatment. It must deliver the patient to an appropriate hospital, by comparing the needs of the patient with the capabilities of the receiving facility and staff. Patient data and care must be efficiently and accurately transferred from EMS to hospital personnel. Meeting these challenges will require further research and the concerted efforts of the larger EMS community.

Transport of Cardiac Arrest Patients

EMS systems in the United States treat and transport approximately 25 million patients per year, the vast majority of whom are not cardiac arrest patients (NAEMSP, 2011). Given the multifaceted nature of post-arrest care, EMS providers need ready access to predetermined protocols and transport plans that are designed to integrate EMS providers into multidisciplinary hospital teams in order to optimize post-resuscitation care. For example, a large proportion of cardiac arrests in adult patients are triggered by an acute coronary artery blockage. Using an electrocardiogram, paramedics could detect this coronary condition as an ST segment elevation myocardial infarction. In these circumstances, it would be advantageous for the patient to be transported to a hospital equipped to perform immediate coronary angiography and stenting, if indicated. Predetermined policies and protocols, along with hospital prenotification that the patient is in transit, can streamline hospital-administered post-arrest care. Furthermore, the EMS system has a responsibility to transport cardiac arrest patients who achieve ROSC but remain comatose to the best, and most appropriate, health care facility regionally available for subsequent treatment. The AHA's 2010 guidelines recommend that, if available, post-arrest patients who are unconscious or unresponsive after cardiac arrest should be directed to a medical center that has a comprehensive care plan that includes not only acute cardiovascular interventions and TTM, but also advanced neurological monitoring and care (Peberdy et al., 2010).

Regionalization of cardiac arrest care, which involves transporting patients to facilities that provide the guideline recommended treatments listed above, has been suggested as another opportunity for ensuring the best possible outcomes following a cardiac arrest. The overarching concept of regionalization is to transport eligible patients to designated centers of excellence (see Chapter 5) that offer the appropriate level of care as soon as possible (Lurie et al., 2005; Mechem et al., 2010). In the case of emergency surgical care, research indicates that regionalization of care can contribute to improved patient access to specialty care (Roche-Nagle et al., 2013). Furthermore, evidence has shown that regionalization of care can improve outcomes and reduce overall health care costs for high-risk patients (Bardach et al., 2004; Chang and Klitzner, 2002). For cardiac arrest patients, research suggests that minimizing transport intervals is not closely associated with improved outcomes (Nichol and Soar, 2010), while the value of guideline-recommended post-arrest treatments, which are not everywhere available, has been demonstrated in studies (Arrich et al., 2012; Reynolds et al., 2009; Sunde et al., 2007). More importantly, EMS systems experimenting with regionalization of care for cardiac arrest patients have seen improvements in survival with good neurological status in association with these programs (Bosson et al., 2014; Spaite et al., 2014). These findings suggest that regionalizing care for patients with cardiac arrest warrants further consideration, testing, and evaluation.

Another emerging practice that is technically feasible and associated with survival in some case reports is the transport of OHCA patients with refractory ventricular fibrillation directly into the cardiac catheterization laboratory, while providing continuous, mechanically aided CPR. This practice can improve the chance of achieving ROSC and survival rates in some patients (Bangalore and Hochman, 2010; Dumas et al., 2010; Frohlich et al., 2013; Kern, 2012). One study of this practice achieved rates of survival to discharge as high as 66 percent (Fothergill et al., 2014). Research also suggests that cardiac catheterization performed shortly after hospital admission may improve outcomes among resuscitated OHCA patients. For example, a retrospective cohort study of resuscitated OHCA patients found that patients who received cardiac catheterization within 6 hours of hospital admission were significantly more likely to survive to discharge than patients who received catheterization more than 6 hours after admission or not at all (Strote et al., 2012), while literature review found that survival with good neurological status among OHCA patients who received acute cardiac catheterization was 58 percent overall, as compared to 35.8 percent among controls (Camuglia et al., 2014). Though limited, this evidence supports further investigation of cardiac catheterization immediately upon hospital admission as a potentially beneficial intervention for some OHCA patients.

Transitions of Care

EMS providers face an exceptionally challenging situation each time they transfer the cardiac arrest care of a patient to the hospital care team or the next health care provider. Within a short period of time, EMS providers must hand off the ongoing treatment of the patient, complete patient care documentation, and prepare their vehicles and themselves for future emergencies. In general, care transitions are associated with increased rates of medical errors (Horwitz et al., 2009; The Joint Commission, 2012, 2013). In the context of cardiac arrest, EMS providers may not be familiar with the hospital settings or personnel, which may affect communication and continuous quality of care. Efforts to improve direct communication between providers, the standardization of some transition components, appropriate feedback, and transparency may help overcome challenges associated with these types of transitions (ACEP, 2012c; Meisel et al., 2015). Available and developing technologies may also improve necessary information exchange (Meisel et al., 2015).

To effectively and safely transfer the care of a cardiac arrest patient from EMS to another health care provider, a formal written or printed report of the EMS care should be provided at the time of the transfer. However, a recent survey found that only 23 of 48 states that provided data have a requirement to "leave a formal copy of the EMS patient care report with the patient's receiving healthcare provider at the time of transfer" (FICEMS, 2012, p. 284).[17] The Joint Commission is currently exploring key elements of care transition models in order "to define methods for achieving improvement in the effectiveness of the transitions of patients between health care organizations, which provide for the continuation of safe, quality care for patients in all settings" (The Joint Commission, 2012, p. 2). These investigations have highlighted the importance of emphasizing collaboration and standardized transition

[17]NASEMSO survey question: "Does your State have a regulatory requirement for EMS Agencies to provide a formal copy of the EMS patient care report to the receiving hospital or healthcare facility at the time care is transferred (before EMS leaves the facility)?"

protocols, and minimizing lapses in accountability and communication (The Joint Commission, 2012, 2013). Although EMS personnel are expected to communicate basic facts about the cardiac arrest patient during the transition to the receiving care facility and health care providers, a lack of formal documentation can lead to information gaps, which may affect patient care.

If documentation is completed and transferred with the patient, the EMS systems must be able to track that patient to hospital discharge in order to evaluate the relationship between specific care components and cardiac arrest survival or neurologic outcomes. According to a recent survey, of 49 states for which data were available, 36 states require local EMS agencies to collect patient data based on the National Emergency Medical Systems Information System (NEMSIS) data set, and 44 states maintain a data repository based on the NEMSIS standard, which includes data elements on patient disposition in the emergency room and hospital (FICEMS, 2012, pp. 286, 288; NEMSIS, 2015).[18] This same survey found that only 4 of 48 states were able to report the number of EMS-treated cardiac arrest patients that survived to emergency department admission, just 1 state could report the number of OHCA patients that survived to hospital admission, and 2 states were able to report the number of patients who survived to hospital discharge (FICEMS, 2012, pp. 451, 453, 454).[19] However, questions about the accuracy of NHTSA's survey exist. The CARES registry, which allows EMS systems to collect OHCA patient data through hospital discharge, reports participation by 400 EMS agencies in 29 states (CDC, 2015). Consolidating surveillance activities into one national database could eliminate confusion about database accuracy and could generate data that are standardized, more accessible, and of higher quality.

[18]NASEMSO Survey Questions: "Does your State by law or regulation require local EMS Agencies to collect data based on the NEMSIS standard dataset?" and "Does your State maintain a State EMS data system?"

[19]NASEMSO Survey Questions: "Do you know how many out of hospital cardiac arrest patients treated by EMS in your State survived to Emergency Department admission?," "Do you know how many out of hospital cardiac arrest patients treated by EMS in your State survived to Hospital admission?," and "Do you know how many out of hospital cardiac arrest patients treated by EMS in your State survived to Hospital discharge?"

OPPORTUNITIES FOR IMPROVING THE RESPONSE

While the efficiency and efficacy of an EMS system is important for all emergencies, activating the chain of survival is especially critical for cardiac arrest patients, for whom any delay or error throughout the resuscitation process could have fatal consequences. Efforts to improve cardiac arrest outcomes need to focus on iniatives that will optimize both the timeliness and performace of care provided by EMS systems across the United States.

Dispatcher-Assisted CPR

Bystander CPR and AED use are often the crucial bridge between collapse and arrival of trained responders. As the initial communication point between the public and the EMS system, trained 911 dispatchers have the potential to guide the preliminary and most critical phases of the cardiac arrest response. Dispatcher-assisted CPR involves the identification of cardiac arrest and the provision of CPR instructions to the 911 caller prior to the arrival of EMS providers at the scene of the cardiac arrest and represents an important area of opportunity for improving outcomes.

Organized and ongoing efforts to improve the early recognition of OHCA during a 911 call and engage individuals to perform bystander CPR are associated with statistically significant improvements in both bystander CPR and patient survival (Lewis et al., 2013; Rea et al., 2001; Tanaka et al., 2012). Specifically, clinical studies have shown a strong association between dispatcher-assisted CPR and increased bystander CPR rates and improved CPR quality and cardiac arrest survival rates (Eisenberg et al., 1985; Kellermann et al., 1989; Lewis et al., 2013; Rea et al., 2001; Song et al., 2014; Vaillancourt et al., 2007). In one study conducted in Korea, bystander CPR rates more than doubled after the implementation of a systemwide dispatcher-assisted CPR program (Song et al., 2014). Tanaka and colleagues (2012) also found that bystander CPR rates increased from 41 to 56 percent when a dispatcher-assisted CPR program was implemented in conjunction with a continuous quality improvement (CQI) program (Tanaka et al., 2012). When dispatcher-assisted CPR protocols, training, and a CQI program were implemented in three large regional 911 centers in Arizona as part of a statewide initiative, these interventions were associated with an increased likelihood of survival (Bobrow, 2014). In King County, Washington, which has one of the highest rates of bystander CPR in the nation, dispatcher-assisted CPR has been credited for approximately half of all bystander CPR performed in the system (Lewis et al., 2013). Importantly, dispatcher-assisted CPR is also effective at improving outcomes in pediatric patients (Akahane et al., 2012; Goto et al., 2014; Rodriguez et al., 2014) as long as dispatchers are aware of the different CPR protocols for children and adults. Moreover, dispatcher-assisted CPR has been found to be cost-effective, because it requires only training costs and no additional capital investments (Dameff et al., 2014; Lewis et al., 2013).

As noted previously, dispatcher-assisted CPR is not provided by all EMS systems, and the programs that do exist are not equivalent to one another (Lerner et al., 2012). Among centers that provide dispatcher-assisted CPR instructions, dispatchers are able to recognize a cardiac arrest and facilitate the initiation of bystander CPR at different time intervals, with reports ranging from 40 seconds to 1 minute and 15 seconds for recognition of the cardiac arrest followed by 2 minutes and 56 seconds to 5 minutes and 30 seconds for the time to first chest compression (Heward et al., 2004; Lewis et al., 2013; Van Vleet and Hubble, 2012).

Training and Certification

Although Web-based training modules for dispatcher-assisted CPR are available, no nationally endorsed dispatcher-assisted CPR curriculum currently exists. Training should acquaint dispatchers with scientific findings that relate to cardiac arrest outcomes and dispatcher-assisted CPR—the nature and frequency of cardiac arrest, the importance of dispatcher-assisted CPR, and the role that dispatchers can play in improving cardiac arrest survival. Training could include didactic and simulation modules that focus on the three phases of dispatcher-assisted CPR: (1) identifying a cardiac arrest (i.e., asking if the patient is unconscious and breathing abnormally), (2) initiating CPR instructions, and (3) providing continuous coaching to keep callers focused and calm until trained first responders can take over. Identification of patients in need of CPR can be hindered by the abnormal breathing sometimes present in cardiac arrest, which bystanders can confuse with normal respiration. Protocols designed to distinguish between these types of respiration can significantly improve identification of cardiac arrest patients and increase rates of bystander CPR (Roppolo et al., 2009). Dispatchers should also be well versed in how AEDs function and be able to assist a bystander in the use of an AED, in case one is available during a 911 call.

As mentioned above, NHTSA has developed a national standard curriculum for emergency medical dispatchers, in response to the need expressed by states and municipalities for a set of "uniform program standards" that mitigate "inconsistencies in program development and implementation" (NHTSA, 1996a). Despite this recognized need for standardization, adherence to NHTSA's curriculum is strictly voluntary (NHTSA, 1996b, p. vi). Consequently, private organizations sometimes base their dispatcher training programs off NHTSA's curriculum, but do not follow it in a consistent or rigorous manner. Efforts made on the part of organizations that currently manage dispatcher training (e.g., APCO, International Academies of Emergency Dispatch, and PowerPhone) to collaborate on the development of a single, national-level training program could aid researchers in their efforts to improve dispatcher-assisted CPR by determining the training-related factors that limit or promote its effectiveness.

Evaluation

As in many other health care interventions, iterative evaluation and quality improvement are correlated with improved adherence to guidelines and outcomes in dispatcher-assisted CPR (Chassin and Galvin, 1998; Tanaka et al., 2012). Numerous strategies exist to evaluate the quality of dispatcher-assisted CPR. For example, auditing 911 recordings to assess dispatcher performance could provide data for CQI efforts (Clegg et al., 2014; Dameff et al., 2014; Lewis et al., 2013). Auditing can also be woven into a 911 center's basic operation plan, whereby 911 CPR calls can be automatically flagged within a computer-aided dispatch system and then reviewed for key performance and quality indicators at a later time. Although the committee does not endorse any particular set of dispatcher-assisted CPR performance metrics or guidelines, there are categories of performance metrics that should be considered by any organization developing a training curriculum for dispatcher-assisted CPR including those listed in Box 4-6.

Training and Participation in High-Performance CPR and Other Quality Improvements

High-quality CPR is associated with improved survival in numerous studies (Bobrow et al., 2013; Cheskes et al., 2011b; Christenson et al., 2009;

BOX 4-6
Examples of Dispatcher-Assisted CPR Performance Metrics

- Percentage of cardiac arrests recognized when dispatchers have a chance to assess patient consciousness and breathing
- Time from call receipt to recognition of cardiac arrest
- Percentage of cases that receive chest compressions when dispatchers have a chance to assess patient status and CPR is not already in progress
- Time from call receipt to first chest compression

Stiell et al., 2012). Yet, observational data from actual OHCA resuscitation attempts reveal that the quality of EMS-provided CPR or both adult and pediatric cardiac arrest patients is frequently suboptimal (Cheskes et al., 2011b; Christenson et al., 2009; Lammers et al., 2014; Wik et al., 2005). Similar findings have also been documented across EMS systems (Kovacs et al., 2015; Sutton et al., 2015; Vadeboncoeur et al., 2014; Wik et al., 2005). The inconsistencies in the CPR quality may, in part, explain the wide-ranging variability in survival among and within communities (Aufderheide and Lurie, 2004; Aufderheide et al., 2005; Meaney et al., 2013; Nichol et al., 2008, 2010; Valenzuela et al., 2005; Wik et al., 2005). For many reasons, EMS providers (and other health care professionals) struggle to consistently deliver high-quality CPR. One factor is the relative lack of experience that EMS providers may have in field resuscitation. Depending on the EMS call volume and acuity, some EMS providers may not provide CPR frequently enough to maintain the necessary psychomotor skills. This holds especially true for pediatric resuscitations, which are less common than adult resuscitations (Atkins et al., 2009). Current guidelines require CPR recertification every 2 years, during which time rescuers often lose resuscitation skill proficiency, especially for pediatric resuscitation skills (Assar et al., 1998; Berden et al., 1993; Su et al., 2000). The lack of team practice for EMS providers may also contribute to lower CPR quality in high-stress and uncontrolled environments.

High-quality CPR is CPR that meets performance standards along a number of fundamental measures identified as clinically relevant in national and international guidelines. *High-performance* CPR emphasizes the importance of team-related factors (e.g., communication, collaboration, teamwork, and leadership) in attaining high-quality CPR, as well as other aspects of performance that affect patient outcomes. Although the scientific literature is inconsistent in its use of these terms, the committee believes this distinction is useful for highlighting the different skillsets requisite to the performance of effective CPR. Optimally, these two concepts will be employed in tandem by any resuscitation team.

Standards for high-quality CPR are available (Meaney et al., 2013a) and include details regarding chest compression fraction (i.e., the proportion of time in which CPR is being performed during cardiac resuscitation), compression rates, length of time between compressions, chest wall recoil, and ventilation parameters—each of which has been independently associated with improved survival rates and outcomes (Aufderheide and Lurie, 2004; Aufderheide et al., 2005; Edelson et al., 2006; Fried et al., 2011; Idris et al., 2012; McInnes et al., 2011; O'Neill and Deakin, 2007; Stiell et al., 2012; Yannopoulos et al., 2005; Yu et al., 2002; Zuercher et al., 2010). Box 4-7 describes key findings specific to high-performance parameters and associated patient outcomes. The AHA recommends monitoring these parameters in order to ensure high-quality CPR (Meaney et al., 2013). Although these are discrete parameters, adjusting one may affect another in actual practice. For example, studies suggest that increasing chest compression rate can lead to decreased chest compression depth and decreased chest wall recoil (Nolan et al., 2012).

Implementation of high-quality CPR can help improve the quality of CPR delivered by EMS personnel, leading to improved cardiac arrest patient outcomes (Bobrow et al., 2013; Idris et al., 2012; Meaney et al., 2013; Monsieurs et al., 2012; Stiell et al., 2012; Travers et al., 2010). However, as described in Chapter 6, like with many aspects of health care, there is a large chasm between national guidelines and actual practice. Evidence indicates that, when measured with electronic devices, chest compressions infrequently meet the guidelines for high-performance CPR. In many cases, compressions are not continued for long enough periods of time during resuscitation attempts, and compressions that are administered are often measured as being too slow, too fast, or too shallow and having exceedingly long pauses around defibrillation attempts. Combined with ventilations that are too fast, all of these common errors can contribute to the poor cardiac arrest outcomes that are found in most communities (Aufderheide et al., 2005; Ko et al., 2005; Kramer-Johansen et al., 2006; Valenzuela et al., 2005).

BOX 4-7
Examples of Research Findings Relevant to Aspects of High-Performance CPR

Chest Compression Fraction: Results from a clinical study of OHCA resuscitations showed that lower chest compression fractions are associated with a decreased rate of ROSC and survival to hospital discharge (Christenson et al., 2009).

Compression Depth: In a study of 593 adult OHCA patients, Vadeboncoeur and colleagues (2014) found that the adjusted likelihood of survival increased by 29 percent and the likelihood of favorable functional outcomes increased by 30 percent for every 5 millimeters increase in compression depth (Vadeboncoeur et al., 2014).

Compression Rate: In a study of more than 3,000 adult OHCA patients, compression rate was found to be significantly associated with ROSC, but not survival to discharge. This study found that ROSC peaked at approximately 125 compressions per minute (Idris et al., 2012).

Compression Release Velocity: A study of more than 700 OHCAs showed that the chest compression release velocity—a measure of how fast the chest wall was released—was independently associated with improved survival (Bobrow et al., 2014).

Perishock Pause in Compressions: A study of 815 adult OHCA patients found that perishock pauses longer than 40 seconds in duration were associated with decreased odds of survival as compared to pauses less than 20 seconds in duration (Cheskes et al., 2011).

Ventilation Rate and Volume: Studies suggest that hyperventilation during CPR is common and can have an adverse effect on outcomes. In one study using animal models, six of seven animals who received 12 breaths per minute (BPM) survived, while only one of seven animals receiving 30 BPM survived (Aufderheide and Lurie, 2004). Another study found that hyperventilation occurred in each of 72 pediatric mock codes and that the mean ventilation rate of 40.8 breaths per minute was significantly higher than the AHA-recommended ventilation rate of 8-20 BPM (Niebauer et al., 2011).

One of the EMS system-level factors that can influence resuscitation quality and effectiveness is the number, training, and experience level of EMS providers who respond to a cardiac arrest. However, the manner in which these factors interact to affect performance and outcomes is not well understood. Some studies found no increase in CPR quality or patient survival among larger or more highly trained ambulance crews (Eschmann et al., 2010; Martin-Gill et al., 2010), while other studies suggest a benefit. For example, one study of more than 16,000 OHCAs found that, as compared to events for which five or six EMS personnel were present, events with seven or eight individuals on scene were associated with higher rates of survival to discharge (Warren et al., 2015). Another study found that OHCA patients treated by EMTs with 4 or more years of experience, or by paramedics with 1 or more years of experience, were more than twice as likely to survive to hospital discharge as were patients treated by less-experienced EMS personnel (Soo et al., 1999). Additional training also seems to affect outcomes in unexpected ways. One study found that crews with two paramedics were more error prone in simulations of cardiac arrests than crews comprising one paramedic and one EMT (Bayley et al., 2008). Another study found that intermediate, but not long-term outcomes, were improved by paramedic-administered ACLS treatments (Ma et al., 2007). Similarly, ACLS treatments did not improve outcomes among pediatric patients with OHCA (Pitetti et al., 2002). At the same time, CPR is a physically demanding psychomotor skill that requires focus and coordination to achieve high quality. Several well-trained EMS providers may be preferred in order to effectively deliver high-performance CPR, rapid defibrillation, and other EMS interventions for cardiac arrest. Without sufficient numbers of care providers, a person performing chest compressions may quickly fatigue, cease to deliver the optimal depth and rate of compressions, and begin leaning on the chest—all of which are associated with worse patient survival rates (Meaney et al., 2013). In some communities as many as eight EMS providers are dispatched to cardiac arrest calls in an effort to ensure the best possible care for each patient (Warren et al., 2015). Taken together, these studies suggest that both competency and composition of ambulance crews are important.

Technology and Treatments to Advance EMS Care

Advances in technology and treatments also hold promise for improving CPR quality and OHCA outcomes. Mechanical CPR devices may be a means of providing consistent, high-quality CPR when on-scene and prehospital transport conditions render manual CPR difficult, although concrete evidence supporting widespread adoption of such devices is lacking (Brooks et al., 2014). For example, one study found that during helicopter transport of OHCA patients, mechanical devices provided higher-quality CPR than did rescuers performing manual CPR (Gassler et al., 2015). Other studies have found that mechanical devices can improve CPR quality by decreasing the pauses in chest compressions and improving the depth and rate of chest compressions (Esibov et al., 2015; Tranberg et al., 2015). However, other studies have found no improvement in survival among patients treated with mechanical CPR devices as compared to trained rescuers (Perkins et al., 2015; Rubertsson et al., 2014). If a rescuer is unfamiliar with a mechanical CPR device, then improper use or delay can result, but this can be remedied through quality improvement activities (Levy et al., 2015).

Other technologies and treatments that may one day be employed by EMS systems to improve OHCA survival rates include thoracic impedance devices, active compression-decompression CPR, extracorporeal CPR, and post-arrest conditioning therapies. Thoracic impedance devices and active compression-decompression CPR were found in recent trials to significantly improve survival with good neurological status when used in concert (Aufderheide et al., 2011; Biondi-Zoccai et al., 2014; Fischer et al., 2014; Frascone et al., 2013; Wang et al., 2015), although a recent meta-analyses found no significant effect on ROSC or survival to hospital discharge among OHCA patients. Extracorporeal cardiopulmonary resuscitation may improve circulation to the brain and, thereby, improve outcomes from cardiac arrest. One study found that extracorporeal cardiopulmonary resuscitation used in conjunction with other experimental therapies significantly improved survival with favorable neurologic status (Sakamoto et al., 2014). Another trial found that OHCA patients treated with extracorporeal cardiopulmonary resuscitation had survival-to-discharge rates similar to IHCA patients receiving the same treatment (Wang et al., 2014). Finally, some post-arrest conditioning strategies have demonstrated the potential to improve cardiac arrest outcomes in animal models. For example, the use of a stutter-CPR protocol, alone or as part of a bundle of experimental treatments, improved neurologic and cardiac function after prolonged cardiac arrest in porcine models (Bartos et al., 2015; Segal et al., 2012). This raises questions about assumed limits on treatment futility, as described in Chapter 6.

The quality of cardiac arrest resuscitation can also be improved through training focused on cognitive knowledge acquisition, psychomotor skill proficiency, realistic scenarios, and team building. Debriefing after resuscitation can also improve CPR quality and team performance (Dine et al., 2008; Edelson et al., 2008; Sutton et al., 2012). As discussed in Chapter 5, teamwork and leadership skills in hospital settings are associated with improved resuscitation performance in both simulation studies as well as real clinical performance (Hunziker et al., 2011; Jankouskas et al., 2011). These findings, along with the growing evidence base, suggest that teamwork and leadership training should be a component of standardized EMS resuscitation courses and training programs (R. A. Berg et al., 2010). High-fidelity, hands-on simulation is another critical aspect of training that promotes functioning as a unit when responding to cardiac arrest in the field.

Basic CPR skills diminish rapidly following CPR training (Assar et al., 1998; Berden et al., 1993; Su et al., 2000). ACLS knowledge and skills may begin to deteriorate in less than 6 weeks after training (Bhanji et al., 2010; Smith et al., 2008; Young and King, 2000). BLS skills also deteriorate, but not as rapidly (Smith et al., 2008). As such, the conventional training paradigm, which includes formal training every 2 years, may be insufficient for some providers without additional opportunities to maintain CPR skills through practice between these official training intervals (Bhanji et al., 2010; Smith et al., 2008). Evolving education and training trends are moving toward a more competency-based approach to resuscitation education with continuous maintenance, as opposed to the traditional time-set certification standards (Bhanji et al., 2010). A potential best practice may include frequent but brief, realistic team practices conducted in conjunction with debriefs from an expert objective observer. Efforts are needed to establish a standardized training curriculum for high-performance CPR, and this curriculum needs to be included as part of basic EMT training and certification. These standards need to be developed in tandem with ongoing research into novel training methods and optimal resuscitation protocols.

Another potential strategy for maintaining and developing resuscitation skillsets is the development of training centers of excellence for EMS personnel. By providing first responders, EMTs, and paramedics with access to sophisticated educational tools and exercises not commonly available outside major medical centers (e.g., high-fidelity manikins and simulation-based training), these centers could improve CPR quality and other aspects of emergency medical care provided by EMS agencies. These centers could also introduce EMS personnel to emerging technologies and therapies, potentially speeding the translation of novel treatments to the patient. Additionally, training centers designed to optimize the resuscitation skillsets of EMS personnel could form mutually informative relationships with NHTSA-recommended Centers of Excellence for EMS Research (NHTSA, 2015d). Although EMS training centers and institutes exist, they vary considerably in their educational resources and offerings and rarely or infrequently offer programming beyond EMT or paramedic certification and continuing education courses.

Institute Systematic Continuous Quality Improvement

Systematic CQI initiatives have been used to elevate outcomes across numerous health care settings and diseases and health conditions. CQI principles can also be transferred and applied equally to cardiac arrest resuscitation and care (Jollis et al., 2012; Nestler et al., 2009; Santana and Stelfox, 2012). At the micro level, CQI information can be used to help EMS personnel maintain and sustain performance standards, such as those discussed for dispatcher-assisted CPR and high-performance CPR. At the macro level, local and state EMS systems need to examine and disseminate overall system performance data to identify areas for improvement and adopt new processes, training, and care protocols.

The AHA has issued a consensus statement on CPR quality recommending that every EMS system "should have an ongoing CPR QI program that provides feedback to the director, managers, and providers" (Meaney et al., 2013, p. 9). Furthermore, the AHA recommended that EMS systems develop CQI programs that monitor and assess CPR performance on a system and individual provider basis. These data could be reviewed on a regular basis to identify deficiencies and improvements, review select cases, and implement improvement plans. This type of continuous and iterative cycle of assessment and improvement efforts can lead to better care and outcomes (Edelson et al., 2008; Fischer et al., 2011b). Without such a continuous process, EMS providers cannot adequately measure and correct performance in order to improve survival.

The AHA recommends that CPR quality be monitored for all resuscitation attempts both inside and outside the hospital setting (Meaney et al., 2013). Monitoring prehospital CPR quality is feasible and effective through numerous techniques, such as electronic measurement devices, metronomes, or written checklists. Despite these guideline recommendations, which are endorsed by ACEP, many EMS systems do not consistently monitor CPR quality. As a result, wide variation persists in CPR quality. EMS systems that have implemented strategies to improve the quality of EMT-provided CPR have documented substantial improvements in both CPR quality and survival rates (Bobrow et al., 2013; Rea et al., 2006).

Guidelines also recommend that EMS providers monitor the patient's physiological response to CPR. Specifically, direct and indirect measures of cardiac output (e.g., arterial diastolic pressure, end-tidal CO_2) can be assessed to determine the effectiveness of CPR and can allow rescuers to alter their performance and adapt protocols to meet physiological targets associated with successful resuscitation (Meaney et al., 2013). Coronary perfusion pressure is another important measure of cardiac output and has been associated with ROSC and survival. Although the invasive procedure required to measure coronary perfusion pressure is not traditionally performed in the prehospital setting, recent studies suggest that it can be feasibly adapted for field use (Manning, 2013; Wildner et al., 2011). The 2011 NHTSA survey found that 21 out of 49 states reported having a performance improvement plan or guidelines in place that were mandatory for local EMS systems, but only 17 states reported having the capacity to actually monitor local EMS system response time data (FICEMS, 2012, pp. 309, 418).[20] By providing EMS agencies and systems with the capacity to collect, store, and analyze performance and outcome data, cardiac arrest registries can help correct this discrepancy between the intent and ability of EMS systems to implement CQI programs, and potentially improve EMS performance and patient outcomes.

A Culture of Excellence Through Leadership and Accountability

Culture is "the norms, attitudes, and beliefs held among a group of people" (Kabcenell and Luther, 2012, p. 68). Cultural change begins with a "constancy of purpose," wherein engaged members of an organization develop and communicate a clear vision for their performance while engaging a wide range of relevant stakeholders, which then leads to action and change (Kabcenell and Luther, 2012). Leaders can promote changes and improvements by establishing infrastructures and policies that support training, facilitate engagement, encourage the development and use of information systems, create mechanisms to ensure accountability, and recognize performance that meets defined standards or benchmarks. For example, specific EMS systems have been able to shift attitudes and promote changes in culture through a range of initiatives that have also

[20] NASEMSO Survey Question: "Does your State have a performance improvement plan or guideline which is required to be implemented within each EMS Agency?" and "Does your State monitor EMS Response times at the local EMS Agency level?"

been used to reduce deaths and disability from cardiac arrest. In some ways, these cultural shifts have been built on the belief that the system should do everything possible to save *every* cardiac arrest patient within the jurisdiction of the system. In these systems, attitude changes have also been supported by implementing recognition programs for performance and outstanding work by individual providers within the system. Furthermore, the providers within these systems are given opportunities to meet cardiac arrest survivors in person, which can personalize resuscitation efforts.

A culture of excellence requires continuous and coordinated leadership across all levels. Because of the diffuse oversight structure for EMS systems, requisite leadership stems from federal agencies, elected representatives, state health departments and medical directors, voluntary professional organizations, and local EMS systems. Leaders across these levels must recognize and support the interdependence between and within the links of the chain of survival—the basis for the team approach to cardiac resuscitation. EMS leadership needs to actively engage all levels of personnel and providers in order to jointly develop and continuously refine protocols and to share data in a multidirectional fashion for purposes of CQI. Figure 4-3 develops the concept of a "chain of survival" first depicted in the executive summary by recognizing the role that leadership, accountability, and a culture of excellence play in promoting the high-quality performance of EMS systems.

State medical directors play a crucial role in contributing to high-functioning EMS systems—a prerequisite for quality care and patient safety (NASEMSO, 2010) However, lack of standardization in experience, training, and assigned responsibilities for state medical directors contributes to large variation in leadership across states. In response, NASEMSO produced a joint statement with ACEP and NAEMSP recommending a minimum set of responsibilities that include the implementation of CQI programs in EMS systems and training requirements for state medical directors. To help enact these recommendations, many federal funding sources include medical direction among their allowable expenditures (Cunningham et al., 2010). Similarly, FICEMS has recommended that state-level EMS systems should be required to have state EMS medical directors as a condition for receiving grants from the federal government (Cunningham et al., 2010). State medical directors

FIGURE 4-3 The enhanced chain of survival.
NOTE: ACLS = advanced cardiac life support; CPR = cardiopulmonary resuscitation.
SOURCE: Resuscitation Academy, 2014.

are key to implementing evidence-based EMS programs, such as high-performance CPR and dispatcher-assisted CPR, and in establishing accountability for local EMS performance and health outcomes, including cardiac arrest survival and outcomes.

Local medical directors have an enormous impact on the culture and performance of individual EMS agencies. In addition to providing on-scene medical direction, they are responsible for setting practice protocols, training and assessing personnel, educating the public, and integrating EMS with other health services (Alonso-Serra et al., 1998). Although medical director responsibility varies among EMS agencies, greater involvement on the part of the medical director has been found to enhance EMS readiness: agencies with response policies in place for handling cardiac arrests and other acute cardiovascular events are more likely to have paid, full-time medical directors who interact frequently with EMS personnel (Greer et al., 2013). Despite this connection, one study reported that less than half of EMT-Bs had interacted with their medical director in the past 6 months and that personnel in rural EMS agencies were significantly less likely to have recently interacted with a medical director than their counterparts in urban agencies (Studnek et al., 2009b). In fact, rural EMS agencies have more difficulty recruiting medical directors, and the directors they do hire are less likely to be trained in emergency medicine or to provide educational support to EMS personnel (Slifkin et al., 2009). In acknowledgment of these and other findings, ACEP, National Association of EMTs, and NAEMSP have all stated that physician medical direction must be available at the local level (ACEP, 2012b; Alonso-Serra et al., 1998; NAEMT, 2010).

The potentially fatal and time-critical nature of cardiac arrest makes team coordination and communication simultaneously more important and more difficult to achieve (Norris and Lockey, 2012). Within teams of EMS providers, the team leader must be capable of supporting effective communication across the team members, as well as coordinating individual efforts through the organization and assignment of tasks and roles. However, in a multinational study of EMTs and paramedics, a general need for leadership training was expressed (Leggio, 2014). A highly competent resuscitation team may require only limited coordination and observations from a team leader, whereas a newly organized or less experienced team may require more intensive and specific direction. Through coordination and guidance, appropriate resuscitation team leadership can limit unnecessary interruptions in chest compressions. In these circumstances, team leaders can help minimize the number of people involved in secondary activities (e.g., trouble-shooting devices, analyzing cardiac rhythms, and securing the patient to a gurney) and ensure that the majority of the team remains directly involved in hands-on patient care (Tschan et al., 2011). Because resuscitations are dynamic events in which the status and needs of the patient fluctuate, leaders and team members must be adaptable (Hunziker et al., 2011). Strong leaders also listen to and support team members, develop the skills of their personnel through feedback and debriefing, and encourage all members of the team to question leadership decisions (Norris and Lockey, 2012). In recognition of the need for more effective and substantial leadership training in existing BLS and ACLS courses, the AHA, the International Liaison Committee on Resuscitation, and the European Resuscitation Council have all recommended that these curricula incorporate training modules targeted to fostering leadership competencies in students.[21] Currently, content on team dynamics (e.g., communication and roles) is included in AHA training materials for ACLS—but not BLS—providers.

[21]In recognition of the roles that teamwork and leadership play in the performance of resuscitation teams, the AHA recommends the incorporation of training in these nontechnical skills into ACLS coursework (Bhanji et al., 2010). ERC recommends an increased emphasis on nontechnical skills, including leadership, teamwork, task management, and structured communication. Training in these skills should be included in the coursework for advanced-level training (Nolan et al., 2010). ILCOR recommends the inclusion of specific training in teamwork and leadership skills within advanced life support courses (Mancini et al., 2010).

CONCLUSION

In general, national EMS system oversight contributes to fragmentation, an absence of systemwide coordination and planning, and suboptimal federal, state, and local leadership and accountability related to cardiac arrest. Yet, the success of a handful of communities at improving patient outcomes through high-quality EMS care shows that these barriers can be overcome. Doing so will require EMS organizations and leaders that are accountable, motivated to excel, and dedicated to improving survival from cardiac arrest. Immediate opportunities exist to markedly enhance OHCA outcomes by improving the delivery and measurement of effective prehospital cardiac arrest treatments. Dispatcher-assisted CPR is an effective means for promoting bystander CPR and AED use, which are associated with better outcomes. Educating and training EMS providers to effectively use high-performance CPR can help improve the quality of CPR and increase the likelihood of survival with good neurologic outcomes. Systematic CQI programs are used in other health-related settings to improve patient health and quality of care, and the principles can be applied equally to EMS system response to arrest. CQI programs can be implemented today, without substantial investments in infrastructure or advances in medical treatments and technology.

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In-Hospital Cardiac Arrest and Post-Arrest Care

Hospitals play a vital role in providing optimal care for all cardiac arrest patients, regardless of whether a patient suffers an in-hospital cardiac arrest (IHCA) or an out-of-hospital cardiac arrest (OHCA). Survival-to-discharge rates and the likelihood of good neurologic outcomes and functional status following cardiac arrest vary substantially between OHCA and IHCA. These disparities are based on various factors, including the predominant etiologies of IHCA and OHCA, the affected patient populations and related comorbidities, the proximity to trained providers and appropriate treatments, and the number of transitions that must occur between various providers, such as emergency medical services (EMS) professionals and hospital staff. There are also significant differences in outcomes among patients who experience an IHCA and require immediate resuscitation and life support treatments. These differences can be influenced by the quality of hospital personnel training, adherence to evidence-based protocols, the implementation of internal quality control mechanisms, as well as other important factors.

Despite the differences in the onset of, and system response to, IHCA and OHCA, most patients who experience return of spontaneous circulation (ROSC) share one common experience—post-arrest care—which most frequently occurs within a hospital setting. The fundamental goal of post-arrest care is to identify and control factors that precipitated the arrest, improve the probability of favorable neurologic recovery and outcomes, and minimize the consequences of cardiac arrest–associated injury and tissue damage. Additionally, post-arrest care focuses on providing a timely and accurate prognosis for neurologic recovery and managing multisystem organ failure. Studies have demonstrated that when coordinated, high-quality, and comprehensive post-resuscitation care is provided, survival-to-hospital discharge with favorable neurologic outcome can be dramatically increased (Knafelj et al., 2007; Sunde et al., 2007). However, patient outcomes are limited by the availability of comprehensive treatments and therapies, lack of a system that ensures well-coordinated transitions of care between providers, and variability in quality of care across institutions. These failures by health care systems and hospitals represent an important national health care issue.

Previous chapters described OHCA, and the role of the public and emergency medical service in providing resuscitation care. This chapter focuses on all aspects of hospital-based resuscitation systems of care, from the individual patient's arrival through discharge. It provides an overview of the transitions of care that occur between the prehospital and hospital setting, as well as within hospitals. The chapter then describes the unique aspects of IHCA, evaluates current resuscitation strategies, and identifies known gaps in knowledge. Next, the current state of post-arrest care in the United States is examined, and available treatment options and assessment tools, as well as the deficiencies in care delivery, are discussed. This section also identifies current best practices that have resulted in favorable clinical outcomes, taking into consideration the existing limitations in evidence within the post-arrest care field. Finally, the chapter ties together common themes across resuscitation care settings and proposes strategies aimed toward improving the quality of care for all cardiac arrest patients within hospitals across the nation. The discussion will include care for adult and pediatric populations because the principles used for assessing, monitoring, providing feedback, and ensuring quality are the same.

TRANSITION OF CARE IN CARDIAC ARREST RESUSCITATION SYSTEMS

Transitions of care occur as patients move between different health care providers and departments and are fundamental components of managing care for patients who initially survive cardiac arrest. Although care transitions from the hospital setting to the outpatient setting (following discharge) have been studied more rigorously than care transitions from the prehospital EMS setting to the hospital emergency department, or between hospital wards, the literature largely finds that a number of patient safety and quality deficiencies arise during transitions of care (Coleman and Berenson, 2004; Halasyamani et al., 2006; Snow et al., 2009). The handoff between providers or care teams can increase adverse events through medication errors, incomplete communication of relevant patient medical history affecting treatments, or lack of appropriate follow-up care (Coleman et al., 2006; Cook et al., 2000; Moore et al., 2003). Studies on the effect of hospital-based care transitions on patient outcomes in the cardiac arrest setting are limited (see Chapter 4 for an in-depth discussion of care transitions from EMS to hospital); much of the following discussion is based on extrapolations of studies done in relevant emergency care settings.

Figure 5-1 illustrates the complex care pathway for cardiac arrest patients. The initial OHCA pathway may involve prehospital responses from bystanders and EMS personnel to the emergency department (ED) care teams. Post-arrest care (e.g., therapeutic hypothermia) for OHCA patients can be initiated prior to arrival in the ED. Therefore, adequate communication between ambulatory care physicians and EMS or hospital physicians is essential for ensuring delivery of continuous, high-quality care (Snow et al., 2009). For cardiac arrest patients, important clinical information should include the patient's clinical history and standardized EMS data (e.g., the location of the arrest, the time from collapse to initiation of cardiopulmonary resuscitation [CPR], initial cardiac rhythm, and administered drugs). As discussed in Chapter 2, establishing a standardized data template for EMS and hospital systems is vital to ensure that clinical decisions requiring timely assessments and implementation occur rapidly and that critical care services are then initiated quickly. Additionally, providers and care teams across multiple settings need to communicate effectively and have access to complete clinical information to be able to make appropriate decisions regarding post-arrest care for individual patients.

Within hospitals, resuscitation teams initially evaluate and manage IHCA patients in various nonintensive care areas. Similar to OHCA, IHCA patients who achieve ROSC and are stabilized should be transported to an intensive care unit (ICU) or critical care unit (CCU), and require timely decisions about subsequent post-arrest treatments and care. Hospital transition protocols and communication infrastructure should be in place to ensure that important information regarding cardiac arrest patients be relayed efficiently and seamlessly among health care providers who work in different teams and units. Post-arrest care for patients within, and subsequently transitioning out of, the ICU into

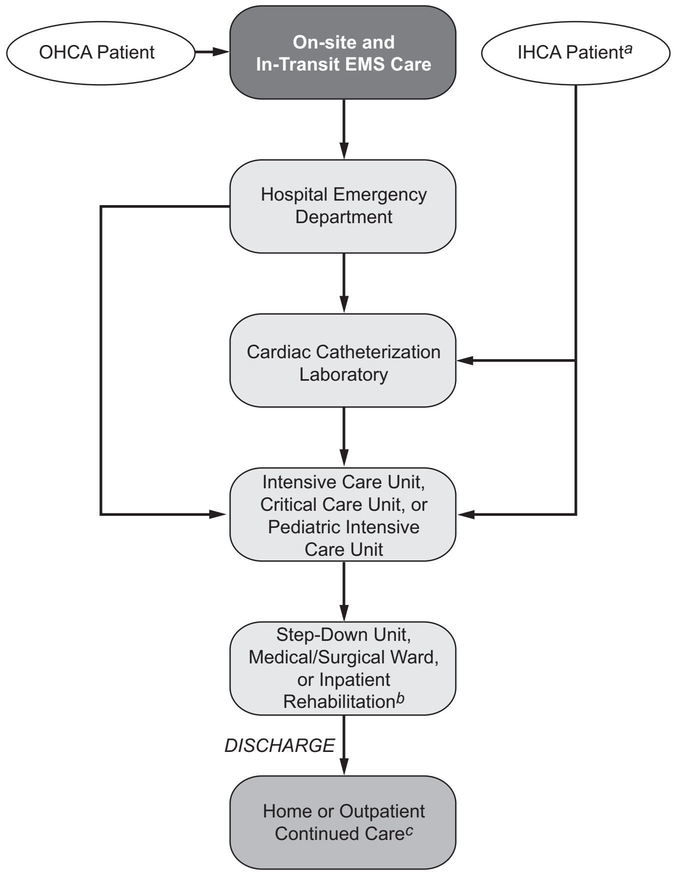

FIGURE 5-1 Transition of care for cardiac arrest patients who survive to hospital discharge.

[a]IHCA care pathway can begin at any location within the hospital (e.g., emergency department, cardiac catheterization laboratory, intensive care unit, medical/surgical wards).

[b]The location of step-down recovery varies across hospitals.

[c]Outpatient continued care can be received in rehabilitation units and skilled nursing facilities, as well as home nursing care and hospice care. Patients who survive to discharge with favorable neurologic and functional outcomes recover at home.

NOTES: Post-arrest treatments can begin at any point in this pathway, once patients achieve return of spontaneous circulation following an out-of-hospital cardiac arrest (OHCA) or an in-hospital cardiac arrest (IHCA). EMS = emergency medical services.

hospital-based step-down units is similar for both OHCA and IHCA survivors, and requires care pathways that are individualized to the needs and preferences of the patient. Care focuses on continued rehabilitation and neurologic recovery, therapy focused on prevention of recurrent events (e.g., management of heart failure and myocardial ischemia burdens and placement of implantable cardioverter defibrillators to respond to future arrests), and comfort care, and requires additional coordination between multidisciplinary providers. Following hospital discharge, patients receive continued care in home-based or rehabilitation facilities.

Each of these transitions of care represents opportunities to improve care quality by reducing errors or miscommunication during handoffs. Successful transitions require the establishment of a communication infrastructure to relay important clinical information between providers and departments in an efficient and effective manner, so that critical data are not lost and the care is not compromised in any way (Snow et al., 2009). Thus, emphasis on transitions of care is a good first step to ensure that patients are receiving the care they need in a continuous manner across sites of care.

IN-HOSPITAL CARDIAC ARREST

Approximately 200,000 cases of IHCA (Merchant et al., 2011) are reported in adults, and another 6,000 IHCA cases occur in children each year, representing a major patient safety and public health concern in the United States (Chan et al., 2010; Morrison et al., 2013; Nadkarni et al., 2006). Although survival rates following IHCA have improved over the past decade, currently, approximately half of all adult patients achieve ROSC following an IHCA, and less than one-quarter survive to hospital discharge (Chan, 2015; Girotra, 2012). IHCA outcomes are somewhat better for children, with 43 percent surviving to hospital discharge in 2009 (Girotra et al., 2013). These limited outcomes occur despite a substantial amount of resources that are devoted to the management and care of IHCA patients each year. Recent studies assessing trends in the Get With The Guidelines-Resuscitation (GWTG-R) registry database have found improvements in patient outcomes; the rates of clinically significant neurologic disability (defined as a Cerebral Performance Category [CPC] score >1) decreased (33 to 28 percent) among survivors (Girotra et al., 2012), while survival rates increased from 16 to 24 percent between 2000 and 2013 (Chan, 2015). While this increase in IHCA survival could be partially due to Hawthorne effects within participating hospitals, or reflect a positive shift in population health, it likely also represents improvements in resuscitation treatments and care.

This section focuses on several unique aspects of IHCA that distinguish it from OHCA. IHCA, in many ways, is a different clinical condition that affects a unique population subset, possibly with more severe illness or comorbidities that can influence treatment strategies and outcomes. This section describes IHCA epidemiology, incidence, and outcomes. It then reviews the current state of evidence regarding hospitals' approaches to managing and treating IHCA, and describes recent shifts in evidence related to teamwork and leadership efforts on resuscitation teams, along with advances in quality improvement tools and technology.

Epidemiology

Although the basic cardiac arrest rhythms and pathophysiology are similar for OHCA and IHCA, their underlying causes can be markedly different. First, approximately 90 percent of OHCAs are of cardiac etiology and occur unexpectedly (Daya et al., 2015). Conversely, IHCA is usually caused by underlying cardiac conditions less than half of the time, and patients often have demonstrable deterioration prior to the event (Chan, 2015; Morrison et al., 2013). The proportions of presenting arrhythmias and corresponding survival rates for OHCA and IHCA also differ, as shown in Table 5-1. The percent of IHCAs that present with pulseless electrical activity (PEA) is more than double that for OHCA, and asystole accounts for approximately 30 percent more cases of OHCAs than IHCAs. Because ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) (i.e., shockable rhythms) that are left untreated for several minutes after onset can degenerate into asystole, it is reasonable to suggest that a higher percentage of OHCAs are initiated by shockable rhythms, which transition to asystole. These factors are associated with marked differences in survival rates by arrhythmias and event location.

Typically, IHCA patients also have more secondary comorbidities and additional acute disease processes, which affect overall health outcomes and recovery following cardiac arrest. Additionally, response times to IHCA compared to OHCA are generally shorter, and the arrests are frequently witnessed, which leads to decreased ischemic burden time (i.e., the time between the onset of the arrest and ROSC). Faster ROSC may reduce the risk, duration, and severity of the post-arrest syndrome.

TABLE 5-1 Percentage of Presenting Arrhythmias and Survival to Discharge for IHCA and OHCA

	IHCA		OHCA	
Presenting Arrhythmia	Percent of Total Cardiac Arrests	Percent Survive to Discharge	Percent of Total Cardiac Arrests	Percent Survive to Discharge
VF/VT (shockable)	17.4	32.6	20.5	30
Asystole (unshockable)	28	2.3	49.4	2.3
PEA (unshockable)	54.3	44.3	24.1	10.7
Other	Not reported	Not reported	4.5	46.4

NOTES: The table is created based on two separate studies; proportions therefore do not add up to 100. PEA = pulseless electrical activity; pVT = pulseless ventricular tachycardia; VF = ventricular fibrillation.
SOURCES: Chan, 2015; Daya et al., 2015

Finally, the types of treatments available to OHCA and IHCA patients are similar, but they have been variably studied across the conditions (e.g., therapeutic hypothermia).

Incidence and Outcomes of Pediatric IHCA

Among children, there are substantial differences between IHCA and OHCA, which plays a major role in their care and outcomes. Most children who experience IHCA have an underlying health condition; 61 percent of children experience respiratory failure prior to the event and 29 percent experience shock (Nadkarni et al., 2006; Reis et al., 2002). These underlying illnesses greatly affect post-arrest management.

Infants and children who suffer arrest from respiratory insufficiency often have preceding prolonged periods of increasing hypotension, hypoxia, and acidosis, resulting in extensive asphyxial end-organ damage (Nadkarni et al., 2006). Patients with congenital heart disease often suffer arrest in the post-operative period, and the altered hemodynamics from unique anatomy and physiology complicated by the consequences of prolonged cardiopulmonary bypass require distinctive care protocols. Examples include patients with single-ventricle physiology or pulmonary artery hypertension. Asystole and PEA are the most frequent initial rhythms observed in IHCA pediatric patients, constituting 85 percent of all arrests, while VF and pVT constitutes 15 percent of all arrests (Girotra et al., 2013). Neonates, especially those in the delivery room, require separate expertise and protocols.

Pediatric outcomes following IHCA, in a select group of hospitals, have improved over the past several decades. The unadjusted survival-to-discharge rate increased from 14.3 percent in 2000 to 43.4 percent in 2009 (Girotra et al., 2012). These improvements have been largely due to improvement in acute resuscitation survival, defined as ROSC for at least 20 minutes, from 43 percent to 81 percent. Encouragingly the number of pediatric survivors with favorable neurologic outcomes is also increasing (Girotra et al., 2013).

Disparities in Incidence and Outcomes of IHCA

There is a paucity of reliable and valid data and subsequently limited studies of IHCA incidence and outcomes among racial and ethnic minority populations. As discussed in Chapter 2, several studies of IHCA have noted disparate outcomes among African American and Hispanic populations, compared to that for white patients. According to the committee's commissioned analysis of GWTG-R data, African American patients were significantly less likely to survive to hospital discharge than were white patients following an IHCA (20.8 percent survival compared to 25.9 percent, respectively) (Chan, 2015). One study found that the disparate outcomes can be partially accounted for by differences in the proportion of shockable initial cardiac rhythm; African American and Hispanic patients had a shockable rhythm 17 and 21 percent of the time, respectively, compared to white patients who had a shockable rhythm 27 percent of the time (Meaney et al., 2010).

The increased IHCA incidence among racial and ethnic minority populations may be due, in part, to differences in socioeconomic factors or individual characteristics, but could also potentially be caused by elements of the health care system. One study found greater delays in time to defibrillation for African American patients compared to white patients (Chan et al., 2008). The same study also noted delayed defibrillation for Hispanic patients; however, these results were not statistically significant. Following arrest, studies have found that African Americans have longer lengths of stay in EDs compared to patients of other races and ethnicities. These longer lengths of stay are associated with adverse outcomes in ICU patients. Adjustment for the hospital location explains a large portion of these IHCA differences. IHCA incidence appears to be highest, and likelihood of survival lower, in hospitals with higher proportions of African American patients compared to hospitals that serve predominantly white populations (Chan et al., 2009). Additionally, decision-support tools to predict IHCA outcomes do not accurately predict mortality in African American patients, which could have profound effects on treatment courses and outcomes. In order to reduce IHCA events and improve survival for all racial and ethnic groups, it is imperative to examine overall process and quality measures in hospitals with high rates of IHCAs. Findings from these reviews must then be used to inform changes in practice that elevate accountability and work toward better outcomes for all patients.

Numerous studies have documented notable variation in outcomes for IHCA across institutions. One study reported that risk-adjusted survival rates varied from 12.4 percent in the bottom decile of hospitals to 22.7 percent in the top decile of hospitals included in the GWTG-R registry (Merchant et al., 2011). Similar variation across hospitals exists for pediatric IHCA survival rates as well, ranging from unadjusted rates of 29 to 48 percent (Jayaram et al., 2014). Differences in patient and health system characteristics can account for some of this variation. There are also additional limitations in availability of reliable, standardized IHCA data that make measurement and interpretation of patient outcomes challenging, described in the following section.

Challenges of Measuring Incidence and Outcomes

Determining accurate IHCA incidence has been challenging because of a lack of standardized definitions and robust surveillance data (see Chapter 2). Different approaches for calculating IHCA incidence have been used in the literature, ranging from counting the number of activations of a resuscitation team to the number of times that chest compressions or defibrillation are used in order to identify the numerator. However, because code teams are not always activated in critical care areas such as EDs, ICUs, or the operating room, counting these activations as a proxy for cardiac arrest can underestimate IHCA incidence (Morrison et al., 2013). Defining an appropriate at-risk population for the denominator of the incidence rates also has been variable, and questions exist about whether only individuals who experience a cardiac arrest after being admitted to the hospital should be counted or whether all visits to the hospital (e.g., those to the emergency department, outpatient clinic, procedure or operating rooms, long-term care units) should be included. Additionally, there is concern about variability in do-not-attempt-resuscitation (DNAR) status orders across hospitals and how these orders may affect reported incidence rates for IHCA.

A recent consensus document by the American Heart Association's (AHA's) recommended definition of IHCA incidence in admitted patients proposes a numerator that includes all patients who receive chest compressions and/or defibrillation, while the denominator reflects the total number of patients admitted to the hospital, including those in the ICUs and the operating and procedure rooms, along with their recovery areas (Morrison et al., 2013). The consensus document also recommended that patients with DNAR status be removed from both the numerator and the denominator. This could be particularly challenging for the denominator using currently available hospital claims data systems, because DNAR status is not routinely collected. This could change substantially with greater use of electronic health records.

The consensus document also suggests incidence of IHCA be reported separately by location for procedure or operating rooms, emergency department, and long-term care patients (Morrison et al., 2013). Patients in these areas often reflect unique clinical circumstances that differentiate them from the acute hospitalized patients and may not use the same hospital response systems. Within hospitals, patients who arrest in nonmonitored units and the ICU are often the least likely to survive to discharge (Chan, 2015). While the nonmonitored unit results are to be expected because of a lack of possible witnesses, factors such as severity of illness could explain the ICU findings.

Even with standardized definitions of incidence, detecting IHCA in administrative claims data can be an arduous task, because of the lack of a specific *International Classification of Diseases* (ICD) diagnostic code distinguishing it from other types of cardiac arrest (e.g., OHCA). There are also no diagnosis-related group (DRG) codes distinguishing IHCA and OHCA, although a DRG does exist for unexplained cardiac arrest. Subsequently, investigators have relied on a combination of algorithms (e.g., counting CPR or defibrillation and hospital admission rates) to calculate incidence, but these have not been clearly validated. The current barriers and potential opportunities for improving IHCA surveillance and identification are discussed later in this chapter.

The process of measuring IHCA outcomes shares many of the same challenges, such as determining the most appropriate patients for inclusion, and selecting an appropriate standard metric. Possible outcome metrics include ROSC for at least 20 minutes and survival to discharge. Other standardized outcomes, including 30-day or longer-term survival rates, neurologic outcome assessments and quality-of-life metrics or functional status assessments, are less frequently reported in the literature. However, these types of measures have not been widely incorporated into studies to date, because they require much greater effort to collect. As with incidence of IHCA, patient DNAR status and eligibility for resuscitation care affect the measurement of outcomes. The types of patients who undergo CPR and resuscitation care for IHCA may vary across hospitals and may significantly influence risk-adjusted survival rates across hospitals.

Hospital Response to IHCA

Cardiac arrest remains a largely unpredictable event that can happen at any time with outcomes that are highly dependent on rapid diagnosis and treatment. The nature of IHCA provides a number of challenges for hospitals and health care systems. For example, smaller facilities may have limited resources for 24-hour, on-site physician availability. Furthermore, many health care providers—including physicians with experience in medical specialties with a low rate of cardiac arrest—may lack the necessary experience and expertise to appropriately respond to an IHCA. A final factor that may affect IHCA outcomes is that most academic or teaching hospitals have historically relied on physicians-in-training (e.g., residents and fellows) to provide resuscitation care. Studies have shown that younger physicians and physicians-in-training may lack competence and confidence in the nontechnical skills, such as leadership and teamwork, required to respond to cardiac arrests (Hayes et al., 2007). Resuscitation teams may have limited opportunities to work together over time in emergency situations, frequently coming together on an ad hoc basis to respond to an IHCA. This approach is innately more stressful and requires greater levels of leadership and teamwork in order to successfully deliver resuscitation care.

Substantial variability in IHCA care delivery throughout the United States, which suggests an opportunity for improving IHCA care processes and closing gaps in care across hospitals. For example, one study determined that delayed defibrillation (defined as provision of defibrillation more than 2 minutes after the initial arrest) occurred in care for approximately 30 percent of patients and was associated with a significantly lower probability of surviving to hospital discharge after multivariable risk adjustment (Chan et al., 2008). Another study reported adjusted rates of delays in time to defibrillation that was nearly 25-fold (delayed defibrillation rates ranging from 2 to 51 percent) across hospitals for patients with VF and pVT cardiac arrests, likely because of differences in hospital-level factors (Chan et al., 2009; Merchant et al., 2009). More recently, Ornato and colleagues (2012) found system-based error rates during IHCA. Some errors identified include discrepancies in alerting hospital-wide resuscitation response, chest compressions, defibrillation, airway management, hyperventilation, medications, vascular access, leadership, protocol deviation, and equipment function problems (Abella et al., 2005; Donoghue et al., 2006; Ornato et al., 2012). Similar deficiencies, related to provision of incorrect compression rate and depth, delays to defibrillation and hyperventilation, have also been noted during IHCA resuscitation in children (Cheng et al., 2015a; McInnes et al., 2011; Sullivan et al., 2014; Sutton et al., 2009, 2013).

Overall IHCA incidence represents the patient burden of illness, the facility's ability to detect deterioration in patients and prevent the cardiac arrest from occuring, and the effectiveness of a faculty's resuscitation response system (Morrison et al., 2013). Hospitals and health care systems have developed a myriad of ways to evaluate and assess patients who suffer cardiac arrest using emergency response plans that are often tailored to their local resources. The following section first describes some of the standard responses used by hospitals across the nation in cardiac arrest care.

General Response

Individual hospitals have varying emergency response protocols and capacities for responding to cardiac arrests. With the exception of patients in CCUs, ICUs, and EDs, designated resuscitation teams are generally alerted to respond to an IHCA occurring anywhere within the hospital using a facility-wide activation system. Typically, team members provide immediate basic and advanced life support (CPR and defibrillation) before transferring patients who achieve ROSC to CCUs or cardiac catherization laboratories for continued diagnostic testing, advanced therapies, neurologic assessment, and post-arrest care. For patients who are deteriorating but have not yet experienced an IHCA, rapid response teams (RRTs), otherwise known as medical emergency teams (METs) in some hospitals, may be activated. These teams differ from resuscitation teams in that their purpose is to prevent an IHCA and not provide resuscitation, through quick evaluation and escalation of care as needed. Similar to resuscitation teams, the composition and organization of RRTs varies substantially across facilities. Box 5-1 describes some of the different types of response teams in the hospital, distinguishing between resuscitation teams and RRTs.

BOX 5-1
In-Hospital Cardiac Arrest Response Teams

Resuscitation Team (i.e., Emergency Code Team). Although The Joint Commission requires that staff be available to respond to the need for resuscitation, and be trained in the use of resuscitation equipment and techniques, it does not mandate the composition of the staff. Therefore code teams can include physicians, nurses, security personnel, respiratory therapists, pharmacists, and even social workers or clergy. Code teams usually have designated leaders, and members are trained in providing life support treatment. They must be available at all times to respond to codes (designated “blue” in some hospitals).

Rapid Response Teams (RRTs), also known as Medical Emergency Teams (METs) were established to respond to identified clinical deterioration in patients prior to the occurrence of a cardiac arrest (Morrison et al., 2013). They are separate and distinct from traditional resuscitation teams which typically respond upon IHCA recognition (AHRQ, 2014a; Thomas et al., 2007b). Team composition varies but includes combinations of physicians, advanced cardiac life support (ACLS)-trained nurses, respiratory therapists, and pharmacists. While resuscitation teams almost always include a physician, RRT teams may not include physicians and are frequently led by nurses. RRT teams are designed to avoid failure to rescue, which is typically associated with failures in planning, including assessments and treatment delivery; breakdown of communication between patients, family, and staff or among staff members; and failure to recognize early signs of deterioration. The evidence on the effectiveness of RRTs is mixed, although studies have found improved IHCA survival outside the ICU when RRT response is activated (Chan et al., 2010).

Pediatric RRT-METs are similar to adult teams, but consist of varying personnel (such as physicians, nurses, and respiratory therapists) with the special expertise of caring for acutely ill children (Sharek et al., 2007). They are designed to respond to the signs of deterioration prior to a cardiac arrest and have demonstrated limited success in reducing cardiac arrests outside the pediatric ICU or reducing mortality overall.

NOTE: The terms RRT and MET are used interchangeably in the published literature and across care facilities.

High-Functioning Resuscitation Teams in Hospitals

Hospital resuscitation teams are required to possess specific clinical skills and therefore, often include a respiratory therapist, critical care nurse, and a physician specializing in emergency or acute hospital care (Baxter et al., 2008). Training designed specifically for resuscitation teams is also common, and the content of these courses is mostly consistent across programs. Most training includes modules on CPR technique and ACLS medication protocols, identification and prevention, and the development of nontechnical skills such as communication, teamwork, leadership, and situational awareness (Baxter et al., 2008; Gordon et al., 2012; Jankouskas et al., 2011). One literature review identified common behaviors and attributes of existing resuscitation teams, such as mutual trust and respect among team members, adaptive leadership, open communication, and a shared conception among team members of the purpose of the team and their individual roles (Manser, 2009).

Guidelines from multiple professional organizations and scientific organizations highlight key resuscitation team components (see Table 5-2). The AHA and the International Liaison Committee on Resuscitation (ILCOR) recommend that all hospital resuscitation team programs must include components that detect cardiac arrests, trigger response mechanisms, monitor resuscitation team performance, and train resuscitation team members (Bhanji et al., 2010). These organizations have also recognized the importance of nontechnical training targeted to the development of team and leadership skills. ILCOR has developed a data reporting form that measures team performance along multiple, clinically relevant dimensions, including team composition, structure, coverage, activation, and interventions; the patient's physiological data prior to, and during, the resuscitation; and outcomes for both the patient and the hospital (Peberdy et al., 2007).

Recent AHA and UK Resuscitation Council consensus statements have recognized the importance of developing systems-based approaches to IHCA response (Morrison et al., 2013; Resuscitation Council, 2013). The European consensus statement recommends direct oversight by a resuscitation officer at the facility level and suggests that at least two physicians with advanced life support training are included on the teams, but otherwise, largely avoids commenting on the composition of the team. Recently, there has been an increased emphasis on the importance of nontechnical skills (e.g., leadership and communication) within the

TABLE 5-2 Key Abilities of Resuscitation Teams

Type of Skills	Key Abilities of Resuscitation Teams
Nontechnical skills	• Team Leader: This includes assigning team member roles, communicating with team members, prioritizing and directing team actions, maintaining situational awareness, providing clear instructions to team members concerning the resuscitation protocol, and displaying assertive behavior. • Team member: This includes adapting to a role within team, communicating and verbalizing, requesting help when necessary, engaging in team decision making, and providing patient information upon arrival of other resuscitation team members • General skills: Teams should possess morale and composure, communicate, cooperate, adapt to and anticipate clinical events, adhere to resuscitation protocols, correct for unnecessary handoff time, and manage tasks.
Technical skills	• Should be able to perform basic life support (BLS) and ACLS interventions according to guidelines. • Should have the ability to provide clinical assessment, intervene to secure airway, provide cardiovascular support, administer appropriate ACLS medication, use ACLS cards and other cognitive aids, and troubleshoot defibrillators and other devices.

resuscitation teams because of data demonstrating an association with improved outcomes, with these skills (Bhanji et al., 2010; Hunziker et al., 2011).

There is considerable variability in the implementation of these resuscitation teams. One study used data from a national survey of 439 hospitals from across the United States and found that nearly one-quarter of facilities failed to report having a pre-nontechnical designated, dedicated resuscitation team as part of their approach to IHCA response, while one-third did not have standardized defibrillators available throughout their facility (Edelson et al., 2014). Among those facilities that did have dedicated resuscitation teams, the composition, leadership roles, and structure of the teams also varied.

Overcoming these challenges has been the recent focus of small quality improvement efforts, many of which emphasize nontechnical skills in addition to core technical skills. In addition to overall leadership, the literature emphasizes the importance of identifying a team leader who is appropriately qualified and trained for this role (Hunziker et al., 2011). Ideally, facilities that have medical training programs should require that physicians in training be backed up by at least one attending physician whose specialty is hospital medicine, intensive care medicine, cardiovascular medicine, or emergency medicine. Teamwork also may be ensured prior to an emergency with a process that clearly delineates team member roles for health care providers who respond to a cardiac arrest. This could include the use of visual tools (e.g., lanyards and badges) and demarcation of positions around a patient (e.g., individual to the left of a patient would be responsible for delivering chest compressions). However, these approaches should never delay the necessary care for a patient experiencing a cardiac arrest. If a team member's arrival is delayed, then other team members must be prepared to fill in and take on other roles in responding to the IHCA.

Together, these sources describe a set of program components and team member actions and behaviors that clinicians and researchers alike consider to be associated with, or essential to, improved team performance and patient outcomes. Table 5-2 lists some of these attributes.

RRT or MET Instituting Earlier Recognition and Response to IHCA

Multiple studies suggest that health care providers often fail to detect changes or abnormalities in patient vital signs hours before an IHCA occurs. Family members or health care providers typically recognize IHCA when the patient has become acutely unresponsive or when an abnormal rhythm is noted on telemetry monitoring. As noted throughout the report, immediate action following collapse is believed to improve outcomes.

The idea of instituting earlier care builds on prior studies examining the use of RRTs (also referred to as METs in some facilities). Many hospitals have implemented RRTs and METs, although evidence demonstrating their effectiveness in improving overall survival rates remains controversial (Chan et al., 2010). In a report from Denmark, failure of RRTs to properly communicate and activate transitions of care for appropriate patients, was identified as a significant limitation. Similarly, several studies of pediatric RRT-MET teams, which are also triggered by the signs of deterioration prior to a cardiac arrest, have reported at best, modest success in reducing cardiac arrests outside the pediatric intensive care unit or reducing mortality overall (Bonafide et al., 2012a, 2014; Brilli et al., 2007; Hunt et al., 2008; Sharek et al., 2007; Tibballs and Kinney, 2009; Winberg et al., 2008). A major obstacle to demonstrating effectiveness of RRTs and METs is the low frequency of events overall, as well as a lack of a consensus on event definition.

Cardiac arrest investigators have also explored different methods for detecting deterioration prior to an IHCA using physiological data. Early recognition would allow for an escalation of care (e.g., transfer to ICU for patients on the general medical floor) prior to the event. Currently, multiple risk stratification tools for evaluating patients have been proposed, including the Modified Early Warning Score for adult and pediatric patients. These tools allow for the early assessment, prediction of IHCA, and possible ICU transfer based on vital signs (Ludikhuize et al., 2014). The Pediatric Early Warning Score (PEWS), first proposed in 2006, can provide more proximate outcome measures to identify deterioration in children in EDs and inpatient units and who were likely to need resuscitation (Duncan et al., 2006; Parshuram et al., 2011). The scores comprise multiple variables including vital signs, clinical assessment, and oxygen therapy, and they have been validated in multicenter studies with high sensitivity and specificity. Implementation of the score has been associated with reduction in clinical deterioration rates and emergency calls to the in-house pediatricians. Randhawa and colleagues (2011) found that cardiac arrest frequency was reduced by 23 percent after the implementation of a bedside PEWS tool. Studies have been performed recently in order to improve current systems by using additional information that is available through the electronic health record, such as clinical data and laboratory results (Churpek et al., 2014). Although such tools hold noteworthy promise, they are still in the early stages of development and implementation and have limitations regarding the generalizability for large-scale adoptions or specificity for IHCA.

Clinical deterioration risk scores that are based on non-vital sign criteria (e.g., age, presence of specific underlying disease, enteral tube, and hemoglobin levels) could also improve outcomes (Bonafide et al., 2012b, 2014; Winberg et al., 2008). Using clinical deterioration scores, combined with METs, the cost-benefit ratio of METs was positive, especially in hospitals with bundled reimbursement. Confirmation of these findings in a broader base of hospitals is needed to develop programs and responses to decrease cardiac arrest among hospitalized patients.

Research Priorities

Variability in the use of specific strategies and care processes and their links to patient outcomes has not been adequately studied to date. Box 5-2 presents the current gaps in evidence and points to future research needs.

POST-ARREST CARE

Post–cardiac arrest syndrome is a complex clinical condition with four primary pathophysiological consequences, which can include any combination of myocardial dysfunction, neurologic injury, systemic

BOX 5-2
Priority Areas for Research in In-Hospital Care

- **Transition of care:** Research needed to understand how to best optimize care transitions for cardiac arrest patients at admission, at discharge, and within hospitals, including key elements of the cardiac arrest that should be passed on to subsequent providers
- **Hospital resuscitation team structure and skill composition:** More research is needed to standardize team composition and technical and nontechnical skillsets and to evaluate the effectiveness of resuscitation teams in improving patient outcomes
- **Early detection of IHCA:** Research is needed to improve early warning scores and telemetry to improve use of METs teams
- **Standardize quality metrics for IHCA:** Define and select appropriate IHCA process and performance metrics
- **Long-term outcomes of IHCA:** Quality-of-life assessments, and patient utilization of health care resources after hospital discharge, should be evaluated
- **Advanced directives, DNAR, and care termination:** There is a need to understand how to best standardize and implement care decisions around advanced directives, DNAR and care termination, including education of patients and families
- **Disparities in IHCA:** Better data on race and ethnicity and socioeconomic factors are needed to identify high-risk populations and evaluate disparities in care and access to care

injury because of oxygen loss (ischemia) and subsequent restoration of blood flow (reperfusion), and other precipitating factors (e.g., secondary cardiovascular or pulmonary diseases and pneumonia) (Morrison et al., 2013; Neumar et al., 2008). Post-arrest care therefore focuses on rapidly assessing cardiac arrest patients who have achieved ROSC, optimizing cardiopulmonary function, stabilizing blood flow, minimizing neurologic injury, controlling body temperature, establishing mechanical ventilation to minimize lung injury, and conducting other related prognostication (Peberdy et al., 2010).

Neurologic injury is a concerning and destructive consequence of cardiac arrest affecting the likelihood of short- and long-term survival, disability, and quality of life. One study reported that neurologic injury was the primary cause of death among 68 percent and 23 percent of OHCA and IHCA patients, respectively (Laver et al., 2004; Peberdy et al., 2010). Thus, many interventions related to enhancing post-arrest care are targeted at improving neurologic outcomes. Post–cardiac arrest cardiovascular injury also affects patient outcomes; approximately 30 percent of all deaths among cardiac arrest patients who were initially resuscitated were caused by reduced blood flow. However, multiple studies based on swine models suggest that permanent damage to the left ventricle can be avoided in the immediate period following resuscitation (Kern et al., 1997a,b; Neumar et al., 2008). Thus, it is possible for an individual patient to make a complete cardiac recovery with appropriate hemodynamic support (Laurent et al., 2002; Nolan et al., 2008). Successful management of post–cardiac arrest syndrome requires the availability of well-equipped medical facilities and ICUs, resources, and treatments that can contribute to the rapid stabilization and minimization of tissue damage and organ injuries.

Treatment

Evaluation and treatment of the patient's immediate clinical condition and prognosis occur in parallel and involve a multidisciplinary team (including emergency and critical care providers, neurologists, cardiologists, nurses, laboratory technicians, and other specialists) that often provides simultaneous expertise and care. Optimal post-arrest treatment begins when the patient achieves ROSC and can begin prior to an OHCA patient's arrival in the hospital ED. The time interval between the onset of the cardiac arrest and ROSC is a critical determinant of the severity of the post–cardiac arrest syndrome. With the exception of cardiac arrests that occur in an ICU, IHCA patients generally have intermediate periods of time between collapse and resuscitation. Collapse-to-treatment times for OHCA patients can be longer and more variable depending on a host of factors (e.g., whether the arrest was witnessed, availability of bystander CPR and EMS response times), thus differentially exposing patients to the conditions that result in post–cardiac arrest syndrome. Patients who experience a brief collapse-to-treatment interval (e.g., an intentionally or inadvertently induced cardiac arrest occurring in a cardiac catheterization or electrophysiology laboratory during diagnostic testing) often do not develop post–cardiac arrest syndrome. Because the cardiovascular system is far more resilient than the neurologic system, patients who achieve ROSC in 5 to 10 minutes may have their hemodynamic status restored, but are more likely to sustain some degree of brain injury. With yet longer delays in ROSC, the likelihood and severity of post–cardiac arrest syndrome increases, and neurologic, hemodynamic and metabolic support all become necessary and more critical for possible recovery.

Studies of optimal post-arrest care are evolving, but there are some important gaps in the current evidence base because of several factors. There is a paucity of published literature on post-arrest care by multidisciplinary investigators, limited basic science research, and relatively few randomized clinical trials evaluating the effectiveness of known post-arrest care treatments. Often existing studies are less meaningful because of the small size of the population studied. There are additional gaps in evidence regarding long-term outcomes following post-arrest care. As a result of these limitations, the scientific evidence to support the therapies and care strategies offered for patients with post–cardiac arrest syndrome is less robust than that for the patients with other cardiovascular conditions such as acute myocardial infarction, often the precursor to cardiac arrest. However, a number of promising post-resuscitation treatments and therapies emerged over the past several decades and have demonstrated effectiveness in treating individual components of post–cardiac arrest syndrome in limited settings (Nolan et al., 2008).

Historically, the approach for treating post–cardiac arrest syndrome has been a one-size-fits-all strategy of care, with patients ideally receiving a range of available guideline-recommended treatments for a given clinical presentation whenever possible (e.g., therapeutic hypothermia and percutaneous coronary intervention), with the goal of mitigating neurologic injury. However, recent data have urged providers to customize post-arrest treatment protocol based on the neurologic and functional status of individual patients, which can range from the awake and stabilized to comatose patients with varying degrees of secondary clinical complications (Nolan et al., 2008; Rittenberger et al., 2011). This approach not only is beneficial to the individual patient, but also can reduce the cost of care. The goal of these therapies, described in Box 5-3, is to promote a full recovery and restore and preserve neurologic function.

Post-arrest care algorithms, supported by AHA guidelines, have proposed multidisciplinary early goal-directed therapy (EGDT) as part of an essential bundle of care to improve survival following cardiac arrest (Peberdy et al., 2010). The post-arrest patient may develop severe systemic inflammatory responses and septic shock syndromes that affect

BOX 5-3
Evidence on Common Treatments for Post-Arrest Syndrome

Targeted Temperature Management (TTM). TTM, also known as therapeutic hypothermia, is an early post-arrest intervention designed to reduce the body temperature in resuscitated, comatose cardiac arrest patients. The rationale is to slow pathophysiological events and biochemical pathways that cause cellular death and complete systemic injury. The original goal was to reduce temperature to 33°C, but recent data suggest that 36°C is sufficient and that the benefit might relate more to prevention of fever than to hypothermia itself. Although TTM has been endorsed by the AHA and ILCOR, the U.S. Food and Drug Administration concluded that existing data do not demonstrate unequivocal therapeutic benefit. The literature is inconclusive about optimal temperature and benefits for patients who present non-shockable initial rhythm. Further research into optimal target temperature and candidate selection is needed.

Special Considerations in Children. The use of therapeutic hypothermia in pediatric populations following cardiac arrest remains an unproven therapy. Studies in infants with birth asphyxia have shown better long-term neurologic outcomes following use of hypothermia (Eicher et al., 2005; Gluckman et al., 2005; Shankaran et al., 2005), but hypothermia in children with traumatic brain injuries appears to worsen outcomes (Hutchison et al., 2008). A multicenter trial of therapeutic hypothermia in children (Therapeutic Hypothermia After Pediatric Cardiac Arrest [THAPCA]) is ongoing.

Cardiovascular and Hemodynamic Management. Post-arrest care to mitigate ischemia or myocardial injury should differentiate between acute myocardial infarction (which can precede and trigger cardiac arrest) and pre-existing chronic myocardial dysfunction that creates

continued

long-term risk for cardiac arrest. Hemodynamic management is needed to improve the impaired pumping function of the heart after ROSC. This requires various medical and device therapies intended to improve blood pressure and blood flow. The optimal blood pressure target in post-arrest patients is unknown, because the relationship between optimal arterial pressure and tissue perfusion, oxygenation, or acidosis requires extensive study.

Cardiac Catheterization and Percutaneous Coronary Intervention (PCI). PCI is a procedure that uses a catheter to place a stent across a blocked artery to hold the artery open. It is most commonly used as a treatment for myocardial ischemia. The goal of cardiac catheterization and PCI is to relieve any potential coronary artery obstruction that contributed to the cardiac arrest, in order to improve immediate electrical and mechanical functions and mitigate the risk of re-arrest. In several observational studies, PCI has emerged as potentially one of the most important hospital-based interventions associated with favorable neurologic outcome. However, there is concern that early PCI may be underutilized in hospitals (Knafelj et al., 2007). This is particularly true in states requiring public reporting of outcomes (Joynt et al., 2012). It is recommended in professional guidelines, but the added benefits conferred by PCI and the associated risks specific to post–cardiac arrest patients with underlying comorbidities are difficult to assess and have not been evaluated in randomized clinical trials. In order to better evaluate the effectiveness of PCI as an intervention for cardiac arrest, encourage its use in these critical patients, and not distort the statistics of facilities that offer these high-risk services, mortality and morbidity laboratory statistics for the post–cardiac arrest patients should be reported separately from the general cardiac catheterization outcomes data. Some studies have found that providers are often reluctant to provide PCI for eligible patients because of concerns regarding public reporting of negative outcomes (Peberdy et al., 2013).

PCI and TTM Combination Therapy. Although the combined effect of PCI and TTM on neurologic outcomes has not been extensively studied, select medical centers report a 60 percent chance of survival to discharge, with 93 percent of patients having good neurologic function if they received a combination of these treatments (Kern, 2012). This combination has not been widely implemented across health care systems because of the limited scientific evidence, as well as the likelihood of poor outcomes for high-risk cardiac arrest patients.

Vasopressors for Hemodynamic Support. Vasopressor therapies, most commonly epinephrine, are used to facilitate the elevation of low blood pressure and have been the accepted standard of care for cardiac arrest patients without immediate ROSC and for post–cardiac arrest patients with compromised hemodynamics. Recent studies of epinephrine use in adults with OHCA demonstrated improvement in ROSC and survival to hospital admission, but not in survival to discharge or neurologic outcomes. One study found improved outcomes with vasopressin-steroids-epinephrine combination (Mentzelopoulos et al., 2013). One IHCA study found that longer dosing intervals in both shockable and nonshockable rhythms was associated with greater survival rates following cardiac arrest (Warren et al., 2014). Both animal and human studies suggest that vasopressors can diminish cardiac function by impairing myocardial metabolism. However, the use of epinephrine in patients who remain significantly hypotensive after ROSC may have great benefits, but more data are needed. Vasodilator therapies, which are used to reduce blood pressure, have shown some benefit in animal studies, but evidence in humans is lacking.

Special Considerations in Children. Myocardial dysfunction and vascular instability are common among children experiencing cardiac arrest (Checchia et al., 2003), and hypotension may be an independent risk factor for mortality after cardiac arrest (Topjian, 2014a). However, there are very limited data to guide physicians on optimal strategies for supporting pediatric cardiovascular systems following an arrest. Several drugs have been shown to improve blood pressure in low-cardiac output states following open-heart surgery (Hoffman et al., 2003), but it is unclear if any is superior or equivalent. Additionally, a randomized pediatric study demonstrated no survival benefit for high-dose epinephrine and potential increases in mortality (Perondi et al., 2004).

Emerging Hemodynamic Support Therapies. Extracorporeal Membrane Oxygenation (ECMO) and Femoral-Femoral cardiopulmonary bypass are two novel, but highly invasive, therapies that are currently used to support systemic circulation and allow the heart to recover and stabilize following a cardiac arrest (Chen et al., 2003). Although they have the potential to provide lifesaving benefit for some patients, because of known risk factors and a lack of robust clinical data to support their efficacy, these therapies have not yet been recommended for broad use in variable hospital settings. Additional research is needed to identify optimal strategies for providing hemodynamic support for post-arrest patients.

Special Considerations in Children. Data in children support use of hemodynamic support for those with cardiac disease when there is an appropriate ECMO team. But therapy is being widely used without definite documentation of benefit.

Oxygenation and Ventilation. Oxygenation and ventilation are designed to increase the amount of oxygen supplied to the body's vital organs

continued

and to avoid high fevers. Avoiding hyperventilation is important following a cardiac arrest, because reductions in the partial pressure of carbon dioxide will lead to reductions in cerebral blood flow, vasoconstriction, and potential worsening of any cerebral hypoxic-ischemic injury. Although most patients are intubated during the resuscitative effort, the immediate post-arrest care must also include appropriate monitoring of the airway, oxygenation, and ventilation. This requires the ability to do rapid diagnostic testing such as chest x-rays, blood sample testing, and point-of-care testing, and it may also require computed tomography (CT) scanning.

Special Considerations in Children. Increasing concerns exist about the deleterious effect of excessive oxygen in newborn infants during resuscitation (Davis et al., 2004; Kilgannon et al., 2011; Rabi et al., 2007). Inappropriate ventilation, especially hyperventilation, may reduce systemic and cerebral blood flow, leading to poor outcomes (Donoghue et al., 2006). Despite limited data, current guidelines recommend that 100 percent oxygen be used for resuscitation in children and that supplemental oxygen concentration be targeted to maintain an arterial oxygen saturation of greater than or equal to 94 percent, thus avoiding hypoventilation. However, these goals are infrequently achieved (Bennett, 2013).

Metabolic Management: Glucose Control. Cardiac arrest patients commonly experience hyperglycemia and require close monitoring of glucose levels (Nolan et al., 2008). Some studies have also noted a substantial increase in the incidence of hyperglycemia following hypothermia therapy (Cheung et al., 2006). By default, and based on inference from retrospective analyses, it is suggested that glucose levels post-arrest be maintained in the range of 150 mg/dl or less. Glucose control has been an area of considerable controversy, however, because even though it has been shown to be beneficial in select critical care situations (e.g., sepsis), it has not been uniformly applied to cardiac arrest patients. Moreover, it has not been tested in clinical trials.

Special Considerations in Children. Hypoglycemia and hyperglycemia are both frequently observed following cardiac arrest in children, and both are associated with increased mortality. However, a causal relationship has not been established (Beardsall et al., 2008; Vlasselaers et al., 2009). The few studies of targeted glucose management in critically ill infants or children report frequent hypoglycemia, but they suffer methodological problems and lack of continuous glucose monitoring.

ultimate disability-free survival to hospital discharge. A number of studies have demonstrated a dramatic reduction in mortality in cases of severe sepsis or shock using EGDT, an intervention aimed at maintaining optimal central venous pressure and oxygen saturation (Rivers et al., 2001). Because of the pathophysiological similarities between sepsis and post–cardiac arrest syndrome, EGDT has been adapted for post-arrest care to provide hemodynamic and oxygenation monitoring, in combination with intravenous medication (Nichol et al., 2010). However, based on two recent studies that found no survival benefit related to EGDT in septic shock states, further evaluation of EGDT for the post–cardiac arrest state is needed (Peake et al., 2014; Yealy et al., 2014).

The data to support specific goal-directed therapies for pediatric patients are generally of low quality. Many therapies from adult care, animal models, or different patient populations who are critically ill with conditions other than cardiac arrest have been extrapolated to pediatric populations (Kleinman et al., 2010b). Examples of goal-directed pediatric therapies derived from other sources include titration of inspired oxygen concentration and target saturation, glucose management, vasoactive drugs, and hypothermia (Checchia et al., 2003; Eicher et al., 2005; Finfer et al., 2007; Gandhi et al., 2007; Gluckman et al., 2005; Kern et al., 1997b; Oksanen et al., 2007; Richards et al., 2007; Vasquez et al., 2004; Wiener et al., 2008).

Personalized Medical Care for Cardiac Arrest

Current cardiac arrest care protocols are largely based on formulaic algorithms and guidelines that do not account for individual needs and variations. Differences in etiology, patient characteristics, and rescuer competency can all contribute to variations in AHA-recommended treatment protocols. Personalized medicine, which employs genetic sequencing and other advanced techniques to customize medical care to the needs of the individual patient, represents the final stage in this ongoing progression from generalized to specific health care. With the growth in the catalogue of genetic mutations correlated with specific disease processes, and the equally rapid drop in the cost of gene sequencing, tests to assess a patient's risk for conditions that can precipitate a cardiac arrest are proliferating (Rubinstein et al., 2013). Long QT syndrome, brugada syndrome, catecholaminergic polymorphic ventricular tachycardia, and hypertrophic cardiomyopathy are all recognized cardiac arrest risk factors that are also associated with one or more genetic mutations

(Ackerman et al., 2011). Tests for these mutations exist and are recommended by the Heart Rhythm Society in some instances. Most importantly, genome-wide association studies have identified at least 36 genetic variants associated with coronary artery disease, which is present in more than 80 percent of patients who die from cardiac arrest in the United States (Roberts and Stewart, 2012). As other genetic risk factors for cardiac arrest are identified, clinicians will increasingly be able to proactively prescribe antiarrhythmic drugs, place implantable cardioverter-defibrillators, and correct structural cardiac abnormalities through surgical intervention.

Customized medicine in the context of cardiac arrest can alter treatment protocols for individual patients based on results from physiological measurements. In contrast to generalized consensus-based guidelines, one approach to individualized resuscitation employs physiologically guided CPR that uses sensor measurements, such as coronary perfusion pressure, blood pressure parameters, or carbon dioxide excretion, to guide a unique resuscitation protocol for each patient (Sutton et al., 2013). As patient monitoring techniques become more precise, CPR protocols can be adapted in real time to the changing physiological status of the arresting patient. In a recent study assessing the efficacy of a dynamic, personalized CPR protocol in animal models, chest compression depth and vasopressor dosage were respectively titrated to systolic blood pressure and coronary perfusion pressure, in order to reach target blood pressure levels. This "patient-centric" CPR protocol was correlated with a significant 24-hour survival benefit over CPR performed according to the AHA guidelines (Sutton et al., 2014b). Another study found that the same experimental protocol improved 45-minute survival over two protocols that coupled the AHA-recommended pharmacological interventions with audiovisual feedback to meet predetermined targets for chest compression depth (Sutton et al., 2014b). These studies support recommendations for physiological monitoring of CPR during resuscitation, in cases where the monitoring systems are already in place (Meaney et al., 2013). As a majority of IHCAs now occur in ICUs, where such monitoring is often already in place, the transition to resuscitation protocols that monitor and adapt to patient vital signs will potentially benefit a large proportion of cardiac arrest patients (Berg et al., 2013; Girotra et al., 2012; Sutton et al., 2014a).

In additional to advances in treatment, new and more powerful diagnostic and prognostic tools allow clinicians to better tailor preventive and emergent care to the needs of the individual patient (Chan et al., 2012).

Highly sensitive imaging techniques such as cardiac magnetic resonance imaging (MRI) and cardiac CT tests can detect specific structural disorders that are known risk factors for cardiac arrest, allowing clinicians to employ preventative care efforts targeted to specific conditions (The Joint Commission, 2011). In post-arrest care, MRI-based imaging techniques provide sensitive and accurate methods of detecting brain lesions and other neurologic features that strongly correlate with poor neurologic outcomes (Choi et al., 2010; Galanaud and Puybasset, 2010; Wijman et al., 2009; Wu et al., 2009), while simple, bedside risk assessments allow for accurate predictions of long-term neurologic status (Chan et al., 2012).

As the list of known risk factors for cardiac arrest grows in tandem with the power of diagnostic tools, it will become easier to preventively treat patients for cardiac arrest, by addressing the specific conditions from which it precipitates. Thus, by fueling continuous refinements in the specificity of treatment protocols, diagnostic and prognostic tools, and preventive risk assessments, the drive to personalize and customize medicine may lead to improvements in cardiac arrest incidence and outcome.

Disparities in Post-Arrest Care

Currently, there is a paucity of literature that specifically examines questions about discrepancies in the application of post-arrest care treatments, leading to differences by gender, race, or ethnicity. The literature suggests that minority populations have not been studied as rigorously for potentially lifesaving therapies such as targeted temperature management (Hypothermia After Cardiac Arrest Study Group). Women were likely underrepresented in the TTM trials focused on patients with an initially shockable rhythm, because women are less likely to have VF as a presenting rhythm (Akahane et al., 2011). Even in more recent research, which included all initial rhythms, women accounted for less than 20 percent of subjects included in the trial (Bro-Jeppesen et al., 2014). Additionally, these studies did not report the racial or ethnic identities of individuals within. However, analysis of CARES data found that therapeutic hypothermia was not differentially used by race or gender among OHCA patients (Mader et al., 2014). Whether there are differences by race and ethnicity in the implementation of TTM in other large database studies, such as the GWTG-R or Resuscitation Outcomes Consortium, remains to be studied.

Disparities in the implementation of cardiac procedures in post-arrest care have been documented. After controlling for potential confounding factors, one study found that among patients admitted to hospitals in California with VF or ventricular tachycardia (VT) arrest, African American patients were significantly less likely than white patients to undergo electrophysiologic studies or to receive an implantable cardioverter-defibrillator (Alexander et al., 2002). Another study determined that younger African Americans had substantially lower odds of receiving at least one potentially lifesaving procedure (e.g., cardiac catheterization or cardioverter-defibrillator) when compared to white patients (Groeneveld et al., 2003). The same study noted a considerable differential in long-term survival, with the life expectancy for white patients (4.1 years) longer than that for African American patients (1.9 years) (Groeneveld et al., 2003). The use of implantable cardioverter-defibrillator has become more widely available, and the use of this technology has increased faster for African American patients than for other populations. However, the disparity in use still exists (Stanley et al., 2007). Similar differences in post-arrest care have been reported for Hispanic patients, with multiple studies demonstrating that Hispanics patients may have poor access to appropriate care with lower odds of receiving implantable defibrillators as well as electrophysiologic studies (Alexander et al., 2002; Groenveld et al., 2003). Although there is limited research devoted to cardiac arrest care for racial and ethnic minority patients, available evidence indicates disparities in both access to care and outcomes. Additional research is required to evaluate the burden of disease among minority populations and to determine the efficacy of appropriate post-arrest treatments for a broader population. Box 5-4 summarizes the key conclusions relevant to disparities in post-arrest treatments.

BOX 5-4
Disparities in Cardiac Arrest Treatments

- Racial and ethnic minorities more frequently present nonshockable initial rhythms.
- Racial and ethnic minorities are more likely to have delayed defibrillation.
- Racial and ethnic minorities are less likely to receive lifesaving cardiac procedures such as electrophysiologic studies, implantable defibrillators, and cardiac catheterization post cardiac arrest.

Assessment and Prognosis

Cardiac arrest survival with significant neurologic damage can be as devastating, but more burdensome, than death for survivors, family members, and society because it can influence both short-term prognosis and long-term quality of life. Neurologic and functional status needs to be evaluated and addressed promptly. Neurologic assessments may include multidisciplinary care coordination to appropriately and accurately evaluate and treat post–cardiac arrest survivors who do not immediately regain consciousness, in order to maximize the likelihood of complete recovery. The assessment may begin with a neurologic exam and urgent neurologic consultation in the ED, and continues as needed, until discharge. The most robust prognostic estimates are usually obtained from a combination of neurologic examinations and neuro-electrophysiological tests (Booth et al., 2004, Kamps et al., 2013). However, serial neurologic observations beyond the first 24 to 72 hours, and in some cases, more than 96 hours following an arrest, are often required to provide reliable prognostic information (Neumar et al., 2008; Peberdy et al., 2010). During serial observations, trained health care providers (including nurses) systematically record results from clinical neurologic exams in ICUs that use standardized scoring schemes for consciousness (Riker and Fugate, 2014). As shown in Box 5-5, multiple tools available for neurologic assessment and scoring have demonstrated prognostic value. However, more research is needed to refine neurologic prognostic scores and extend observations beyond the acute hospitalization phase of post–cardiac arrest care, in order to more accurately evaluate longer-term cognitive outcomes.

Similar to adults, no single test can clearly provide accurate prognostication in children. Information to guide clinicians on neuroprognostication in the pediatric population is even more limited than in adults, although assessment and testing to assess level of brain function are similar for both populations. Repeated examinations, electrophysiological assessment, and imaging all contribute to determining the extent of brain injury after a cardiac arrest. To date, there are no composite scores similar to CASPRI or GO-FAR (see Box 5-1) for children. The most commonly used score is the Pediatric Cerebral Performance Score, which also has significant shortcomings in differentiating mild from moderate disability and was designed to assess neurologic function after pediatric intensive care—not in-hospital cardiac arrest (Fiser et al., 2000).

BOX 5-5
Available Tools for Neurologic Assessment Following Cardiac Arrest

Neurologic consultative expertise should be used to assess the patient within the first 24 hours of a cardiac arrest to provide a baseline comprehensive neurologic examination, interval serial monitoring, team-based care regarding therapeutic hypothermia, help with decisions about appropriate neurologic testing, advice on treatment of any seizures, and input on comprehensive prognostication (Booth et al., 2004; Peberdy et al., 2010; Puttgen et al., 2009).

Standard neurologic examination in an unresponsive post–cardiac arrest patient will help document cortical and brainstem functions (e.g., response to verbal commands or physical stimulation, pupillary light and corneal reflex, spontaneous eye movements, gag, cough, and spontaneous breaths). The presence of sedation, neuromuscular blockade, or analgesia, which are sometimes used in post-arrest care, can impair the ability to monitor neurologic examinations.

Neurologic assessment scores have been developed in order to provide insights into short and long-term neurologic outcomes. There are multiple scoring systems, including the following:

- The **Cerebral Performance Category (CPC[a])** has traditionally been used to assess outcomes following cardiac arrest, but has limited ability to differentiate between mild and moderate neurologic injury (Rittenberger et al., 2011).
- The **modified Rankin Scale (mRS[a])** is a clinician-reported measure of global disability, applied in the evaluation of neurologic outcomes following cardiac arrest, stroke, and other brain injuries (Banks and Marotta, 2007; Rittenberger et al., 2011).
- The **Glasgow Coma Scores (GCS)** assessment can be provided by trained nursing staff and is the most basic form of neurologic monitoring available. It has demonstrated predictive value and is often included as part of serial neurologic examinations.
- The **brain arrest neurologic outcome scale** is a 16-point scale composed of three variables: duration of arrest, reversed GCS, and Hounsfield unit density ratio of the caudate nucleus over the posterior limb of the internal capsule on noncontrast CT scan of the head (Torbey et al., 2004).

- The s**even-point 5-R score** consists of the following variables: VF or VT as the first presenting cardiac rhythm, arrest-to-first CPR attempt time interval of less than 5 minutes, arrest-to-ROSC time interval of less than 30 minutes, recovery of pupillary light reflex in the ED, absence of rearrest before leaving the ED (Okada et al., 2012).
- The **Cardiac Arrest Survival Post-Resuscitation In-hospital (CASPRI) score** was developed specifically for IHCA and includes 11 predictor variables: age, initial cardiac arrest rhythm, duration of resuscitation, mechanical ventilation, defibrillation time, baseline neurologic status, sepsis, malignancy, renal insufficiency, hepatic insufficiency, and hypotension (Chan et al., 2012; Girotra et al., 2014). Although a relatively simple score, it is perceived as being unwieldy and has not been validated in OHCA patients. It can, however, provide estimates of the probability of favorable neurologic survival after IHCA.
- The **Good Outcome Following Attempted Resuscitation (GO-FAR)** score is used to predict neurologically intact survival after in-hospital cardiopulmonary resuscitation has also been developed. This score is based on 13 pre-arrest variables and can identify patients likely to survive IHCA with good neurologic prognosis or with minimal deficits (Ebell et al., 2013).

Brain imaging with CT or MRI is common for comatose patients. MRI is more sensitive than CT for detecting early ischemic injury but may not be advisable if certain magnetically activated implanted devices (e.g., cardiac pacemakers, insulin pumps, neurostimulators, or cochlear implants) or other metal implants are present, because these devices could impact the usefulness of the data. Brain imaging that shows multilobar, or diffuse, cortical involvement, termed as extensive cortical lesion pattern, was determined to be a reasonable predictor of poor prognosis and adds to the sensitivity of the GCS motor score (Topcuoglu et al., 2009). Additionally, noncontrast brain CT has also been used to predict prognosis.

Various **neurophysiological monitoring tests** can help assess post-arrest patients for seizures and providing prognostic assessments.

- **Continuous electroencephalogram (EEG) monitoring** is helpful among unresponsive post-arrest patients to assess for status epilepticus and monitor for nonconvulsive status epilepticus. The latter can easily evade detection if no discernable motor movements exist. One study found non-convulsive status epilepticus in 27 percent of post–cardiac arrest patients who were initially unresponsive after hypothermia (Rundgren et al., 2010).

continued

- **Continuous amplitude-integrated EEG (aEEG)** can begin in the ICU and continued until the patient regains consciousness or for no longer than 120 hours, if the patient remains in coma (Rundgren et al., 2006). Various EEG patterns have been associated with specific possible outcomes including a likelihood of recovery of consciousness, likelihood of major central nervous system (CNS) injury, good neurologic outcomes, poor neurologic prognosis, and persistent comatose state until death (Cloostermans et al., 2012; Rundgren et al., 2010).
- **Cortical N20 somatosensory evoked responses** can be a reliable indicator of poor prognosis when found to be absent bilaterally and have been reported to have exceptionally low false-positive rates when measured at 4 days among patients treated or not with TTM (Kamps et al., 2013). Long-latency somatosensory evoked potentials on day 4 have been shown to have some association with cognitive recovery (Prohl et al., 2007).

Other measurements that could be helpful to improve neurologic prognostic estimation include the following:

- Noninvasive **regional cerebral oxygen saturation** after hospital admission.
- Serum levels **of neuron-specific enolase (NSE) and neuron-enriched S100 beta (S100β)** measured at 24, 48, or 72 hours after cardiac arrest (Prohl et al., 2007; Stammet et al., 2013).
- **Bispectral index** continuously monitored during the first 48 hours after cardiac arrest (Stammet et al., 2009, 2013).

[a]Neurologic assessment scores such as the CPC and mRS are described in greater detail in Chapter 2, Box 2-2.

However, some literature suggests that pupillary response within 12 to 24 hours after arrest, NSE and biomarkers, and EEG findings may provide some guidance for clinicians on possible prognosis and outcomes (Nishisaki et al., 2007; Topjian et al., 2014b). Making predictions in children is further complicated by developmental stage and the recognized plasticity of the immature brain.

Appropriate Timing of Prognosis

Post-arrest patients often require sequential and frequent neurologic evaluations in the ICU. Determination of neurologic prognosis can be difficult during the period immediately following ROSC and, as a result, some experts have recommended waiting at least 72 hours or longer to allow the brain to recover from ischemia after an arrest before making major decisions (Neumar et al., 2008; Peberdy et al., 2010). Neuroprognostication is often delayed to beyond 96 hours for patients who have been treated with TTM, to allow recovery from the possible side effects of sedation and other drugs. One study among adult comatose patients treated with hypothermia, absence of pupillary light responses or corneal reflexes 72 hours after CPR, and absence of somatosensory evoked potentials during and after hypothermia were determined to be reliable predictors of poor outcomes. Other investigators confirm that the motor response to painful stimuli, corneal reflexes at 72 hours and neuron-specific enolase (NSE) levels after cardiac arrest were not a reliable tool for the early prediction of poor outcome for patients who had received TTM (Kamps et al., 2013). The GCS system can also reliable assess post–cardiac arrest patients who are no longer on sedatives and, as a result, its prognostication is delayed for patients who received TTM (Schefold et al., 2009).

Prognostication and Withdrawal of Care

Patient preferences should be of paramount importance in determining end-of-life care decisions (IOM, 2015). But clinical decisions regarding withdrawal of life support for comatose and unresponsive patients following cardiac arrest are complicated, particularly in the absence of advance directives. These decisions are determined by multiple factors: older age and secondary comorbidities of patients, race, a poor initial neurologic exam, and multiple organ failure (Albaeni et al., 2014). Factors such as the existence of living wills, health care proxies, family perspectives, and religious beliefs of patient and family members also influence such decisions.

Although neurologic prognostic assessments can provide reasonable accuracy regarding the likelihood of meaningful recovery, there are no clear guidelines beyond maintaining a 72 hours or longer observation period, with respect to termination of care for cardiac arrest patients.

Albaeni and colleagues found that post-arrest care is withdrawn early (within 48 hours of hospital admission) for more than half of all cardiac arrest patients (Albaeni et al., 2014). This is particularly alarming because less than 20 percent of these patients had advance directives authorizing early care withdrawal (Albaeni et al., 2014). Another study of

89 OHCA patients found that 10 patients regained consciousness 72 hours after receiving hypothermia, which suggests that early care withdrawal may prematurely terminate care that could result in survival with good neurologic recovery (Gold et al., 2014). The factors that influence such decisions have not been studied and require further research.

Existence and early implementation of a DNAR order portends a fatal outcome and has been associated with less aggressive hospital care (Jackson et al., 2004), including lower rates of potentially critical hospital interventions, procedures, and survival to discharge (Richardson et al., 2013). Although there is a paucity of literature on differences between DNAR orders in women versus men for cardiac arrest, evidence from other medical conditions (such as sepsis and trauma) suggests that early DNAR placement may partially explain the differences in post-arrest interventions for women compared to men (Chang and Brass, 2014; Salottolo et al., 2015). However, it does not account for the lower rates of cardiac procedures and the placement of implantable cardioverter-defibrillator in racial and ethnic minority patients, because they are more likely to have lower rates of DNAR order placement compared to white patients (Richardson et al., 2013). Survival is never possible if care is withdrawn prematurely, but the patient's preferences and values should always be the guiding principles in customized approaches to care.

Variability in Post–Cardiac Arrest Care

The literature reports remarkable variation in survival-to-discharge rates that range from 2 to 41.5 percent among all cardiac arrest patients with varying degrees of post–cardiac arrest syndrome (Go et al., 2014; Nadkarni et al., 2006; Sirbaugh et al., 1999). As discussed in previous chapters, this variation in outcomes is partially due to differences in individual patient characteristics or factors unique to the cardiac arrest event (e.g., witness status and availability of bystander CPR), as well as a reflection of differences in health system characteristics, including structural factors such as differences in available resources and care facilities.

Multiple studies have confirmed that varying levels of access to high-quality health care for minority populations (by gender, race and ethnicity, and socioeconomic factors) lead to diminished health outcomes and notable disparities across many diseases and health conditions (IOM, 2003). In 2003, the Institute of Medicine noted, for example, that minority populations are less likely to undergo recommended invasive procedures or to receive life-saving therapies. Additional research on disparities in post–cardiac arrest care is needed to inform decisions regarding resource allocation to correct access to care, as well as to determine the efficacy and generalizability of treatments to a wider population.

The variation of reported outcomes in post–cardiac arrest patients suggests that there are unique characteristics of high-performing health care systems across the United States that could, in theory, be adopted and implemented more broadly. As discussed in Chapter 2, there is a high degree of variation across communities in terms of survival. Identifying important best practices in these high-performing health care systems is the necessary first step in improving outcomes nationwide and gaining a better understanding of the underlying factors that contribute to positive outcomes. Some high-performing resuscitation systems have implemented regionalization of care, as a way of improving outcomes of cardiac arrest. The following section describes these centers of excellence in greater detail.

Cardiac Arrest Centers of Excellence

Because care for the post-arrest patient is complex and often requires multidisciplinary team approaches, some regions in the United States (Arizona, Minnesota, New York, Ohio, Texas, and Virginia) have developed regional systems-of-care to improve OHCA resuscitation care and patient outcomes (Nichol et al., 2010). The primary goal for regionalizing care is to improve health outcomes by transporting patients to medical facilities with optimal resources and expertise in cardiac arrest care (Bobrow and Kern, 2009; Lurie et al., 2005). However, these established systems do not have common process or performance standards or have similar funding and reimbursement criteria. Moreover, because of the lack of comprehensive evidence for a standard post-arrest care strategy, there are substantial differences between available treatments and therapies at these cardiac arrest centers of care. For example, in some regions, EMS is authorized to bypass the nearest hospital and transport patients to a facility capable of providing specific post-arrest care treatments such as TTM, while in other regions there are no such protocols in effect (Nichol et al., 2010). In spite of these preliminary efforts, regionalization of resuscitation care has not yet become a national practice in the United States (Nichol et al., 2010; van Diepen et al., 2013).

The body of evidence demonstrating the effectiveness of centers of excellence is expanding. A study of a statewide regionalization of post-arrest care, along with the implementation of a bypass protocol that allowed EMS providers to transport select patients (comatose patients with ROSC) to specialized centers, was associated with improved survival and functional outcomes after OHCA (Spaite et al., 2014). A recent study proposed a tiered-transport concept, in which conscious patients with ROSC are transported to the nearest appropriate ED, according to local EMS jurisdictional policies, irrespective of bypass status. For more complicated post–cardiac arrest cases, the concepts of either bypass or early transfer to a higher level cardiac care facility promptly after initial stabilization in the closer facility are being evaluated as potentially useful strategies (Myerburg, 2014). Figure 5-2 illustrates a four-tiered priority-based hospital bypass system, which aligns immediate post–cardiac arrest status of patients to the level of required care.

Much of the evidence for regionalization of care in the cardiac arrest field has been based on extrapolation from other similar fields such as trauma or stroke. The health care field has determined that these patients who experience similarly complex conditions (e.g., stroke) are better managed in centers of excellence, or within systems, that are equipped and designated to provide higher levels of advanced care. These centers of excellence have demonstrated improvement in patient outcomes and reduced costs by implementing guideline-based systemwide protocols within a region for prehospital and hospital care, enhancing communication capabilities and creating trauma registries (MacKenzie et al., 2006; Share et al., 2011; Singh and MacDonald, 2009). Outcomes for stroke have also improved because of greater regionalization of care. The American Stroke Association encouraged EMS integration into stroke systems of care and recommended the transport of stroke patients to a specialized facility whenever feasible (Acker et al., 2007).

In an ideal setting, cardiac arrest centers of excellence that receive post-arrest care patients should have the structural components (e.g., cardiac catheterization laboratory) and therapeutic capabilities (e.g., TTM, PCI, dialysis) to be able to provide a bundle of essential treatments that have demonstrated benefit in treating post-arrest care syndrome and improving patient outcomes. For example, patients commonly develop renal failure following cardiac arrest and may thus require hemodialysis (Neumar et al., 2008). These hospitals must also be able to provide a multidisciplinary team that has the requisite knowledge, skills, and abilities to provide advanced, coordinated post-resuscitation care. This multidisciplinary team will require the intensive care team to manage hemodynamic and metabolic status; the electrophysiology teams to assess and manage the arrhythmias; the neurology teams to manage, assess, and

Level	Patient Status	Hospital Resource Minimums
1	Failure to restore circulation; ROSC without regaining consciousness ± hemodynamic instability ± acute coronary syndrome ± recurrent arrhythmias	Local or regional facility capable of providing highest level of neuro-logical, cardiovascular, and intensive care support—24/7 (ICU/CCU/NICU)
2	ROSC with restoration of consciousness Persistent hemodynamic instability ± acute coronary syndrome ± recurrent arrhythmias	Nearest facility capable of providing high level cardiovascular and inten-sive care support 24/7; cardiac cath-eterization laboratory capable of providing PCI within 90 minutes
3	ROSC with restoration of consciousness; hemodynamically stable Evidence of acute coronary syndrome ± recurrent arrhythmias	Nearest facility with cardiac catheterization laboratory capable of providing PCI within 90 minutes—24/7
4	ROSC with restoration of consciousness; hemodynamically stable; no evidence of acute coronary syndrome ± recurrent arrhythmias	Nearest facility capable of providing standard ED, ICU/CCU; cardiac catheterization desirable with PCI capability within 24 hours

FIGURE 5-2 Targeted urgency scale to reflect a priority-based hospital bypass system.
NOTES: CCU = critical care unit; ED = emergency department; ICU = intensive care unit; NICU = neonatal intensive care unit; PCI = percutaneous coronary intervention; ROSC = return of spontaneous circulation.
SOURCE: Myerburg, 2014.

limit the CNS complications; and the cardiology team to perform cardiac catheterization and coronary angiography. Because of the limitations in scientific evidence described earlier, these elements have not yet been implemented uniformly across existing cardiac arrest centers of excellence.

Research Priorities

The complex nature of post-arrest syndrome and the multiple global body injuries that need to be managed simultaneously complicate studies of this condition. As a result, there is limited scientific evidence available that demonstrates the benefit of the therapies designed for post-arrest stabilization for patients who have varying degrees of post-arrest syndrome. In some instances, the justification for the use of the therapies that are described in this section is based on extrapolation of benefits that have been found in other clinical situations with the similar initial pathophysiology (e.g., acute myocardial infarction or sepsis). In other instances, the treatments discussed above have demonstrated effectiveness in limited settings using small cohorts, or are supported by using population health data, rather than in large randomized clinical trials. In spite of these challenges and existing knowledge gaps, health care systems and academic medical centers that practice aggressive, multidisciplinary post-resuscitation care often report excellent patient outcomes, with upward of 80 percent of survivors having favorable neurologic outcomes at discharge (Langhelle et al., 2003; Nolan et al., 2010). Some investigators have put forth the concept of a multilevel approach to care delivery based on whether the patient has neurologic function, is comatose, or has biomarkers of severe neurologic injury. This approach suggests a more aggressive treatment protocol (using PCI or hypothermia) in patients with neurologic function and a more metabolically directed approach to care in those with more severe injury. Thus, not only is this an area ripe for further investigation and evidence building, but also it is an area where emulation of local best practices could result in improved survival and outcomes on a broader scale throughout the nation. Box 5-6 presents the current gaps in evidence and points to future research needs.

STRATEGIES TO IMPROVE THE QUALITY OF CARDIAC ARREST CARE IN HOSPITAL SETTINGS

The essential components of any continuous quality improvement (CQI) program are measurement of care processes and outcomes, benchmarking of performance within and among organizations, and implementation of changes in practice in an effort to improve quality and patient outcomes. These iterative processes also inform, and are informed by, revisions to consensus-based guidelines, as discussed in Chapter 6. Hospitals and EMS systems alike have reported improvements in cardiac arrest survival rates after implementing CQI programs (Ewy and Sanders, 2013; Girotra et al., 2013). Such results provide strong support for ongoing efforts to strengthen data collection, research, and CQI activities related to IHCA. Chapter 6 also discusses CQI on a broader level in terms of ensuring the implementation of effective treatments and care settings across communities.

BOX 5-6
Priority Areas for Next Steps in Post-Arrest Care Research

- Implementation of documented plans and systems for care transitions
- Appropriate composition of the multidisciplinary teams, including skills related to emergency medicine, intensive care, acute cardiac care, and neurology
- Appropriate timing for prognosis and care withdrawal
- Identification of optimal therapies for hemodynamic support, metabolic support, and neurologic recovery
- Implementation of timely deployment of TTM therapy in ED, cardiac catheterization, critical care, neurologic testing and assessment, and appropriate radiology support
- Use of triage to ensure that advance therapies are directed to patients most likely to benefit and where the risks are justified
- Determination of effectiveness of regionalized centers for providing the most appropriate care based on post-arrest clinical status
- Widespread implementation of best practices and care models and continuous quality improvement programs
- Development and adoption of performance measures for IHCA, OHCA, and post-arrest care
- Identification and implementation methods to rectify health care disparities in post-arrest care

Hospital-based resuscitation systems in the United States are an essential component of the cardiac arrest chain of survival and, in addition to responding to IHCA, provide the bulk of specialized post-arrest care for both OHCA and IHCA patients. Recognizing that there are some clear differences in the immediate treatments required by IHCA and post-arrest care patients and that care is provided by different providers, some common themes applicable to both have emerged. Multiple guidelines on IHCA and post-arrest care treatment protocols exist; however, the scientific evidence base demonstrating the effectiveness of specific protocols and guidelines are limited or, at best, mixed. Relatively few hospitals regularly monitor cardiac arrest outcomes, and there are currently few national standards that require performance benchmarking. This section explores some overarching themes and presents strategies to enhance the quality of care within hospitals.

Establish Separate Diagnosis Codes for IHCA and OHCA

Differences in epidemiology, etiology, and treatment for IHCA and OHCA exist. As compared to patients with OHCA, those experiencing a cardiac arrest in the hospital are fewer in number and more likely to survive. Additionally, IHCAs are less likely to occur as a result of preexisting cardiovascular disease and, notwithstanding substantial variations in the quality of care, IHCA patients are more likely to receive early treatment. Hospital systems can benefit from separate administrative billing codes for OHCA and IHCA, because the cost of inpatient care for IHCA patients and OHCA-patients who receive hospital-based post-arrest care are markedly different. To achieve a more nuanced understanding of the differences and commonalities between IHCA and OHCA, formal classification and codification to recognize the conditions as unique is needed.

As described earlier, identifying IHCA using hospital claims and administrative data is challenging because of the lack of a unique diagnostic code for this clinical condition. The ICD coding system, developed and maintained by the World Health Organization, defines medical diagnoses and procedure codes that are commonly used for data collection, research analysis, and billing purposes. The Centers for Disease Control and Prevention's North American Collaborating Center collaborates with the Centers for Medicare & Medicaid Services (CMS) to adapt ICD diagnosis codes for hospitals in the United States. Currently, no specific ICD diagnosis code exists for IHCA, although ICD-9 and -10 include codes for cardiac arrest in general (shown in Table 5-3). Select medical procedures (e.g., cardiac arrest during surgery, and anesthesia during pregnancy or labor) and at-risk populations (e.g., neonates) also have special codes for cardiac arrest.

Established ICD-9 coding practice defines primary and secondary diagnoses largely based on whether an underlying cause of cardiac arrest can be determined rather than on whether a patient arrives at a hospital in a state of cardiac arrest. As a result, researchers studying IHCA attempt to identify IHCA in administrative data using specific algorithms that often use a combination of diagnosis codes, hospital-specific procedure, and present on admission codes to make educated guesses about the location of the initial event. However, this procedure can be inaccurate. A number of situations may contribute to these low rates of accuracy. For example, if IHCA is identified using codes for the delivery of chest compressions in order to determine a numerator, an individual who dies from cardiac arrest, but does not receive CPR, is not counted in the numerator.

TABLE 5-3 Examples of ICD-9 and -10 Codes for Cardiac Arrest

Version	Population	Code	Definition
ICD-9	Adult	427.5	Cardiac arrest
		V12.53	Personal history of sudden cardiac arrest
	Pediatric	779.85	Cardiac arrest of newborn
ICD-10	Adult	I46.0	Cardiac arrest with successful resuscitation
		I49.1	Sudden cardiac death
		I462.1	Cardiac arrest due to underlying cardiac condition
		I468.1	Cardiac arrest due to other underlying condition
		I469.1	Cardiac arrest, cause unspecified
		I9712.0	Postprocedural cardiac arrest
		I9771.0	Intraoperative cardiac arrest
		O2911.0	Cardiac arrest due to anesthesia during pregnancy
		Z8674.1	Personal history of sudden cardiac arrest
	Pediatric	P2981.1	Cardiac arrest of newborn

SOURCES: CMS, 2015a,b.

Moreover, current ICD-9 guidance instructs hospital coders not to code for cardiac arrest to indicate an inpatient death if the cause is known because the Uniform Hospital Discharge Data set uses a separate item. A recent study that tried to identify hospitalized patients who had IHCA (and did not have DNR orders) using the ICD-9 codes 427.5 (cardiac arrest), 99.60 (CPR), and 99.63 (closed chest massage) found that this method had only 76 percent positive predictive value (Bucy et al., 2015).

Other available codes do not adequately correct for the absence of separate ICD codes. Moreover, at this time there is only one diagnosis related group (DRG) code for all cardiac arrest used to determine Medicare reimbursement to hospitals for inpatient stays. Although a separate indicator code can be used to identify a diagnosis code (e.g., cardiac arrest) as present on admission, this code (by definition) does not attach to a patient unless that patient is admitted to the hospital. Thus, a person can have a cardiac arrest within a hospital, receive treatment but die within a hospital emergency department, and not be identified in the data as having experienced an IHCA. This affects efforts to measure and improve the quality of cardiac arrest care provided by hospital personnel, including initial resuscitation efforts and the post-arrest care of patients in ROSC. A separate ICD-10 code differentiating IHCA and OHCA would improve the reliability and validity of research, allow for precise calculation of incidence and survival.

CPR Quality Improvement: Devices, Debriefing, and Simulation Training

Many different strategies have been applied in efforts to improve the quality of resuscitation care for IHCA. CPR feedback devices provide one technology-driven opportunity to improve resuscitation care. These devices give guidance and feedback during CPR and have been used in both training and clinical settings. The devices can assess and provide information on compression rate, depth, and force, ranging in complexity from a simple metronome that guides compression rate to more complex tools that monitor and provide audiovisual feedback about actual CPR performance in real time. Impedance threshold devices (ITDs) and active compression-decompression (ACD) devices also have been studied as tools to augment cardiac and cerebral blood flow during CPR. ITDs create a negative pressure vacuum as the chest recoils during chest compressions, while ACDs are suction tools used during CPR to actively decompress the chest wall. Both enhance blood flow return to the heart and brain (Cochrane, 2013; Resuscitation Central, 2010). Finally, several mechanical devices provide CPR directly to patients in a more standardized manner, completely removing providers from this role. Although studies have demonstrated that mechanical devices are able to be used quickly and may improve the CPR performance, available evidence neither supports nor discourages widespread adoption of these devices (Brooks et al., 2014).

Implementing personnel debriefings immediately following a cardiac arrest presents another opportunity for improving cognitive skills rather than psychomotor skillsets relevant to resuscitation performance. This approach has been examined as a potential strategy for improving CPR performance and resuscitation care for IHCA. Historically, early debriefing as a tool for performance assessment has been challenging, because of the lack of objective data available after resuscitation with the exception of code sheets and medical records. The availability of new technology, however, has made it possible to directly measure resuscitation quality, including factors such as the rate and depth of chest compressions (Idris et al., 2012; Stiell et al., 2014). Using monitoring devices to provide detailed transcripts of CPR quality from actual resuscitations, a recent report examined the impact of early debriefing on CPR performance for a group of internal medicine residents at a university hospital. During the study period, the residents were required to attend weekly debriefing sessions where the prior week's resuscitations were discussed and analyzed based on the objective metrics of CPR performance (Edelson et al., 2008). The researchers found that CPR quality and outcomes during the intervention period improved with the early debriefings in terms of both ventilation rate decrease and compression depth increase. Overall, these changes correlated with a higher rate of ROSC in the group with early debriefing (59.4 percent versus 44.6 percent), but there was no change in the survival-to-discharge rates. Other studies have shown similar patterns of results (Couper et al., 2013). In a large tertiary care children's hospital, implementation of formalized debriefing after cardiac arrest was associated with improved survival to hospital discharge and improved survival with favorable neurologic outcome (Wolfe et al., 2014). Debriefings often involve a post-resuscitation review of provider performance. For example, one study of a debriefing program included analysis of quantitative CPR variables (e.g., chest compression rate and depth, fraction of time during resuscitation spent providing chest compressions, and fraction of chest compressions without rescuer allowing for chest wall recoil) obtained from feedback-enabled defibrillators. Sessions were held within 3 weeks of the event, scheduled during normal educational conference times, and were open to the entire pediatric ICU staff, not just those who participated in the event (Zebuhr et al., 2012).

Simulation training may also improve provider performance during resuscitations (Wayne et al., 2008). In 2011, the Agency for Healthcare Research and Quality (AHRQ) supported multiple demonstration projects to evaluate the effectiveness of various simulation methods in improving patient safety and quality of care delivery, including one specifically on pediatric resuscitation in the emergency department (AHRQ, 2014b). A number of other studies have found an association between targeted simulation training and improvements in the timeliness and quality of CPR (Cheng et al., 2015a; Sullivan et al., 2014) as well as the development of nontechnical leadership skills (Hunziker et al., 2010). One benefit of simulation training, compared to actual cardiac arrests, is that it can provide a controlled and standardized experimental setting that allows assessment of multiple interventions. Subsequently, training is focused on high yield processes and targeted to different types of providers. Simulation also provides a safe environment where students can learn from mistakes without harming patients. Simulation studies have shown particular insights into the importance of leadership, communication, and teamwork. These studies have also allowed for the tailoring of resuscitation care toward current gaps in treatment, although the link between process improvement during simulation training and real-world resuscitation care remains uncertain.

Team Training to Improve IHCA and Post-Arrest Care Response

Effective resuscitation and post-arrest care requires multidisciplinary teamwork with efficient and coordinated action between prehospital providers and hospital-based staff (including ED nurses or physicians, critical care, neurologists, pediatricians, and laboratory technicians, among others). When a cardiac arrest occurs, these teams need to rapidly execute a care plan for individual patients and then may need to collaborate with providers in the outpatient care setting (primary care providers or rehabilitation staff) following discharge. Developing and implementing training protocols for multidisciplinary resuscitation teams (RRT or MET teams in IHCA care) or post-arrest care teams can enhance and streamline the quality of resuscitation care within hospitals. In their respective guidelines and statements, the ILCOR, the European Resuscitation Council, and the AHA have recognized the importance of teamwork, communication and leadership to the performance of resuscitation teams, and the effectiveness of targeted training to develop these vital behaviors (Bhanji et al., 2010; Mancini et al., 2010; Nolan et al., 2010). Discussion of team dynamics (e.g., communication and roles) and different types of resuscitation teams is included in AHA coursework for ACLS—but not BLS—providers.

The quality of leadership within a resuscitation team affects provision of care, as does the effectiveness of communication, coordination, and collaboration among team members; all of which may influence patient outcomes. Breakdowns of leadership and teamwork alike affect performance, thereby detrimentally affecting patient outcomes (Hunziker et al., 2011; Norris and Lockey, 2012). Fortunately, effective training programs designed to enhance leadership and teamwork exist, and through modification of relevant behaviors these training programs are able to improve team performance and patient survival alike. Although effective leadership is difficult to define, successful leaders in the resuscitation field share similar traits of extroversion, self-confidence, flexibility, and a calm demeanor (Norris and Lockey, 2012). By definition, good team leaders are also interested in processes and actions that can improve team performance, such as CQI programs and the professional development of team members (Andersen et al., 2010; Norris and Lockey, 2012). Developing these traits is the goal of targeted leadership training, which can be more effective than technical training at improving team performance (Hunziker et al., 2010).

Many leadership training programs exist and can be used to cultivate better leaders throughout the medical field. Simulation training for cardiac arrest resuscitation teams, described in the previous section, is one method of developing necessary technical and nontechnical skills. Crew resource management (also known as crisis resource management)—a proven, and widely employed method of leadership training—was first developed by the aviation industry and has been applied with success in the similarly complex and high-risk environments of emergency medicine (Ornato and Peberdy, 2014). Examples of crew resource management techniques that have been modified for use in resuscitation medicine include checklists for leadership activities; cross-checks to ensure team members are clear of the patients prior to defibrillation; and use of standardized, non-ambiguous calls and responses (DePriest et al., 2013; Ornato and Peberdy, 2014). Effective training programs do not require extensive resources, because even brief leadership training can have a measurable and lasting impact on leadership behaviors (Cooper, 2001). Therefore, this type of training could be useful for a broad spectrum of health care providers involved in resuscitation care whenever possible.

Specific benefits of teamwork training include reductions in human error and improvements in communication, leadership, coordination, decision making, and the cognitive and behavioral capabilities of team members within a team context (Delise et al., 2010; Salas et al., 2008; Schmutz and Manser, 2013; Thomas et al., 2007a). The methods and objectives of team training are varied and affect the impact of training on performance in different ways (Salas et al., 2008). Often combining the use of lectures, demonstrations, and simulations, team training seeks to develop communication strategies, increase practitioner knowledge, prevent errors, and promote utilization of available resources (Weaver et al., 2014). Successful team training often aligns training objectives with institutional goals, provides institutional support for team training initiatives, prepares the health care environment and trainees for team training, promotes use of teamwork skills in the workplace, and monitors the effectiveness of the team training program (Salas et al., 2009).

Develop Standardized Performance Metrics

Accurate measurement is a cornerstone of a quality improvement program. Standards that require the collection of outcome metrics across the continuum of IHCA and post-arrest care are needed in order to promote meaningful improvements in hospitals across the United States. Performance measures are vital to the provision of quality health care because they allow for benchmarking across and within hospitals and provide firm evidentiary basis to guide clinical patient or family decision making.

There is a need for formally endorsed standards that allow benchmarking at the national level. However, currently no quality metrics are endorsed by The Joint Commission, National Quality Forum, or CMS that could be used to specifically assess quality of IHCA or post-arrest care. Hospitals that are accredited by The Joint Commission are required to adhere to some general standards for in-hospital resuscitation services. In 2008, The Joint Commission endorsed a patient safety goal aimed at improving recognition and response to changes in a patient's clinical condition (Revere, 2008). This could be adapted for assessment of IHCA quality of care, because these patients often present changes in vital signs and show clinical signs of deterioration prior to an arrest. There are general Joint Commission standards related to resuscitation services in hospitals for quality improvement review, evaluation, and action that apply to resuscitation care; however, none are specifically designed for in-hospital cardiac arrest (see Box 5-7 for a summary of relevant standards). Adding specificity to the general standards to support collection of common data elements to enable the identification of people that have experienced in-hospital adult and pediatric arrest would be a good first step to help organizations (and a national performance improvement effort) to understand how best to optimize the outcomes of arrest patients.

Efforts to develop national performance measures for IHCA and post-arrest care have been unsuccessful to date. In 2012, The Joint Commission, in collaboration with private corporations, completed pilot testing of four cardiac arrest–specific inpatient measures (shown in Table 5-4) that have demonstrated effectiveness in improving patient survival and neurologic outcomes (The Joint Commision, 2014). However, due to the small number of participating hospitals (seven) and the estimates of limited data reliability, the measures were not advanced for endorsement (The Joint Commission, 2014). These metrics also did not

BOX 5-7
The Joint Commission Standards Related to Resuscitation Services in Hospitals

Standard PC.9.30
Resuscitation services are available throughout the hospital.

- Policies, procedures, processes, or protocols govern the provision of resuscitation services.
- Equipment is appropriate to the patient population (i.e., adult, pediatric).
- Appropriate equipment is placed strategically throughout the hospital.
- An evidence-based training program(s) is used to train appropriate staff to recognize the need for and use of designated equipment and techniques in resuscitation efforts.

Standard PI.1.10
The hospital collects data to monitor the performance of potentially high-risk processes (e.g., resuscitation and its outcomes).

Standard PI.2.10
Data are systematically aggregated and analyzed.

- Data are analyzed and compared internally over time and externally with other sources of information when available.
- Comparative data are used to determine whether there is excessive variability or unacceptable levels of performance when available.

Standard PI.2.20
Undesirable patterns or trends in performance are analyzed.

Standard PI.3.10
Information from data analysis is used to make changes that improve performance and patient safety and reduce the risk of sentinel events.

SOURCE: The Joint Commission, 2007.

capture outcomes longitudinally across the continuum of care or include assessments of care related to the post–cardiac arrest state. Some of these proposed metrics may be difficult for some hospitals to achieve (e.g., determining timeliness to first defibrillation attempt), without making substantial improvements in the care delivery process.

TABLE 5-4 Relevant ICHA and Post-Arrest Measures Piloted by The Joint Commission

Measure ID	Measure Short Name	Definition and Description
SCA-01	Timeliness of First Defibrillation Attempt	IHCA with VF/pVT in which first defibrillation shock is delivered within 2 minutes of cardiac arrest time
SCA-02	Timely Confirmation of Correct Endotracheal Tube	Confirmation within 1 minute of initial placement via capnometry, electronic waveform capnography, esophageal detection devices, exhaled CO_2 colorimetric monitor, or revisualization with direct laryngoscopy that the endotracheal tube is correctly placed in the trachea, rather than in the esophagus
SCA-03	Initiation of Therapeutic Hypothermia	Availability and provision of therapeutic hypothermia following OHCA
SCA-04	Maintenance of Thermoregulation in Therapeutic Hypothermia	Assessment of the maintenance of the goal temperature of 32°-34°C when therapeutic hypothermia is used for survivors of sudden cardiac arrest

NOTE: Table created based on information provided by The Joint Commission report.
SOURCE: The Joint Commission, 2014.

The AHA recently developed a set of performance metrics related to IHCA. Unlike previously proposed quality standards, the AHA inpatient metrics aim to monitor overall incidence and survival rates, and CPR quality as a first step, rather than point toward many specific process of care measures. It includes the following metrics applicable to adult and pediatric IHCA populations: (1) IHCA survival rate, (2) IHCA incidence rate in noncritical care, nonprocedural, inpatient areas per 1,000 patient-days, (3) proportion of hospitals (with more than 200 beds) reporting IHCA to a national registry, and (4) proportion of IHCA with attempted resuscitation, in which CPR performance data were objectively monitored (Neumar, 2015). Studies of existing in-hospital registries such as GWTG-R have shown substantial improvements in patient outcomes over time (overall survival rate increased from approximately 13.7 percent to 22.3 percent from 2000 to 2009) among hospitals that regularly monitor and report data on cardiac arrest and resuscitation related variables. Adopting these standard metrics may be a potential next step in driving in-hospital resuscitation care and patient outcomes (Girotra et al., 2012).

Aligning improvements with related national initiatives has been successful in driving advances in quality of care for other conditions. For example, certified primary and comprehensive stroke centers were developed by The Joint Commission, in collaboration with the American Heart Association and the Brain Attack Coalition, after leaders recognized the parallels between stroke care for patients and the success of trauma centers in improving care and outcomes for people with traumatic injuries (Alberts, 2014). Since the launch of the stroke centers of excellence concept, standard performance measures for stroke treatment have been adopted, and certified centers are required to collect and benchmark their performance as part of CQI programs (The Joint Commision, 2015). Developing and formally endorsing standard performance metrics for cardiac arrest could improve resuscitation care processes, enhance patient outcomes, and support future research efforts to optimize care for IHCA, OHCA, and post-arrest care.

Quality Collaborative to Continuously Assess Performance

Quality improvement collaboratives have been adopted by a number of health care organizations in the United States, across different clinical areas (Schouten et al., 2008). The objective is for participating organizations to close the gap between aspired and actual performance related to a process or outcome of care by testing and implementing best practices across organizations. Although there is limited research on the effectiveness of the method for cardiac arrest and resuscitation care, similar collaborative strategies have improved patient outcomes in other clinical domains (e.g., surgery or stroke). Quality collaboratives and registries share some common challenges including decisions related to evidence standards, measurement, prognostication, and withdrawal of care.

Hospitals generally follow basic performance requirements, typically endorsed by The Joint Commission. In the cardiac arrest care continuum, The Joint Commission requires that appropriate resuscitation care and equipment be available through a defined protocol, and that outcomes data be collected and reviewed periodically (The Joint Commission, 2007; Morrison et al., 2013). Additionally, the requirements indicate that evidence-based programs should be used to train providers and staff to recognize cardiac arrest and use resuscitation equipment and techniques, with BLS as the required minimum.

Some hospitals in the United States have also opted to participate in national quality improvement programs for cardiac arrest and resuscitation. The GWTG-R registry collects data on every cardiac arrest that receives treatment in a hospital through a standardized Utstein template, which allows for comparability and benchmarking across hospitals. Studies show that participating hospitals see improvements in survival, if not survival to discharge (Bradley et al., 2012). However, participation in a registry or collaborative alone may not be wholly responsible for these improvements, and a multi-pronged approach to improvement may be necessary (Bradley et al., 2012). Finally, it appears that CQI efforts for resuscitation care need to focus directly on the unique aspects of in-hospital cardiac arrests or post-arrest care, because it is unlikely that spillover effects will occur from similar efforts related to other disease processes. In a recent study of hospitals in the GWTG-R registry, there was no correlation between IHCA survival and publicly reported outcomes for acute myocardial infarction, pneumonia, or heart failure (Chen et al., 2013). The committee's commissioned analyses demonstrate improvements in survival in the GWTG-R database over time (Chan, 2015). This could be a reflection of changing patient populations, as well as potential improvements in resuscitation systems of care within hospitals.

Implementing Patient- and Family-Centered Care

Patient-centered care is an increasingly recognized goal within many health care delivery systems. This can have unique challenges in the field of cardiac arrest, given that resuscitation, and continued post-arrest care may not be desirable for all patients given individual prognoses, care preferences, and values. Possible misconceptions about outcomes following CPR among the general public, and poor explanations about treatment options for cardiac arrest can affect patients and families decisions, which affects outcomes (both desired and unwanted). Recent studies suggest that patient knowledge of CPR is inadequate, but can be improved by brief education videos and discussions with providers

(Heyland et al., 2006; Wilson et al., 2015). Many patients and family members may choose not to have aggressive care, when they are appropriately educated about resuscitation (Choudry et al., 2003). As discussed in earlier sections, there is wide variability in institutional withdrawal of care protocols for patients with severe neurologic deficit. Although advanced directives and end-of-life discussions are encouraged for many types of high-risk patients, large proportions of patients with significant cardiac comorbidities (such as advanced heart failure), implantable defibrillators, and pacemakers do not participate (Dunlay et al., 2012; Pasalic et al., 2014; Tajouri et al., 2012). Because withholding resuscitation care requires an order that establishes DNAR status, hospitals should have a standard protocol for discussing advance directives with patients, emphasizing patient autonomy and informed decision making. Studies have demonstrated that these discussions are not harmful and may ultimately reduce unnecessary or unwanted aggressive resuscitation and continued post-arrest care interventions in patients (Temel et al., 2010; Wright et al., 2008).

An important, but controversial, aspect of in-hospital resuscitation efforts involves whether, and in what way, family members should be present during resuscitation efforts following an IHCA (Kramer and Mitchell, 2013). Although there is no broad consensus, inviting family presence during resuscitation has been weakly endorsed by the AHA as being potentially beneficial, with no evidence of harm to family members at risk of posttraumatic stress or anxiety (Goldberger et al., 2015; Morrison et al., 2010). Theoretical benefits include transparency, a sense of closure for family members, and possible assurance that delivery of resuscitation was, in fact, congruent with patient wishes. Potential harms include introduction of legal risks, interference with resuscitation, and exposure of family members to what may be an intense and unsettling scene. Pediatric settings potentially magnify the need for transparency and closure for parents and loved ones of children experiencing cardiac arrest. Despite initial concerns, recent data indicate that both families and staff support the concept, with many families expressing a strong desire to be close to their child in the final moments of their life (Duran et al., 2007). Multiple pediatric associations support family presence (ENA, 2009; Henderson and Knapp, 2005; Kleinman et al., 2010a).

In either adults or children, the collective literature suggests that ideally family presence should not be an ad hoc experience. Rather, hospitals should have explicit, detailed policies regarding whether family presence will be invited. These policies should also identify specific roles for resuscitation team members, such as escorting family members to the scene, explaining the events, and—critically—debriefing with the family afterward to answer questions and identify potential adverse effects of the experience. Box 5-8 summarizes the key points in this chapter.

BOX 5-8
Chapter Summary and Key Points

- In-Hospital Cardiac Arrest
    - IHCA is in many ways different from OHCA, and represents a unique population subset.
    - There are a number of knowledge gaps in this field, and challenges related to measurement of IHCA incidence resulting from the absence of separate diagnostic and procedure codes for OHCA and IHCA.
    - Substantial variability exists in the approach, availability, and quality of resuscitation care provided by hospitals around the nation.
- Post-Arrest Care
    - Treatments (such as therapeutic hypothermia) have demonstrated the potential to improve patient outcomes, but scientific evidence to support many post-arrest treatments are still nascent.
    - More research is needed to develop standardized tools for accurate neurologic prognosis.
    - Ethical questions regarding withdrawal of care remain challenging to answer.
- Strategies for Improvement
    - Separate diagnosis codes for IHCA and OHCA should be established.
    - More research targeting simulation training, debriefing strategies, and mechanical devices can improve quality of CPR and resuscitation care.
    - Team training is needed to improve IHCA and post-arrest care response.
    - Standardized performance metrics for cardiac arrest need to be developed and endorsed by national organizations to assess the quality of hospital care.
    - Create and maintain multicenter collaboratives can promote and advance continuous quality improvement efforts.
    - Patient- and family-centered cardiac arrest care can emphasize advanced directives, DNAR, withdrawal of care, and family presence during resuscitation.

CONCLUSION

There are many opportunities to improve and optimize care for cardiac arrest patients within hospitals, and to increase the likelihood of survival with good neurologic outcomes for all cardiac arrest patients. Today, there are remarkable variations between hospitals in treatments protocols for IHCA and post-arrest care, which lead to differential and often poor outcomes. These differences occur partially because of a lack of scientific evidence and known standards in resuscitation care. In response to the growing literature that highlights these systemic failures, experts in the resuscitation field, guideline-setting organizations, and some hospital administrators are placing an increased emphasis on developing quality improvement strategies. This requires stakeholders to sequentially prioritize performance-standard setting, the measurement and collection of patient data, and the development and implementation of continuous quality improvement programs within hospital-based resuscitation systems of care. This will allow each system to assess its performance and benchmark against other similar institutions and will drive improvements in quality of care.

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6

Resuscitation Research and Continuous Quality Improvement

Research, along with the implementation of best practices that are based on that research, provides the foundation necessary to improve cardiac arrest outcomes over the next decade. Despite being a leading cause of death in the United States (Taniguchi et al., 2012), cardiac arrest lacks prioritization in terms of national support and collaboration to enhance research efforts. Fundamental gaps in knowledge about the epidemiology, etiology, pathophysiology, and treatment of cardiac arrest contribute to difficulties in establishing national evidence-based practice standards to guide local decision making about practice protocols that can lead to optimal patient care and outcomes. State-level regulation of emergency medical services (EMS) and health care systems, as well as variation in available resources and capacities, further complicates the process. A broader focus on, and investment in, cardiac arrest research is needed to overcome these challenges.

Paradoxically, as knowledge about cardiac arrest expands, it can be increasingly difficult to analyze this knowledge and to uniformly and rapidly translate it into enhanced patient care. Within the current systems of response to cardiac arrest, there are many occasions to generate waste that can affect patient care. In general, patient outcomes are dependent on the following components: (1) a culture that supports scientific pursuit; (2) science that expands the existing knowledge base; (3) translation of this knowledge into evidence-based practice on a wide scale; and (4) care that is provided by competent, well-trained individuals and is subject to formal and continuous quality assessment. Specific barriers and limitations between each component contribute to missed opportunities, waste, and harm, as illustrated in Figure 6-1.

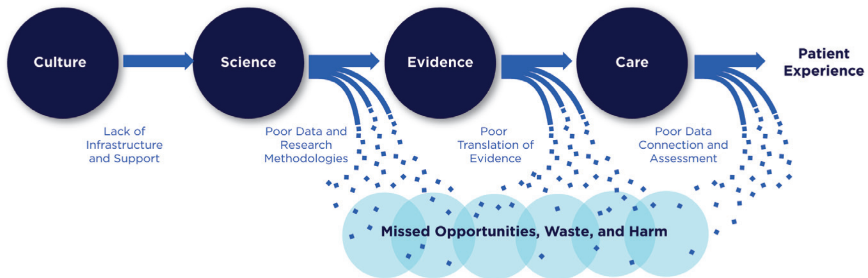

FIGURE 6-1 Schematic of today's system of response to cardiac arrest.
SOURCE: Adapted from IOM, 2012, p. 15.

Reducing the missed opportunities, waste, and harm at a national level requires known treatments and strategies to improve the system of response, as well as a renewed commitment to research—not only the execution of sound basic, clinical, and translational research, but also a steadfast commitment to the principle of continuous measurement and assessment between and within EMS and health care systems. To achieve this goal, the field of resuscitation science must not only evaluate the current approaches to the treatment of cardiac arrest, but also fundamentally reassess its approach to research and existing mechanisms for generating new knowledge. First, there is a need to improve the current methods for quantifying and understanding the public health problem of cardiac arrest, including both care process and outcomes. Second, it is essential to consider a paradigm shift in how scientific investigation is conducted in order to appreciate the likely complexity of patient populations and treatment effects. Third, it is critical to identify and implement new strategies and devices for improved care delivery. Finally, it is important to reconsider the processes by which experts evaluate scientific evidence and develop and implement guidelines for recommended treatments. In other words, the resuscitation field needs to reappraise how knowledge about cardiac arrest is generated and how best to translate that knowledge into improved patient outcomes (Neumar, 2010). This will require both internal and external support for the resuscitation field.

Previous chapters have examined the evidence on treatments and interventions for out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) and have explored strategies to optimize post-arrest care. In this chapter, the committee evaluates the current state of resuscitation research and identifies potential areas for improvement. The first two sections describe the state of current infrastructure, highlighting promising new areas of research to improve cardiac arrest survival, and the overarching status of cardiac arrest research infrastructure and support. The next section discusses the need for a learning system of response to cardiac arrest based on principles of a learning health care system and formal adoption of continuous quality improvement principles to improve accountability for system performance and cardiac arrest outcomes. The final section talks about the need for increased advocacy to generate sustained and sufficient support for resuscitation research and dissemination of research findings to positively affect clinical practice and patient outcomes.

THE STATE OF RESUSCITATION RESEARCH: ENHANCING THE SCIENCE

To better understand the physiological, social, and environmental risk factors for cardiac arrest and unfavorable health outcomes associated with cardiac arrest, research and specialized expertise are needed across an array of disciplines. High-quality, innovative investigations across the spectrum of research are needed to support further progress in valuable research areas, such as cellular and molecular medicine. From basic science to the translation of evidence into practice in communities across the country, there are a multitude of opportunities along the translation research continuum where the resuscitation field could benefit from targeted improvements. Figure 6-2 depicts the phases of this continuum.

Applying the phases of translational research to cardiac arrest, the figure starts with basic science (T0), where diminishing funding has led to a paucity of cardiac arrest research that focuses on the etiology and physiological mechanisms that underlie many of the complexities noted throughout this report. Without an understanding of physiological mechanisms of action, the translation of new therapies to human studies (T1) decreases. When innovative new therapies are not tested in humans, the translation to patients (T2) is not possible. Translation to practice (T3) and the broader community (T4) is then stifled, resulting in missed opportunities to affect the survival and outcomes of individuals and populations within communities. This section assesses the potential of research, new research models, and emerging technologies and devices to improve treatment protocols for cardiac arrest that will improve patient outcomes.

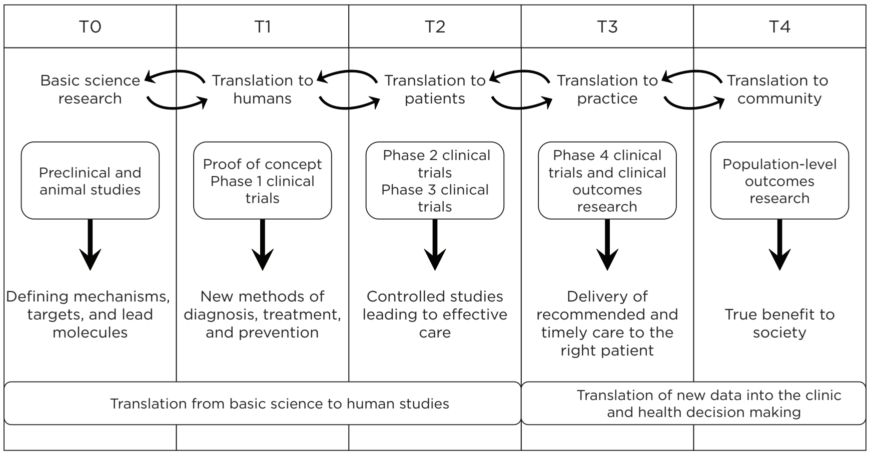

FIGURE 6-2 Operational phases of translational research (T0-T4).
SOURCE: Adapted with permission from Macmillan Publishers Ltd.: *Nature Medicine* (Blumberg et al., 2012).

Research to Improve Treatments

In recent years, a new paradigm for cardiac arrest response proposed a three-phase model (i.e., electrical, circulatory, and metabolic phases) "to reflect the time-sensitive progression of resuscitation physiology, which in turn requires time-critical interventions" (Weisfeldt and Becker, 2002, p. 3035). Research has demonstrated that early access to existing therapies during the electrical phase (from time of cardiac arrest to approximately 4 minutes following arrest) and the circulatory phase (between 4 and 10 minutes after arrest) can be highly effective (Weisfeldt and Becker, 2002; see also Ewy et al., 2006). After approximately 10 minutes without treatment, patients enter the metabolic phase of cardiac arrest, which involves a number of cascading biochemical pathways that may extend beyond localized organ damage and can result in full-body systemic injury (Bainey and Armstrong, 2014; Frohlich et al., 2013; Kalogeris et al., 2014). The metabolic phase of cardiac arrest is associated with poor survival rates and neurologic and functional outcomes. In this late phase, the standard guideline-recommended therapies, such as CPR and defibrillation, are usually unsuccessful (Weisfeldt and Becker, 2002). Additional research is needed to define the role of alternate techniques for improving blood flow during a cardiac arrest to maximize the period for successful intervention. Box 6-1 provides other examples of possible research areas by treatment phase.

Metabolic therapies that target specific injury pathways have demonstrated increasing potential to improve survival following prolonged, untreated cardiac arrest (Bartos et al., 2014, 2015; Riess et al., 2014). Furthermore, some studies suggest that the commonly accepted 4-minute time limit beyond which ischemic injuries begin to irreversibly damage critical organs may be extended (Allen and Buckberg, 2012; Allen et al., 2012a,b; Athanasuleas et al., 2006; Trummer et al., 2010, 2014).

Recent investigations have reported that a combination of protective drugs and other treatments may be more effective in delaying the severe biological consequences of prolonged cardiac arrest (Bartos et al., 2015; Boller et al., 2011). Using a combination of therapies targeting the circulatory and metabolic phases of cardiac arrest, animal model research suggests the potential to restore life after sustained periods of clinical death. For example, in a recent laboratory experiment using porcine models, Bartos and colleagues (2015) demonstrated improved rates of survival with minimal or no neurological deficits after 17 minutes of cardiac arrest after administering medications and treatments to mitigate the tissue damage associated with reperfusion injury. Another swine experiment achieved survival following 30 minutes of isolated brain ischemia by infusing a warm blood reperfusate that consisted of free radical scavengers, a calcium chelating compound, inflammatory controls, osmotic controls, and energy substrates for 20 minutes instead of oxygenated blood during reperfusion (Allen et al., 2012a).

In a recent human trial, Australian investigators treated cardiac arrest patients who had an initial cardiac rhythm of ventricular fibrillation (VF), had received traditional advanced cardiac life support (ACLS), but had not achieved return of spontaneous circulation after 30 minutes (among other inclusion criteria) (Stub et al., 2015a). Researchers employed a combination of treatments that included mechanical cardiopulmonary resuscitation (CPR) (due to long periods of resuscitation), intra-arrest cooling via intravenous ice cold saline, rapid initiation of extracorporeal membrane oxygenation, and rapid percutaneous coronary intervention for patients with coronary artery occlusion (Stub et al., 2015a). Of the 26 patients who participated in this study, 14 (54 percent) were discharged from the hospital with favorable neurologic status (Stub et al., 2015a). Although this was a small feasibility study, it demonstrates new possibilities in cardiac arrest recovery and the importance of funding research to explore new treatment models and therapies in efforts to improve patients' lives.

BOX 6-1
Examples of Possible Research Areas by Treatment Phase

Electrical Phase
Research to reduce time to defibrillation, including the use of automated external defibrillators (AEDs), implantable medical devices (e.g., implantable cardioverter defibrillators), and wearable defibrillators.

Circulatory Phase
Research to improve efficiency of CPR, which currently only provides 10 to 30 percent of regular blood flow to the heart and approximately 30 to 40 percent to the brain, as demonstrated in animal studies (Meaney et al., 2013).

Research into the effects of alternate manual CPR techniques, such as those that employ active compression and decompression and impedance threshold devices (Pirrallo et al., 2005; Wolcke et al., 2003).

Research involving advanced circulatory systems, such as emergency cardiopulmonary bypass resuscitation, which involves the rapid placement of the arrested patient on a heart-lung machine to provide full blood circulation to the heart and brain (Johnson et al., 2014; Nagao et al., 2000, 2010; Nichol et al., 2006; Wallmuller et al., 2013).

Metabolic Phase
Investigation of interventions designed to control and minimize reperfusion injury, the inflammatory response responsible for cellular death and diminished organ function (Anderson et al., 2006; Bainey and Armstrong, 2014; Becker, 2004; Frohlich et al., 2013; Lavani et al., 2007).

Research on the effects of hypothermia on the cellular, molecular, and physiological effects of ischemia and reperfusion (Bro-Jeppesen et al., 2015; Cronberg et al., 2015; Nolan et al., 2010).

Research on the effects of other interventions targeting post-anoxic and ischemic brain injury.

Research Methodology and Trial Design

Over the past 30 years, many large randomized clinical trials for specific cardiac arrest treatments have found no demonstrated benefit (Aufderheide et al., 2011; Stiell et al., 2011). For instance, a recent study found that targeted temperature management at 33°C did not improve survival or neurological outcomes over targeted temperature management at 36°C (Nielsen et al., 2013). Similarly, research findings related to the impact of mechanical CPR devices are mixed, with trials demonstrating increases in CPR quality, but only nonsignificant impacts on survival to discharge (Hallstrom et al., 2006; Ong et al., 2012b; Wik et al., 2014).

The lack of measured impact in these trials may be attributable to a variety of systemic factors and methodological limitations. One possible explanation is that specific treatments are simply ineffective. As a result, researchers may focus on therapies with a limited likelihood of measurable benefit, including therapies that are based on insufficient preclinical work, that have unknown or unclear mechanisms of action, or have documented ineffectiveness. Decisions made during the design of clinical trials may also reduce the likelihood that the study will result in a demonstrated benefit or identify optimal use. This is especially true if the trials are based on sparse prior information related to the optimal treatment population, treatment efficacy, and the most appropriate biomarker or patient-centered outcome measure. The urgency of identifying new therapies for cardiac arrest can create incentives for researchers to perform confirmatory or even pragmatic trials before clearly establishing efficacy in more controlled and limited settings.

Resuscitation research investigating the efficacy of new treatments should utilize clinical designs and research strategies that have the highest probability of demonstrating benefit after accounting for the heterogeneous nature of cardiac arrest and cardiac arrest patients. Traditional drug and device development processes, which largely uniformly apply and evaluate one therapy at a time regardless of important variations in patient populations, may fail to detect clinically important benefits when therapies are combined or used in select subsets of patients. The complex nature of cardiac arrest will likely require simultaneous testing of multiple treatment and treatment modalities in order to identify new effective treatments. The biggest successes may materialize when multiple treatment approaches are combined and carefully tailored to individual patient characteristics and responses to treatment (i.e., individualized resuscitation).

There is now broader recognition in the scientific community that the traditional sequential series of individual clinical trials—each testing a single treatment in a relatively homogeneous population—is time consuming, resource intensive, and increasingly leads to failed trials late in the testing phase (Berry et al., 2015). An analysis of research into neuroprotectants for ischemic strokes—an area that involves local effects of ischemia and reperfusion—identified more than 40 failed Phase III trials (Minnerup et al., 2014). Recent analyses of the increasing overall failure rates in Phase III pharmaceutical clinical trials have concluded that inadequate Phase II trials (or "learn phase" trials) contribute to, as a primary factor, the low success rates in Phase III trials (Lavine and Mann, 2012; McAuley et al., 2010; Retzios, 2009).

Examples of research strategies and clinical trial designs that could increase the efficiency and success rate of resuscitation research include the increased use of small, hypothesis-generating studies; a more robust exploration of dose effects and modifiers of efficacy (i.e., interactions between treatments and patient characteristics) in learn phase trials; the use of randomized, withdrawal trials; and the implementation of adaptive clinical trials and platform trials (see Table 6-1). For example, a randomized, withdrawal trial could be used to study the use of therapeutic hypothermia. This type of trial would treat all patients with therapeutic hypothermia and then randomize the time of rewarming (the withdrawal of the treatment) only in the subset of patients who demonstrated some benefit as determined by a defined biomarker. Other novel approaches include adaptive and platform trials, which often use response-adaptive randomization so that patients who are enrolled later in the trial are preferentially randomized to treatment arms that are most likely to be beneficial (Berry et al., 2015; HHS, 2010). This approach may improve the risk-to-benefit balance for research subjects, increase the chance of a definitive trial outcome, and increase the number of subjects ultimately treated with the best-performing treatment arm (Meurer et al., 2012). Criteria for defining a positive adaptive or platform trial result should be selected to ensure protection from false positive results (FDA, 2015a).

A strategic approach to implementation of resuscitation science discoveries and new therapies is required to foster evidence adoption, use, and sustainability. Once a new treatment has demonstrated benefit in controlled clinical trials, it must be tested in increasingly realistic settings to confirm effectiveness and to identify the optimal clinical practice

TABLE 6-1 Traditional and Alternative Clinical Trial 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.
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, 2015a).
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).

protocols. Translational research focuses on the translation of new findings in basic science into new treatments and the adoption of those treatments in practice (Rubio et al., 2010). Table 6-2 offers a summary of key areas of focus for possible future resuscitation research across the spectrum of translational research. In the resuscitation field, guidelines are a predominant mechanism for translating research into practice. (The strengths and weaknesses of national guidelines related to cardiac arrest treatment are discussed later in this chapter.) The rapid translation of basic research findings into new treatments and the adoption of new treatments into practice is more likely if clinical trials and related studies are designed to produce results that can facilitate evidence-based practice.

TABLE 6-2 Key Areas for Resuscitation Science Research

Major Research Area	Research Subjects
Basic science	Mitochondria, energetics, and metabolism; cellular death pathways; loss of ionic control and membrane integrity; reperfusion injury biology; pharmacology, receptors, and channels; endothelial barrier and injury; inflammatory pathways; genetics and epigenetics; neurological injury and cardiovascular injury mechanisms
Bioengineering and biosensor science	Sensors of micro- and macro-hemodynamic function; EKG and defibrillator developments; metabolic sensors, redox sensors, and mitochondrial function sensors; optimization of CPR and external compressors; ventilator devices; modulation of thoracic impedance; cardiopulmonary bypass technologies; artificial oxygenation; oxymetry, capnography; early EMS notification technology; prediction of cardiac arrest technologies; vascular access technologies
Preclinical science	Oxygenation during resuscitation; pharmacological ACLS protocol testing; combinatorial therapies (multidrug cocktail development); one-size-fits-all versus patient-centered physiologically guided CPR; translational studies on favorable basic science and bioengineering technologies; optimization of hypothermia studies and new hypothermia technology; impact of differing age on resuscitation; ventricular fibrillation mechanisms; defibrillation waveforms; emergency cardiopulmonary bypass mediated resuscitation

Clinical studies	Optimal airway and oxygenation studies; ACLS pharmacological studies of epinephrine, vasopressor drugs, and anti-arrhythmic drugs; hypothermia studies; optimized CPR technique and protocol studies; clinical studies focused on special populations: studies of neonates, children, and geriatric populations; studies of combinatorial strategies
Systems of care	Simulation training, team training, and high-performance CPR; dispatcher-assisted CPR, telemedicine, and remote resuscitation care; social media, crowdsourcing to improve notification, bystander action, and community survival rates; willingness-to-act-to-rescue studies, early recognition of symptoms; optimization of training studies; implementation strategy studies; studies on the impact of public policy, informed consent, and ethics of resuscitation
Population studies	Risk factor and genetic markers of cardiac arrest; diversity studies focusing on communities with high- and low-survival rates; racial, ethnic, and socioeconomic factors in incidence and survival; effects of age on incidence and survival; special populations: focused on underserved communities, resource-scarce communities, and diverse populations

NOTES: This list was generated by review of two prior consensus statements on resuscitation research priorities and was then amended with additional consideration by the IOM Committee on the Treatment of Cardiac Arrest: Current Status and Future Directions. In 2002, the NIH-sponsored PULSE Conference identified five domains for high-priority research that included (1) mechanisms, (2) pharmacology, (3) translational studies, (4) bioengineering, and (5) clinical evaluative research (Becker et al., 2002). In 2005, the American Heart Association sponsored the 2005 Guidelines Conference and identified categories that included medical emergency teams; recognition of cardiac arrest and its causes; body position; electrical defibrillation; blood flow generation; airway management; ventilation; oxygenation; pharmacological interventions; metabolic, temperature, and post-resuscitation management; physiological monitoring and feedback; ethical issues; education and training; and outcomes (Gazmuri et al., 2007). ACLS = advanced cardiac life support; CPR = cardiopulmonary resuscitation; EKG = electrocardiogram.

Emerging Technologies and Devices

Recent progress in science, engineering, health informatics, and mobile technologies has created the potential to revolutionize treatments and care delivery in the field of cardiac arrest and resuscitation. The committee was charged with evaluating the "research, technology transfer and innovation, and implementation gaps," as well as promising new strategies that have the potential to improve cardiac arrest outcomes (see Box 1-1). Previous chapters have described innovative new therapies (e.g., hemodynamic support therapies such as extracorporeal membrane oxygenation) and care strategies (e.g., prediction models for early detection of deterioration in IHCA patients) for OHCA and IHCA resuscitation and post-arrest treatment, as well as devices to improve quality of resuscitation treatment (e.g., monitoring and impedance threshold devices). This section examines emerging technologies and devices that are currently in prototype or early preclinical phase testing and, therefore, have not been widely incorporated into clinical practice. Although many of these devices and mobile applications have not yet met the U.S. Food and Drug Administration (FDA) criteria for broad distribution because of the lack of evidence from large-scale clinical trials, the committee recognizes that these state-of-the-art technologies have the potential to significantly improve worldwide survival of cardiac arrest.

Innovations in smartphone and mobile applications, social media, home monitoring devices, and wearable technologies could significantly reduce the time interval between collapse and treatment and substantially improve patient survival rates (Scholten et al., 2011). Collection of data from many of these devices could be used to enhance research and surveillance activities, with appropriate privacy protections, and drive improvements in prevention of cardiac arrest as well as quality of care delivery (Bosley et al., 2013; Chang et al., 2013). Similarly, analytics of patient data from hospital and other health care facilities have the potential to predict cardiac arrest, thereby improving medical treatment and response (Churpek et al., 2012; Ong et al., 2012a). Emerging technologies may support better CPR training and performance by monitoring the rhythm and compression depth with real-time feedback and could be an effective aid in continuing education for first responders (Chang et al., 2015; Fischer et al., 2011; Martin et al., 2013). Finally, outpatient monitoring of patients who are already at greater risk for cardiac arrest (such as a recovering cardiac arrest patient or a patient with a predisposing cardiac condition) could potentially reduce the cost of care across a greater number of patients, especially in rural or underserved areas (Przybylski et al., 2009; Reynolds et al., 2006). Technological innovations for assessing patients undergoing resuscitation have the potential to personalize our approach to patients in cardiac arrest.

Adoption of these mechanical devices and wearable technologies has been limited because of a lack of robust evidence collected from clinical trials, as well as challenges related to data management and patient privacy issues, reliability and interoperability (Honeyman et al., 2014). Moreover, there are few consensus statements on best practices or implementation of these technologies. FDA recently issued guidelines regarding mobile medical applications, but it has not yet evaluated these in the context of cardiac arrest treatment and care strategies (FDA, 2015c). Box 6-2 provides additional examples of new technologies and devices that could enhance the cardiac arrest chain of survival.

Although the private sector plays an integral role in developing technologies to improve cardiac arrest treatment, the public sector can also support progress through a variety of mechanisms. Research to determine the effectiveness of mobile applications, social media, and innovative devices such as wearable alert systems in improving cardiac arrest survival is paramount. The National Institutes of Health's (NIH's) National Institute of Biomedical Imaging and Bioengineering supports research that integrates physical, engineering, and life sciences to accelerate the development and application of biomedical technologies (NIBIB, 2015). Research into new areas, such as advances in imaging or thermometry, may lead to new therapies to restore spontaneous circulation and diagnose or prevent neurological damage after cardiac arrest. Additional research is necessary to develop more complex devices targeting early recognition and response to cardiac arrest, as well as the quality of resuscitation and post-arrest care.

Regulatory controls, such as the premarket approval process, must promote safety without stifling innovation; this constitutes a major challenge within health policy and translational science, both in general and in the field of cardiac arrest in particular (FDA, 2011). As of February 2015, FDA now requires that AEDs and AED accessories (e.g., batteries, electrodes, and adapters) undergo premarket approval before being released for sale to the general public (FDA, 2015b). This decision was made in light of device recalls and reported problems with the design and manufacture of AEDs. The premarket approval process is meant to provide reasonable assurance of the safety and effectiveness of the device, and it includes review of the methods, facilities, and controls involved in the manufacturing, processing, packing, and installation of devices (FDA, 2014). To improve efficiencies in regulatory approval of technology for cardiac arrest, fast-track review, and expedited premarket approval within FDA may be appropriate with post-market surveillance.

BOX 6-2
Examples of Emerging Technologies and Devices

Early Detection and Emergency Alert System
A majority of cardiac arrests occur in the home and are often unwitnessed. Mobile applications, technologies, and devices that can track outpatient physiological data, monitor electrocardiograms and pulse and cardiac arrhythmias, and activate the "chain of survival" could have a profound effect on saving lives. A recent study tested a wrist watch that is designed to send a radio signal to alert emergency medical systems when it detects a loss of pulse (Rickard et al., 2011). It includes a motion sensor that can cancel the alert if the patient is conscious. Although an initial clinical trial demonstrated a 10 percent false-positive rate, such outpatient monitoring can significantly reduce collapse-to-treatment times in cardiac arrest and shows great promise.

Bystander Response Assistance
There are more than 50 smartphone applications currently on the market that can perform a variety of tasks including providing a platform that connects cardiac arrest patients with the nearest bystander or trained first responder, and providing CPR instructions and locating the nearest AEDs (Sakai et al., 2011, 2015; Scholten et al., 2011). Multiple EMS agencies have these mobile applications, which are simultaneously activated by the local public safety agencies along with EMS dispatch for patients who arrest in public locations (PulsePoint, 2015). One study in Sweden found that bystanders arrived before the ambulance over half of the time and performed CPR 30 percent of the time (Ringh et al., 2011). Innovative prototypes for "ambulance drones" have been developed and proposed as a model strategy for reducing collapse-to-defibrillation time (TU Delft, 2014). The EMS provider can air deliver the "ambulance" which contains a functional AED, camera, and speaker, using a built-in global positioning system and can locate the cardiac arrest patient and bystander.

Internal, External, and Wearable Technologies for Defibrillation
Patients at increased risk of cardiac arrest can use wearable external defibrillators as a promising and noninvasive alternative to implantable cardioverter-defibrillators. Wearable defibrillators are FDA approved, covered by many health plans in the United States, and can effectively detect and reverse ventricular tachyarrhythmia (Feldman et al., 2004; Lee and Olgin, 2009). They consist of a lightweight garment that sounds an alarm before delivering a shock. Patients who are conscious can manually turn this off to avoid receiving defibrillation. A number of nonwearable and portable AEDs also are available on the market.

Research and Surveillance Capacity
Data stored by AEDs and implantable cardioverter defibrillators can be transmitted via smartphones and cellular networks to providers for remote monitoring (Crossley et al., 2011). Traditional surveillance systems often cannot accurately capture the time interval between patient collapse and treatment. Data from AEDs as well as wearable devices that allow wireless data export of global-positioning-system or patient-monitored data, can provide information regarding time of collapse, location, and other important factors, and can fill an important gap in current knowledge regarding unwitnessed cardiac arrests. Some investigators have harnessed the power of social media outlets such as Twitter to analyze trends in cardiac arrest and better understand factors that determine public action and response (Bosley et al., 2013).

Devices to Guide and Individualize Treatment
New technologies have the potential to guide and individualize resuscitation efforts. Mechanical CPR devices that allow for individualization (such as discrete input [e.g., gender or body size] or continuous input [e.g., carbon dioxide levels]) have demonstrated efficacy in limited settings. However, a meta-analysis found mixed evidence from clinical trials and did not find a substantial difference between mechanical and manual CPR in increasing survival to discharge (Ong et al., 2012b). Currently, end-tidal carbondioxide monitoring is recommended but is limited to intubated patients (Neumar et al., 2010). Noninvasive tools such as ultrasound and devices that are capable of measuring blood flow during CPR have the potential to change the approach to the treatment of patients in cardiac arrest (Volpicelli, 2011).

INFRASTUCTURE AND SUPPORT FOR RESUSCITATION RESEARCH

Many barriers within the resuscitation research field limit the impact of much-needed cardiac arrest research. Fragmented administrative oversight and coordination across federal research agencies and in academia complicates efforts to better understand the state of resuscitation research and engage in coordinated, collaborative research and funding efforts. Funding that is available for resuscitation research is disjointedly allocated and lacks transparency. Based in part on these persistent challenges, advocacy efforts have not been able to successfully expand available research resources across all levels—from basic research to population-level studies. Ideally, a robust cardiac arrest research agenda would ensure that research findings at the T0 level are transformed into practices that benefit the community (T4) and improve health. To successfully implement such a broad research agenda, the resuscitation community must first overcome the infrastructure barriers described below in order to ensure a sustainable and active research pipeline that includes sufficient numbers of researchers.

Administrative Oversight and Coordination

Federal agencies charged with activities related to the public's health and high-quality health care play an important role in the success and failure of local, state, and national efforts to improve outcomes from disease, health conditions, and health-related events—such as cardiac arrest. For example, NIH credits its research for major health advances related to declines in mortality from cancer, heart disease, and stroke, as well as improvements in antiviral therapies for people infected with the human immunodeficiency virus (NIH, 2012b). However, fractured federal oversight, a lack of interagency coordination, and overlapping authorities within federal agencies pose substantial barriers to advancing basic, clinical, and translational research in cardiac arrest treatment. At a national level, federal oversight of responding to and treating cardiac arrest has been largely prescribed by the site of cardiac arrest, with OHCA largely the province of EMS and IHCA the responsibility of hospital-based systems of care. For example, agencies or departments involved with EMS, including the U.S. National Highway Transportation and Safety Administration and the U.S. Department of Defense, may view cardiac arrest treatment as one indicator of the quality of the overarching EMS system (NHTSA, 2009).

NIH, the Centers for Disease Control and Prevention (CDC), and the U.S. Health Resources and Services Administration (HRSA) provide traditional support for general resuscitation research through various grant mechanisms that fund individual research studies, large-scale data collection, and infrastructure. However, within agencies, resuscitation research grants may be spread across a wide range of institutes or offices and various topics (e.g., basic science, training, and treatment protocols) related to, but not necessarily dedicated to, the study of cardiac arrest. For example, although the National Heart, Lung, and Blood Institute (NHLBI) is the official lead institute for resuscitation research within the NIH, funding is spread across multiple NIH institutes, including the National Institute of Neurological Disorders and Stroke (NINDS) and the National Institute of Child Health and Human Development (NICHHD) (see Figure 6-3). A pediatric cardiac arrest study that targets the circulatory phase of resuscitation could theoretically be funded as a cardiovascular, neurologic, or pediatric study within different NIH institutes. Because the missions and priorities of individual institutes may overlap, the appropriate funding institute is not always apparent to investigators or the public, leading to confusion and suboptimal coordination of activities within the research community. Although this challenge is not unique to cardiac arrest research, it has an ongoing impact on efforts to streamline cardiac arrest research.

NIH also houses the Office of Emergency Care Research, which "coordinates, catalyzes and communicates about NIH funding opportunities in emergency care research and fosters the training of future researchers in this field" (NIH, 2013b). It is a trans-NIH office but, unlike other trans-NIH offices, has no budget for funding research (NIH, 2012a). Although it does not focus exclusively on resuscitation research, the office has worked with NINDS and the NICHHD on research and training activities related to post-resuscitation hypothermia (NIH, 2015c). As mentioned in Chapter 2, the office will also play a role in NIH's new cross-collaborative clinical trials network for emergency care, Strategies to Innovate EmeRgeNcy Care Clinical Coordinating Center (SIREN), which could be used for resuscitation research.

In addition to support provided by NIH, CDC, and HRSA, a number of other federal agencies and private organizations provide support for cardiac arrest and resuscitation research or whose missions aligns with improving cardiac arrest treatment and care. The U.S. Department of Veterans Affairs (VA) funds multiple projects with various academic institutions to better understand the incidence and response to cardiac arrest. The VA also requires its care facilities to establish an interdisciplinary committee to "review each episode of care where resuscitation was attempted for the purpose of identifying problems, analyzing trends, and improving processes and outcomes," but the enforcement of this rule between facilities varies (VA, 2015). Although the Patient-Centered Outcomes Research Institute has not focused on cardiac arrest specifically, its mission "to improve patient care and outcomes through patient-centered comparative clinical effectiveness research" is generally applicable to resuscitation research (PCORI, 2014). The Centers for Medicare & Medicaid Services (CMS) reimburses health care providers for particular services and treatments related to cardiac arrest, but the committee

NIH Institute	# Grants	Count
NHLBI		42
NINDS		23
NICHD		6
NIDDK		2
NIDA		2
NIMH		2
NHGRI		1
NIA		1
NIGMS		1
NCI		1
NIEHS		1
NCATS		1

FIGURE 6-3 Location and number of grants related to cardiac arrest within the National Institutes of Health in 2013.
SOURCE: Lathrop, 2014.

did not find any recent initiative that focuses specifically on cardiac arrest survival.[1]

The Need for Sustained and Coordinated Research Funding

The ability of resuscitation research to improve cardiac arrest outcomes relies on sustained funding and widespread implementation of practices based on newly generated evidence (described in greater detail in the next section). In 1962, Senator Hubert H. Humphrey urged "the creation of NIH centers or institutes that focus on the physiology of death, *on resuscitation* and on related topics," underscoring the desire to prolong life, postpone death, and possibly reverse death (Humphrey, 1962, emphasis added). This spurred interest and research related to cardiac arrest treatment. Unfortunately, evolving and shifting priorities within federal agencies and among congressional leadership shifted focus away from cardiac arrest treatment as early as the 1990s and continues to affect current research activities (Thompson et al., 1996).

Many federal agencies and private-sector organizations provide research support related to the study and treatment of cardiac arrest. However, even within a single Institute or office, the exact amount of annual research funding is often difficult to calculate. The majority of NIH funding for cardiac arrest, as for other biomedical research funding through NIH, supports investigator-initiated research applications. As a whole, cardiac arrest funding is not reported as a separate line item in NIH's annual research portfolio, as other research and disease areas are (e.g., Alzheimer's disease, brain cancer, traumatic brain injury, and stroke) (NIH, 2015a). Estimates of total annual funding related to cardiac arrest are available, calculated by a search and review of all funded grant awards by search term. The search terms "cardiac arrest" and "resuscitation science" generally identify grants related to the treatment of cardiac arrest, whereas the term "sudden cardiac death" is categorized as an arrhythmia, which also includes prevention-related research on "arrhythmogenesis, genetic and environmental bases of normal cardiac electrical activity and arrhythmias, and etiology of rare and common arrhythmias" (NIH, 2014).

Based on these searches, NIH's total support related to cardiac arrest in fiscal year 2013 was approximately $107.7 million ($40.3 million for cardiac arrest and $67.4 million for sudden cardiac death and resuscita-

[1]CMS and CDC are joint leaders of the Million Hearts® Initiative, which focuses on the prevention of heart attacks and stroke (CDC, n.d.).

tion sciences), of which NHLBI provided $85.4 million (Lathrop, 2014). However, these estimates are likely inflated because of overlap in the awards identified using search terms (i.e., more than one search term may be included in the same grant award). Comparatively, stroke, which kills approximately 130,000 people annually received approximately $282 million of NIH's research budget in 2013 (CDC, 2015; NIH, 2015a). In fiscal year 2013, NIH invested an estimated $5.27 billion on cancer research and about $1.96 billion on cardiovascular disease research (NIH, 2015a). Recent studies have identified potential, untapped sources of funding, including private philanthropy and foundations, the biomedical industry, the insurance industry, and more traditional private-sector organizations, which can be used to complement federal agency investment in resuscitation research (Myerburg and Ullmann, 2015).

Cardiac arrest support falls short when compared to other critical diseases and conditions using additional metrics. A recent study found that, between 1996 and 2006, "advancement in the treatment of acute ST Segment Elevation Myocardial Infarction (STEMI) has led to gradual reduction in the incidence of STEMI related cardiogenic shock irrespective of ethnicities or gender suggesting improving outcome of patients presenting with STEMI" (Movahed et al., 2014). Similarly, acute cardiovascular disease and stroke hospitalizations, mortality, and readmissions rates declined more rapidly between 1999 and 2011 than did other conditions (Krumholz et al., 2014). Figure 6-4 provides a comparison of the number of published randomized control trials, NIH-funded studies, and deaths by STEMI (a specific type of heart attack), stroke, heart failure, and cardiac arrest. Although this is only one study limited by its date of publication, when combined with documented declines in deaths from other, more, well-funded diseases and conditions, this figure further supports assertions of the important relationship between research levels and patient outcomes from cardiac arrest.

Similarly, the grants supporting resuscitation research are distributed across multiple academic institutions throughout the United States, and the current administrative structure of these grants provides very little incentive for cross-institutional collaboration. Some academic institutions have attempted to create translational "centers of excellence" that conduct research from the bench to the bedside. For example, in 2010, four academic medical centers formed the National Post-Arrest Research Consortium through NIH's Clinical and Translational Research Award program, seeking to "advance science and foster partnerships to speed innovation and accelerate laboratory discoveries into treatments for [cardiac

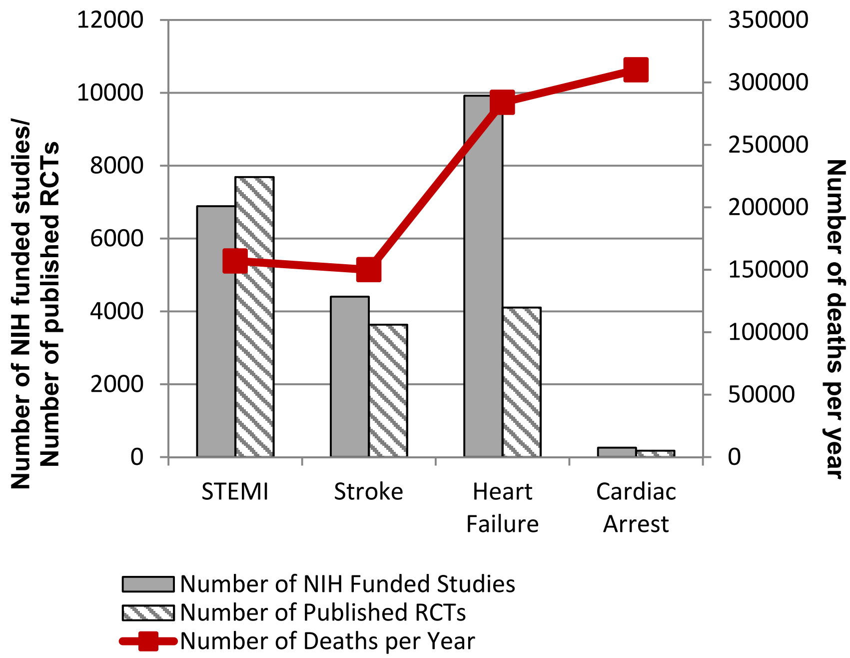

FIGURE 6-4 Comparison of four diseases by annual deaths and specific research support.
NOTE: NIH = National Institutes of Health; RCT = randomized controlled trial; STEMI = ST segment elevation myocardial infarction.
SOURCE: Ornato et al., 2010.

arrest] patients" (Virginia Commonwealth University, 2011). Despite the consortium's potential, its impact was limited by the number of partnerships within the consortium and available funding.

The ability to successfully treat cardiac arrest depends on having a workforce that knows how to conduct research and translate that research into practice. In addition to the lack of population health data for cardiac arrest (see Chapter 2), there is also a striking lack of a viable preclinical research laboratory enterprises. A viable preclinical enterprise must exist that includes sustainable animal laboratories that use robust animal models, but the current number of active basic science and preclinical laboratories working in the area of cardiac arrest in the United States is in the single digits (Yannopoulos, 2014). Some experts suggest that fewer young scientists are choosing to pursue basic, preclinical, and clinical research in resuscitation because of a lack of sustainable funding opportunities (Daniels, 2015; Yannopoulos, 2014). This deficit in the academic pipeline has led some organizations to include programs to develop a new generation of researchers in resuscitation and trauma as part of more traditional resuscitation research grants. For example, the Resuscitation Outcomes Consortium funded five training sites as "core leaders" in resuscitation research training and has trainees attend meetings to learn from mentors as they conduct research (Ornato, 2014). Current funding priorities are not likely to entice individual researchers to pursue careers in the treatment of cardiac arrest, which will affect the potential to develop new, effective treatments and therapies.

TRANSLATING SCIENCE INTO PRACTICE: THE ROLE OF EVIDENCE-BASED GUIDELINES

The Institute of Medicine (IOM) defines a "clinical practice guidelines" as a "systematically developed statement to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances" (IOM, 1990, p. 38). "Evidence-based" implies sufficient clinical trial evidence to document the impact and need for each element of a specific guideline. To fully capitalize on the potential of novel research, therapies, and treatment protocols to reduce cardiac arrest death and disability, widespread implementation of evidence-based practice is required. Unfortunately, evidence related to cardiac arrest is lacking.

In the resuscitation field, a number of organizations—including the International Liaison Committee on Resuscitation (ILCOR), the American Heart Association (AHA), American Red Cross, and American College of Cardiology—offer consensus-based guidelines on various cardiac arrest topics (e.g., defibrillation, CPR, IHCA, ACLS, basic life support [BLS], and pediatric treatments). Guidelines, formal recommendations, and advisory statements are updated every 5 years after expert panels analyze all available international science and evidence (see Meaney et al., 2013; Morrison et al., 2013; Nolan et al., 2003; Peberdy et al., 2010). While some guideline-setting organizations have released joint consensus statements on several occasions, there remain slight variations in various guidelines, such as those for pediatric populations or for special circumstances, such as drowning. The availability of different guidelines through different organizations may contribute to general confusion about which guidelines best reflect the current literature and are most appropriate for different audiences.

Because comprehensive data and research studies are largely absent in the resuscitation field, guidelines may reflect extrapolations from existing data and research, as well as practical considerations, rather than a strict interpretation of solid evidence (Neumar, 2010). For example, the AHA and ILCOR guidelines recommend at least 50 millimeters for chest-compression depth during CPR. Yet, there are no high-level studies, such as randomized clinical trials, that compare compression depth. A recent study by Stiell and colleagues (2012) assessed chest compression depth in patients undergoing CPR and found that although a compression depth of 38-51 millimeters was associated with better survival, compression depth greater than 51 millimeters did not further improve rates of return of spontaneous circulation, 1-day survival, or survival to discharge. There was also an inverse relationship between compression depth and compression rate (Stiell et al., 2012). Similar questions about specific guidelines related to optimal chest compression rates or the sequence of treatments in the algorithms for cardiac arrest exist (Wallace et al., 2013). Moreover, the 5-year process for evaluating new evidence and updating recommendations raises questions about whether guidelines can be a timely reflection of a developing evidence base, especially in the time leading up to a new review cycle.

The effect of guidelines, standards, and advisory statements on patient outcomes from cardiac arrest is unclear. Some studies have failed to identify a direct association between implementation of cardiac arrest guidelines and improved patient outcomes (Deasy et al., 2011). For example, a study in which Resuscitation Outcomes Consortium (ROC) investigators assessed the effect of the 2005 Emergency Cardiovascular Care guidelines on survival to hospital discharge using before and after data from 85 EMS agencies found no significant difference in overall survival, which was 5.8 percent prior compared to 6.5 percent after implementation of the new guidelines (Bigham et al., 2011). However, other studies have found that adherence to specific guideline protocols is associated with improved patient outcomes (Kirves et al., 2007; Stub et al., 2015b).

Many factors contribute to difficulties in assessing the impact of guidelines. Numerous organizations, entities, and members of the public rely on guidelines to respond to cardiac arrest, but do not typically engage in systematic analyses of how adherence to guidelines affects cardiac arrest outcomes (Meaney et al., 2013). In addition to the complex nexus of cofounding factors that affect patient outcomes, compliance rates with guideline-recommended practice is low and can be difficult to measure (Kampmeier et al., 2014; Kirves et al., 2007), and compliance with Utstein guidelines for reporting and research design can be incomplete (Donoghue et al., 2005). Many health care organizations rely on BLS and ACLS certificates to ensure that professional staff is sufficiently trained in various emergency skills, but it can be difficult to assess whether professional certification affects patient outcomes (IOM, 2014). More research is needed to demonstrate the impact of guideline adherence on patient outcomes following cardiac arrest.

Despite the limitations described above, guidelines and associated dissemination efforts do contribute to patient care in cardiac arrest. Guidelines and their associated checklists can reduce unnecessary variations in practice and are a reasonable place to begin process and health outcome assessment. However, recommending specific elements that are based on insufficient evidence as a standard of care has the potential to impede beneficial innovation. Systems of care should be encouraged to adopt guidelines and monitor outcomes to determine optimal, local protocols to enhance survival and good neurologic function following cardiac arrest. This approach will allow for local-level innovations that account for local needs and resources while contributing to a broader and more authoritative evidence base from which to update guidelines.

CONTINUOUS QUALITY IMPROVEMENT

Continuous quality improvement (CQI) is a "process-based, data-driven approach to improving the quality of a product or service, [which] operates under the belief that there is always room for improving operations, processes, and activities to increase quality" (RWJF, 2014). The basic premise of CQI involves capturing, analyzing, and regularly reporting data; translating the data and resulting information into actionable opportunities to improve performance at the local level; and developing plans for process changes that will further support effective, efficient, and value-added interventions (IOM, 2013a). An important component of any CQI effort is evaluating interventions and making adjustments, as needed. Even unsuccessful interventions can ultimately be used to improve survival rates, because they may provide evidence about ineffective treatments and protocols.

In the resuscitation field, adoption of CQI initiatives across EMS systems, health care systems, and hospitals has several distinct advantages. First, the chain of survival identifies groups of care providers that already or can naturally engage in CQI activities. Using a CQI process to drive clinical excellence based on familiar guidelines reduces disruption and improves adoption of new practices. Second, CQI processes focus on modifiable structures and processes within existing systems with the goal to improve patient, provider, and system outcomes (National Learning Consortium, 2013). Cardiac arrest research and monitoring implementation of best practices can be a natural extension of established CQI activities in different care settings. Third, standardized data collection is central to CQI. Incorporation of standardized cardiac arrest data elements that are harmonized across multiple settings can be collected for purposes of local and national benchmarking to improve cardiac arrest outcomes.

Numerous experts and studies have found that many systems with documented improvements in cardiac arrest survival rates and neurologic and functional outcomes in patients use CQI strategies (Bobrow et al., 2008b; Cobb et al., 1999; Meaney et al., 2013). In a 2013 consensus statement, the American Heart Association noted that, although measuring, reporting, and reacting to resuscitation performance data can positively influence cardiac arrest survival, such activities are not universally employed by health care systems; consequently, outcomes from cardiac arrest remain at unacceptably low and disparate levels (Meaney et al., 2013). The report goes on to recommend that all health care providers should implement a "CPR CQI program that provides feedback to the director, managers and providers" (Meaney et al., 2013, p. 9). Implementation of novel interventions should be monitored and adjusted based on locally identified needs and resources, areas for improvement, and innovations in order to promote the adoption of evidence-based practice. CQI programs should not be used as a disciplinary tool but may be combined with periodic retraining (Resuscitation Academy, 2013). Specific CQI strategies in cardiac arrest include:

- Measuring processes and outcomes associated with resuscitation activities across all settings,
- Benchmarking against best practices and data from comparable systems,
- Providing feedback to teams of providers, and
- Developing strategies to continually improve resuscitation practices (Travers et al., 2010).

Communities and health care systems that have made the greatest strides in improving outcomes have typically established a culture of data collection, evaluation, and reporting that results in necessary adjustments that best fit local needs and capacities. Most communities that have demonstrated the greatest aptitude for reducing deaths from cardiac arrest share one common characteristic—CQI. The examples included in Box 6-4 highlight select communities within the United States that have adopted CQI approaches and local implementation approaches to available guidelines. Proactive leaders within these communities have encouraged and supported the adoption of innovative and adaptive strategies informed by active CQI programs, which use locally available data to improve cardiac arrest survival rates and health outcomes.

There are a number of commonalities shared across the examples provided in Box 6-3. Each of the examples started with recognizing a gap or an area for improvement that required strong leadership to operationalize needed changes. Success was predicated on the implementation of a reliable database that employed standard outcome parameters that could be used to measure and compare outcomes. The systems continually monitored outcomes data and developed non-punitive strategies and interventions to improve survival. These new interventions relied on a culture of innovation and continuous learning with the understanding that not all new approaches were going to lead to success. These elements, combined with appropriate responsibility and authority, need to serve as the foundation for a new paradigm in the treatment of cardiac arrest.

To promote adoption of CQI activities on a widespread scale, organization and agencies have a variety of options, including

- Disseminating guidelines and training materials that incorporate CQI training and examples of innovation;
- Providing forums for exchanging information and sharing experiences in adopting CQI principles;
- Offering and seeking competitive grants for CQI adoption and innovations;
- Hosting regional meetings for EMS agencies to exchange information and best practices for implementing CQI programs on a local level; and
- Creating prizes and other incentives for best innovations, improvement, regional survival rate, and so on.

Effective implementation of CQI programs, whether in the context of OHCA or IHCA, requires ongoing data collection, formal accountability, and flexibility to allow for innovation. As described in Chapter 2, NIH and CDC have supported cardiac arrest data collection and research through various mechanisms, including the ROC Epistry and CARES, respectively. However, CDC shifted funding to the private sector in 2012 for CARES, which has since had to adopt a sustainable, subscription model to support the data set infrastructure and personnel (CDC, 2013a; Slattery and McNally, 2015). Similarly, NIH is not renewing its grant support for ROC, shifting its focus to the newly established SIREN network, which will combine ROC and Neurological Emergencies Treatment Trials resources to better enable research on emergency medicine.[2] The creation of a national database of cardiac arrest information may capitalize on natural efficiencies and enable CQI efforts to enhance resuscitation science, therapies, and treatment protocols. Benchmarking associated with CQI and the adoption of guidelines by consensus organizations will also contribute to more reliable systems of data collection.

Implementation science is an important concept in cardiac arrest research and has specific relevance to CQI programs. Implementation science—"the scientific study of methods to promote the integration of research findings and evidence-based interventions into healthcare policy and practice"—is a key element of translational research (Schackman, 2010, p. S27). Implementation science seeks "to understand the behavior of [health care] professionals and other stakeholders as a variable in the sustainable uptake, adoption, and implementation of evidence-based interventions" (NIH, 2013a). The principles of implementation science can complement and inform efforts to adopt a meaningful, system-wide CQI program to improve cardiac arrest outcomes.

As part of performance assessment, organizations need to identify and analyze implementation gaps affecting cardiac arrest research, technology transfer and innovation, and adoption of new discoveries and therapies. Analysis of factors affecting implementation can identify barriers to the adoption of new practices and develop strategies to overcome those barriers. Implementation science may also provide information about perceived acceptability, appropriateness, costs, feasibility, sustainability, safety, effectiveness, and patient-centeredness, in addition to patient outcomes (Proctor et al., 2011). Different implementation models

[2] Personal communication with J. Brown, NIH, May 22, 2015.

BOX 6-3
Examples of Local Continuous Quality Programs

Arizona implemented a statewide database to measure OHCA incidence and care processes, and EMS systems throughout Arizona initiated a range of interventions and CQI efforts. Based on evidence from laboratory investigations and observational data, some EMS systems implemented and monitored the impact of efforts to increase bystander compression-only CPR training and a new CPR protocol—termed cardiocerebral resuscitation—which called for uninterrupted chest compressions and delayed intubation for OHCA. Between 2005 and 2009, the bystander CPR rate increased from 28.2 to 39.9 percent (Bobrow et al., 2010). Adherence to the cardiocerebral resuscitation protocol was associated with an increase in survival-to-discharge rates from 1.8 to 5.4 percent, in general, and from 4.7 to 17.6 percent for patients with witnessed VF arrest (Bobrow et al., 2008a). Similarly, a 5-year prospective observational study involving 90 EMS agencies found survival-to-discharge rates were 5.2 percent for patients with no bystander CPR, 7.8 percent for patients who received conventional CPR, and 13.3 percent for patients who received compression-only CPR (Bobrow et al., 2010).

The Cardiac Arrest Registry to Enhance Survival (CARES) was established in collaboration between Emory University and CDC with the goal of helping communities determine standard outcome measures for OHCA. CARES promoted the use of quality improvement efforts and benchmarking capability at the local level to improve care and survival (CDC, 2013b). CARES allows participating communities to compare performance data with statistics at the local, state, and national levels in order to improve EMS system practices and improve care (CDC, 2013b). A recent analysis of temporal trends between 2005 and 2012 found that communities enrolled in CARES demonstrated improved risk-adjusted survival rates (from 5.7 to 7.2 percent) for all first-observed cardiac arrest rhythms (i.e., shockable and nonshockable) and decreased rates of neurological disability (Chan et al., 2014). Geographical differences were observed, with the Northeast showing greatest improvements while the Midwest's survival rates remained stagnant (Chan et al., 2014).

Denver, Colorado, participated in a pilot implementation trial of the Denver High Arrest Neighborhoods to Decrease Disparities in Survival project, applying the principles of CQI systems to improve rates of bystander CPR in "high-risk" neighborhoods. The project involved three phases in which areas with high cardiac arrest rates, and barriers to performing CPR in those areas, were identified. Culturally sensitive CPR programs were implemented, and in the final phase, the program was evaluated (Sasson et al., 2014). Because of the initial success of this pilot implementation and community engagement, a larger initiative is now being created.

The Get With The Guidelines–Resuscitation Registry is a quality improvement program designed to promote adherence to treatment guidelines for IHCA, by collecting IHCA patient data and providing hospitals with feedback (AHA, 2014). An analysis of IHCA survival and neurologic outcomes between 2000 and 2009 found significant improvements in both outcome measures (Chan et al., 2012). These improvements were consistently observed across all cardiac arrest rhythms, regardless of response to defibrillation (Chan el al., 2012).

King County, Washington, which includes Seattle, has been recognized as a model of innovation and progressive improvement in OHCA treatment, improving survival rates from 35 to 62 percent over a 10-year period (Chatalas and Plorde, 2014; Plorde et al., 2005). The EMS leaders in Seattle and King County have been monitoring outcomes for more than three decades and consistently review data and consider systemwide changes that could further improve the index outcome measure: survival to hospital discharge of patients with witnessed VF arrest. Local CQI efforts have included developing a reliable OHCA database, which is used to conduct formal studies of ways to improve resuscitation, provide feedback on performance, and inform training methods. King County also evaluates the effectiveness of interventions after implementation. For example, a review of pauses in CPR revealed long periods without chest compressions. Based on these findings, the CPR protocol was changed to deliver single shocks with immediate CPR after each shock, increasing survival rates from 33 percent to 46 percent and influencing national CPR guidelines (Rea et al., 2006).

Wake County, North Carolina, which has a population of approximately 840,000 people, implemented a community-wide, three-phase program. Researchers designed interventions that included new CPR training that taught an approach to CPR that minimized interruptions and avoided hyperventilation, the application of the impedance threshold device, and prompt institution of therapeutic hypothermia once the patient arrived at the hospital. An EMS database was also designed to monitor each phase of intervention. After the complete implementation of the program, researchers reported that overall rate of survival to hospital discharge improved by 7.3 percent and that survival for witnessed ventricular tachycardia/VF increased by 27 percent (Hinchey et al., 2010).

with varying degrees of flexibility, emphasis, and applicability exist (Tabak et al., 2012) and can be molded to the specific context and goals of an EMS or health care system (Straus et al., 2013). By integrating CQI programs into existing systems of care, with an understanding of likely barriers affecting both the adoption of CQI principles and implementation of new evidence-based protocols, care providers will learn from their experience and solve problems using a formal, transparent, and systematic approach within the system to achieve improved patient outcomes following cardiac arrest.

STRENGTHENING COORDINATION AND ADVOCACY

Advocacy groups play an important role in providing support for cardiac arrest survivors and for families who have lost loved ones to cardiac arrest. They can also be influential in raising awareness; promoting education and training efforts in communities; lobbying for regulatory changes; and driving policy at the local, state, and national levels. A number of cardiac arrest–related advocacy groups exist, including the Sudden Cardiac Arrest Foundation, Parent Heart Watch, and the Sudden Cardiac Arrest Association. Despite remarkable work in expanding public education and awareness of cardiac arrest, these groups have been less successful at expanding resources for research and education campaigns at a national level when compared with advocacy groups focused on cancer, AIDS, and Alzheimer's disease research.

Lack of progress may be due, in part, to the poor outcomes associated with cardiac arrest. Because of low survival rates, a large cohort of cardiac arrest survivors is not available to serve as living champions for better treatment and health outcomes. Conversely, those living with conditions such as cancer or AIDS have a more visible and vocal presence in the media and are better able to advocate on behalf of others living with the same condition. The field of resuscitation also suffers from fragmentation and the absence of a single, unified voice to generate the necessary political, private, and public support to advance resuscitation research.

Forming partnerships or collaborations is a common strategy used to promote integrated service delivery across health care and public health service systems. Defined as a "process by which groups come together, establishing a formal commitment to work together to achieve common goals and objectives" (NACCO, 2014), formal collaborations can help align programs and activities across different stakeholders with unique knowledge, resources, and skills to achieve greater efficiencies, impact, and political and public support. Meaningful partnerships among researchers, health care providers, advocacy organizations, and the community can build an environment of mutual trust and understanding, information exchange and education, and active support and participation (NACCO, 2014).

Collaboratives can have various structures and purposes. Some collaboratives have focused on expanding research capacity and reach. For example, in 2006, NIH established the Clinical and Translational Science Award (CTSA) program to accelerate the translation of research from the most basic levels through the widespread application of research findings at the population level (IOM, 2013b). In addition to providing research resources and support tools, sites within participating academic health centers are required to actively engage community organizations, health care providers, and public health professionals (NIH, 2015b). As noted in the IOM's 2013 evaluation of the CTSA program, "partnerships with community representatives can identify community health needs and priorities, provide critical input and data on clinically relevant questions, develop culturally appropriate clinical research protocols, promote successful enrollment and retention of research participants, and, ultimately, disseminate and implement research results more effectively" (IOM, 2013b, p. 117). Many of the CTSAs are creating long-term partnerships that are in turn leading to successful community programs and interventions that focus on areas such as diabetes, reducing health disparities, substance abuse, increasing clinical trial participation, and training community leader (IOM, 2013b).

Other collaboratives are formed to promote evidence-based practice. For example, the Brain Attack Coalition was formed to strengthen and promote relationships between its member organizations (including professional, voluntary, and governmental entities) in order to "reduc[e] the occurrence, disabilities and death associated with stroke" (Brain Attack Coalition, n.d.). The Coalition website is maintained by NINDS. The Coalition has engaged in activities related to messaging for National Stroke Awareness Month, a list of stroke systems for public education initiatives, and authored papers outlining guidelines for national stroke centers. The Coalition's success is due, in part, to adoption of an inclusive multidisciplinary approach to advance large projects and overarching goals, adopting a deliberative process, limiting research to high-impact publications, and focusing on big projects and concepts (Alberts, 2015).

Still other collaboratives have a much broader focus, engaging wide ranges of stakeholders at every level of society to advance short- and long-term goals and change a culture. The Partnership for a Healthier America (PHA) has more than 150 private-sector partners and supporters, "who are increasing access to healthier, affordable meals; creating safer places for children to play; offering more opportunities for kids to get up and move before, during and after school; and helping parents understand how to provide healthier meals" (PHA, 2015b). Each year, PHA holds a national summit, which gathers health experts, policy makers, and business and industry leaders to talk with nonprofit, academic, and government counterparts to find actionable solutions to improve health and well-being in the United States (PHA, 2015a). Although its focus is not research necessarily, PHA provides an example of how a public–private partnership can have a rapid impact on the consciousness of individuals within the United States to catalyze large-scale changes in behaviors, interventions, and education.

Similarly, the epilepsy advocacy community provides an exemplar for inclusive collaboration that could be easily adapted and quite beneficial to the cardiac arrest field. Like cardiac arrest, the epilepsy field has struggled with limited research funding despite a large public health burden. The Epilepsy Leadership Council includes advocacy organizations, health professional organizations, government agencies, NIH institutes, health care providers, and researchers, and was created to explore opportunities for collaboration, common areas of interest, and funding possibilities within the epilepsy research community (American Epilepsy Society, 2015). The members of the Epilepsy Leadership Council meet on a semiannual basis and have established working groups that focus on surveillance and prevention; health care providers; patients, families, and education; and clinical trials (Jacobs, 2015). Following the release of an IOM report on the public health dimensions of epilepsy in 2012, sudden unexpected death in epilepsy became a condition monitored by the Sudden Death in the Young Registry—a step forward in epilepsy surveillance that holds promised for future epidemiological research (Epilepsy Foundation, 2015; Sudden Cardiac Arrest Foundation, 2015). The Epilepsy Leadership Council also maintains websites that focus on clinical trials and opportunities for participation (HERO, 2015) and education for patients and their families (Jacobs, 2015).

Federal support for research and infrastructure and engagement in public health campaigns is more likely when a field has a united front of advocates to communicate the urgency of a problem, why that problem should be addressed now, and how best to solve the problem. The resuscitation field has the leaders and tools necessary to develop an advocacy network that can help advance the field as a whole in an effort to save lives. Formal collaboration could shape long-term strategies for the field of resuscitation in general, creating an effective advocacy base, unified platform, and evidence-based policies to improve research support and health outcomes from cardiac arrest over the next decade.

CONCLUSION

In conclusion, the committee urges the reprioritization of resuscitation research within the national research agenda. Research is a key component in any national framework to reduce death and disability from cardiac arrest within the next decade. Basic and clinical research offers insights related to the cardiac arrest etiology, pathophysiology, and treatment, and new approaches to the design and conduct of randomized controlled trials may better address the heterogeneity of affected patient populations, cardiac arrest events, and treatment protocols. New technologies and devices are on the near horizon, and regulatory policies and procedures should facilitate rapid evaluation and approval of successful devices and drugs without sacrificing patient safety. Translational research can also inform decisions about how to implement evidence-based practice and spur adoption of emerging therapies and evolving treatment protocols.

Continuous quality improvement is a relatively simple but essential concept to optimize system performance and contribute evidence related to existing treatments and protocols. As new knowledge emerges, local EMS and health care systems have an important responsibility to translate consensus guidelines into local practice protocols that reflect the resources and needs of a specific community. Numerous communities have demonstrated the ability to improve cardiac arrest outcomes through adoption of CQI programs, and these communities should serve as examples to other lower-performing systems. By implementing CQI programs to capture data and generate timely feedback, EMS and health care systems can produce an environment that promotes innovation and inform guideline-setting processes. As more communities begin to engage in data collection and assessment, these data can be used to benchmark additional CQI initiatives, leading to better-informed cardiac arrest research, practice, and policy at national, state, and local levels.

In order to make substantial gains in cardiac arrest treatment, a renewed commitment to resuscitation research support and infrastructure is needed. This commitment requires enhanced transparency and accountability within research-sponsoring organizations and from policy makers for the level and coordination of support dedicated to the treatment of cardiac arrest. This commitment is not likely to occur in a vacuum, however. Examples of successful stakeholder collaborations in various fields demonstrate the potential to effectuate change through coordinated action. With united leadership from key stakeholders, the resuscitation field can elevate its presence and effectively advocate for needed support to engage local, state, and federal stakeholders in a vision to improve cardiac arrest treatment and outcomes through research, evidence-based practice, innovation, and an unwavering commitment to saving lives in communities across the United States.

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7

Recommendations and Key Opportunities

On the morning of February 14, 2007, 3 minutes before my heart stopped, three people made choices that saved my life. A postman was selecting his route, a nurse with an unexpected day off was heading to Starbucks, and my business partner called just before I ran out the door of my home… something compelled me to answer the call, so that 3 minutes later, instead of being on the highway going 60 miles per hour, I was driving up a side street near my home when I had my cardiac arrest. The postman and nurse appeared at just the right time to perform CPR for 8 minutes until the medics arrived. Which meant that it was not my day to die.

—Sue Nixon, 2014

Cardiac arrest is a treatable medical event that requires immediate action to save a life. Affecting nearly 600,000 people per year (Daya et al., 2015; Merchant et al., 2011), cardiac arrest can strike indiscriminately and without warning, often leaving grieving family members and friends to question what could have been done differently. Regardless of the outcome, individuals who experience a cardiac arrest encounter many care providers—including bystanders, first responders, emergency medical services (EMS) personnel, and health care providers. These providers administer essential and interdependent treatments along a continuum of care that may vary in quality and effectiveness. Given the range of negative effects that cardiac arrest can have on the length and quality of a person's life, intensive efforts are needed in order to expand the use of evidence-based practices and to optimize the delivery of known, effective treatments, which can increase likelihood of survival. In the long term, a reexamination of the current understanding of the causes, diagnosis, and treatment of cardiac arrest will be necessary to generate new knowledge that can be used to enable high-quality care across the continuum of care and overcome the longstanding plateau in cardiac arrest survival rates. Additionally, a more cohesive and coordinated approach is required to enhance public education, training, and advocacy across all communities and settings.

In 2012, the Institute of Medicine published a report focused on improving care at reduced cost for patients within the health care system (IOM, 2013). The report described a vision for a learning health care system, which is characterized by the alignment of "science and informatics, patient-clinician partnership, incentives, and culture … to promote and enable continuous and real-time improvement in both the effectiveness and efficiency of care" (IOM, 2013, p. 17). The learning health care system expands upon the concepts of continuous quality improvement (CQI) discussed in Chapter 6 by focusing not only on the practical and technical elements required to engage in CQI, but also on action-oriented, system-level characteristics that are essential to encourage continous learning through measurement and evaluation across and throughout a system of care. In the case of cardiac arrest, the system of care encompasses numerous facets including the public, EMS systems, health care systems, and hospitals. Building on the concept of a continously learning health care system, the committee identified foundational elements of a learning system of response for cardiac arrest and resuscitation research (see Table 7-1).

These foundational elements provide substance to the framework presented in Chapter 1, defining overarching principles—across multiple dimensions and stakeholders—that can be used to guide efforts to save additional lives each year. Given the current gaps in cardiac arrest knowledge, care, and training, the committee examined the available evidence on cardiac arrest surveillance, epidemiology, treatment, training, and education programs and then developed recommendations and priorities for further research to improve existing cardiac arrest programs, protocols, and outcomes. The evidence-based recommendations described in this chapter present interrelated, action-oriented steps that, when combined, should enable short- and long-term improvements for people with cardiac arrest. The research opportunities provide directions for further developing the evidence base for the resuscitation field.

TABLE 7-1 Foundational Elements of a Continuously Learning System of Response to Cardiac Arrest and Resuscitation Research

Elements	Description
Science and informatics	Real-time access to knowledge—A learning system of response continuously and reliably captures, organizes, and delivers the best available data and data analyses to guide, support, tailor, and improve guidelines, clinical decision making, and care safety and quality, ultimately leading to improved health outcomes. In cardiac arrest, this requires data at federal, state, and local levels.
	Digital capture of the care experience—A learning system of response captures the care experience on digital platforms for real-time generation, exchange, and application of know-ledge between different types of care providers (e.g., hospitals and EMS and health care systems) for care improvement and improved health outcomes.
Multi-stakeholder partnerships	Multi-stakeholder partnerships—A learning system of response is based on the assumption that patients and patient advocates should be included on teams to help EMS or health care professionals identify and improve processes of care. Patient and advocate engagement allows care teams to understand the perspectives of individual patients, caregivers, and families, which can lead to a better understanding of the factors affecting care, the type of care desired, and insights into how to improve treatments and related health outcomes.
Incentives	Accountability and transparency—In learning systems of response, incentives to improve care are created through the availability of data and accountability to the public for local cardiac arrest incidence, survival, and neurological outcomes. Through dissemination of data and benchmarking at local, state, and national levels, the public and policy makers are better able to understand the public health burden of cardiac arrest as well as the quality of cardiac arrest treatment in their communities. National quality initiatives can foster inter-

continued

	disciplinary efforts and promote transparency and improvement in health care performance by identifying valid and reliable in-hospital cardiac arrest and out-of-hospital cardiac arrest metrics.
Culture of continuous learning	Leadership and a culture of learning—A learning system of response is stewarded by leaders committed to a culture of teamwork, collaboration, and adaptability in support of continuous learning and improvement as core aims. In the resuscitation field, this includes leadership at federal, state, and local levels.
	Supportive system competencies—In a learning system of response, complex care operations and processes are constantly refined through ongoing team training and skill building, systems analysis and information development, and creation of feedback loops for continuous learning and system improvement. System competencies must exist within individual systems to support high-quality care and well-informed transitions of care between systems.

SOURCE: Adapted from IOM, 2013, p. 18.

ESTABLISH ROBUST DATA COLLECTION AND DISSEMINATION

Resuscitation research in the United States is hindered by a paucity of high-quality data for both out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA). Because of the lack of national EMS and health care system performance metrics to guide cardiac arrest treatment, the quality, scope, and type of data collected varies across health care organizations. Existing cardiac arrest registries are voluntary, which leads to questions about generalizability of the data and analyses. Furthermore, decreasing support for registries threatens existing data sources and current quality improvement activities. As a result, researchers are limited not only in their ability to estimate the public health burden of cardiac arrest, but also in their capacity to identify correlations between patient characteristics and incidence rates, and associations among treatments, care quality, and outcomes. Consequently, current guidelines for many cardiac arrest treatments may be based on incomplete and insufficient evidence.

Despite these limitations, some epidemiological trends have been observed, and factors correlated with incidence and survival have been identified. For example, reducing the time between collapse and initiation of cardiopulmonary resuscitation (CPR) and defibrillation has been significantly associated with better survival rates and improved outcomes. The available data can help identify geographic variation in cardiac arrest outcomes, and wide regional variation has been identified. While patient characteristics such as race and gender have been associated with disparities in outcomes, these factors cannot explain the wide variations that have been observed, thus pointing to concerns about access and quality of care.

Holding EMS and health care systems accountable for performance first requires improving the state of data collection, reporting, and analysis across the cardiac arrest field. The committee has identified several key areas for action related to data collection and dissemination, including the development of a national cardiac arrest registry, standardization of terms used to measure patient treatment and outcomes, and identification of performance metrics that should be measured and recorded for all cardiac arrest patients. Further opportunities are discussed in Box 7-1.

Currently, a national surveillance system for cardiac arrest does not exist. Registries for OHCA and IHCA rely on voluntary participation, and, therefore, do not provide comprehensive geographic coverage. In fact, many communities and states do not track cardiac arrest incidence and outcomes nor do they report to a larger registry. Moreover, data on important determinants of outcomes (e.g., race and ethnicity, socioeconomic factors) are not fully captured and may not be reliable in existing registries. This lack of data leads to an under-representation of the disparities that relate to factors such as variation in care, race and ethnicity, and urban versus rural settings. There are also limited data on long-term outcomes of cardiac arrest following hospital discharge. As a result, significant knowledge gaps about the incidence and predictors of cardiac arrest, as well as the effectiveness of specific treatments, persist.
With some of the larger cardiac arrest registries expected to lose funding soon, a lead organization is needed to develop and maintain the infrastructure and oversee national data collection related to cardiac arrest. These efforts would allow for more reliable and accurate data aggregation, enabling benchmarking and continuous quality improvement initiatives. The existence of one national data collection effort would also reduce unnecessary confusion in an already complex field of study.

BOX 7-1
Data Collection and Dissemination

Key Research Opportunities

- Measure the incidence and the quality of outcomes for cardiac arrests occurring inside and outside the hospital, and determine the impact of factors such as gender, race, socioeconomic status, age, medical history, and location of arrest on cardiac arrest incidence, treatment, and survival.
- Research strategies to enhance the utility of existing cardiac arrest registries by improving the quality of data through the use of standardized definitions and outcome measures, engaging more EMS and hospital systems in data-collection efforts, enabling and enforcing transparent and accountable health care systems, consolidating and harmonizing data repositories, and investigating new ways to leverage registry data to improve cardiac arrest treatment.

Other Opportunities

- Define the nature and scope of the public health burden of cardiac arrest for at-risk or underserved populations, including minorities, women, children, and those living in rural areas. Subsequent research that is tailored to the unique needs of these populations as revealed by surveillance data.
- Determine how evidence-based strategies for improving outcomes can be adapted to the needs, limitations, strengths, and capabilities of particular health care systems.
- Identify factors associated with high- and low-performing systems in order to develop best practice guidelines for health care systems.
- Conduct basic science research on causes of cardiac arrest with an emphasis on the genetic, behavioral, environmental, and other factors associated with cardiac arrest.
- Provide an objective basis for performance standards by identifying and mapping the correlations between the context and characteristics of a treatment and the quality of subsequent outcomes.

Recommendation 1. Establish a National Cardiac Arrest Registry
The Centers for Disease Control and Prevention (CDC)—in collaboration with state and local health departments—should expand and coordinate cardiac arrest data collection through a publicly reported and available national cardiac arrest registry, including both out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) data, to help increase federal and state accountability for current system performance and promote actions to improve cardiac arrest outcomes.

Specifically, CDC should

- establish a cardiac arrest surveillance system for the nation that includes IHCA and OHCA data in pediatric and adult populations;
- make data publicly available through appropriate mechanisms to enable comparisons across data sets in order to increase public awareness about cardiac arrest incidence and treatments, improve accountability for the emergency medical services system and health care system performance, and target interventions that will reduce disparities and improve patient outcomes;
- identify and implement standardized definitions, criteria, and metrics (such as age, gender, race and ethnicity, socioeconomic status, and primary language) for cardiac arrest identification, treatment, and outcome assessment; and
- promote and coordinate the development and implementation of unique diagnostic codes for OHCA and IHCA in *International Classification of Diseases* (ICD) coding models through its North American Collaborating Center, working with the Centers for Medicare & Medicaid Services and the World Health Organization.

Specifically, state, territorial, and local health departments should

- mandate tracking and reporting of all cardiac arrest events; and
- publicly report the incidence and outcomes of IHCA and OHCA within and across various areas within states and territories, taking appropriate steps to protect patient privacy and confidentiality.

CDC has traditionally served as the primary institution responsible for creating and maintaining national surveillance systems for infectious, chronic, and acute conditions, often in collaboration with appropriate state government and local health agencies. For example, a federal mandate provided CDC with funds for creating new registries and setting national quality standards for the National Program for Cancer Registries. This mandate also granted states the authority to require data reporting and ensure that patient privacy and confidentiality were maintained (Izquierdo and Schoenbach, 2000). In its effort to create a national cardiac arrest registry for reporting and tracking OHCA and IHCA incidence and outcomes, CDC should ensure that data from EMS agencies and hospitals are sufficient and reliable enough to provide a precise assessment of the public health burden of cardiac arrest in the United States.

Importantly, the national cardiac arrest registry should allow public reporting of both incidence and outcomes, while maintaining compliance with patient privacy regulations. This serves multiple purposes. It allows members of the public, policy makers, and advocates to be aware of how their locality performs on a national scale and to make informed decisions regarding resource allocation and targeted interventions for vulnerable populations within their community. It also allows participating EMS agencies and hospitals to assess their own performance, and allows benchmarking at the local, regional, and national levels. Enhanced transparency is likely to drive accountability at multiple levels, improving quality of care and ultimately patient outcomes.

Implementing a national registry will require using a standard data-reporting template that identifies essential, core data elements for mandatory reporting and includes additional supplementary metrics that can enrich the data source and enhance research efforts. Existing databases such as the Cardiac Arrest Registry to Enhance Survival (CARES) and the Resuscitation Outcomes Consortium (ROC) Epistry[1] have already created reporting templates for OHCA, while the Get With The Guidelines-Resuscitation (GWTG-R) registry has done the same for IHCA. These registries have certain limitations, as described in previous

[1]The National Institutes of Health (NIH) has not renewed funding for ROC, and this clinical trials network will end in 2015 (personal communication, J. Brown, NIH, May 22, 2015). NIH recently announced plans to form a new clinical trials network for emergency care, SIREN, which will focus on "heart, lung, and blood-related emergency care in adults" (NHLBI, 2015).

chapters, but they could be used as an initial template from which the national registry could be built.

Although the international resuscitation community has proposed standard definitions and metrics for reporting OHCA and IHCA, these have not yet been uniformly adopted by existing registries (Cummins et al., 1997; Jacobs et al., 2004; Perkins et al., 2014). The 2014 Utstein-Style update, as described in Chapter 2, also reversed the previous guidelines, which had proposed a common data collection template for both OHCA and IHCA, because of differences in the epidemiology, treatment, and care delivery of the two types of cardiac arrest. The updated guidelines expanded the list of core (essential) and supplemental (desirable) data elements (see complete list in Appendix F), but they did not include race and ethnicity or socioeconomic factors (e.g., primary language, income) as either core or supplemental metrics. These data are important in identifying vulnerable populations that are traditionally less likely to have adequate access to, and utilization of, care. CDC could collaborate with other federal agencies, such as the National Institutes of Health (NIH), to create a working group of multidisciplinary experts to identify standard metrics for optimal use in a national cardiac arrest registry. The committee suggests expanding data collection to include important predictors such as race and ethnicity, socioeconomic status, and primary language, when available, in order to identify potential disparities in cardiac arrest and to better target interventions to rectify these with the goal of improving national survival rates.

A national surveillance system should collect accurate and complete data for OHCA and IHCA, regardless of whether the data sets are combined or separate. Current surveillance for IHCA, based on hospital claims and administrative data, presents unique challenges for investigators because of the lack of a specific diagnostic code for IHCA. The multiple codes for "cardiac arrests," as well as the comorbidities that IHCA patients often have, can also lead to preferential coding by hospital administrators, who may choose to rank other conditions higher than the arrest experienced by the patient (Morrison et al., 2013). Investigators currently rely on algorithms that use a combination of different diagnostic and procedural codes for other proxy conditions to capture incidence. This approach can lead to an inaccurate picture of the overall situation. Creating separate diagnosis codes for IHCA and OHCA will facilitate more accurate data collection and analysis, which will benefit activities to improve both IHCA and OHCA treatment in the long run. CDC's North American Collaborating Center currently serves as the U.S. liaison to the World Health Organization, which maintains and amends the ICD coding system, and is therefore the national authority to take the lead on developing and implementing unique ICD codes for OHCA and IHCA.

PUBLIC AWARENESS AND EDUCATION

Bystanders who witness an OHCA are key to providing early access, CPR, and defibrillation—the first links in the chain of survival and the links that are most strongly associated with improved outcomes (see Chapter 1). Many communities that demonstrate high rates of survival and positive neurological outcomes have succeeded with the help of high-performing EMS systems and an engaged public that is trained in bystander CPR and the use of automated external defibrillators (AEDs). Despite strong evidence indicating that bystander CPR and AED use can significantly improve survival and outcomes, rates of annual bystander CPR training remain low across the United States (Anderson et al., 2014). Rates of training vary based on a number of factors, which could be used to develop targeted interventions to reach broader populations. For example, individuals over the age of 50 are less likely than younger populations to attend traditional CPR training courses (Brennan and Braslow, 1998; Selby et al., 1982), yet they are more likely to experience cardiac arrest, especially in a home setting (see Chapter 1).

Communities are faced with many challenges in developing programs to educate and motivate the public to respond to cardiac arrest with CPR and AEDs. Funding for CPR training programs is difficult for many communities, CPR guidelines vary and can create confusion, and concerns about harm when delivering CPR and subsequent liability are common. Further complicating the situation is the lack of a single AED registry, so members of the public and emergency care providers who do know how to use AEDs are often unaware of the location, number, and operational status of AEDs in their area. Dispatcher-assisted CPR can also be an effective tool for treating cardiac arrests that are witnessed by bystanders, but individuals must first know when and how to initiate and engage the EMS system.

An informed, coordinated, and effective campaign to promote public education and training opportunities and to reduce barriers to bystander CPR and defibrillation use would greatly contribute to efforts to reduce mortality and poor outcomes from cardiac arrest. Further opportunities and areas for action are discussed in Box 7-2.

BOX 7-2
Public Awareness and Education

Key Research Opportunities

- Measure the association between bystander CPR and cardiac arrest outcomes. Identify factors that promote or discourage the effectiveness of bystander CPR and strategies to improve effectiveness.
- Determine the rate at which a given population will provide or receive bystander CPR. Identify educational, legal, and psychological barriers to bystander CPR, and ways to mitigate or eliminate those barriers.
- Determine the extent and effect of existing school-based CPR training programs and public access defibrillation (PAD) programs, and identify factors associated with successful and unsuccessful programs, including level of instructor training; methods, tools, and content of training; and location, accessibility, and visibility of AEDs. Identify or develop strategies for designing laws, school-based programs, and CPR training and PAD programs that promote improved outcomes through increases in early bystander CPR and defibrillation.
- Identify proven and potential strategies for increasing rates of bystander CPR. Specifically, measure the impact of dispatcher-assisted CPR on the rate and quality of bystander CPR and determine the effect of bundling interventions and which combinations produce the best results. Identify ways to make CPR training and AEDs suitable for use and placement in private homes.
- Research the effect of PAD programs and the conditions and factors relevant to their comparative success or failure. Develop strategies to improve placement, tracking, accessibility, visibility, and adverse event reporting of AEDs in public spaces. Identify legal, financial, technological, educational, and other barriers to purchase, placement, registration, and proper use of AEDs by private businesses and citizens.
- Explore and identify ways to utilize mobile technology to improve cardiac arrest research and treatment. Determine the capacity of existing and novel social media platforms to support cardiac arrest research and public awareness campaigns. Assess the impact of smartphone applications

continued

targeted to training the general public in CPR and alerting bystanders to cardiac arrest incidents, and use these data to develop improved applications.

Other Opportunities

- Explore ways to incorporate cardiac arrest public awareness messages and campaigns into the content of major media and entertainment outlets, as well as in public spaces (e.g., advertisements viewed prior to streaming video content, movie theaters, government and public websites, transportation hubs, museums).
- Develop strategies to enhance and expand moral obligation, intention, and willingness to provide lifesaving aid to cardiac arrest patients.
- Invest in educational programs and other public awareness campaigns targeted to underserved and at-risk populations.

Recommendation 2. Foster a Culture of Action Through Public Awareness and Training

State and local departments of health and education, and leading organizations in cardiac arrest response and treatment, should partner with training organizations, professional organizations, public advocacy groups, community and neighborhood organizations and service providers, and local employers to promote public awareness of the signs, symptoms, and treatment of cardiac arrest. These efforts require public cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED) training across the lifespan, creating a culture of action that prepares and motivates bystanders to respond immediately upon witnessing a cardiac arrest. Specifically,

- State and local education departments should partner with training organizations and public advocacy groups to promote and facilitate CPR and AED training as a graduation requirement for middle and high school students;
- Employers (e.g., federal agencies, private business owners, and schools) should be encouraged to maintain easy-to-locate and clearly marked AEDs, provide CPR and AED training to their employees, and specifically include cardiac arrest in formal emergency response plans; and

- Local health departments should engage with community and neighborhood organizations and service providers to expand the types and locations of available CPR and AED training to populations over age 65 and caregivers for this population.

Developing and implementing strategies to better educate members of the public about what cardiac arrest is, how to identify it, and how to respond to it is a public health priority that can improve health outcomes in the near future. To create a culture of action, public awareness campaigns and CPR and AED training initiatives must target whole communities, including older children, young adults, the workforce, and retired populations. School-based CPR and AED training programs present an opportunity for great impact, because these programs can educate large numbers of individuals across a wide range of age groups, all socioeconomic groups, and all geographic locations. Furthermore, these programs can be administered at a comparatively low cost and in a short amount of time. Another naturally occurring ideal training location is the workplace, where employers have many opportunities to provide CPR and AED training. For example, new employee orientation, recurring professional education requirements, and annual health fairs could all be used to teach employees who have never received training and to refresh skills.

CPR and AED training initiatives should also prioritize the mitigation of disparities in bystander CPR rates, by training populations that have a high risk of experiencing cardiac arrest, or that are more likely to witness an arrest. For example, a variety of community and neighborhood organizations in partnership with state and local health departments should develop training programs that specifically target retirement communities and older adults. Targeted training programs could also focus on populations that are currently underrepresented in CPR training programs or that are less likely to receive rapid, high-quality prehospital care. Moreover, existing and newly developing training modules or platforms that account for differences in community and neighborhood characteristics, socioeconomic factors, race and ethnicity, and language barriers in the most at-risk populations should be explored.

To respond to concerns about liability, CPR and AED training programs and modules should explain what Good Samaritan laws are and how they apply within specific jurisdictions. Additionally, federal and state governments have an obligation to review and strengthen existing Good Samaritan laws in order to protect any lay rescuer who provides emergency care, including CPR and use of an AED, from civil liability, regardless of the lay rescuer's CPR and AED certification status.

Effectively educating the public to respond to cardiac arrest is no small undertaking. Implementation of such training programs throughout individual communities will require the expertise, resources, and commitment from multiple organizations and government entities. State and local governments, philanthropic organizations, and advocacy groups could serve as possible funding sources, while medical, public health, and local community organizations could be sources of necessary training equipment and personnel. Digital coursework, simplified training aids, and abbreviated courses provide alternative ways to decrease the costs, without diminishing the effect of basic life support education.

Creating a culture of action will not be easy, but it is necessary in order to make a real difference in survival rates nationwide. In addition to improving outcomes, training the public to respond to cardiac arrest will likely have the added benefit of improving the public's response to many other types of emergencies that require the timely activation of the emergency medical system.

IMPROVE THE DELIVERY OF HIGH-QUALITY RESUSCITATION CARE

IHCA and OHCA each have unique epidemiological patterns, etiologies, and treatments. IHCA is less common and is less often fatal than OHCA; the arrests within monitored units of the hospitals are witnessed more often, and therefore response times are shorter. In comparison to IHCA, a greater portion of OHCA patients has an initial ventricular fibrillation/ventricular tachycardia (shockable) rhythm. Hospitalized patients who experience an arrest tend to be older and have more severe illnesses and secondary comorbidities. While a majority of OHCAs result from preexisting cardiovascular conditions and occur unexpectedly, IHCA cases often exhibit a period of decline prior to an arrest and are caused by cardiac conditions less than half the time (Chan et al., 2015; Morrison et al., 2013). These factors and others contribute to differences in the available treatments, care protocols, and likelihood of survival with positive neurologic and functional outcomes by location following a cardiac arrest.

The health care providers and systems responsible for treating OHCA and IHCA all have distinct limitations, strengths, challenges, and opportunities. High-performing EMS systems exist. However, the extreme heterogeneity of agencies and systems across the United States makes the successful adaptation of organizational models a sizable challenge. Promising interventions, such as high-performance and dispatcher-assisted CPR, have been developed, but the effective implementation of these types of interventions requires a culture dedicated to CQI efforts. Among hospitals, there is considerable variability in staffing models, patient monitoring, emergency code protocols, and resuscitation team characteristics (e.g., size, composition, organization, team member expertise). Variation in these factors affects treatment and can cause considerable disparities in outcomes, which often affects minority patients disproportionately. Although multiple professional organizations and consensus committees have issued guidelines informing treatments (e.g., targeted temperature management) and care models (e.g., goal-directed therapy) for post-arrest care, the evidence base for such therapies is often limited and/or mixed. Persistent gaps in post-arrest research will need to be filled in order to have a considerable impact on the quality of treatment and outcomes.

Advancing cardiac arrest treatment inside and outside the hospital will require developing a cardiac arrest registry with standardized definitions and metrics upon which research efforts can be based. Additional opportunities for improving patient outcomes include the creation of powerful diagnostic tools, training programs to development non-technical resuscitation skills, and regional cardiac arrest care centers. These and other opportunities identified by the committee are discussed below, and further opportunities and action areas are discussed in Box 7-3.

A number of EMS and hospital actions have been associated with higher cardiac arrest survival rates in some communities. These exemplar EMS and hospitals systems offer promising strategies that could be more widely adopted in order to reduce the public health burden of cardiac arrest. For example, dispatcher-assisted CPR has been associated with improved patient outcomes from OHCA (Eisenberg et al., 1985; Kellermann et al., 1989; Lewis et al., 2013; Song et al., 2014). Like dispatcher-assisted CPR, high-performance CPR has been demonstrated to have a positive impact on cardiac arrest survival (Bobrow et al., 2013; Christenson et al., 2009; Stiell et al., 2012). However, there is no standardized training program available for dispatcher-assisted CPR. Moreover, a single, nationally recognized definition of high-performance CPR does not exist, making training and implementation efforts difficult.

BOX 7-3
EMS and Hospital Cardiac Arrest Treatment and Post-Arrest Care

Key Research Opportunities

- Investigate ways to strengthen each link in the chain of survival through broader research into, and implementation of, specific interventions, including dispatcher-assisted CPR, high-performance CPR, CQI programs, and mechanisms to promote accountability and transparency.
- Research the impact of different EMS staffing models, including variations in size and expertise, on treatment and outcomes.
- Assess the role of local, state, and national governments in EMS, and develop strategies to improve system administration, funding, and performance through revision of policies and practices.
- Measure the extent of variation in outcomes from IHCA; conduct research into the causes of, and potential solutions to, possible disparities.
- Identify ways to improve hospital resuscitation team responses by examining the impact of team size, expertise, composition, and training on cardiac arrest treatment and outcomes.
- Determine the effect of different training methods, tools (e.g., debriefing, mock codes, high-fidelity simulation), and objectives (e.g., cultivation of technical and nontechnical skills) on treatment and the quality of survival.
- Explore the impact of standardized performance metrics and quality collaboratives on the capacity to measure and compare performance and outcomes data.
- Investigate the effects of guidelines and patient-centered care models on hospital performance and patient outcomes.
- Develop technologies and protocols related to post-arrest care treatments, including temperature, cardiovascular, and metabolic management; emergent cardiac catheterization; hemodynamic support; extracorporeal membrane oxygenation; and oxygenation and ventilation.
- Examine the utility, feasibility, and implications of conceptual models of care, such as goal-directed therapy and customized patient care.

- Conduct research to identify and standardize post-arrest treatment performance metrics and standards, and to inform clinical guidelines for diagnostic tools (e.g., neuro-prognostication tools) and post-arrest treatments.
- Use IHCA registries to measure the cost of, and disparities within, post-arrest care.
- Identify capabilities required for optimal post-arrest care, assess facilities for the presence of these capacities, and develop evidence-based protocols regarding transportation to these regional care centers.

Other Opportunities

- Improve access to emergency response systems through research on next-generation 911 system capabilities, including collection of call data from text and Voice over Internet Protocol sources, and real-time data sharing and transfer among multiple EMS agencies, hospitals, and public service access points.
- Research the effect of state medical director actions on EMS system performance to inform national guidelines on state medical directors' authority and responsibilities.
- Determine the safety and effectiveness of novel treatments and devices, such as targeted temperature management and mechanical CPR device, in order to propose guidelines for their use.

Standardized definitions, training, and performance evaluation measures for care processes and protocols would promote a more rapid and uniform adoption and assessment of cardiac arrest quality of care from the community to the national level.

Recommendation 3. <u>Enhance the Capabilities and Performance of Emergency Medical Services (EMS) Systems</u>
As the informal agency for EMS, the National Highway Traffic Safety Administration (NHTSA) should coordinate with other federal agencies and representatives from private industry, states, professional organizations, first responders, EMS systems, and nonprofit organizations to promote uniformly high-quality emergency medical systems by

- convening interested stakeholders to develop standardized dispatcher-assisted cardiopulmonary resuscitation (CPR)

protocols and national educational standards for use by all public safety answering points, and
- establishing a standardized definition and training curriculum for high-performance CPR to be used in basic emergency medical technician training and certification.

Developing standardized protocols, educational standards, and training curricula is the first step to encourage the adoption of practices that have demonstrated a positive effect on saving lives from cardiac arrest. By establishing standardized protocols and educational standards for dispatcher-assisted CPR, as well as standardized definitions and training for high-performance CPR, NHTSA will accomplish two things. First, it will light a clear path for communities that want to adopt dispatcher-assisted CPR and high-performance CPR. These protocols and standards should be based on collective knowledge and experience that have been gained through the successful implementation of such programs in the field. Second, it provides a standardized foundation from which communities can measure improvements in cardiac arrest outcomes as part of CQI activities. This information can then be used to develop a stronger evidence base for updating protocols, educational standards, and curricula.

One way to effectively disseminate and educate EMS professionals about new dispatcher-assisted CPR and high-performance CPR standards may be for NHTSA to create "EMS Training Centers of Excellence." EMS agencies could send appropriate personnel to these centers for training in state-of-the-art treatment, monitoring, and CQI strategies and practices. NHTSA has offered similar programs in the past. For example, NHTSA established a course called "Development of Trauma Systems" (NHTSA, 2004). As part of this program, NHTSA provided instructors to train individuals.[2] By establishing regional training centers of excellence, NHTSA could bring in leaders from EMS systems across the country, who could then train others in their states, counties, and communities.

ASSESSING HOSPITAL PERFORMANCE TO IMPROVE CARDIAC ARREST OUTCOMES

There is considerable variation in the treatment, care delivery, and outcomes across hospitals in the nation for IHCA and post-arrest care. A

[2]Personal communication with D. Dawson, NHTSA, March 10, 2015.

majority of hospitals in the United States do not monitor patient outcome following cardiac arrest nor do they publicly report standard measures of cardiac arrest survival to discharge and neurological outcomes. As discussed throughout the report, this lack of data collection and reporting creates a dearth of available evidence from which new treatments and care models can be developed. Although the American Heart Association's GWTG-R registry provides a platform for data reporting, benchmarking, and quality improvement, a majority of hospitals do not participate in this type of registry. Furthermore, it is unclear whether the hospitals that do participate in the GWTG-R registry use the data to improve processes and outcomes. A lead organization that is responsible for setting minimal monitoring and reporting standards for cardiac arrest and that requires hospitals to adhere to such standards as part of accreditation criteria is needed. This change would create new levels of accountability and transparency in hospitals across the nations, and it represents an important opportunity for improving nationwide survival rates.

> **Recommendation 4. Set National Accreditation Standards Related to Cardiac Arrest for Hospital and Health Care Systems**
> **The Joint Commission—in collaboration with the American Red Cross, the American Heart Association, hospital systems, hospitals, professional organizations, and patient advocacy groups—should develop and implement an accreditation standard for health care facilities specific to cardiac arrest care for adult and pediatric populations.**

The Joint Commission provides accreditation for approximately 3,300 hospitals across the United States, ensuring that these facilities meet required standards in order to maintain high levels of quality of care and patient safety (The Joint Commission, 2014). Although accredited hospitals must adhere to standards for resuscitation services and general standards for quality improvement, currently there are no requirements for hospitals to report patient outcomes for cardiac arrest. Because many state governments, regulatory agencies, and third-party payers require The Joint Commission accreditation as a condition for payment or reimbursement (The Joint Commission, 2011), setting national accreditation standards for cardiac arrest would create incentives for hospitals to improve cardiac arrest care and outcomes.

Numerous studies of cardiac arrest registries, both in-hospital and out-of-hospital, have demonstrated significant improvements in overall outcomes among health care systems that regularly monitor and report data on patient outcomes. These positive results are likely due to the fact that participating hospitals are using outcomes data to inform processes and protocols, thus continuously improving the quality of care. Precisely measuring and meeting standards for care process (e.g., delivery of defibrillation within 2 minutes of arrest) may be difficult for all hospitals to achieve; however, hospitals that participate in the GWTG-R registry regularly measure and report Utstein guideline's recommended data elements for survival and neurologic outcomes, which can be easily implemented in most hospital settings (Cummins et al., 1991; Peberdy et al., 2003). The Joint Commission could consider adopting this achievable and widely recognized cardiac arrest measurement tool as a part of national accreditation criteria. The outcome data collected could be tied to a formal CQI system in order to inform better care processes. As an example of similar efforts, The Joint Commission's ORYX initiative assists accredited hospitals in improving quality of care by making the collection of outcomes data a part of the accreditation process (The Joint Commission, 2014). This initiative provides flexibility for small hospitals and critical care hospitals to meet reporting standards, by requiring internal data collection but providing exemptions for external reporting. The committee recognizes that a small rural hospital with limited specialty coverage is very different from a major teaching hospital that has numerous residents and trainees who are capable of responding 24 hours per day. However, all hospitals should be capable of assessing their cardiac arrest treatment protocol and working to improve survival.

The committee encourages The Joint Commission to work with guideline-setting organizations, such as the American Red Cross and the American Heart Association, and collaborate with hospitals, health care systems, and related stakeholders, including professional organizations and patient advocacy groups, in order to develop achievable national standards for hospital accreditation. This collaborative effort to develop national standards complements the committee's recommendation to create a national surveillance system for OHCA and IHCA, because accreditation standards will ensure completeness of data from hospitals as they adhere to collection and reporting requirements for accreditation. This effort would also complement the following recommendation, which builds on the concept of measuring outcomes, as a first step in improving overall quality of care.

Recommendation 5. Adopt Continuous Quality Improvement Programs
Emergency medical services (EMS) systems, health care systems, and hospitals should adopt formal, continuous quality improvement programs for cardiac arrest response that

- assign responsibility, authority, and accountability within each organization or agency for specific cardiac arrest measures;
- implement core technical and nontechnical training, simulation, and debriefing protocols to ensure that EMS and hospital personnel can respond competently to both adult and pediatric cardiac arrests; and
- actively collaborate and share data to facilitate national, state, and local benchmarking for quality improvement.

As described throughout this report, the small number of EMS systems, hospitals, and health care systems that have adopted CQI programs or are informally monitoring performance are demonstrating tremendous improvements in outcomes over time (Chan, 2015; Travers et al., 2010). The communities that are achieving the greatest improvements in survival rates are doing so by

- establishing systems that regularly collect and evaluate data on system processes, patient outcomes, and overall performance;
- benchmarking performance against comparable health care systems or national standards;
- providing nonpunitive feedback to providers; and
- developing strategies for making adjustments in care protocols, as necessary, in order to improve outcomes.

Cardiac arrest is a complex systems problem in health care settings and is a public health problem in communities. Each community is unique—a small, rural community with volunteer EMS providers and long transport times is very different from an urban city with a well-equipped EMS system that is connected to major academic medical centers. Even different hospitals in the same community may have varying functions, staffing patterns, and capabilities. Therefore, one protocol may not be optimal in all community and hospital settings. However, the committee concludes that every hospital and EMS system that treats cardiac arrest patients should be capable of analyzing its outcomes, protocols, training, and performance using CQI. Although not every system may achieve the results seen in the highest-performing systems, each health care agency and institution should be able to continuously work to improve its survival rates.

In the recommended CQI system, every cardiac arrest would be entered into a database that could then be reviewed by leaders within that EMS or hospital. Thus, each arrest and treatment would contribute crucial information that could be used to improve treatment protocols and care for future cardiac arrest patients. The committee recognizes that CQI has been recommended in the American Heart Association's guidelines for the past decade (Meany et al., 2013). However, few CQI initiatives have been adopted and are fully functional despite current recommendations. Meaningful CQI requires a strong commitment from hospitals and EMS systems, and it also requires adequate resources, data, authority, and accountability. Communities that have succeeded in improving survival clearly define the people and entities that are responsible for the survival rates and often identify a leader who is charged with overseeing and managing cardiac arrest CQI efforts. This leader must have access to necessary resources in order to identify and assess the gaps (e.g., less than optimal bystander CPR rates, resuscitation protocols) and work with health care professionals to improve outcomes.

Another example of how CQI could be used by hospitals and EMS systems to improve care and outcomes is the assessment and improvement of training and teamwork. Recently, a number of international and national consensus committees and professional organizations recognized the critical importance of multidisciplinary teamwork in high-quality resuscitation care, and these groups issued statements regarding training that emphasize both technical and nontechnical skills (Bhanji et al., 2010; Nolan et al., 2010). Technical training focuses on improving basic and advanced life support skills, while nontechnical training targets skills to enhance communication, cooperation, leadership, and decision making (see Chapter 5). Strategies such as formalized debriefing sessions, which assess provider performance and review resuscitation interventions, have been associated with improved survival rates and positive neurological outcomes (Wolfe et al., 2014; Zebuhr et al., 2012). Simulation training has also been identified as an effective strategy for enhancing performance; studies have found improvements in both technical and nontechnical skills when simulation training is used. In the recommended CQI paradigm, systems and hospitals would assess how well health care providers work together and whether they are delivering high-quality CPR in order to determine how often retraining is necessary and the best strategies for providing feedback. The committee reiterates that a fully functioning CQI program with clearly defined lines of responsibility, strong leadership, and authority to make necessary changes is essential to improving systems of cardiac arrest treatment and care.

CARDIAC ARREST RESEARCH AND THERAPIES

The challenges within cardiac arrest research go beyond a simple lack of data and reporting. There are also fundamental limitations in the trial designs and research methods that are employed by resuscitation scientists that lead to inefficient, expensive, and often inconclusive studies. The sequential nature of multiphase trials forces researchers to focus on research questions one at a time, while the highly controlled conditions of randomized trials limit the populations for which a given treatment is demonstrated to be effective. Adaptive trial designs that concurrently test multiple hypotheses and update experimental conditions as the trial progresses are less likely to lead to increased expenses and failures and are more likely to lead to rapid translation of research findings to clinical treatments.

Effective treatment of cardiac arrest is also limited by enduring misconceptions of health care systems and professionals regarding the status of scientific guidelines and recommendations. Although the American Heart Association and International Liaison Committee on Resuscitation (ILCOR) guidelines are based on rigorous reviews of the best available evidence, they are consensus statements that reflect varying levels and strength of evidence. Therefore, a number of guideline statements, many of which apply to usual cardiac arrest care, are based of expert opinion and consensus rather than strong evidence. Additionally, guidelines may not represent the most recent research findings and are often developed by extrapolating from available evidence because of limitations of existing data and lengthy review processes. In order to activate the principles of a learning health care system, health care leaders and systems must adapt best-practice guidelines to their own needs and limitations and must be prepared to revise treatment protocols as evidence changes, rather than waiting for guidelines to be updated. In order to better prepare health care systems for the practical challenges of operating a CQI program, the committee also identified a need for more robust research efforts within implementation and translational science. Further opportunities and areas for action within cardiac arrest research and therapies are discussed in Box 7-4.

Resuscitation science is a major force in advancing patient outcomes. New research findings and emerging discoveries in pharmaceuticals, devices, and biosensors provide compelling promise for boosting survival and positive outcomes. These advances also hold promise for reshaping approaches to the cardiac arrest treatments and care delivery models. However, federal support for resuscitation research is dwindling, and resources are insufficient given the impact of cardiac arrest on society and the potential to decrease this burden through research advances.

BOX 7-4
Cardiac Arrest Research and Therapies

Key Research Opportunities

- Identify mechanisms to expand funding for cardiac arrest research.
  consolidate potential granting organizations, and streamline the grant application and approval process.
- Promote research assessing the state of existing research methods and clinical trial designs, and explore strategies to augment their efficiency, cost-savings, and power.
- Investigate the strengths and weaknesses of guideline-setting processes, and explore ways to improve these processes and the education of clinicians regarding the appropriate role of guidelines within cardiac arrest care.
- Apply the tools and methods of implementation and translational science to design CQI programs and support the development of learning health care systems.

Other Opportunities

- Prioritize research into the development and implementation of less costly and more effective iterations of existing treatments and devices.
- Analyze and compare the performance of learning health care systems to inform strategies for design and implementation of specific CQI programs.
- Investigate ways to enhance the impact of resuscitation research advocacy groups.

Large knowledge gaps about the etiology, pathophysiology, epidemiology, and the effectiveness of current therapies for cardiac arrest persist. Future research must focus on basic, clinical, and translational science that supports the development of progressively newer therapies. Additionally, clinical studies are needed in order to evaluate the effectiveness of existing and new therapies, develop a stronger evidence base for currently accepted best practices, and promote the widespread adoption of evidence-based models of care.

Recommendation 6. <u>Accelerate Research on Pathophysiology, New Therapies, and Translation of Science for Cardiac Arrest</u>
In order to identify new, effective treatments for cardiac arrest, the National Institutes of Health (NIH), the American Heart Association, and the U.S. Department of Veterans Affairs should lead a collaborative effort with other federal agencies and private industry to build the nation's research infrastructure, which will support and accelerate innovative research on the causal mechanisms of onset, pathophysiology, treatment, and outcomes of cardiac arrest. These actions should

- strengthen laboratory, clinical, and translational resuscitation research support to levels commensurate with the public health burden of cardiac arrest for adult and pediatric populations across federal agencies and NIH institutes; and
- establish a balanced and comprehensive portfolio of grants across the full spectrum of science translation to encourage the development and application of novel and efficient research strategies and innovative trial designs in preclinical, clinical (e.g., exploratory and hypothesis-generating studies), and population-based resuscitation research.

Recommendation 7. <u>Accelerate Research on the Evaluation and Adoption of Cardiac Arrest Therapies</u>
The National Institutes of Health should lead a collaborative effort with the U.S. Department of Veterans Affairs, the Agency for Healthcare Research and Quality, and the Patient-Centered Outcomes Research Institute to prioritize health services research related to the identification, evaluation, and adoption of best practices; the use of innovative technologies (e.g., mobile

and social media strategies to increase bystander cardiopulmonary resuscitation or automated external defibrillator use); and the development of new implementation strategies for cardiac arrest treatments.

To speed the development, evaluation, and use of effective treatments for cardiac arrest, and thus increase survival rates with positive neurological outcomes, the research enterprise will require sufficient scientific expertise, research capacity, efficiency, and focus on population health. A coordinated effort among multiple federal and nonfederal funders will be needed in order to increase support for pathophysiological and treatment research across the full time course of cardiac arrest—from onset to long-term neurological outcome. Additional emphasis should also be placed on the inclusion and study of populations most affected by cardiac arrest and the settings in which arrests occur. Maximizing the yield of research investments will require improving the efficiency of both early- and late-stage clinical research, by leveraging innovative in clinical trial design that have demonstrated value in other medical domains. Combined, these efforts could increase the rate at which new treatments are identified, evaluated, and found to be effective, in need of further testing or refinement, or definitively without benefit.

The demonstration of benefit from new approaches to treatment is not sufficient, in and of itself, to improve patient outcomes. New approaches must be applied broadly and consistently and in a manner that can be sustained, regardless of the setting (i.e., in-hospital or out-of-hospital setting). Translating clinical research findings into improvements in patient outcomes will require substantial efforts to define evidence-based best practices and to understand the factors that influence adoption in routine care. When adoption is lagging, new implementation strategies that overcome existing barriers must be developed. Similar efforts will be needed to effectively employ new technologies that can be used to improve the speed and effectiveness at which cardiac arrest care is delivered.

To fully realize the potential and promise of the resuscitation field, research that focuses on advancing treatment options and translating science into effective care models must be pursued in parallel with implementation research that focuses on strategies for deploying new treatments and care options in a widespread manner throughout communities across the United States. The full spectrum of research from the most basic science through the translation of findings into care through the implementation of evidence-based practices across populations will be vital in overcoming the stagnation in cardiac arrest survival rates and outcomes. Furthermore, advances in the field will not be made without cohesive support and meaningful collaboration across the research community, from individual researchers to advocacy and professional organizations to government agencies that support the research.

STAKEHOLDER COLLABORATION

Collaboration among cardiac arrest stakeholder groups, and the promise of advances in treatment that collaboration could bring, has been a largely missed opportunity in the resuscitation field to date. Not only is collaboration between organizations with different objectives and responsibilities (e.g., research institutions and patient advocacy organizations) uncommon, but also even stakeholder groups with similar missions (e.g., multiple EMS agencies) rarely connect in meaningful ways. In the first case, varying goals lead to differences in administration, funding, staffing, and culture that make cooperation difficult because of structural challenges. In the second case, organizations may perceive competition across organizations and stakeholders, as research institutions, educational groups, and hospital facilities often vie for grants, students, and patients. This type of challenge originates with the social and economic systems that define organizations. In both cases, stakeholders are governed by values that may not overtly discourage cooperation, but do not necessarily promote or require it. Cultural shifts will be required for organizations to fully embrace and maximize effective partnerships and collaboration.

The recent emphasis on establishing a culture of accountability within health care systems across the United States offers a new impetus for cooperation among stakeholders. Because collaboration can be foundational to performance improvements, fully accountable organizations must seek it out and actively engage with other organizations. To compare and improve their performance, hospitals and EMS systems must be able to standardize and share patient data and be willing to undertake quality collaboratives and other CQI efforts. Furthermore, building a more collaborative culture may also allow organizations to more easily overcome structural, contextual, and systemic barriers that may hinder collaboration. In light of the potential for collaboration to affect cardiac arrest outcomes and advance the field, the efforts of educational, advocacy, professional, and guideline-setting organizations must be better aligned and leveraged wherever possible. The committee has identified specific opportunities for collaboration that are detailed in Box 7-6.

Numerous organizations and institutions have supported valuable activities to advance the science and implementation of resuscitation, and these activities have led to critical progress within the field over the years. However, these efforts have not established a united advocacy presence to heighten the visibility of cardiac arrest and convey the message that cardiac arrest is a treatable public health threat that warrants the attention and support of policy makers and the public. To develop shared goals and strategies, identify and support new leaders and advocates, and maximize the impact of limited resources within a field, formal and sustained collaboration is essential.

BOX 7-6
Stakeholder Collaboration

Key Research Opportunities

- Identify existing stakeholders and support the development of new stakeholders, including
  - social organizations (e.g., municipal and intramural sports leagues, religious organizations, fraternal and philanthropic societies, and youth education groups [Boy Scouts and Girl Scouts]);
  - survivors of cardiac arrest and families of deceased cardiac arrest patients;
  - special interest and advocacy groups (e.g., Sudden Cardiac Arrest Foundation);
  - representatives in local, state, and national governments;
  - research and academic institutions, as well as government agencies involved in cardiac arrest policy and research (e.g., the American Heart Association, the American Red Cross, NIH, CDC, and NHTSA); and
  - health care profession and medical organizations (e.g., American College of Emergency Physicians [ACEP], American Medical Association, American Hospital Association, the National Association of State EMS Officials, and National EMS Advisory Council).
- Explore ways to create and incentivize opportunities for collaboration, while expanding the capacity of individual and collective stakeholder groups to support cardiac arrest research, treatment, and education.

Recommendation 8: Create a National Cardiac Arrest Collaborative
The American Heart Association and the American Red Cross—with the U.S. Department of Health and Human Services and other federal agencies, national and international resuscitation councils, professional organizations, private industry, and patient advocates—should establish a National Cardiac Arrest Collaborative (NCAC) to unify the cardiac arrest field, identify common goals, and build momentum within the field to ultimately improve survival from cardiac arrest with good neurologic and functional outcomes. The Collaborative should

- provide a platform for information exchange about key successes and failures in different systems and settings and for stakeholder communication about new research findings and initiatives;
- convene working groups on short- and long-term national research priorities for cardiac resuscitation and post-arrest care, which focus on critical knowledge gaps (such as the impact of care transitions; the organization, composition, and training of resuscitation teams; optimal timing of initial neurological evaluation; and appropriate withdrawal-of-care protocols);
- develop action strategies related to health policy, research funding and translation, continuous quality improvement, and public awareness and training;
- produce and update toolkits for different stakeholders (e.g., emergency medical services [EMS] systems, hospitals, local health departments, and local health care providers) in order to facilitate effective system and individual responses to cardiac arrest;
- hold an annual collaborative meeting in conjunction with a regularly scheduled health professional conference to discuss short- and long-term goals and progress; and
- encourage public–private partnerships to support activities that focus on reducing the time to defibrillation for cardiac arrest, including the development of technologies to facilitate automated external defibrillator registries for use by the public, EMS systems, and other stakeholders.

Successfully improving cardiac arrest outcomes in the coming decades will require more resources—resources to train and educate emergency responders, health care personnel, and the public; resources to identify and assess current practices; resources to disseminate findings about best practices; and resources to pursue new research goals and treatment opportunities. In order to generate enough visibility and momentum to propel changes in policy and initiate action in communities across the United States, a broad alliance of stakeholders is needed.

With the goal of developing strategic collaborations that could advance the resuscitation field, the NCAC would find the most success by actively engaging an inclusive array of cardiac arrest stakeholders, such as government agencies, professional organizations, academic researchers, state and local public health officials, patient and family advocacy groups, industry, health care providers, and international entities. Specific stakeholders could include, but are not limited to, ACEP, American Academy of Neurology, American College of Cardiology, the American Heart Association, American Hospital Association, American Nurses Association, the American Red Cross, Association of State and Territorial Health Officials, CDC, the Centers for Medicare & Medicaid Services, Heart Rhythm Society, The Joint Commission, Metropolitan Municipalities EMS Medical Directors Consortium, National Association of Community and County Health Officials, National Association of EMS Physicians, NHTSA, NIH institutes, Parent Heart Watch, Sudden Cardiac Arrest Association, Sudden Cardiac Arrest Foundation, U.S. Army Medical Research and Material Command, U.S. Food and Drug Administration, and the VA, as well as leading academics institutions, researchers, and policy makers.

The NCAC would provide an essential venue for promoting shared experiences and expertise, creating an effective communications platform for ongoing information exchange and developing a widely support research agenda that could be used to frame high-priority research areas for a national dialogue and collective action. The NCAC could also produce materials and informational resources based on member input, which could be used to facilitate action in local communities. For example, action strategies targeting different stakeholders and community needs would be more effective if these strategies were part of a comprehensive plan to elevate cardiac arrest response and treatment. Toolkits that present effective strategies for EMS and health care systems to adopt CQI programs could be developed and disseminated. The results of these efforts could then be shared and evaluated across the collaborative.

Involving such a wide range of perspectives in activities and initiatives with shared goals could help identify the most salient challenges and limitations and may generate novel approaches to overcoming traditional obstacles that continue to bedevil cardiac arrest survival rates nationally.

Given the number of lives affected by cardiac arrest each year, it is important that the NCAC have a sustained presence and be built on mutually agreed upon terms by the collaborators. As described in Chapter 6, there are many examples of successful collaboratives and partnerships from other fields that can provide guidance and lessons learned, especially in the context of public–private partnerships. The necessary tools to effect change are available; now the resuscitation field must work together to build a successful trajectory.

CONCLUSION

A national responsibility exists to significantly improve the likelihood of survival and favorable neurologic outcomes following a cardiac arrest. This will require important changes in cardiac arrest data capture and reporting, research, citizen and professional rescuer training, and EMS- and hospital-based care and treatment. Specifically, it requires collaboration among informed stakeholders and a new framework for cardiac arrest care that promotes real-time access to knowledge, multistakeholder partnerships, accountability and transparency, leadership to instill a culture of learning, and supportive system competencies.

The consequences of inaction when faced with a cardiac arrest suggest that bystanders need to be prepared and willing to deliver basic life support (BLS). BLS training programs based in schools, the workplace, and other public locations and adapted to the needs of the communities can foster a lay public that is willing a capable of providing lifesaving care. Training EMS dispatchers to provide CPR and AED instruction to 911 callers can provide additional support for members of the public when they activate emergency response systems.

Surviving cardiac arrest depends on the provision of high-quality care by first responders, EMS providers, and hospital personnel. These individuals must be adequately educated and properly trained to deliver the best possible care in team environments. High-performing communities provide examples of how functional public health infrastructures and well-organized health system responses can facilitate timely and effective treatment, including high-performance CPR.

Improvements in cardiac arrest outcomes will require sustained federal, state, and local commitment to the development of evidence-based practice. At a national level, enhanced surveillance is key to informing national research, implementation, and evaluation efforts. Basic and clinical research can provide insights about causal mechanisms and pathophysiology of cardiac arrest, potentially leading to novel treatments and therapies. Local translation of research and guidelines into practice and adoption of CQI programs could generate new data streams across all care sites, enabling benchmarking of cardiac arrest outcomes within and between systems to identify more effective treatment protocols and inform evidence-based practices.

Many of the necessary pieces and strategies to improve cardiac arrest outcomes and to save lives already exist throughout the resuscitation field and within individual communities and health care systems across the United States. To effect change, this knowledge must be strategically shared and communicated among all stakeholders. By mobilizing transparent, coordinated levels of action and accountability, the resuscitation field can generate change that is necessary to improve cardiac arrest outcomes across the United States.

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A

Acronyms

ACEP	American College of Emergency Physicians
ACLS	advanced cardiac life support
AED	automated external defibrillator
AMI	acute myocardial infarction
ARREST	Amsterdam Resuscitation Study of North Holland
BLS	basic life support
CAD	coronary artery disease
CARES	Cardiac Arrest Registry to Enhance Survival
CCU	critical care unit
CDC	Centers for Disease Control and Prevention
CMS	Centers for Medicare & Medicaid Services
CNS	central nervous system
COCPR	compression-only cardiopulmonary resuscitation
CPC	Cerebral Performance Category
CPR	cardiopulmonary resuscitation
CQI	continuous quality improvement
CT	computed tomography
CTSA	Clinical and Translational Science Awards
DHS	U.S. Department of Homeland Security
DNAR	do-not-attempt-resuscitation status
DOT	U.S. Department of Transportation
DRG	diagnosis-related group

ECC	emergency cardiac care
ECMO	extracorporeal membrane oxygenation
ECPR	extracorporeal cardiopulmonary resuscitation
ED	emergency department
EGDT	early goal-directed therapy
EKG	electrocardiogram
EMDPRS	emergency medical dispatch protocol reference system
EMS	emergency medical services
EMT	emergency medical technician
ERC	European Resuscitation Council
EuPSF	European Patient Safety Foundation
EuReCa	European Registry of Cardiac Arrest
FAA	Federal Aviation Administration
FDA	U.S. Food and Drug Administration
FICEMS	Federal Interagency Committee on EMS
FRP	first responder program
FRR	first recorded cardiac rhythm
GCS	Glasgow Coma Scale
GWTG-R	Get With The Guidelines-Resuscitation
IAEMSC	International Association of EMS Chiefs
ICD	*International Classification of Diseases*
ICU	intensive care unit
IHCA	in-hospital cardiac arrest
ILCOR	International Liaison Committee on Resuscitation
IOM	Institute of Medicine
MAUDE	Manufacturer and User Device Experience
MET	medical emergency team
mRS	Modified Rankin Scale
NAEMSP	National Association of EMS Physicians
NAS	National Academy of Sciences
NASEMSO	National Association of State EMS Officials
NATA	National Athletic Trainers' Association
NCAC	National Cardiac Arrest Collaborative
NEMSAC	National EMS Advisory Council

NEMSIS	National Emergency Medical Systems Information System
NG911	Next Generation 911
NHLBI	National Heart, Lung, and Blood Institute
NHTSA	National Highway Transportation Safety Administration
NICHHD	National Institute of Child Health and Human Development
NIH	National Institutes of Health
NINDS	National Institute of Neurological Disorders and Stroke
NRC	National Research Council
NRCPR	National Registry for CPR
OHCAR	National Out-of-Hospital Cardiac Arrest Register Project
OHCA	out-of-hospital cardiac arrest
OPALS	Ontario Prehospital Advanced Life Support Study
OR	odds ratio
OSHA	Occupational Safety and Health Administration
PAD	public access defibrillation
PALS	pediatric advanced life support
PAROS	Pan-Asian Resuscitation Outcomes Study
PATH	Penn Alliance for Therapeutic Hypothermia
PCI	percutaneous coronary intervention
PCNASR	Paul Coverdell National Acute Stroke Registry
PCORI	Patient-Centered Outcomes Research Institute
PEA	pulseless electrical activity
PEWS	Pediatric Early Warning Score
PMA	premarket approval
PSAP	public safety answering point
PSHSB	Public Safety & Homeland Security Bureau
pVT	pulseless ventricular tachycardia
QALY	quality-adjusted life-year
ROC	Resuscitation Outcomes Consortium
ROSC	return of spontaneous circulation
RRT	rapid response team

SCAR	Swedish Cardiac Arrest Register
SES	socioeconomic status
SHARE	Save Hearts in Arizona Registry and Education
SIREN	Strategies to Innovate EmeRgeNcy Care Clinical Coordinating Center
STEMI	ST segment elevation myocardial infarction
T-CPR	telecommunicator-assisted cardiopulmonary resuscitation
THAPCA	Therapeutic Hypothermia After Pediatric Cardiac Arrest
TOR	termination of resuscitation
TTM	targeted temperature management
VA	U.S. Department of Veterans Affairs
VACAR	Victorian Ambulance Cardiac Arrest Registry
VF	ventricular fibrillation
VoIP	Voice over Internet Protocol
VT	ventricular tachycardia
WFSA	World Federation of Societies of Anaesthesiologists

B

Meeting Agendas

FIRST WORKSHOP ON THE TREATMENT OF CARDIAC ARREST: CURRENT STATUS AND FUTURE DIRECTIONS

National Academy of Sciences Building
2101 Constitution Avenue, NW, Room 120
Washington, DC 20418

Wednesday, March 12, 2014

10:30 – 10:45 a.m.	**Welcome and Introductions** *Robert Graham*, Committee Chair *Mickey Eisenberg*, Committee Vice-Chair
10:45 a.m. – 12:15 p.m.	**Discussion of the Charge to the Committee** *Brian Eigel*, American Heart Association *Jennifer Deibert*, American Red Cross *David Lathrop*, National Institutes of Health's (NIH's) National Heart, Lung, and Blood Institute
12:15 – 1:00 p.m.	**Lunch**
1:00 – 3:15 p.m.	**Government-Related Activities About Cardiac Arrest**

	Joseph Ornato, Resuscitation Outcomes Consortium *Robin Boineau*, NIH's National Heart, Lung, and Blood Institute *Jeremy Brown*, NIH Office of Emergency Care Research *Bryan McNally*, Emory University
3:15 p.m.	**Adjourn Open Session**

SECOND WORKSHOP ON THE TREATMENT OF CARDIAC ARREST: CURRENT STATUS AND FUTURE DIRECTIONS

Seattle City Hall
600 Fourth Avenue, Berthe Knight Landes Room
Seattle, WA 98104

Monday, June 16, 2014

8:45 – 8:55 a.m.	**Welcome and Opening Remarks** *Robert Graham*, Committee Chair *Chief Gregory Dean*, Seattle Fire Department *Director Jim Fogarty*, King County Emergency Medical System
8:55 – 9:10 a.m.	**Overview of the Day** *Robert Graham*, Committee Chair *Mickey Eisenberg*, Committee Vice-Chair
9:10 – 9:50 a.m.	**Overview of Cardiac Arrest in the United States: Public Health Burden and Evolution of the Field** *Robert Neumar*, University of Michigan
9:50 – 10:00 a.m.	**BREAK**

10:00 – 11:30 a.m.	**Panel 1: Hemodynamic (or Circulatory) and Neurological Outcomes, Risk Factors, and Disparities in Cardiac Arrest** Moderator: *Dianne Atkins*, Committee Member Short- and Long-Term Hemodynamic Outcomes of Cardiac Arrest • *Peter Kudenchuk*, University of Washington (*via WebEx*) Short- and Long-Term Cognitive Outcomes of Cardiac Arrest • *Romer Geocadin*, Johns Hopkins University Pediatrics (i.e., adolescents and young adults) • *Vinay Nadkarni*, Children's Hospital of Philadelphia Disparities in OHCA Outcomes • *Comilla Sasson*, American Heart Association
11:30 a.m. – 12:30 p.m.	**LUNCH**
12:00 – 12:30 p.m.	**Seattle Fire Department's Demonstration of a Simulated Cardiac Arrest and Emergency Medical Services Response** *Jonathan Larsen*, Captain, City of Seattle Fire Department
12:30 – 1:40 p.m.	**Panel 2: The Public's Experience with Cardiac Arrest** Moderator: *Ben Bobrow*, Committee Member Surviving Cardiac Arrest • *Sue Nixon*, Ardent Sage Reducing Cardiac Arrest in Youth • *Michele Wenhold*, Parent Heart Watch

	National Efforts to Raise Public Awareness of Sudden Cardiac Arrest • *Mary Newman*, Sudden Cardiac Arrest Foundation Improving Bystander Usage of AEDs and CPR • *Amer Aldeen*, Chicago Cardiac Arrest Resuscitation Education Service
1:40 – 3:00 p.m.	**Panel 3: Prehospital Cardiac Arrest and Emergency Medical Services Systems—Challenges and Opportunities for Improvement** Moderator: *David Markenson*, Committee Member Characteristics of High-Performing EMS Systems in the United States • *Thomas Rea*, South King County Medic One Program 911-Dispatcher Training and Telecommunicator CPR • *Cleo Subido*, King County EMS Cardiac Arrest: The Perspective of First Responders • *David Jacobs*, Durham Fire Department Performance Standards and Enhancing EMT/Paramedic Training • *Louis Gonzales*, Office of the Medical Director at Austin-Travis County EMS System
3:00 – 3:15 p.m.	**BREAK**
3:15 – 4:30 p.m.	**Panel 4: Out-of-Hospital Cardiac Arrest Databases, Clinical Trial Design, and Research—Current Limitations and Future Directions** Moderator: *Tom Aufderheide*, Committee Member

	Challenges Associated with Data Collection, Measurement, and Clinical Trial Design: Short- and Long-Term Goals • *Graham Nichol*, University of Washington-Harborview Center for Pre-hospital Emergency Care Strategies to Improve Local and National Cardiac Arrest Data Registries • *Bryan McNally*, Emory University Model Systems for Cardiac Arrest Research Across Multiple Jurisdictions • *Ahamed Idris*, University of Texas Southwestern Medical Center
4:30 – 4:55 p.m.	**Public Testifiers**
4:55 – 5:00 p.m.	**Closing Remarks** *The Honorable Nick Licata*, Seattle Councilman *Mickey Eisenberg*, Committee Vice-Chair
5:00 p.m.	**ADJOURN**

THIRD WORKSHOP ON THE TREATMENT OF CARDIAC ARREST: CURRENT STATUS AND FUTURE DIRECTIONS

National Academies' Keck Center
500 Fifth Street, NW, Room 100
Washington, DC 20001

Tuesday, August 25, 2014

9:00 – 9:15 a.m.	**Welcome and Introductions** *Robert Graham*, Committee Chair *Mickey Eisenberg*, Committee Vice-Chair

9:15 – 10:45 a.m.	**Panel 1: Treatment of Cardiac Arrest in Hospitals** Moderator: *Nisha Chandra-Strobos*, Committee Member Cardiac Arrests in Hospitals: Where Have We Been and Where Do We Go from Here? • *Paul Chan*, St. Luke's Health System In-Hospital Treatment of Out-of-Hospital Cardiac Arrest • *Mary Ann Peberdy*, Virginia Commonwealth University State of In-Hospital Resuscitation in the United States • *Dana Edelson*, University of Chicago Medicine Efforts to Improve Outcomes of In-Hospital Cardiac Arrest in the VA • *Steven Bradley*, Veterans Affairs Eastern Colorado Health Care System
10:45 – 11:00 a.m.	**BREAK**
11:00 a.m. – 12:15 p.m.	**Panel 2: Evolving Understanding of Known and Emerging Therapies and Treatments** Moderator: *Lance Becker*, Committee Member Questioning the Science: What Is Known About Existing Therapies • *Mike Weisfeldt*, Johns Hopkins University Evaluating and Developing Cardiac Arrest Drug Cocktails and Devices in the Next Decade • *Demetris Yannopoulos*, University of Minnesota Medical School Emerging Therapies in Europe • *Bernd Böttiger*, University Hospital of Cologne, Germany
12:15 – 1:15 p.m.	**LUNCH**

1:15 – 2:45 p.m.

Panel 3: Enhancing the Pathway from Bench to Bedside
Moderator: *Roger Lewis*, Committee Member

The Need for Basic and Translational Research in Cardiac Arrest
- *Robert Berg*, University of Pennsylvania

The Promise of New Trial Designs
- *Scott Berry*, Berry Consultants

Topics in FDA Regulation of Resuscitation Drugs
- *Stephen Grant*, Division of Cardiovascular and Renal Products, Food and Drug Administration

Facilitating Resuscitation Device Development: An FDA Division of Cardiovascular Devices Perspective
- *Bram Zuckerman*, Center for Devices and Radiological Health, Food and Drug Administration

2:45 – 3:00 p.m.

BREAK

3:00 – 4:30 p.m.

Panel 4: New Strategies to Promote Improved Performance and Health Outcomes
Moderator: *Robin Newhouse*, Committee Member

Harnessing the Power of National Databases: Progress in Japan
- *Robert Berg*, University of Pennsylvania

The Role of National Quality Improvement Efforts: Performance Measures and Centers of Excellence for the Care of Stroke Patients
- *Mark Alberts*, University of Texas Southwestern Medical Center

The Influence of Social Marketing and Public Health Campaigns
- *Amy Burnett Heldman*, Centers for Disease Control and Prevention

	Options to Create a Sustainable Business Model • *Allison Crouch*, Emory University
4:30 – 4:55 p.m.	**Public Comment**
4:55 – 5:00 p.m.	**Closing Remarks** *Robert Graham*, Committee Chair *Mickey Eisenberg*, Committee Vice-Chair
5:00 p.m.	**ADJOURN**

C

Committee Biographies

Robert Graham, M.D. (*Chair*), currently serves as the director of the Aligning Forces for Quality Program (AF4Q). AF4Q is one of the Robert Wood Johnson Foundation's major initiatives to improve the quality, efficiency, and equity of the U.S. health care system. There are presently 16 sites throughout the United States participating in the project. AF4Q is based at George Washington University in Washington, DC, where Dr. Graham is also a research professor in the Department of Health Policy, Milken Institute School of Public Health. He has served as executive vice president/CEO of the American Academy of Family Physicians, (AAFP), the head of the Academy's Foundation, and the administrative officer of the Society of Teachers of Family Medicine (STFM). He has served on the faculty of the Department of Family & Community Medicine at the University of Cincinnati and held the Robert and Myfanwy Smith Endowed Chair from 2005 to 2011. Moreover, Dr. Graham is the former administrator of the Health Resources and Services Administration (HRSA) and also worked at the Agency for Healthcare Research and Quality (AHRQ). He has supported universal coverage, federal health workforce policy, and the organizational characteristics of effective health systems. His current areas of interest are leadership development, organizational change, and improving the effectiveness of the U.S. health care system. He was elected to the Institute of Medicine in 1990.

Mickey Eisenberg, M.D., Ph.D. (*Vice-Chair*), is medical director of King County, Washington Emergency Medical Services (EMS) and professor of medicine at the University of Washington in Seattle. He has been a researcher and educator in the field of EMS since 1975. In 1978

Dr. Eisenberg and his colleagues demonstrated the benefit of emergency medical technician (EMT) defibrillation and in 1983 developed the first dispatcher-assisted cardiopulmonary resuscitation (CPR) program. Both EMT defibrillation and dispatcher-assisted CPR have become national standards in EMS care throughout the United States. Since 1985 he has promoted innovative methods to teach CPR including websites (learn-cpr.org) and smartphone apps. He has published more than 200 articles on cardiac arrest and resuscitation and has authored a dozen books. Most noteworthy among these are *Life in the Balance: Emergency Medicine and the Quest to Reverse Sudden Death*, an account of the history of resuscitation, as well as *Resuscitate! How Your Community Can Improve Survival from Sudden Cardiac Arrest (2nd edition)* and *10 Steps for Improving Survival from Sudden Cardiac Arrest* (Apple bookstore). In 2009 he helped found the Resuscitation Academy (resuscitationacademy.org), a training program for medical directors and EMS directors, attended by participants from various parts of the world. He was elected to the Institute of Medicine in 1994.

Dianne Atkins, M.D., is a professor of pediatrics at the University of Iowa Carver College of Medicine, in the Division of Pediatric Cardiology. She has particular expertise in cardiac electrophysiology. She is involved with diagnostic evaluations, pharmacotherapy, pacer and *International Classification of Diseases* (ICD) follow-up, as well as optimizing defibrillation techniques and evaluating automated defibrillation for children. She recently established the University of Iowa Children's Hospital Familial Arrhythmia Clinic to provide information and care to families with inherited cardiac arrhythmia syndromes. Dr. Atkins was previously an investigator on several industry trials evaluating automated external defibrillator (AED) algorithms in children and was also a co-investigator on the National Institutes of Health (NIH) Resuscitation Outcomes Consortium, a multi-center clinical trial of interventions in out-of-hospital cardiac arrest and severe trauma. She currently serves as the chair of the Science Committee of the Emergency Cardiovascular Care Committee of the American Heart Association and is a member of the Pediatric Task Force for the International Liaison Committee on Resuscitation (ILCOR).

Tom P. Aufderheide, M.D., M.Sc., is a professor of emergency medicine, associate chair of research affairs, and director of the NIH-funded Resuscitation Research Center in the Department of Emergency Medicine at the Medical College of Wisconsin. He is an internationally recognized researcher in the field of emergency cardiac care, whose discoveries and scholarly achievements include pioneering the use of out-of-hospital 12-lead electrocardiography for rapid identification and treatment of the ischemic patient, which now forms the basis for identification of patients with acute myocardial infarction in most urban and rural communities throughout the world. He discovered hemodynamically detrimental effects of many previously common cardiac arrest resuscitation practices, including hyperventilation during CPR, incomplete chest recoil, and variable delivery of CPR quality. He also originated improvement in CPR hemodynamics through the novel use of intrathoracic pressure regulation, doubling the effectiveness of CPR. These discoveries have had a significant effect on the practice of emergency medicine, emergency cardiac care guidelines, and improved outcomes for patients with cardiac arrest and acute cardiac emergencies. He has also been instrumental in developing a system of care approach in communities as part of the Take Heart American initiative, whose mission is to improve survival from sudden cardiac arrest. He is currently the president of the Citizen CPR Foundation and former chair of the Emergency Cardiac Care committee of the American Heart Association. He has been an Institute of Medicine member since 2009.

Lance B. Becker, M.D., is a professor of emergency medicine at the University of Pennsylvania. He has founded two resuscitation research centers at major universities and currently is the director of Penn's Center for Resuscitation Science, a multidisciplinary team focused on improving survival from sudden death. He has research interests that are translational; extending across the basic science laboratory into animal models of resuscitation and to human therapies. He is board certified in internal medicine, emergency medicine, and critical care medicine. He has been an international thought leader in the field of resuscitation for more than 25 years, working to improve the quality of CPR, pioneer advances in the use of AEDs and therapeutic hypothermia, and develop the "three phase" phase model for cardiac arrest care. He has worked closely with the American Heart Association in emphasizing the importance of a "systems of care" approach to improving survival within communities. He is also an active basic science researcher with a particular interest in the role of mitochondria in "life-versus-death decision making" for cells and tissues exposed to and recovering from ischemia. His cellular studies have helped define reperfusion injury mechanisms, mitochondrial oxidant generation, free radical responses to ischemia, cellular signaling pathways, new cellular cytoprotective strategies, and hypothermia protection. Additional new studies are ongoing on the importance of mitochondria medicine, development of novel human coolants, emergency cardiopulmonary bypass, and combined anti-reperfusion injury drugs for recovery after prolonged ischemia. He has been an Institute of Medicine member since 2006.

Bentley J. Bobrow, M.D., is professor of emergency medicine at the University of Arizona College of Medicine—Phoenix Campus and practices emergency medicine at Maricopa Medical Center in Phoenix, Arizona. His focus is on improving outcomes of time-sensitive emergency medical conditions such as out-of-hospital cardiac arrest and traumatic brain injury. He has partnered with public health officials, EMS agencies, municipal fire departments, hospitals, university researchers, and the public to develop a statewide reporting and educational network for responding to out-of-hospital cardiac arrest. This system of care has resulted in a significant increase in the rates of bystander CPR and a tripling of survival from sudden cardiac arrest in Arizona (www.azshare.gov). Dr. Bobrow is a past chair of the American Heart Association Basic Life Support Subcommittee and the medical director for the Bureau of Emergency Medical Services and Trauma System at the Arizona Department of Health Services. He is the principal investigator for the HeartRescue Program—Arizona, director of the Maricopa Integrated Health Services (MIHS) Resuscitation Science Center, and the chair of the MIHS In-hospital Resuscitation Committee. He is an advisory board member for the Cardiac Arrest Registry to Enhance Survival (CARES) Program, a member of the Arizona Emergency Medicine Research Center, the Sarver Heart Center at the University of Arizona, and co-investigator for the NIH-funded R01 EPIC Prehospital Traumatic Brain Injury Study. Dr. Bobrow is medical director of a Clinton Global Health Initiative to implement and measure telephone-CPR across the United States and in 11 countries in Asia.

Nisha Chandra-Strobos, M.D., currently serves as the chief of cardiology at the Johns Hopkins Bayview Medical Center, where she specializes in cardiac critical care. She completed her residency and fellowship in cardiology at Johns Hopkins and was promoted to full professor in 1996. Dr. Chandra-Strobos has more than 30 years of experience in bench and clinical CPR research. Her interests include women's health, cost-effective health care delivery, difficult second opinion patients, premature coronary artery disease (CAD) treatment and diagnosis, and pregnancy with heart disease. An acclaimed teacher and master clinician, Dr. Chandra-Strobos became an inaugural member of the Miller-Coulson Academy of Clinical Excellence in 2009. She was previously a chair of the American Heart Association's National Basic Life Support Sub-Committee and remains active in the organization. She has published more than 230 peer-reviewed chapters, papers, and abstracts.

Marina Del Rios, M.D., M.Sc., is an assistant professor, health disparities research coordinator, and assistant director of emergency ultrasound at the University of Illinois at Chicago. She is a member of the steering committee and physician leader in the Illinois Heart Rescue Project, a state-wide quality assessment and improvement project tasked with more than doubling neurologically intact survival of out-of-hospital cardiac arrest victims in Illinois. She has extensive experience with community engagement and CPR education as well as research related to both hypertension and the cardiovascular-associated risks of high-risk populations. Dr. Del Rios has planned and executed large-scale CPR trainings for the Chicago Cubs and Chicago Fire as well as the Illinois State Fair. Additionally, she uses a mixed methods approach including epidemiological and community-based participatory research to identify and address regional population needs. Dr. Del Rios has dedicated her professional life to identifying and addressing health disparities found in low-income, minority, and immigrant populations.

Al Hallstrom, Ph.D., is professor emeritus of biostatistics at the University of Washington. Dr. Hallstrom was the director of the University of Washington Clinical Trials Center, where he directed the statistical aspects of many clinical trials including CAST (Cardiac Arrhythmia Suppression Trial), ASPIRE (AutoPulse Assisted Prehopsital International Resuscitation Trial), and DAVID (Dual Chamber and VVI Implantable Defibrillator Trial). He has a long record of investigations in cardiovascular medicine, including both chronic and emergency services applications. Dr. Hallstrom has published more than 200 papers, many of which are very widely cited in the field. He previously directed the University of Washington Coordinating Center for ROC (Resuscitation Outcomes Consortium) and is a fellow of the American Heart Association.

Daniel B. Kramer, M.D., M.P.H., is a cardiac electrophysiologist at Beth Israel Deaconess Medical Center and research scientist at the Institute for Aging Research, both at Harvard Medical School, where he is an assistant professor in medicine. Dr. Kramer graduated from Brown University with an A.B. in philosophy before receiving his M.D. and M.P.H. from Harvard, and he completed training in internal medicine at Massachusetts General Hospital prior to fellowships in cardiology and cardiacelectrophysiology at Beth Israel Deaconess Medical Center as well as the Medical Device Fellowship at the U.S. Food and Drug Administration's (FDA's) Center for Devices and Radiologic Health. Dr. Kramer's research encompasses clinical outcomes, healthy policy, and ethical problems arising from the use of cardiac devices, particularly implantable cardioverter-defibrillators (ICDs). Dr. Kramer has served on the Heart Rhythm Society task force, which developed consensus guidelines for managing cardiac devices at the end of life, as well as the National Cardiovascular Data Registry task force evaluating strategies for improving post-market device surveillance. Recent work, funded by NIH, U.S. Department of Health and Human Services (HHS), and Pew Charitable Trusts Medical Device Initiative, includes approaches to medical device regulation, risk stratification for recipients of ICDs, and qualitative research evaluating the views of patients, physicians, and nurses on the ethics and clinical aspects of ICD deactivation. Dr. Kramer's current research is supported by the Paul B. Beeson Scholars program and includes projects evaluating patient-centered outcomes following ICD implantation as well comparative approaches to pre- and post-market device evaluation.

Roger J. Lewis, M.D., Ph.D., is currently a professor at the David Geffen School of Medicine at University of California, Los Angeles (UCLA), and the chair of the Department of Emergency Medicine at Harbor-UCLA Medical Center. His academic interests focus on clinical research methodology, including adaptive and Bayesian trial design; translational, clinical, health services and outcomes research; interim data analysis; data monitoring committees; and informed consent in emergency research studies. Dr. Lewis has served as the research methodologist for many laboratory, clinical, and health services research studies, including multiple NIH-supported investigations of resuscitation strategies, and has authored or co-authored more than 200 original research publications, reviews, editorials, and chapters. Dr. Lewis has served as a grant reviewer for numerous federal and foreign public agencies and is a member of the Medicare Evidence Development & Coverage Advisory Committee of the Centers for Medicare & Medicaid Services. He is a past president of the Society for Academic Emergency Medicine (SAEM) and currently a member of the Board of Directors for the Society for Clinical Trials. Dr. Lewis has been an Institute of Medicine member since 2009.

David Markenson, M.D., FAAP, EMT-P, is a board-certified pediatrician with fellowship training in both pediatric emergency medicine and pediatric critical care. He is the chief medical officer for Sky Ridge Medical Center, a HealthOne facility in Colorado, as well as chair of the American Red Cross Scientific Advisory Council. Dr. Markenson previously served as the medical director of Disaster Medicine and Regional Emergency Services at the Westchester Medical Center and Maria Fareri Children's Hospital. He has directed development of national guidelines for emergency preparedness for both children and persons with disabilities. He has authored or co-authored more than 50 peer-reviewed articles and 2 text books (*Pediatric Prehospital Care* and *Healthcare Emergency Preparedness*); served as deputy editor for *Basic Disaster Life Support*; and led more than 30 research grants in the areas of pediatric emergency medicine, resuscitation, health care provider education, and disaster medicine. Additionally, Dr. Markenson has served as an advisor to multiple governmental activities and agencies, including the Federal Emergency Management Agency (FEMA) National Advisory Council.

Raina M. Merchant, M.D., M.S.H.P., is an assistant professor of emergency medicine at the University of Pennsylvania and has a secondary appointment in the Department of Internal Medicine. She is also the director of the University of Pennsylvania Social Media and Health Innovation Lab. She attended Yale University for her undergraduate degree, University of Chicago for Medical School, and the University of Pennsylvania for an M.S.H.P. and the Robert Wood Johnson Foundation Clinical Scholars Program. Her research interests are in diffusion of innovation, social media, public health, and resuscitation science. Her work involves development and testing of health-related mobile apps, and she has conducted several projects evaluating health communication on social/mobile media sites such as Facebook, Twitter, Yelp, Foursquare, and others. Much of her work bridges new technologies in the field of cardiovascular health. In this context, she is the director of the MyHeartMap Challenge—a social media and crowdsourcing project aimed at improving AED access and awareness by engaging the public to serve as citizen scientists. She has received numerous awards for her work in social media and crowdsourcing. Dr. Merchant was recently recognized by the Robert Wood Johnson Foundation as 1 of 10 young investigators likely to have a significant impact on the future of health and health care in the United States.

Robert J. Myerburg, M.D., is professor of medicine and physiology and has been a distinguished member of the University of Miami Miller School of Medicine faculty for more than 35 years. Dr. Myerburg served as director of the Division of Cardiology for 31 years and holds the American Heart Association Chair in Cardiovascular Research. Dr. Myerburg earned his medical degree from the University of Maryland, where he also completed his internship. He was a resident in internal medicine at Tulane University and a cardiology fellow at Emory University/Grady Memorial. He was a research fellow in the Department of Pharmacology at Columbia University College of Physicians and Surgeons. Dr. Myerburg has served as principal investigator on multiple NIH grants on the mechanisms and clinical profiles of arrhythmias and sudden cardiac death. From 2005 to 2012, he was the principal investigator (PI) for the University of Miami site of a multi-PI international consortium on sudden cardiac death funded by the Leducq Foundation, and he currently directs the Cardiovascular Genetics and Athlete Heart Disease Clinic of the Division of Cardiology at the University of Miami Miller School of Medicine. Dr. Myerburg lectures on sudden cardiac death and arrhythmias, and has a special interest in heart disease in adolescents and athletes. He has served as president of the Association of University Cardiologists, the Association of Professors of Cardiology, and the Association of Subspecialty Professors, and he received an honorary doctorate degree (*honoris causa*) from Oulu University in Finland in 2009.

Brahmajee K. Nallamothu, M.D., M.P.H., is an associate professor in the Division of Cardiovascular Diseases and the Department of Internal Medicine at the University of Michigan and at the Ann Arbor Veterans Affairs Medical Center. He received his M.D. from Wayne State University in 1995, and he completed his residency in internal medicine and fellowship in general and interventional cardiology at the University of Michigan. He has completed research training through a fellowship sponsored by the Agency for Healthcare Research and Quality (AHRQ), and subsequently an NIH-funded K12 grant focusing on dissemination of specialized cardiac technologies and services. Dr. Nallamothu holds an M.P.H. in health management and policy. His research focus has been on improving the delivery and quality of specialized cardiovascular procedures through population-based approaches. His contributions include (1) examining the quality and appropriateness of percutaneous coronary intervention (i.e., stenting) in ST-segment elevation myocardial infarction and (2) care of hospitalized patients with cardiac arrests.

Robin P. Newhouse, Ph.D., RN, NEA-BC, FAAN, is professor and chair of the Department of Organizational Systems and Adult Health at the University of Maryland School of Nursing (UMSON) and is director of the Center for Health Outcomes Research. Her most recent studies have focused on improving the adoption of evidence-based practices in health systems. She has published extensively on issues related to health services improvements, strategies to address quality issues in acute care services, and evidence-based practice. Dr. Newhouse was appointed to the Methodology Committee of the Patient-Centered Outcomes Research Institute (PCORI) by the Comptroller General of the U.S. Government Accountability Office, and now serves as chair. She was also appointed to the Institute of Medicine Standing Committee on Credentialing Research in Nursing (2012-2014), serves on the American Nurses Credentialing Center's (ANCC's) Research Council, and is the immediate past chair of the Research and Scholarship Advisory Council for Sigma Theta Tau International (2009-2013). Dr. Newhouse holds a Ph.D. and an M.S. from UMSON; an M.G.A. from the University of Maryland University College; and a B.S.N. from the University of Maryland Baltimore County.

Ralph L. Sacco, M.D., M.S., FAHA, FAAN, is the chairman of neurology; Olemberg Family Chair in Neurological Disorders; Miller Professor of Neurology, Epidemiology and Public Health Sciences, Human Genetics, and Neurosurgery; executive director of the Evelyn McKnight Brain Institute at the Miller School of Medicine, University of Miami; and chief of the neurology service at Jackson Memorial Hospital. A graduate of Cornell University in bio-electrical engineering and a cum laude graduate of Boston University School of Medicine, he also holds an M.S. in epidemiology from the Columbia University Mailman School of Public Health. Dr. Sacco completed his neurology residency training and post-doctoral training in stroke and epidemiology at Columbia Presbyterian in New York. He was previously professor of neurology, chief of stroke and critical care division, and associate chairman at Columbia University before taking his current position as chairman of neurology at the University of Miami Miller School of Medicine. He is the PI of the National Institute of Neurological Disorders and Stroke (NINDS)-funded Northern Manhattan Study, the Florida Puerto Rico Collaboration to Reduce Stroke Disparities, and the Family Study of Stroke Risk and Carotid Atherosclerosis, as well as co-investigator of multiple other NIH grants. He has also been the co-chair of international stroke treatment and prevention trials. Dr. Sacco has published extensively with more than 425 peer-reviewed articles and 102 invited articles in the areas of stroke prevention, treatment, epidemiology, risk factors, vascular cognitive impairment, human genetics, and stroke recurrence. His research has also addressed stroke and vascular disparities. He has been the recipient of numerous awards, including the Feinberg Award of Excellence in Clinical Stroke, the Chairman's Award from the American Heart Association, and the NINDS Javits Award in Neuroscience. He has lectured extensively at national and international meetings. Dr. Sacco is a fellow of both the Stroke and Epidemiology Councils of the American Heart Association, the American Academy of Neurology, and the American Neurological Association, and he currently serves as vice president of the American Academy of Neurology. He is also a member of the American Association of Physicians. He was the first neurologist to serve as the president of the American Heart Association (2010-2011) and he is the current co-chair of the American Heart Association's International Committee. Dr. Sacco has been a member of the World Stroke Organization since 2008. He currently chairs the Research Committee (2012-2016) and is on the Board of Directors (2012-2016).

Arthur B. Sanders, M.D., is a professor in the Department of Emergency Medicine at the University of Arizona, as well as a member of the Arizona Emergency Medicine Research Center and the University of Arizona Sarver Heart Center. He has been involved in resuscitation research, in both experimental models as well as clinical research, for more than 30 years. Dr. Sanders's academic accomplishments have focused on improving cardiac arrest survival, improving geriatric emergency care, understanding the ethical issues involved in emergency medicine, and educating students, physicians, and other health care professionals. His cardiac arrest research has led to a better understanding of cardiopulmonary resuscitation resulting in new protocols for assessment and treatment of patients. His work in geriatric emergency medicine has resulted in a better understanding of the special needs of elder patients who seek emergency medical care. He has been an Institute of Medicine member since 2012.

Clyde W. Yancy, M.D., is a cardiologist and clinician-investigator at Northwestern Memorial Hospital and Northwestern University Feinberg School of Medicine, where he is both chief of the Division of Cardiology and the Magerstadt Professor of Medicine and Professor of Medical Social Sciences. He is a fellow of the American College of Cardiology and the American Heart Association (AHA) and is a master of the American College of Physicians. His academic and professional interests include hypertension, heart failure, heart transplantation, and ethnic and racial disparities in cardiovascular disease. He has participated in more than 30 multi-center clinical research studies. He has authored or co-authored more than 300 contributions to the medical literature and has received numerous "best doctor" and teaching awards. Among his many honors, are the AHA's national "Physician of the Year" award and the AHA Distinguished National Leadership Award. He is associate editor for the *Journal of the American College of Cardiology* and a member of the editorial board of the journal *Circulation*. He currently serves as chair-person of the American College of Cardiology/AHA Guideline Writing Committee for Heart Failure. Dr. Yancy is the current chair of FDA's Circulatory Devices Panel and a member of the Methodology Committee for the Patient-Centered Outcomes Research Institute. He is a former president of the AHA and continues to serve as a volunteer and a national spokesperson.

D

Selected Results from Commissioned Analyses

The following maps and tables include selected results from the Committee's commissioned analysis of data from Cardiac Arrest Registry to Enhance Survival (CARES), Resuscitation Outcomes Consortium (ROC) Epistry, and Get With The Guidelines-Resuscitation (GWTG-R) registry. The commissioned reports are available on the Institute of Medicine website.

TABLE D-1 2013 Incidence and Outcomes of Out-of-Hospital Cardiac Arrest

	Cardiac Arrest Registry to Enhance Survival (CARES)		Resuscitation Outcomes Consortium (ROC)	
	Incidence (%)	Survival (%)	Incidence (%)	Survival* (%)
Total, EMS-treated arrests of presumed cardiac etiology	87.1	10.6	84.1	11.2
Patient characteristics				
Mean patient age	62.8		62.1	
Gender				
Male	60.8	11.8	60.6	12.5
Female	39.2	9.6	39.4	9.2

continued

	Cardiac Arrest Registry to Enhance Survival (CARES)		Resuscitation Outcomes Consortium (ROC)	
	Incidence (%)	Survival (%)	Incidence (%)	Survival* (%)
Race				
White	46.2	11.5	51.9	12.6
American-Indian/ Alaskan	0.5	10.8		
Asian	1.6	10.4		
Black/African-American	18.8	9.3		
Hispanic/Latino	6.2	11.9		
Native Hawaiian/ Pacific Islander	0.7	7.1		
Unknown	26.1	10.9	19.3	9.3
Other			28.8	
Income				
<$20,000	3.6	8.4		
$20,000-$29,999	11.0	8.9		
$30,000-$39,999	17.9	8.7		
$40,000-$49,999	18.4	8.6		
$50,000-$59,999	15.9	8.8		
$60,000-$69,999	11.8	8.7		
$70,000-$79,999	8.2	9.2		
$80,000-$89,999	5.3	8.5		
$90,000-$99,999	3.0	8.4		
>$100,000	5.0	10.7		
Event characteristics				
Initial cardiac rhythm				
VF/VT/shockable rhythm	21.1	29.4	20.5	30.0
Unknown/ unshockable rhythm	11.0	12.2	1.1	36.4
Asystole	46.4	2.8	49.4	2.2
PEA	21.5	9.7	24.1	9.8
Etiology of arrest				
Presumed cardiac	87.1	10.6	92.2	
Other causes	12.9		7.8	
Location of arrest				
Home/residence	70.1	9.0		48.3
nursing home/ALF	10.4	4.8		12.7

	Cardiac Arrest Registry to Enhance Survival (CARES)		Resuscitation Outcomes Consortium (ROC)	
	Incidence (%)	Survival (%)	Incidence (%)	Survival* (%)
Witness status				
Unwitnessed	49.9	4.8	50.3	4.5
Bystander witnessed	37.7	16.4	35.9	
911/EMS-responder witnessed	12.4	18.8	12.1	
Bystander or EMS-responder witnessed				17.5
EMS characteristics				
Bystander CPR provided	39.6	12.5	43.1	
Bystander AED applied	4.4	21.7	2.4	
Yes	15.2	20.0	4.1	
No	84.8	9.3	95.9	
Hypothermia provided (in hospital)				
Yes	50.1	36.6	41.6	
No	49.9	40.0		
Additional information				
Good neurologic status at discharge (CPC = 1; mRS ≤3)				
VT/VF		70.5		89.9
PEA		45.8		81.8
Asystole		42.8		73.6
Cardiac catheterization performed			26.4	

NOTES: ROC data on survival outcome was only available for the year 2011.
AED = automated external defibrillator; ALF = assisted living facility; CPC = cerebral performance category; CPR = cardiopulmonary resuscitation; mRS = Modified Rankin Score; PEA = pulseless electrical activity; VF = ventricular fibrillation; VT = ventricular tachycardia. The prepublication version of this report listed the PEA data point (under "additional information") as 42.8 and the asystole data point as 45.8.
SOURCES: Based on data from the CARES and ROC registries. Daya et al., 2015; Vellano et al., 2015.

TABLE D-2 Incidence and Outcomes of In-Hospital Cardiac Arrest in 2013

	Get With The Guidelines - Resuscitation	
Patient Characteristics	Incidence (%)	Survival (%)
Mean age	65.1	
Gender		
Male	58.8	24.5
Female	41.2	24.4
Race		
White	68.7	72.9
Black	23.5	20.0
Other	1.8	1.7
Unknown	6.0	5.4
Event Characteristics		
Etiology of arrest		
Medical-cardiac	37.2	40.2
Medical-noncardiac	45.9	36.6
Surgical-cardiac	6.6	11.3
Surgical-noncardiac	10.4	11.9
Location of arrest		
ICU	48.8	39.7
Monitored unit	15.0	18.0
Non-monitored unit	14.4	12.9
ED	12.4	13.8
Initial cardiac rhythm		
Asystole	28.0	23.1
PEA	54.6	44.3
VF	10.0	18.9
pVT	7.4	13.7
Other		
Day and Time of Arrest		
Daytime	49.3	27.5
Night time	16.6	20.7
Weekend	32.7	21.3
AED use (among non-ICU patients only)		
Yes	34.0	27.7
No	66.0	29.5

Patient Characteristics	Get With The Guidelines - Resuscitation	
	Incidence (%)	Survival (%)
U.S. Region		
North Mid-Atlantic	13.8	24.1
South Atlantic	20.7	23.4
North Central	15.2	27.9
South Central	17.8	22.9
Mountain Pacific	8.9	26.0
Is Hospital Rural or Urban?		
Rural	2.6	24.4
Urban	74.0	24.6

NOTE: AED = automated external defibrillator; ED = emergency department; ICU = intensive care unit; PEA = pulseless electrical activity; pVT = pulseless ventricular tachycardia; VF = ventricular fibrillation; VT = ventricular tachycardia.
SOURCE: Based on data from the GWTG-R registry.

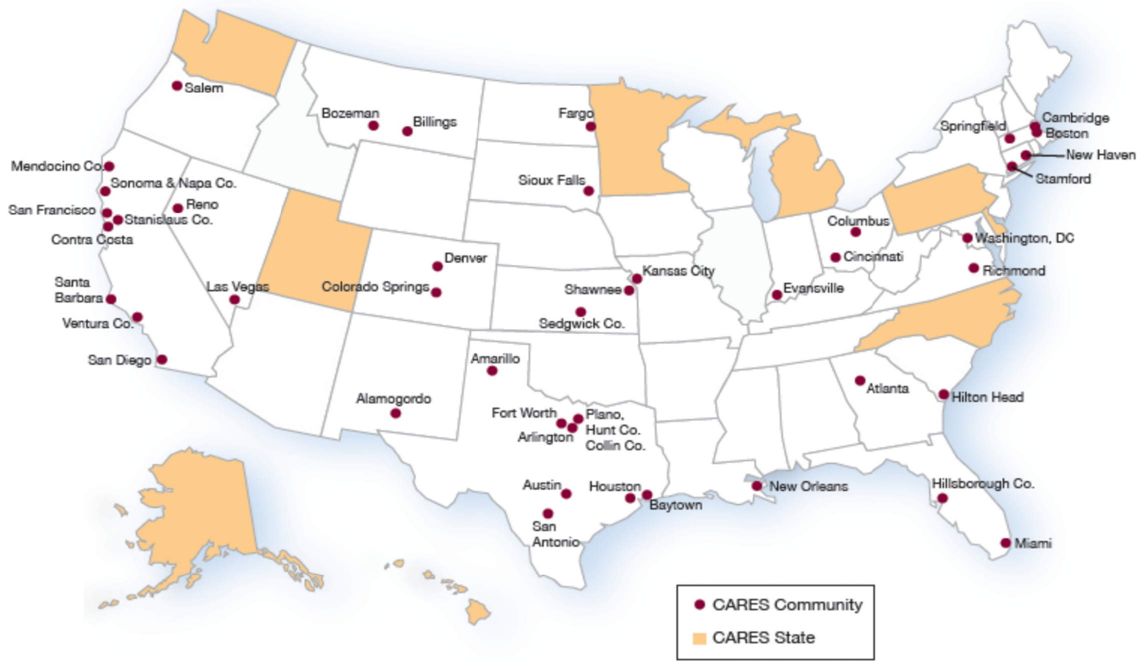

FIGURE D-1 Cardiac Arrest Registry to Enhance Survival (CARES) participating sites.
SOURCE: Vellano et al., 2015.

FIGURE D-2 Resuscitation Outcomes Consortium (ROC) participating sites.
SOURCE: Daya et al., 2015.

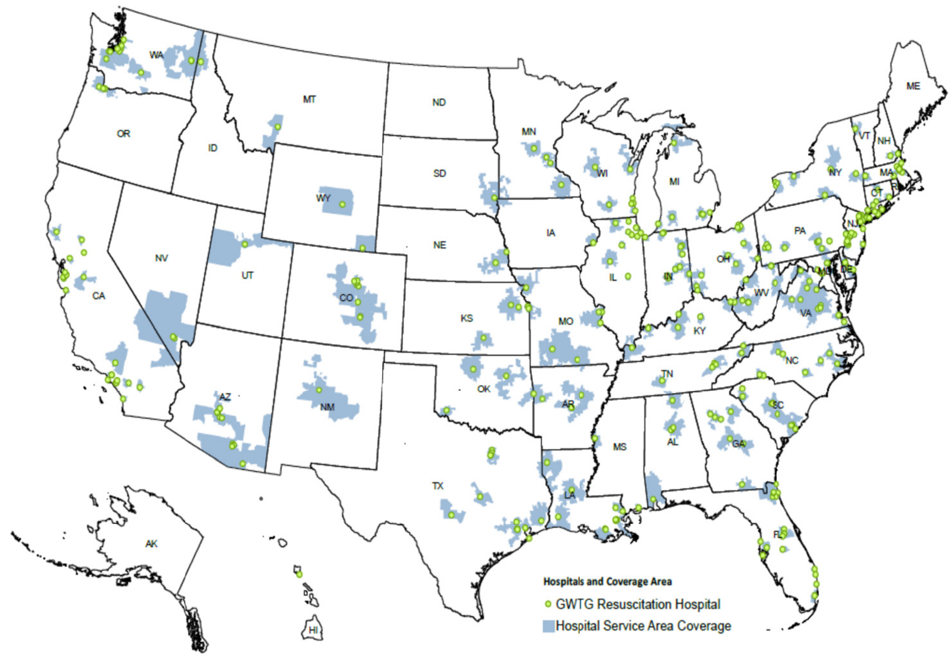

FIGURE D-3 Get With The Guidelines-Resuscitation registry.
NOTE: This map displays 317 hospitals.
Data years: The American Heart Association hospital data from July 18, 2014; Dartmouth Atlas hospital service areas 2005; 2011 Environmental Systems Research Institute population estimates.
SOURCE: Reprinted with permission from Microsoft Dynamics.

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Vellano, K., A. Crouch, M. Rajdev, and B. McNally. 2015. Cardiac Arrest Registry to Enhance Survival (CARES) report on the public health burden of out-of-hospital cardiac arrest. http://www.iom.edu/~/media/Files/Report%20Files/2015/CARES.pdf (accessed June 19, 2015).

E

Map of U.S. States with CPR Training as a High School Graduation Requirement

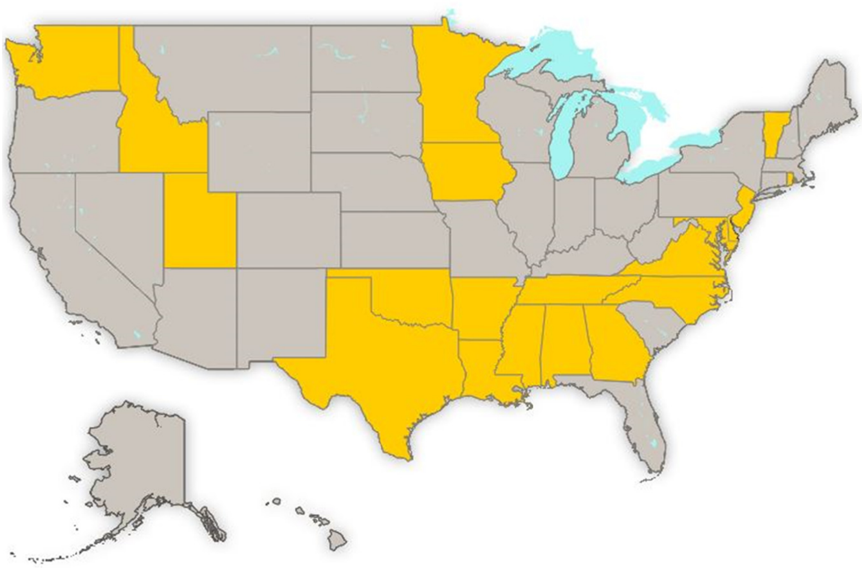

FIGURE E-1 U.S. States that require or will require cardiopulmonary resuscitation (CPR) training as a high school graduation requirement.
SOURCE: Reprinted with permission from the American Heart Association.

State	Year of Enactment
Alabama	1984
Arkansas	2014-15
Delaware	2014-15
Georgia	2013-14
Idaho	2015-16
Iowa	2008
Louisiana	2014-15
Maryland	2014
Minnesota	2014-2015
Mississippi	2014
New Jersey	2014
North Carolina	2014-15
Oklahoma	2015-16
Oregon	2015-16
Rhode Island	2013
Tennessee	2012
Texas	2014-15
Utah	2014-15
Vermont	2012
Virginia	2016-17
Washington	2014-15
West Virginia	2015-16

SOURCE: The American Heart Association, 2015. http://www.heart.org/HEARTTORG/CPRAndECC/CommunityCPRandFirstAid/CPRinSchools/States-CPR-Regulations-for-Schools_UCM_470097_SubHomePage.jsp (accessed June 19, 2015).

F

Utstein Guideline—Endorsed Data Elements for Reporting Out-of-Hospital Cardiac Arrest

TABLE F-1 International Liaison Committee on Resuscitation—Core and Supplementary Data Element Domains Endorsed by the 2014 Updated Utstein-Style Guidelines for OHCA

	System	Dispatch	Patient	Process	Outcomes
Core	Population served Cardiac arrests attended Resuscitation attempted System description	Dispatcher-identified cardiac arrest Dispatcher CPR instructions	Age Gender Witnessed arrest Arrest location Bystander CPR/AED First monitored rhythm Arrest etiology	Response times Defibrillation time Target temperature control Drugs Reperfusion attempted	Survived event Any ROSC 30-day survival/survival-to-discharge Neurological outcome
Supplemental	DNAR legislation Termination of resuscitation rules Dispatch software used Resuscitation algorithms followed Data quality activities Prehospital EKG capability		Independent living Comorbidities Presence of STEMI Ventricular assist devices Cardioverter-defibrillator	Airway control type Number of shocks Drug timings CPR quality Vascular access type Mechanical CPR Targeted Oxygenation/Ventilation/BP ECMO IABP pH, Lactate, glucose, 12-lead ECG Neuroprognostication Hospital type/volume	Transport to hospital Treatment withdrawal Cause of death Organ donation Patient-reported outcomes measures Quality-of-life measures 12-month survival

NOTE: AED = automated external defibrillator; BP = blood pressure; CPR = cardiopulmonary resuscitation; DNAR = do not attempt resuscitation; EKG = electrocardiogram; ECMO = extracorporeal membrane oxygenation; IABP = intra-aortic balloon pump; ROSC = return of spontaneous circulation; STEMI = ST-segment elevated myocardial infarction.
SOURCE: Perkins et al., 2014. Adapted with permission from the American Heart Association, 2015.

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Perkins, G. D., I. G. Jacobs, V. M. Nadkarni, R. A. Berg, F. Bhanji, D. Biarent, and J. P. Nolan. 2014. Cardiac arrest and cardiopulmonary resuscitation outcome reports: Update of the Utstein Resuscitation Registry templates for out-of-hospital cardiac arrest: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. *Circulation*. http://www.ncbi.nlm.nih.gov/pubmed/25391522 (accessed June 19, 2015).