Circulation

AHA SCIENTIFIC STATEMENT

Out-of-Hospital Cardiac Arrest Resuscitation Systems of Care

A Scientific Statement From the American Heart Association

ABSTRACT: The American Heart Association previously recommended implementation of cardiac resuscitation systems of care that consist of interconnected community, emergency medical services, and hospital efforts to measure and improve the process of care and outcome for patients with cardiac arrest. In addition, the American Heart Association proposed a national process to develop and implement evidence-based guidelines for cardiac resuscitation systems of care. Significant experience has been gained with implementing these systems, and new evidence has accumulated. This update describes recent advances in the science of cardiac resuscitation systems and evidence of their effectiveness, as well as recent progress in dissemination and implementation throughout the United States. Emphasis is placed on evidence published since the original recommendations (ie, including and since 2010).

James J. McCarthy, MD, Chair
Brendan Carr, MD, MA, MS
Comilla Sasson, MD, PhD, FAHA
Bentley J. Bobrow, MD, FAHA
Clifton W. Callaway, MD, PhD
Robert W. Neumar, MD, PhD, FAHA
Jose Maria E. Ferrer, MD
J. Lee Garvey, MD†
Joseph P. Ornato, MD, FAHA
Louis Gonzales, MPH
Christopher B. Granger, MD, FAHA
Monica E. Kleinman, MD
Chris Bjerke, RN, MBA
Graham Nichol, MD, MPH, FAHA, Co-Chair
On behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; and the Mission: Lifeline Resuscitation Subcommittee

†Deceased.

Key Words: AHA Scientific Statements ■ delivery of health care ■ emergency medical services ■ out-of-hospital cardiac arrest ■ resuscitation

http://circ.ahajournals.org

Cardiac arrest is loss of mechanical activity of the heart confirmed by the absence of signs of circulation.[1] Approximately 356 461 people are treated for out-of-hospital cardiac arrest (OHCA) annually in the United States.[2] One third of cases occur without any prior recognized heart disease; half occur without any prodromal symptoms.[3] Despite robust systems of care for patients with trauma and rapidly evolving systems of care for patients with ST-segment–elevation myocardial infarction (STEMI) and stroke, the majority of communities do not achieve optimal survival after OHCA because of large discrepancies in resuscitation-related processes of care.[4–6] As a result, survival to hospital discharge varies significantly both across different regions and by presenting rhythm.[7,8]

Survival increases significantly if the OHCA is quickly recognized and responded to with prompt activation of 9-1-1, bystander-initiated cardiopulmonary resuscitation (CPR), bystander and/or basic first responder application of an automated external defibrillator (AED) before arrival of other emergency medical services (EMS) providers on scene, advanced life support, and postresuscitation care.[9]

The American Heart Association (AHA) previously recommended implementation of cardiac resuscitation systems of care that consist of interconnected community, EMS, and hospital efforts to measure and improve the process and outcome of care for patients with cardiac arrest.[10] Simultaneously, the AHA proposed a national process to develop and implement evidence-based guidelines for the implementation and measurement of such systems. The 2015 AHA guidelines for CPR and emergency cardiovascular care delved deeper into the elements of an effective system of care for both OHCA and in-hospital cardiac arrest.[11] This update on OHCA resuscitation systems of care describes recent advances, evidence

of their effectiveness, and recent progress in their dissemination and implementation throughout the United States. Emphasis is placed on evidence published since the original recommendations (ie, including and since 2010).

MISSION: LIFELINE RESUSCITATION PROGRAM

The initial call to implement cardiac resuscitation systems deliberately did not specify how such systems should be implemented.[10] In subsequent deliberations about how to implement and maintain cardiac resuscitation systems of care, experts recognized that many patients resuscitated from OHCA have STEMI or STEMI equivalent and require emergent angiography with primary percutaneous coronary intervention (PCI).[12–14] Centers providing comprehensive, evidence-based care for cardiac arrest need to be capable of providing PCI 24 hours a day, 7 days a week. Furthermore, experts recognized that insufficient resources are available to support acute cardiovascular care delivery and quality improvement. With this understanding, a strategic decision was made to integrate cardiac resuscitation systems of care with STEMI systems of care under the AHA's Mission: Lifeline program. Mission: Lifeline is the AHA's initiative to develop and improve systems of care for high-risk, time-sensitive conditions.[15] The percentage of the United States covered by a Mission: Lifeline–registered cardiac resuscitation system lags significantly behind the STEMI system coverage (Figure).

DISSEMINATION OF RESUSCITATION SYSTEMS OF CARE

Since 2010, many municipalities and regions have continued or begun to implement cardiac resuscitation systems modeled on prior experience implementing and maintaining similar interconnected systems for patients with traumatic injury, STEMI, and acute stroke. To assist in the evolution of regional resuscitation systems of care, several national organized efforts have emerged, including Mission: Lifeline,[16,17] Take Heart America,[18] and the HeartRescue Project.[19] Each of these initiatives is intended to facilitate implementation of evidence-based treatments across the continuum of care delivery and to establish an interconnected community, EMS, and hospital response to improve cardiac arrest outcomes. These programs are still early in their implementation, and evaluations of impact and success of these initiatives are ongoing.

In the description of these developing systems, it is important to distinguish between resuscitation referral hospitals, resuscitation centers, and regional resuscitation systems of care. The first is a hospital that receives patients with cardiac arrest from ≥1 EMS agencies but does not meet the criteria for a resuscitation center. Resuscitation centers provide a designated set of specialized services for patients with cardiac arrest. Regional resuscitation systems of care are interconnected community, EMS, and hospital efforts across an entire region to improve care for patients with cardiac arrest. Complicating the landscape, some institutions have designated themselves as resuscitation centers without necessarily integrating into a local, regional, or statewide system of care. In many cases, the development of specialized resuscitation centers is an important first step in that they have demonstrated improved outcomes with the implementation of evidence-based guidelines and resource allocation.[20,21] A resuscitation referral hospital will have demonstrated the ability to safely transfer patients with return of spontaneous circulation (ROSC) after cardiac arrest to specialized receiving facilities.[22,23] The referred patient should demonstrate similar survival with good neurological outcome despite any differences in time from onset of arrest to hospital arrival.[24,25] Local politics, geography, EMS coverage, and hospital affiliations may complicate the landscape and remain challenges to true regional integration. Although resuscitation referral centers are an important step, the evolution to a regional system of care requires full integration of all community stakeholders, which may include survivors, family members, civic groups, businesses, the 9-1-1 dispatch system, EMS providers, healthcare providers, hospitals, public health entities, rehabilitation centers, payers, and municipal governments.

LOCAL IMPLEMENTATION

In selected counties from North Carolina that participated in the HeartRescue program,[17] there were efforts to increase training of laypeople on how to perform bystander CPR, to provide dispatcher/telecommunicator instructions for CPR, and to improve layperson and first responder use of AEDs. All of these were done as components of the implementation of a cardiac resuscitation system of care. This significantly improved survival after OHCA compared with a historical control period[26] in those counties. Analysis demonstrated that this improvement was associated with improved rates of bystander CPR and early defibrillation.

In a large metropolitan area in the United States with an already established regional STEMI system of care, an EMS protocol was implemented to transport patients with OHCA with an initial shockable rhythm and with field ROSC to a specialized STEMI receiving center. The center used a protocol to induce therapeutic hypothermia after resuscitation and was associated with a 40% rate of cerebral performance category 1 or 2 at hospital discharge compared with a 6% rate with historical controls (2001) at the same institution. Use

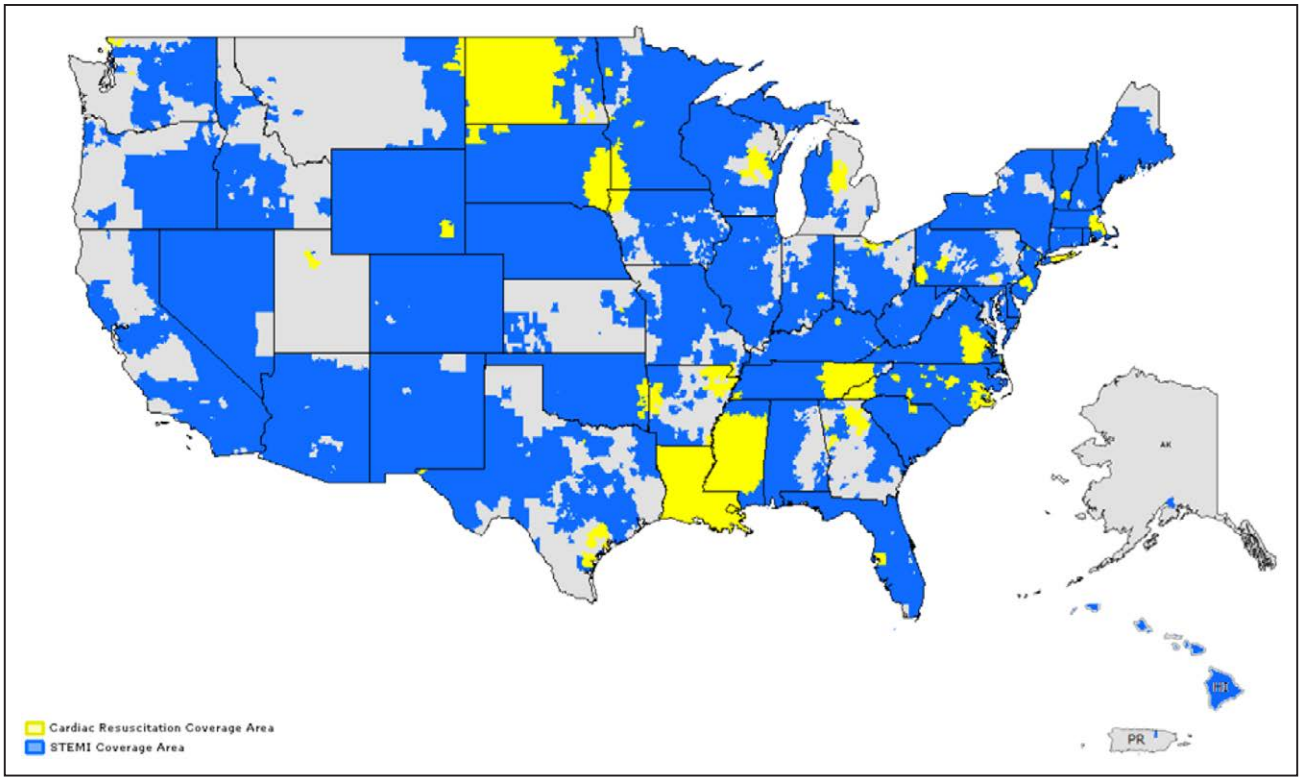

Figure. Coverage of ST-segment–elevation myocardial infarction (STEMI) systems of care in the United States. STEMI plus cardiac resuscitation system coverage as of April 16, 2015 (848 STEMI systems, 83.67% population coverage; 83 cardiac resuscitation systems, 92.5% population coverage). All systems data, including coverage are, are self-reported data. Note: Cardiac resuscitation coverage areas listed are also indicative of an STEMI system in place. Mission: Lifeline does not recognize cardiac resuscitation systems that are not also associated with an active STEMI system. Yellow indicates cardiac resuscitation coverage area; and blue, STEMI coverage area. Source: Centers for Disease Control and Prevention (CDC), National Center for Health Statistics. Compressed Mortality File 1999 through 2006. CDC Wonder online database. *International Classification of Diseases, 10th Revision*, codes I21 through I22. Adapted from Mission: Lifeline Program.[15]

of therapeutic hypothermia was associated with significantly greater favorable neurological status compared with no hypothermia (adjusted odds ratio [OR] for survival with good neurological recovery [cerebral performance category 1 or 2], 2.0; 95% confidence interval [CI], 1.2–3.5; *P*=0.01).[27]

In the same large metropolitan area, treatment of patients with STEMI complicated by OHCA that included therapeutic hypothermia, early coronary angiography, and PCI was associated with better outcome after an initial shockable rhythm than after a nonshockable rhythm (risk ratio, 2.7; 95% CI, 1.1–6.8).[28]

In a large metropolitan area in the United Kingdom, patients with STEMI complicated by OHCA who were resuscitated and then transported to a specialist STEMI center for angiography and selective PCI had a high rate of survival (66%).[29]

In a secondary analysis of data from a multicenter randomized trial of field interventions in patients with OHCA,[30] use of hospital-based intervention was observed but not mandated or randomly allocated. Rates of early coronary catheterization (19.2%), coronary reperfusion (17.7%), and induced hypothermia (39.3%) varied among hospitals and were higher in hospitals treating more patients per year. Odds of survival to discharge and favorable neurological status at discharge (ie, modified Rankin Scale score <3) increased with hospital volume (per every increase by 5 subjects per year: OR, 1.06; 95% CI, 1.04–1.08; and OR, 1.06; 95% CI, 1.04–1.08, respectively). Survival and favorable outcome were independently associated with early coronary angiography (OR, 1.69; 95% CI, 1.06–2.70; and OR, 1.87; 95% CI, 1.15–3.04), coronary reperfusion (OR, 1.94; 95% CI, 1.34–2.82; and OR, 2.14; 95% CI, 1.46–3.14), and therapeutic hypothermia (OR, 1.36; 95% CI, 1.01–1.83; and OR, 1.42; 95% CI, 1.04–1.94), although these analyses may be limited by survivor bias and unmeasured confounders.

STATEWIDE IMPLEMENTATION

Increasing experience with the development of cardiac arrest centers followed by EMS integration and devel-

opment of regional referral centers continues to result in improved outcomes for patients with OHCA.

In 2007, Arizona rolled out a statewide model of regionalizing postarrest care that included state-recognized cardiac receiving centers, implementation of postarrest care focused on therapeutic hypothermia, emergent coronary angiography, and delayed prognostication of neurological status, along with an EMS bypass protocol triaging comatose, postarrest patients with OHCA with ROSC to the closest recognized cardiac arrest center. Arizona reported that implementation of a cardiac receiving center system resulted in a dramatic survival increase from 21.4% (21 of 98) to 39.2% (115 of 293; adjusted OR, 2.96; 95% CI, 1.63–5.38) and that cerebral performance category 1 or 2 on hospital discharge increased from 19.4% (19 of 98) to 29.8% (87 of 292; adjusted OR, 2.12; 95% CI, 1.14–3.93).[31] Collectively, these initial reports of the impact of local and statewide implementation of cardiac resuscitation systems of care suggest that such implementation of systems directing appropriate postarrest patients to specialty centers improves both the process of care and outcomes.

MEASUREMENT AND FEEDBACK

A foundation for any quality improvement program is the collection and feedback of data in a way that can be useful to guide implementation and refinement. Currently available systems include the Cardiac Arrest Registry to Enhance Survival, the National EMS Information System registry, the Resuscitation Outcomes Consortium program, statewide programs such as Save Hearts in Arizona Registry and Education, and regional or local databases. These systems provide robust platforms for internal benchmarking and process improvement activities.

LINKS IN THE CHAIN

Bystander CPR and Public-Access Defibrillation

Broad community-based campaigns have increased the use of CPR and survival after OHCA.[8,32–35] In areas where such campaigns have been conducted over a sustained period of time, the majority of citizens in these select communities report that they have been trained in CPR at some point in their life.[36] Furthermore, data from the Cardiac Arrest Registry to Enhance Survival demonstrate that both bystander CPR and AED use have significant direct impacts on improving survival. Currently, bystander AEDs are applied to 4% of patients with OHCA. Predictive modeling suggests that if all OHCAs had bystander AED use, survival would increase from 9% to 14%. For witnessed arrest, survival would increase from 16% to 29%.[9] Unfortunately, these improvements are not universal; underserved communities appear to have significantly lower rates of CPR training than their counterparts throughout the United States.[37]

Neighborhoods composed of lower-income black residents, compared with higher-income white residents, are 51% less likely to have someone perform CPR.[38] Rates of bystander CPR also vary significantly by neighborhood characteristics, with observed of outcomes ranging from community to community.[39,40] Furthermore, growing evidence suggests that low-socioeconomic-level communities might be particularly appropriate targets for community-based CPR education and awareness campaigns.[41] Strategies to increase lay training in CPR include public safety department training programs (eg, Medic II program in Seattle, WA) and hands-only CPR media messaging,[42] and state legislation to encourage or require training before graduation from high school should continue to be explored and studied. Simultaneous implementation of multiple strategies appears to increase use of bystander CPR and survival.[32,33]

Telephone CPR

An integral but sometimes incompletely implemented aspect of emergency first response is delivery of CPR instructions via the 9-1-1 system, which plays a pivotal role in bridging lay rescuers and trained EMS providers. The 9-1-1 system can play a key role if the telecommunication staff are well trained and experienced in identifying suspected cardiac arrest and providing telephone CPR instructions to callers.[43] Simplified protocols and guidelines improve both the rates of bystander CPR[44] and the time to initiation.[45] This novel aspect of the resuscitation system should be measured, compared with benchmarks, and then improved as needed.[46] When these aspects of telephone CPR were combined as part of a statewide public health initiative in Arizona, significant improvements in the percentage of CPR instructions given, time to first chest compression, bystander CPR, and survival were found.[47]

EMS Response

A highly-trained and well-equipped team of prehospital providers is a critical component for the ideal resuscitation system of care. Application of an AED by a layperson before the arrival of EMS providers on scene,[48] briefer time from the call for assistance to the arrival of EMS providers on scene (ie, response time interval),[49–54] and better quality of CPR[55–61] are associated with improved outcomes.

Simultaneous or "dual dispatch" activation of first responders with AEDs in conjunction with ALS units

decreases time to defibrillation and improves survival.[62] Without ROSC before hospital arrival, survival to hospital discharge is rare.[63] Airway management in the prehospital setting continues to be an important area of investigation, with recent data suggesting that although overall success rates are high, first-attempt failure rates are noted to be higher in patients with cardiac arrest compared with those without cardiac arrest.[64] Endotracheal intubation is associated with improved outcomes compared with the use of supraglottic airway devices.[6] The initiation of therapeutic hypothermia in the field is not more effective than induction after hospital arrival.[65–68]

Referring and Receiving Facilities

The AHA model for cardiac resuscitation systems identifies 2 different levels of resuscitation centers: level I and II (Table 1). Although recognition of level I resuscitation centers of expertise makes sense, it is logical for all hospitals in a region to seek and achieve accreditation as a level II resuscitation center even if they are to be bypassed when an ambulance is transporting a patient with OHCA who has achieved ROSC to a level I center. This is important because some patients will experience cardiac arrest in hospital or may arrive at the emergency department by some means other than EMS ambulance. In either case, each hospital should have the ability to initiate advanced post-ROSC care to include induction of targeted temperature management (TTM), cardiopulmonary stabilization, and potential transfer to a level I facility. Such regionalization of resuscitation care is already in place and is serving as a model for the establishment of similar systems throughout the United States.[10,24,31,69–71]

A PCI center is an ideal candidate to become a level I resuscitation center because it can provide comprehensive cardiovascular care, including primary PCI, for the ≈25% of patients who experience their OHCA in the setting of an acute STEMI. However, although STEMI and stroke centers provide a solid initial framework, both involve a single-organ system, not the multisystem insult experienced by most patients with OHCA. Therefore, such hospitals may lack the multidisciplinary team and resources required to provide optimal care to the postarrest patient. For a hospital seeking accreditation as a level I resuscitation center, an important prerequisite should be to first demonstrate the need for an additional resuscitation center and the impact that it would have on the community's regional plan for patients with OHCA. For most urban and suburban areas where ambulance transport times from the scene to hospital are not unduly long, it is reasonable to bypass the closest hospital and bring the patient directly to a level I center because survival is not significantly affected by transport interval.[72,73]

Table 1. Resuscitation Center Criteria

Level I
Must meet all requirements of an STEMI receiving center
Is a designated hospital champion for cardiac resuscitation
Actively participates in multidisciplinary group to monitor, provide feedback, and improve cardiac resuscitation process and outcome
Implements and maintains standard triage and treatment protocols for patient who received cardiac resuscitation consistent with AHA guidelines
Works with EMS medical direction and cardiac resuscitation referral centers to develop cardiac resuscitation treatment plan
Initiates hypothermia as soon as possible when indicated
Initiates cardiology consult as soon as possible
Universal 24 h/d, 7 d/wk acceptance of cardiac resuscitation patients regardless of diversion status of ED
Has plan to treat simultaneous cardiac resuscitation patients
Has plan for and ability to treat rearrest, including mechanical CPR or pharmacological support
Is capable of assessing need for ICD placement and providing appropriate follow-up
Defers assessment of prognostication and withdrawal of care for at least 72 h after cardiac resuscitation
Participates in regional or national quality improvement program to monitor and improve cardiac resuscitation care processes and outcome
Integrates plans for return of the patient to the local community for follow-up care after discharge from the cardiac resuscitation receiving hospital on a routine basis
Provides CPR training for community with the goal of achieving bystander CPR rates >50%
Provides CPR, ACLS, and PALS training for appropriate staff
Has external certification, not self-designation, as part of cardiac resuscitation system of care
Should include at least compression-only CPR training for all employees (The AHA hands-only campaign produces short, easy-to-understand videos to help the general public learn compression-only CPR [http://cpr.heart.org/AHAECC/CPRAndECC/Programs/HandsOnlyCPR/UCM_475516_CPR-Demos-and-Videos.jsp])
Level II
Must meet criteria for ideal STEMI referral center
Is designated hospital champion for cardiac resuscitation
Actively participates in multidisciplinary team meetings to monitor, provide feedback, and improve cardiac resuscitation care process and outcome
Implements and maintains standard triage and treatment protocols for patient who received cardiac resuscitation consistent with ACC/AHA guidelines
Implements and maintains a plan with EMS to ensure that interhospital transfers receive priority response
Initiates hypothermia as soon as possible when indicated
Is not capable of PPCI
Transports early patients resuscitated from OHCA to cardiac resuscitation receiving center to allow angiography of catheterization-eligible/appropriate patients as soon as possible to achieve the goal of first door-to-device time within 120 min
Implements and maintains the ability to treat rearrest, including mechanical CPR or pharmacological support if indicated
Provides CPR training for community with the goal of achieving bystander CPR rates >50%

(*Continued*)

Table 1. Continued

Provides CPR and ACLS training for appropriate staff
Has external certification, not self-designation, as part of cardiac resuscitation system of care
Should include at least compression-only CPR training for all employees (The AHA hands-only campaign produces short, easy-to-understand videos to help the general public learn compression-only CPR [http://cpr.heart.org/AHAECC/CPRAndECC/Programs/HandsOnlyCPR/UCM_475516_CPR-Demos-and-Videos.jsp])

ACC indicates American College of Cardiology; ACLS, advanced cardiac life support; AHA, American Heart Association; CPR, cardiopulmonary resuscitation; ED, emergency department; EMS, emergency medical services; ICD, implantable cardioverter-defibrillator; OHCA, out-of-hospital cardiac arrest; PALS, pediatric advanced life support; PPCI, primary percutaneous coronary intervention; and STEMI, ST-segment–elevation myocardial infarction.

Adapted from Mission: Lifeline Program.[15] Copyright © 2017, American Heart Association, Inc.

Post-ROSC Care

Targeted Temperature Management

On the basis of the results of randomized trials,[74,75] the International Liaison Committee on Resuscitation and the AHA recommended in 2010 the use of mild therapeutic hypothermia for comatose hospitalized victims of OHCA with ROSC.[76] Recently, a large randomized[77] trial comparing rigorous temperature control at 33°C versus 36°C in unconscious survivors of OHCA found that neither temperature was superior for the outcomes of survival and functional status. Another recent trial has suggested that there was no large significant difference in long-term neurological outcome among children unconscious after OHCA who received TTM to 33°C compared with those who received TTM to 36°C.[78] The first 2 trials that suggested that hypothermia was beneficial achieved their intended target temperature much faster than the later 2 trials. With these considerations and as part of a broader TTM strategy, the AHA and International Liaison Committee on Resuscitation now recommend selecting and maintaining a constant temperature between 32°C and 36°C for at least 24 hours for comatose patients with ROSC after cardiac arrest.[79,80]

Access to PCI

Up to 70% of patients with OHCA have coronary artery disease. Although 50% have acute coronary occlusion,[81–91] only a minority of patients with OHCA with ROSC who were transported to hospital have an ST-segment elevation on a 12-lead ECG.[92,93] Mortality after emergent angiography for STEMI patients in the setting of post-ROSC OHCA is greater than that in the setting of STEMI alone.[94,95] A barrier to the use of emergent angiography in post-ROSC patients with OHCA is that multiple registries track the mortality of patients with STEMI. Third-party payer reimbursement and individual- and hospital-level incentive programs are linked to public reporting of outcomes after STEMI. Because patients who have OHCA associated with STEMI have a higher mortality than those with STEMI alone, individual providers and hospitals have disincentives to provide potentially efficacious care to the newly resuscitated.[96] Recognizing the absence of accurate symptoms or signs to assess neurological prognosis in the emergency department,[76,97] AHA guidelines have argued that case selection for emergent angiography after resuscitation should be independent of neurological assessment. This conflicts with hospital and physician concerns about reportable outcomes data related to postprocedure, specifically mortality, and the public perception of publicly reported numbers.[96] As a consequence, the proportion of patients who undergo emergent angiography may not include all of those who the data suggest may benefit from it.[30,98] Experts have recommended disaggregating patients with OHCA from public reporting of outcomes after STEMI to reduce unintended consequences.[96] Ongoing efforts are warranted to understand and disseminate appropriate use of emergent angiography in patients resuscitated from OHCA.

Prognostication and Neurological Intensive Care

AHA guidelines state that after cardiac arrest, prognostication should be reserved until at least 72 hours after return to normothermia if the patient is treated with TTM and until at least 72 hours after ROSC if the patient is not treated with TTM.[79] Evidence-based approaches to discontinue life support after this time have been well described.[99]

The electroencephalogram and loss of the N20 component on testing median nerve somatosensory evoked potentials in experienced hands are helpful for prognostication.[100–103] Premature declaration that the patient has a poor prognosis by an inexperienced clinician or consultant may contribute to early decisions to withdraw care as a "self-fulfilling prophecy."[104] In general, it is not possible to determine the patient's prognosis accurately until at least 72 hours after resuscitation in the era of TTM.[105,106]

Care guidelines recommend that an electroencephalogram should be performed with prompt interpretation as soon as possible and should be monitored frequently or continuously in comatose patients after ROSC because nonconvulsive status epilepticus occurs frequently after resuscitation from cardiac arrest.[76,107–111] In such patients, the brain has suffered a prolonged episode of global ischemia, is hypothermic, and often is under the influence of sedatives and paralytics. Electroencephalographic tracings in this setting present a challenge even for experienced interpreters of electroencephalograms unless they have managed a significant number of these patients and have had the opportunity to correlate their findings with the patient's clinical course. A subset of patients may benefit from access to experienced neurocritical care services.

IMPORTANT COMPONENTS THAT REQUIRE MORE EMPIRICAL DATA AND CONSENSUS

One Versus Many Centers in a Region

Transport of patients with life-threatening traumatic injuries from the field to a receiving trauma center with a higher volume of patients is most likely to benefit the sickest or most complex patients.[112–114] In contrast to this and international work,[115–117] recent assessments of the relationship between the volume of patients with OHCA who are transported to hospital and their subsequent outcome have provided conflicting data. It is not clear if higher volumes or hospital size has an impact on mortality in the US population. In a retrospective analysis of a subset of Nationwide Emergency Department Sample data describing patients with cardiac arrest or ventricular fibrillation in the out-of-hospital or emergency department setting, greater survival to admission was seen in teaching hospitals (OR, 1.3; 95% CI, 1.1–1.5; *P*=0.001), hospitals with ≥20 000 annual emergency department visits (OR, 1.3; 95% CI, 1.1–1.6; *P*=0.003), and hospitals with PCI capability (OR, 1.6; 95% CI, 1.4–1.8; *P*<0.001).[118] Although some analyses have demonstrated that larger, teaching, and urban centers have lower mortality[70,115–117,119–121] and that intensive care unit admission volume is an important factor in outcomes,[70] others have failed to demonstrate that volume is significantly associated with outcomes after risk adjustment.[119,120] The question of volume needs to be further explored in terms of how patient volume affects outcomes at individual hospitals.

Unlike other more common cardiovascular emergencies such as STEMI or stroke, there may be few viable patients with OHCA in most communities who are candidates for structured, multidisciplinary, in-hospital postresuscitation care. In a typical US community with a population of ≈1 000 000, there are ≈1000 to 1500 patients with STEMI a year. However, only ≈100 to 150 patients with OHCA on average will achieve sustained ROSC. If the community has 10 hospitals capable of providing STEMI care and all receive patients with OHCA, each hospital would each treat 100 to 150 STEMI patients a year, which would likely be enough to maintain proficiency on the part of the nurses and physicians caring for the patients and to generate enough revenue to sustain any upgrades in equipment necessary over time. On the other hand, if the case volume were evenly distributed between the same 10 STEMI hospitals, each would treat only 10 to 15 patients with OHCA a year (roughly 1–1.5 patients a month). This would make it difficult to maintain professional and institutional competency and to justify the cost of specialized equipment and programs necessary to meet the needs of these patients.

The strong relationship between the volume of patients received at a trauma center and their subsequent outcome implies that there is a need for ongoing assessment of the relationship between the volume of patients with cardiac arrest received at hospital and their outcome.

Interfacility Transport

Further discussion is warranted about whether and how patients who have in-hospital cardiac arrest at a facility that does not have expertise in resuscitation should be transferred after ROSC to a facility with such expertise. The intent of transfer would be to provide care that is not available at the primary hospital. However, this may affect the ability of the primary hospital to initiate appropriate postresuscitation care before transfer.

Extracorporeal CPR

Extracorporeal CPR (ECPR) is the rapid initiation of cardiopulmonary support and extracorporeal maintenance of circulation until restoration of an effective cardiac output.[122,123] ECPR has been proposed as a rescue therapy in patients with cardiac arrest refractory to standard therapy. Case-control studies suggest that ECPR is associated with better outcomes compared with no ECPR in cardiac resuscitation systems of care with a low overall survival.[124,125] ECPR may be considered for select patients for whom the suspected cause of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support.[126] Such specialized care is promising, but more research is needed to support implementation in standard practice.

Neurocritical Care

The evolution of neurocritical care as a subspecialty discipline over the past 25 years has led to the development of neurocritical care as a distinct medical specialty, bridging neurosurgery, neurology, and critical care and neurocritical care intensive care units from theoretical constructs to focused closed units that provide comprehensive care to the neurologically injured patient.[127] Although many have logically advocated that closed specialty intensive care units managed by critical care physicians should improve care and outcomes,[128] debate about the broad efficacy remains.[129] The ideal staffing and unit model has yet to be defined.[130] Across the spectrum of neurological emergencies, care delivery in neurocritical care specialty units by neurointensivists improves outcomes in patients with traumatic brain injury,[131,132] intracerebral hemorrhage,[133] cerebrovascular accident,[134] and subarachnoid hemorrhage.[135] How this specialty could be integrated into the continuum of

care delivery for survivors of OHCA represents in important area of future inquiry.

Implementation and Operationalizing

Operationalizing the comprehensive components of an optimal resuscitation system of care may face challenges at each level of implementation, from overall community leadership, bystander engagement with CPR, EMS provider and emergency telecommunications, and roles of the referring and receiving hospitals to the infrastructure of data and quality management. With each challenge, specific opportunities for improvement can be identified.[136] It is incumbent on the medical community to lead in the improvement of our local and regional resuscitation system of care. However, it is mandatory that the entire cross section of stakeholders become engaged in the process of building and continually improving such a system if any sustainable improvements are to be realized. The medical community, along with other local stakeholders, can advocate for dedicating appropriate resources to advance bystander engagement and education and EMS operations and for appropriate resuscitation and postresuscitation systems to be put into place. Successful systems are usually led by a champion who could, in theory, be any stakeholder in OHCA resuscitation but is frequently someone in the medical field who can mobilize the talent and resources needed for the effort.[137] A fundamental quality of such leaders is their ability to build alliances and coalitions.

Multiple barriers may exist to implementing or maintaining a cardiac resuscitation system of care in a community (Table 2). Borrowing techniques for implementing change in business, the first key barrier to address is lack of understanding that change is needed.[138] For communities, EMS agencies, and hospitals that treat patients with cardiac arrest, this need for change is driven by the large regional disparities in the process and outcome of care. The second is resource limitations, which force organizations to change allocations of resources. The third is a lack of desire among individuals to make changes. The final key barrier is institutional politics. Use of local opinion leaders, mentors, and a tipping point approach was previously recommended to implement change in resuscitation organizations.[137] Regional consortia such as those organized for Mission: Lifeline in STEMI care[139] may provide a logical starting place for extending those consortia to other high-risk, time-sensitive conditions, including resuscitation and stroke.

Financial Impact

The variation among EMS system designs may create challenges to operationalizing regional resuscitation systems of care. These challenges may be both financial and operational in nature. EMS systems with limited

Table 2. Potential Barriers to Improvements in Cardiac Outcomes

Community
Lack of bystander CPR
Lack of recognition of cardiac arrest
Lack of knowledge of basic first aid emergency care/CPR
Apprehension about performing CPR correctly
Apprehension about liability issues and needing a current certification
Lack of public access to defibrillators
Lack of education on need
Lack of education on how to use an AED
Lack of funding to purchase AEDs and train the public
Lack of knowledge of AED location
No system for maintaining AEDs
Need for local and state government support and commitment for sustainability
Discrepancy of who owns AEDs for access, maintenance, and repair
Emergency dispatch
Delayed identification of patient with cardiac arrest
Lack of formal dispatch protocols
Lack of training needed to recognize the need for CPR
Lack of telecommunicator-assisted CPR
Lack of formal telecommunicator-assisted CPR protocols
Difficulty instructing bystanders to perform CPR
Lack of real-time data on the location of AEDs so callers can be directed to them by telecommunicators
EMS
Lack of resources to implement cardiac resuscitation systems of care
Lack of understanding why change is needed
Lack of reallocation of resources (high-effort, low-yield activities)
Insufficient integration of first responder training
Insufficient quality review or quality improvement programs for cardiac resuscitation at a systems level
Providing high-quality CPR
Compressions are interrupted for performing various interventions such as intubation and intravenous insertion
Compression interruption to move the patient
Insufficient quality review or quality improvement programs for chest compression and ventilation quality
Lack of destination protocols
Lack of cardiac resuscitation designation for hospitals
No national certification process to identify destination hospitals
Need early alert to hospitals of arrival of patient with cardiac arrest
Referral center
Lack of comprehensive postarrest care
Lack of active engagement from multidisciplinary team
Lack of multiprofessional engagement
Lack of organization of in-hospital resources to care for patients who received cardiac resuscitation
Lack of established treatment protocols for cardiac resuscitation

(*Continued*)

Table 2. Continued

Limited resources
Rural geography
Receiving center
Lack of comprehensive postarrest care
Lack of active engagement from multidisciplinary team
Lack of multiprofessional engagement
Lack of organization of in-hospital resources to care for survivors
Lack of established treatment protocols for postarrest survivors
Effect of increases in postarrest survivors requiring PCI on nationally reported hospital data and outcomes
Lack of resources
Data measurement
Staffed infrastructure
System level
Lack of system-wide implementation
Need for qualified medical leadership
Conflicting interests
Lack of reporting system
Reporting bias

AED indicates automatic external defibrillator; CPR, cardiopulmonary bypass; and PCI, percutaneous coronary intervention.

Adapted from Mission: Lifeline Program.[15] Copyright © 2017, American Heart Association, Inc.

resources, particularly those with a limited number of response units, may find it difficult to bypass a closer hospital in favor of a designated receiving center if this bypass removes a unit from service for a longer period of time. This difficulty compounds as transportation distances increase. EMS systems may find transporting to a referring resuscitation center followed later by transferring to a receiving center to be a more practical/realistic option.

Regional systems of care may require equipment and devices when supported by appropriate evidence. Many EMS systems have implemented relatively simple therapies involving equipment or devices such as therapeutic hypothermia and compression/ventilation rate control. Metronomes and other devices have been used to improve compression and ventilation rates during manual CPR.[140] Multiple randomized trials have shown that mechanical chest compression devices are not demonstrably better than optimized manual CPR.[141] However, these devices may have a role in reducing risks to EMS providers associated with performing manual compressions in a moving vehicle[142] or in facilitating emergent coronary angiography in a patient with ongoing cardiac arrest and a high likelihood of acute coronary occlusion.[143]

Although the acceptance of regionalized approaches to systems of care and designated centers has increased, some EMS systems remain challenged by local concerns related to bypassing closer hospitals and the resultant loss in patient volume and case-mix index. Concerns about loss of complex patients and subsequent revenue remain an important challenge in many competitive marketplaces. EMS systems and resuscitation centers should work together to inform the lay community and medical community of the benefits of resuscitation centers and the evidence supporting EMS transport to such centers.

The increased use of electronic patient records within EMS systems has created remarkable improvement opportunities for systems of care. EMS systems may have difficulty obtaining useful results from an analysis of these data without simple, effective data analysis and reporting tools. Data solutions used by EMS systems should incorporate analytical and reporting methods that allow the EMS systems and the systems of care to use the data to improve performance and outcomes. Essential to this approach is the need for effective data sharing processes between EMS and resuscitation centers. These processes may include processes that provide bidirectional data exchange or data sharing within a single data repository.

Hospitals seeking to be a level I resuscitation center for patients with OHCA require significant infrastructure investment and bear the incremental cost of supporting interventional cardiology, critical care, and the myriad other providers and equipment required for the comprehensive care of the postarrest patient. Smaller-volume facilities or those in financially disadvantaged areas face challenges in establishing or maintaining these comprehensive services.

Reportable Hospital Mortality

There are some challenges to operationalizing the creation of resuscitation centers. One potential barrier is in the public reporting of disease-specific hospital mortality. If a hospital chooses to become a resuscitation center, the number of cardiac arrest victims who are transported to the hospital will increase. The mortality rate of the hospital across time is likely to increase because ≈11% of patients who sustain an OHCA survive to hospital discharge.[2] A potential way to mitigate this increase in hospital mortality is either to exclude all patients with OHCA from the calculation of hospital mortality rates or to report mortality for patients with cardiac arrest separately, as is currently being done for other conditions (myocardial infarction, pneumonia, heart failure, etc).[144] It is also possible that cardiac arrest–specific rates could be calculated for each of the participating resuscitation centers and systems of care, which would allow both local and national benchmarking for similar types of hospitals.

CONCLUSIONS

OHCA remains a major public health challenge in the United States. Over the past decade, significant scientific advancements in 9-1-1 telephone CPR instructions, by-

stander CPR, optimal CPR technique, public AED availability, and postresuscitation care have been shown to improve outcome in the patient with OHCA. Despite these advancements, widespread implementation lags reveal large regional variation in outcome with opportunities for improvement.

Lessons from the implementation of local, regional, and statewide systems center and the maturation of STEMI, stroke, and trauma systems of care provide important road maps for developing OHCA systems of care. Many of these lessons have been distilled and disseminated by the AHA Mission: Lifeline program. Early examples of cardiac arrest centers and regionalization have revealed promising results, but much work remains to be done to further understand regional differences and to optimize care for the patient with OHCA.

ARTICLE INFORMATION

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on October 13, 2017, and the American Heart Association Executive Committee on December 11, 2017. A copy of the document is available at http://professional.heart.org/statements by using either "Search for Guidelines & Statements" or the "Browse by Topic" area. To purchase additional reprints, call 843-216-2533 or e-mail kelle.ramsay@wolterskluwer.com.

The American Heart Association requests that this document be cited as follows: McCarthy JJ, Carr B, Sasson C, Bobrow BJ, Callaway CW, Neumar RW, Ferrer JME, Garvey JL, Ornato JP, Gonzales L, Granger CB, Kleinman ME, Bjerke C, Nichol G; on behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; and the Mission: Lifeline Resuscitation Subcommittee. Out-of-hospital cardiac arrest resuscitation systems of care: a scientific statement from the American Heart Association. *Circulation*. 2018;137:e645–e660. doi: 10.1161/CIR.0000000000000557.

Expert peer review of AHA Scientific Statements is conducted by the AHA Office of Science Operations. For more on AHA statements and guidelines development, visit http://professional.heart.org/statements. Select the "Guidelines & Statements" drop-down menu, then click "Publication Development."

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
James J. McCarthy	University of Texas Medical School, Houston Emergency Medicine	None	None	None	None	None	None	None
Graham Nichol	University of Washington–Harborview Center for Prehospital Emergency Care	US Food and Drug Administration, Silver Spring, MD/ ZOLL Medical Inc, Chelmsford, MA*; NHLBI (U01HL077863-07†; 1UH2HL125163-03*; UH2HL129722-01*, Bethesda, MD; Agency for Health Care Research Quality, Rockville, MD*	None	None	None	None	ZOLL Circulation, San Jose, CA†	University of Washington (Leonard A. Cobb Medic One Foundation Endowed Chair in Prehospital Emergency Care)*
Chris Bjerke	Self-employed	None	None	None	None	None	None	None
Bentley J. Bobrow	Arizona Department of Health Services	None	None	None	None	None	None	None
Clifton W. Callaway	University of Pittsburgh	NHLBI†	None	None	None	None	None	None
Brendan Carr	Thomas Jefferson University Department of Emergency Medicine	AHRQ†; NIH†; Department of Health and Human Services†	None	None	None	None	None	Thomas Jefferson University†
Jose Maria E. Ferrer	American Heart Association	None	None	None	None	None	None	None
J. Lee Garvey	Carolinas Medical Center	Philips Healthcare*	None	None	None	None	Philips Healthcare*	None
Louis Gonzales	City of Austin, Office of the Medical Director	None	None	None	None	None	None	None

(*Continued*)

Writing Group Disclosures Continued

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Christopher B. Granger	Duke University Medicine-Cardiology	None	None	None	None	None	None	None
Monica E. Kleinman	Children's Hospital Boston Anesthesia/ Critical Care Medicine	None	None	Westchester Medical Center*	Hall, Booth, Smith PC*	None	American Heart Association*	Children's Hospital Anesthesia Foundation†
Robert W. Neumar	University of Michigan Emergency Medicine	NIH/NHLBI†; American Heart Association†; PhysioControl*	None	None	None	None	None	None
Joseph P. Ornato	Virginia Commonwealth University Health System	Non	None	None	None	None	None	Virginia Commonwealth University Health System†; Richmond Ambulance Authority†
Comilla Sasson	American Heart Association	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Riyaz Bashir	Temple University	None	None	None	None	None	None	None
Sheilah A. Bernard	Boston Medical Center	None	None	None	None	None	None	None
Robert T. Brennan	Harvard School of Public Health	None	None	None	None	None	None	None
Raúl J. Gazmuri	Rosalind Franklin University of Medicine and Science	None	None	None	None	None	None	None
Thomas W. Lindner	Stavanger University Hospital (Norway)	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

REFERENCES

1. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, Cassan P, Coovadia A, D'Este K, Finn J, Halperin H, Handley A, Herlitz J, Hickey R, Idris A, Kloeck W, Larkin GL, Mancini ME, Mason P, Mears G, Monsieurs K, Montgomery W, Morley P, Nichol G, Nolan J, Okada K, Perlman J, Shuster M, Steen PA, Sterz F, Tibballs J, Timerman S, Truitt T, Zideman D; ILCOR Task Force on Cardiac Arrest and Cardiopulmonary Resuscitation Outcomes. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation*. 2004;110:3385–3397. doi: 10.1161/01.CIR.0000147236.85306.15.
2. Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, de Ferranti SD, Floyd J, Fornage M, Gillespie C, Isasi CR, Jimenez MC, Jordan LC, Judd SE, Lackland D, Lichtman JH, Lisabeth L, Liu S, Longenecker CT, Mackey RH, Matsushita K, Mozaffarian D, Mussolino ME, Nasir K, Neumar RW, Palaniappan L, Pandey DK, Thiagarajan RR, Reeves MJ, Ritchey M, Rodriguez CJ, Roth GA, Rosamond WD, Sasson C, Towfighi A, Tsao CW, Turner MB, Virani SS, Voeks JH, Willey JZ, Wilkins JT, Wu JHY, Alger HM, Wong SS, Muntner P; on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2017 update: a report from the American Heart Association [published corrections appear in *Circulation*. 2017;135:e646 and *Circulation*. 2017;136:e196]. *Circulation*. 2017;135:e146-e603. doi: 10.1161/CIR.0000000000000485.
3. Müller D, Agrawal R, Arntz HR. How sudden is sudden cardiac death? *Circulation*. 2006;114:1146–1150. doi: 10.1161/CIRCULATIONAHA.106.616318.

4. Zive D, Koprowicz K, Schmidt T, Stiell I, Sears G, Van Ottingham L, Idris A, Stephens S, Daya M; Resuscitation Outcomes Consortium Investigators. Variation in out-of-hospital cardiac arrest resuscitation and transport practices in the Resuscitation Outcomes Consortium: ROC Epistry-Cardiac Arrest. *Resuscitation*. 2011;82:277–284. doi: 10.1016/j.resuscitation.2010.10.022.
5. Glover BM, Brown SP, Morrison L, Davis D, Kudenchuk PJ, Van Ottingham L, Vaillancourt C, Cheskes S, Atkins DL, Dorian P; Resuscitation Outcomes Consortium Investigators. Wide variability in drug use in out-of-hospital cardiac arrest: a report from the Resuscitation Outcomes Consortium. *Resuscitation*. 2012;83:1324–1330. doi: 10.1016/j.resuscitation.2012.07.008.
6. Wang HE, Szydlo D, Stouffer JA, Lin S, Carlson JN, Vaillancourt C, Sears G, Verbeek RP, Fowler R, Idris AH, Koenig K, Christenson J, Minokadeh A, Brandt J, Rea T; ROC Investigators. Endotracheal intubation versus supraglottic airway insertion in out-of-hospital cardiac arrest. *Resuscitation*. 2012;83:1061–1066. doi: 10.1016/j.resuscitation.2012.05.018.
7. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, Rea T, Lowe R, Brown T, Dreyer J, Davis D, Idris A, Stiell I; Resuscitation Outcomes Consortium Investigators. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA*. 2008;300:1423–1431. doi: 10.1001/jama.300.12.1423.
8. Chan PS, McNally B, Tang F, Kellermann A; for the CARES Surveillance Group. Recent trends in survival from out-of-hospital cardiac arrest in the United States. *Circulation*. 2014;130:1876–1882. doi: 10.1161/CIRCULATIONAHA.114.009711.
9. Abrams HC, McNally B, Ong M, Moyer PH, Dyer KS. A composite model of survival from out-of-hospital cardiac arrest using the Cardiac Arrest Registry to Enhance Survival (CARES). *Resuscitation*. 2013;84:1093–1098. doi: 10.1016/j.resuscitation.2013.03.030.
10. Nichol G, Aufderheide TP, Eigel B, Neumar RW, Lurie KG, Bufalino VJ, Callaway CW, Menon V, Bass RR, Abella BS, Sayre M, Dougherty CM, Racht EM, Kleinman ME, O'Connor RE, Reilly JP, Ossmann EW, Peterson E; on behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Arteriosclerosis, Thrombosis, and Vascular Biology; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; Council on Cardiovascular Nursing; Council on Clinical Cardiology; Advocacy Committee; Council on Quality of Care and Outcomes Research. Regional systems of care for out-of-hospital cardiac arrest: a policy statement from the American Heart Association [published correction appears in *Circulation*. 2010;122:e439]. *Circulation*. 2010;121:709–729. doi: 10.1161/CIR.0b013e3181cdb7db.
11. Kronick SL, Kurz MC, Lin S, Edelson DP, Berg RA, Billi JE, Cabanas JG, Cone DC, Diercks DB, Foster JJ, Meeks RA, Travers AH, Welsford M. Part 4: systems of care and continuous quality improvement: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2015;132(suppl 2):S397–S413. doi: 10.1161/CIR.0000000000000258.
12. Kim MJ, Ro YS, Shin SD, Song KJ, Ahn KO, Hong SO, Kim YT. Association of emergent and elective percutaneous coronary intervention with neurological outcome and survival after out-of-hospital cardiac arrest in patients with and without a history of heart disease. *Resuscitation*. 2015;97:115–121. doi: 10.1016/j.resuscitation.2015.08.019.
13. Zanuttini D, Armellini I, Nucifora G, Carchietti E, Trillò G, Spedicato L, Bernardi G, Proclemer A. Impact of emergency coronary angiography on in-hospital outcome of unconscious survivors after out-of-hospital cardiac arrest. *Am J Cardiol*. 2012;110:1723–1728. doi: 10.1016/j.amjcard.2012.08.006.
14. Cronier P, Vignon P, Bouferrache K, Aegerter P, Charron C, Templier F, Castro S, El Mahmoud R, Lory C, Pichon N, Dubourg O, Vieillard-Baron A. Impact of routine percutaneous coronary intervention after out-of-hospital cardiac arrest due to ventricular fibrillation. *Crit Care*. 2011;15:R122. doi: 10.1186/cc10227.
15. American Heart Association. Mission: Lifeline website. http://www.heart.org/HEARTORG/Professional/MissionLifelineHomePage/Mission-Lifeline-Home-Page_UCM_305495_SubHomePage.jsp. Accessed August 20, 2016.
16. Bjerke C, Wingrove G, Pratt F, Garvey JL, Ellrodt AG. Mission: Lifeline will incorporate EMS recognition in STEMI & cardiac resuscitation systems of care. *JEMS*. 2013;38:58.
17. van Diepen S, Abella BS, Bobrow BJ, Nichol G, Jollis JG, Mellor J, Racht EM, Yannopoulos D, Granger CB, Sayre MR. Multistate implementation of guideline-based cardiac resuscitation systems of care: description of the HeartRescue project. *Am Heart J*. 2013;166:647–653.e2. doi: 10.1016/j.ahj.2013.05.022.
18. Lick CJ, Aufderheide TP, Niskanen RA, Steinkamp JE, Davis SP, Nygaard SD, Bemenderfer KK, Gonzales L, Kalla JA, Wald SK, Gillquist DL, Sayre MR, Osaki Holm SY, Oski Holm SY, Oakes DA, Provo TA, Racht EM, Olsen JD, Yannopoulos D, Lurie KG. Take Heart America: a comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest. *Crit Care Med*. 2011;39:26–33. doi: 10.1097/CCM.0b013e3181fa7ce4.
19. HeartRescue project. http://www.heartrescueproject.com/. Accessed August 20, 2016.
20. Gaieski DF, Band RA, Abella BS, Neumar RW, Fuchs BD, Kolansky DM, Merchant RM, Carr BG, Becker LB, Maguire C, Klair A, Hylton J, Goyal M. Early goal-directed hemodynamic optimization combined with therapeutic hypothermia in comatose survivors of out-of-hospital cardiac arrest. *Resuscitation*. 2009;80:418–424. doi: 10.1016/j.resuscitation.2008.12.015.
21. Rittenberger JC, Guyette FX, Tisherman SA, DeVita MA, Alvarez RJ, Callaway CW. Outcomes of a hospital-wide plan to improve care of comatose survivors of cardiac arrest. *Resuscitation*. 2008;79:198–204. doi: 10.1016/j.resuscitation.2008.08.014.
22. Roberts BW, Kilgannon JH, Mitchell JA, Mittal N, Aji J, Kirchhoff ME, Zanotti S, Parrillo JE, Chansky ME, Trzeciak S. Emergency department inter-hospital transfer for post-cardiac arrest care: initial experience with implementation of a regional cardiac resuscitation center in the United States. *Resuscitation*. 2013;84:596–601. doi: 10.1016/j.resuscitation.2012.09.018.
23. Hartke A, Mumma BE, Rittenberger JC, Callaway CW, Guyette FX. Incidence of re-arrest and critical events during prolonged transport of post-cardiac arrest patients. *Resuscitation*. 2010;81:938–942. doi: 10.1016/j.resuscitation.2010.04.012.
24. Heffner AC, Pearson DA, Nussbaum ML, Jones AE. Regionalization of post-cardiac arrest care: implementation of a cardiac resuscitation center. *Am Heart J*. 2012;164:493–501.e2. doi: 10.1016/j.ahj.2012.06.014.
25. Mooney MR, Unger BT, Boland LL, Burke MN, Kebed KY, Graham KJ, Henry TD, Katsiyiannis WT, Satterlee PA, Sendelbach S, Hodges JS, Parham WM. Therapeutic hypothermia after out-of-hospital cardiac arrest: evaluation of a regional system to increase access to cooling. *Circulation*. 2011;124:206–214. doi: 10.1161/CIRCULATIONAHA.110.986257.
26. Malta Hansen C, Kragholm K, Pearson DA, Tyson C, Monk L, Myers B, Nelson D, Dupre ME, Fosbøl EL, Jollis JG, Strauss B, Anderson ML, McNally B, Granger CB. Association of bystander and first-responder intervention with survival after out-of-hospital cardiac arrest in North Carolina, 2010–2013. *JAMA*. 2015;314:255–264. doi: 10.1001/jama.2015.7938.
27. Bosson N, Kaji AH, Niemann JT, Eckstein M, Rashi P, Tadeo R, Gorospe D, Sung G, French WJ, Shavelle D, Thomas JL, Koenig W. Survival and neurologic outcome after out-of-hospital cardiac arrest: results one year after regionalization of post-cardiac arrest care in a large metropolitan area. *Prehosp Emerg Care*. 2014;18:217–223. doi: 10.3109/10903127.2013.856507.
28. Thomas JL, Bosson N, Kaji AH, Ji Y, Sung G, Shavelle DM, French WJ, Koenig W, Niemann JT. Treatment and outcomes of ST segment elevation myocardial infarction and out-of-hospital cardiac arrest in a regionalized system of care based on presence or absence of initial shockable cardiac arrest rhythm. *Am J Cardiol*. 2014;114:968–971. doi: 10.1016/j.amjcard.2014.07.006.
29. Fothergill RT, Watson LR, Virdi GK, Moore FP, Whitbread M. Survival of resuscitated cardiac arrest patients with ST-elevation myocardial infarction (STEMI) conveyed directly to a Heart Attack Centre by ambulance clinicians. *Resuscitation*. 2014;85:96–98. doi: 10.1016/j.resuscitation.2013.09.010.
30. Callaway CW, Schmicker RH, Brown SP, Albrich JM, Andrusiek DL, Aufderheide TP, Christenson J, Daya MR, Falconer D, Husa RD, Idris AH, Ornato JP, Rac VE, Rea TD, Rittenberger JC, Sears G, Stiell IG; ROC Investigators. Early coronary angiography and induced hypothermia are associated with survival and functional recovery after out-of-hospital cardiac arrest. *Resuscitation*. 2014;85:657–663. doi: 10.1016/j.resuscitation.2013.12.028.
31. Spaite DW, Bobrow BJ, Stolz U, Berg RA, Sanders AB, Kern KB, Chikani V, Humble W, Mullins T, Stapczynski JS, Ewy GA; Arizona Cardiac Receiving Center Consortium. Statewide regionalization of postarrest care for out-of-hospital cardiac arrest: association with survival and neurologic outcome. *Ann Emerg Med*. 2014;64:496–506.e1. doi: 10.1016/j.annemergmed.2014.05.028.
32. Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, Vadeboncoeur TF, Clark LL, Gallagher JV, Stapczynski JS, LoVecchio F, Mullins TJ, Humble WO, Ewy GA. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. *JAMA*. 2010;304:1447–1454. doi: 10.1001/jama.2010.1392.

33. Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, Jans H, Hansen PA, Lang-Jensen T, Olesen JB, Lindhardsen J, Fosbol EL, Nielsen SL, Gislason GH, Kober L, Torp-Pedersen C. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. *JAMA*. 2013;310:1377–1384. doi: 10.1001/jama.2013.278483.
34. Kitamura T, Iwami T, Kawamura T, Nitta M, Nagao K, Nonogi H, Yonemoto N, Kimura T; for the Japanese Circulation Society Resuscitation Science Study Group. Nationwide improvements in survival from out-of-hospital cardiac arrest in Japan. *Circulation*. 2012;126:2834–2843. doi: 10.1161/CIRCULATIONAHA.112.109496.
35. Wong MK, Morrison LJ, Qiu F, Austin PC, Cheskes S, Dorian P, Scales DC, Tu JV, Verbeek PR, Wijeysundera HC, Ko DT. Trends in short- and long-term survival among out-of-hospital cardiac arrest patients alive at hospital arrival. *Circulation*. 2014;130:1883–1890. doi: 10.1161/CIRCULATIONAHA.114.010633.
36. Sipsma K, Stubbs BA, Plorde M. Training rates and willingness to perform CPR in King County, Washington: a community survey. *Resuscitation*. 2011;82:564–567. doi: 10.1016/j.resuscitation.2010.12.007.
37. Anderson ML, Cox M, Al-Khatib SM, Nichol G, Thomas KL, Chan PS, Saha-Chaudhuri P, Fosbol EL, Eigel B, Clendenen B, Peterson ED. Rates of cardiopulmonary resuscitation training in the United States. *JAMA Intern Med*. 2014;174:194–201. doi: 10.1001/jamainternmed.2013.11320.
38. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes*. 2010;3:63–81. doi: 10.1161/CIRCOUTCOMES.109.889576.
39. Root ED, Gonzales L, Persse DE, Hinchey PR, McNally B, Sasson C. A tale of two cities: the role of neighborhood socioeconomic status in spatial clustering of bystander CPR in Austin and Houston. *Resuscitation*. 2013;84:752–759.
40. Fosbøl EL, Dupre ME, Strauss B, Swanson DR, Myers B, McNally BF, Anderson ML, Bagai A, Monk L, Garvey JL, Bitner M, Jollis JG, Granger CB. Association of neighborhood characteristics with incidence of out-of-hospital cardiac arrest and rates of bystander-initiated CPR: implications for community-based education intervention. *Resuscitation*. 2014;85:1512–1517. doi: 10.1016/j.resuscitation.2014.08.013.
41. Sasson C, Keirns CC, Smith DM, Sayre MR, Macy ML, Meurer WJ, McNally BF, Kellermann AL, Iwashyna TJ. Examining the contextual effects of neighborhood on out-of-hospital cardiac arrest and the provision of bystander cardiopulmonary resuscitation. *Resuscitation*. 2011;82:674–679. doi: 10.1016/j.resuscitation.2011.02.002.
42. American Heart Association. Hands-only CPR. http://www.handsonlycpr.org. Accessed September 19, 2016.
43. Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. *Circulation*. 2001;104:2513–2516.
44. Stipulante S, Tubes R, El Fassi M, Donneau AF, Van Troyen B, Hartstein G, D'Orio V, Ghuysen A. Implementation of the ALERT algorithm, a new dispatcher-assisted telephone cardiopulmonary resuscitation protocol, in non-Advanced Medical Priority Dispatch System (AMPDS) Emergency Medical Services centres. *Resuscitation*. 2014;85:177–181. doi: 10.1016/j.resuscitation.2013.10.005.
45. Painter I, Chavez DE, Ike BR, Yip MP, Tu SP, Bradley SM, Rea TD, Meischke H. Changes to DA-CPR instructions: can we reduce time to first compression and improve quality of bystander CPR? *Resuscitation*. 2014;85:1169–1173. doi: 10.1016/j.resuscitation.2014.05.015.
46. Lerner EB, Rea TD, Bobrow BJ, Acker JE 3rd, Berg RA, Brooks SC, Cone DC, Gay M, Gent LM, Mears G, Nadkarni VM, O'Connor RE, Potts J, Sayre MR, Swor RA, Travers AH; on behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Emergency medical service dispatch cardiopulmonary resuscitation prearrival instructions to improve survival from out-of-hospital cardiac arrest: a scientific statement from the American Heart Association. *Circulation*. 2012;125:648–655. doi: 10.1161/CIR.0b013e31823ee5fc.
47. Bobrow BJ, Eisenberg MS, Panczyk M. Telecommunicator CPR: pushing for performance standards. *Prehosp Emerg Care*. 2014;18:558–559. doi: 10.3109/10903127.2014.942483.
48. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA, Zalenski R, Becker LB, Schron EB, Proschan M; Public Access Defibrillation Trial Investigators. Public-access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med*. 2004;351:637–646. doi: 10.1056/NEJMoa040566.
49. Sladjana A, Gordana P, Ana S. Emergency response time after out-of-hospital cardiac arrest. *Eur J Intern Med*. 2011;22:386–393. doi: 10.1016/j.ejim.2011.04.003.
50. Do HQ, Nielsen SL, Rasmussen LS. Response interval is important for survival until admission after prehospital cardiac arrest. *Dan Med Bull*. 2010;57:A4203.
51. Agarwal DA, Hess EP, Atkinson EJ, White RD. Ventricular fibrillation in Rochester, Minnesota: experience over 18 years. *Resuscitation*. 2009;80:1253–1258. doi: 10.1016/j.resuscitation.2009.07.019.
52. Vukmir RB. Survival from prehospital cardiac arrest is critically dependent upon response time. *Resuscitation*. 2006;69:229–234. doi: 10.1016/j.resuscitation.2005.08.014.
53. Pons PT, Haukoos JS, Bludworth W, Cribley T, Pons KA, Markovchick VJ. Paramedic response time: does it affect patient survival? *Acad Emerg Med*. 2005;12:594–600. doi: 10.1197/j.aem.2005.02.013.
54. Shy BD, Rea TD, Becker LJ, Eisenberg MS. Time to intubation and survival in prehospital cardiac arrest. *Prehosp Emerg Care*. 2004;8:394–399.
55. Cheskes S, Schmicker RH, Verbeek PR, Salcido DD, Brown SP, Brooks S, Menegazzi JJ, Vaillancourt C, Powell J, May S, Berg RA, Sell R, Idris A, Kampp M, Schmidt T, Christenson J; Resuscitation Outcomes Consortium (ROC) Investigators. The impact of peri-shock pause on survival from out-of-hospital shockable cardiac arrest during the Resuscitation Outcomes Consortium PRIMED trial. *Resuscitation*. 2014;85:336–342. doi: 10.1016/j.resuscitation.2013.10.014.
56. Cheskes S, Schmicker RH, Christenson J, Salcido DD, Rea T, Powell J, Edelson DP, Sell R, May S, Menegazzi JJ, Van Ottingham L, Olsufka M, Pennington S, Simonini J, Berg RA, Stiell I, Idris A, Bigham B, Morrison L; on behalf of the Resuscitation Outcomes Consortium (ROC) Investigators. Perishock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest. *Circulation*. 2011;124:58–66. doi: 10.1161/CIRCULATIONAHA.110.010736.
57. Stiell IG, Brown SP, Nichol G, Cheskes S, Vaillancourt C, Callaway CW, Morrison LJ, Christenson J, Aufderheide TP, Davis DP, Free C, Hostler D, Stouffer JA, Idris AH; Resuscitation Outcomes Consortium Investigators. What is the optimal chest compression depth during out-of-hospital cardiac arrest resuscitation of adult patients? *Circulation*. 2014;130:1962–1970. doi: 10.1161/CIRCULATIONAHA.114.008671.
58. Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, Bigham B, Morrison LJ, Larsen J, Hess E, Vaillancourt C, Davis DP, Callaway CW; Resuscitation Outcomes Consortium (ROC) Investigators. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? *Crit Care Med*. 2012;40:1192–1198. doi: 10.1097/CCM.0b013e31823bc8bb.
59. Idris AH, Guffey D, Aufderheide TP, Brown S, Morrison LJ, Nichols P, Powell J, Daya M, Bigham BL, Atkins DL, Berg R, Davis D, Stiell I, Sopko G, Nichol G; Resuscitation Outcomes Consortium (ROC) Investigators. Relationship between chest compression rates and outcomes from cardiac arrest. *Circulation*. 2012;125:3004–3012. doi: 10.1161/CIRCULATIONAHA.111.059535.
60. Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, Callaway CW, Bishop D, Vaillancourt C, Davis D, Aufderheide TP, Idris A, Stouffer JA, Stiell I, Berg R; Resuscitation Outcomes Consortium Investigators. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. *Circulation*. 2009;120:1241–1247. doi: 10.1161/CIRCULATIONAHA.109.852202.
61. Vaillancourt C, Everson-Stewart S, Christenson J, Andrusiek D, Powell J, Nichol G, Cheskes S, Aufderheide TP, Berg R, Stiell IG; Resuscitation Outcomes Consortium Investigators. The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. *Resuscitation*. 2011;82:1501–1507. doi: 10.1016/j.resuscitation.2011.07.011.
62. Saner H, Morger C, Eser P, von Planta M. Dual dispatch early defibrillation in out-of-hospital cardiac arrest in a mixed urban-rural population. *Resuscitation*. 2013;84:1197–1202. doi: 10.1016/j.resuscitation.2013.02.023.
63. Wampler DA, Collett L, Manifold CA, Velasquez C, McMullan JT. Cardiac arrest survival is rare without prehospital return of spontaneous circulation. *Prehosp Emerg Care*. 2012;16:451–455. doi: 10.3109/10903127.2012.695435.
64. Sunde GA, Heltne JK, Lockey D, Burns B, Sandberg M, Fredriksen K, Hufthammer KO, Soti A, Lyon R, Jäntti H, Kämäräinen A, Reid BO, Silfvast T, Harm F, Sollid SJ; Airport Study Group. Airway management by physician-staffed helicopter emergency medical services: a prospective, multicentre, observational study of 2,327 patients. *Scand J Trauma Resusc Emerg Med*. 2015;23:57. doi: 10.1186/s13049-015-0136-9.
65. Castrén M, Nordberg P, Svensson L, Taccone F, Vincent JL, Desruelles D, Eichwede F, Mols P, Schwab T, Vergnion M, Storm C, Pesenti A, Pachl J, Guérisse

F, Elste T, Roessler M, Fritz H, Durnez P, Busch HJ, Inderbitzen B, Barbut D. Intra-arrest transnasal evaporative cooling: a randomized, prehospital, multicenter study (PRINCE: Pre-ROSC IntraNasal Cooling Effectiveness). *Circulation*. 2010;122:729–736. doi: 10.1161/CIRCULATIONAHA.109.931691.

66. Bernard SA, Smith K, Cameron P, Masci K, Taylor DM, Cooper DJ, Kelly AM, Silvester W; for the Rapid Infusion of Cold Hartmanns (RICH) Investigators. Induction of therapeutic hypothermia by paramedics after resuscitation from out-of-hospital ventricular fibrillation cardiac arrest: a randomized controlled trial. *Circulation*. 2010;122:737–742. doi: 10.1161/CIRCULATIONAHA.109.906859.
67. Kim F, Maynard C, Nichol G. Prehospital therapeutic hypothermia in patients with out-of-hospital cardiac arrest–reply. *JAMA*. 2014;311:2233–2234. doi: 10.1001/jama.2014.2679.
68. Bernard SA, Smith K, Finn J, Hein C, Grantham H, Bray JE, Deasy C, Stephenson M, Williams TA, Straney LD, Brink D, Larsen R, Cotton C, Cameron P. Induction of therapeutic hypothermia during out-of-hospital cardiac arrest using a rapid infusion of cold saline: the RINSE trial (Rapid Infusion of Cold Normal Saline). *Circulation*. 2016;134:797–805. doi: 10.1161/CIRCULATIONAHA.116.021989.
69. Donnino MW, Rittenberger JC, Gaieski D, Cocchi MN, Giberson B, Peberdy MA, Abella BS, Bobrow BJ, Callaway C. The development and implementation of cardiac arrest centers. *Resuscitation*. 2011;82:974–978. doi: 10.1016/j.resuscitation.2011.03.021.
70. Carr BG, Goyal M, Band RA, Gaieski DF, Abella BS, Merchant RM, Branas CC, Becker LB, Neumar RW. A national analysis of the relationship between hospital factors and post-cardiac arrest mortality. *Intensive Care Med*. 2009;35:505–511. doi: 10.1007/s00134-008-1335-x.
71. Bobrow BJ, Kern KB. Regionalization of postcardiac arrest care. *Curr Opin Crit Care*. 2009;15:221–227.
72. Kajino K, Iwami T, Daya M, Nishiuchi T, Hayashi Y, Kitamura T, Irisawa T, Sakai T, Kuwagata Y, Hiraide A, Kishi M, Yamayoshi S. Impact of transport to critical care medical centers on outcomes after out-of-hospital cardiac arrest. *Resuscitation*. 2010;81:549–554. doi: 10.1016/j.resuscitation.2010.02.008.
73. Cudnik MT, Schmicker RH, Vaillancourt C, Newgard CD, Christenson JM, Davis DP, Lowe RA; ROC Investigators. A geospatial assessment of transport distance and survival to discharge in out of hospital cardiac arrest patients: implications for resuscitation centers. *Resuscitation*. 2010;81:518–523. doi: 10.1016/j.resuscitation.2009.12.030.
74. Bernard SA, Gray TW, Buist MD, Jones BM, Silvester W, Gutteridge G, Smith K. Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. *N Engl J Med*. 2002;346:557–563. doi: 10.1056/NEJMoa003289.
75. Hypothermia After Cardiac Arrest Study Group. Mild therapeutic hypothermia to improve the neurologic outcome after cardiac arrest. *N Engl J Med*. 2002;346:549–556.
76. Peberdy MA, Callaway CW, Neumar RW, Geocadin RG, Zimmerman JL, Donnino M, Gabrielli A, Silvers SM, Zaritsky AL, Merchant R, Vanden Hoek TL, Kronick SL. Part 9: post-cardiac arrest care: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care [published corrections appear in *Circulation*. 2011;123:e237 and *Circulation*. 2011;124:e403]. *Circulation*. 2010;122(suppl 3):S768–S786. doi: 10.1161/CIRCULATIONAHA.110.971002.
77. Nielsen N, Wetterslev J, Cronberg T, Erlinge D, Gasche Y, Hassager C, Horn J, Hovdenes J, Kjaergaard J, Kuiper M, Pellis T, Stammet P, Wanscher M, Wise MP, Åneman A, Al-Subaie N, Boesgaard S, Bro-Jeppesen J, Brunetti I, Bugge JF, Hingston CD, Juffermans NP, Koopmans M, Køber L, Langørgen J, Lilja G, Møller JE, Rundgren M, Rylander C, Smid O, Werer C, Winkel P, Friberg H; TTM Trial Investigators. Targeted temperature management at 33°C versus 36°C after cardiac arrest. *N Engl J Med*. 2013;369:2197–2206. doi: 10.1056/NEJMoa1310519.
78. Moler FW, Silverstein FS, Holubkov R, Slomine BS, Christensen JR, Nadkarni VM, Meert KL, Clark AE, Browning B, Pemberton VL, Page K, Shankaran S, Hutchison JS, Newth CJ, Bennett KS, Berger JT, Topjian A, Pineda JA, Koch JD, Schleien CL, Dalton HJ, Ofori-Amanfo G, Goodman DM, Fink EL, McQuillen P, Zimmerman JJ, Thomas NJ, van der Jagt EW, Porter MB, Meyer MT, Harrison R, Pham N, Schwarz AJ, Nowak JE, Alten J, Wheeler DS, Bhalala US, Lidsky K, Lloyd E, Mathur M, Shah S, Wu T, Theodorou AA, Sanders RC Jr, Dean JM; THAPCA Trial Investigators. Therapeutic hypothermia after out-of-hospital cardiac arrest in children. *N Engl J Med*. 2015;372:1898–1908. doi: 10.1056/NEJMoa1411480.
79. Callaway CW, Donnino MW, Fink EL, Geocadin RG, Golan E, Kern KB, Leary M, Meurer WJ, Peberdy MA, Thompson TM, Zimmerman JL. Part 8: post-cardiac arrest care: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care [published correction appears in *Circulation*. 2017;136:e197]. *Circulation*. 2015;132(suppl 2):S465–S482. doi: 10.1161/CIR.0000000000000262.
80. Donnino MW, Andersen LW, Berg KM, Reynolds JC, Nolan JP, Morley PT, Lang E, Cocchi MN, Xanthos T, Callaway CW, Soar J; ILCOR ALS Task Force. Temperature management after cardiac arrest: an advisory statement by the Advanced Life Support Task Force of the International Liaison Committee on Resuscitation and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation [published correction appears in *Circulation*. 2016;133:e13]. *Circulation*. 2015;132:2448–2456. doi: 10.1161/CIR.0000000000000313.
81. Lo YS, Cutler JE, Blake K, Wright AM, Kron J, Swerdlow CD. Angiographic coronary morphology in survivors of cardiac arrest. *Am Heart J*. 1988;115:781–785.
82. Kern KB, Rahman O. Emergent percutaneous coronary intervention for resuscitated victims of out-of-hospital cardiac arrest. *Catheter Cardiovasc Interv*. 2010;75:616–624. doi: 10.1002/ccd.22192.
83. Reynolds JC, Callaway CW, El Khoudary SR, Moore CG, Alvarez RJ, Rittenberger JC. Coronary angiography predicts improved outcome following cardiac arrest: propensity-adjusted analysis. *J Intensive Care Med*. 2009;24:179–186. doi: 10.1177/0885066609332725.
84. Hosmane VR, Mustafa NG, Reddy VK, Reese CL 4th, DiSabatino A, Kolm P, Hopkins JT, Weintraub WS, Rahman E. Survival and neurologic recovery in patients with ST-segment elevation myocardial infarction resuscitated from cardiac arrest. *J Am Coll Cardiol*. 2009;53:409–415. doi: 10.1016/j.jacc.2008.08.076.
85. Anyfantakis ZA, Baron G, Aubry P, Himbert D, Feldman LJ, Juliard JM, Ricard-Hibon A, Burnod A, Cokkinos DV, Steg PG. Acute coronary angiographic findings in survivors of out-of-hospital cardiac arrest. *Am Heart J*. 2009;157:312–318. doi: 10.1016/j.ahj.2008.09.016.
86. Tadel-Kocjancic S, Zorman S, Jazbec A, Gorjup V, Zorman D, Noc M. Effectiveness of primary percutaneous coronary intervention for acute ST-elevation myocardial infarction from a 5-year single-center experience. *Am J Cardiol*. 2008;101:162–168. doi: 10.1016/j.amjcard.2007.07.083.
87. Pleskot M, Babu A, Hazukova R, Stritecky J, Bis J, Matejka J, Cermakova E. Out-of-hospital cardiac arrests in patients with acute ST elevation myocardial infarctions in the East Bohemian region over the period 2002-2004. *Cardiology*. 2008;109:41–51. doi: 10.1159/000105325.
88. Merchant RM, Abella BS, Khan M, Huang KN, Beiser DG, Neumar RW, Carr BG, Becker LB, Vanden Hoek TL. Cardiac catheterization is underutilized after in-hospital cardiac arrest. *Resuscitation*. 2008;79:398–403. doi: 10.1016/j.resuscitation.2008.07.015.
89. Werling M, Thorén AB, Axelsson C, Herlitz J. Treatment and outcome in post-resuscitation care after out-of-hospital cardiac arrest when a modern therapeutic approach was introduced. *Resuscitation*. 2007;73:40–45. doi: 10.1016/j.resuscitation.2006.08.018.
90. Sunde K, Pytte M, Jacobsen D, Mangschau A, Jensen LP, Smedsrud C, Draegni T, Steen PA. Implementation of a standardised treatment protocol for post resuscitation care after out-of-hospital cardiac arrest. *Resuscitation*. 2007;73:29–39. doi: 10.1016/j.resuscitation.2006.08.016.
91. Marcusohn E, Roguin A, Sebbag A, Aronson D, Dragu R, Amikam S, Boulus M, Grenadier E, Kerner A, Nikolsky E, Markiewicz W, Hammerman H, Kapeliovich M. Primary percutaneous coronary intervention after out-of-hospital cardiac arrest: patients and outcomes. *Isr Med Assoc J*. 2007;9:257–259.
92. Spaulding CM, Joly LM, Rosenberg A, Monchi M, Weber SN, Dhainaut JF, Carli P. Immediate coronary angiography in survivors of out-of-hospital cardiac arrest. *N Engl J Med*. 1997;336:1629–1633. doi: 10.1056/NEJM199706053362302.
93. Dumas F, Cariou A, Manzo-Silberman S, Grimaldi D, Vivien B, Rosencher J, Empana JP, Carli P, Mira JP, Jouven X, Spaulding C. Immediate percutaneous coronary intervention is associated with better survival after out-of-hospital cardiac arrest: insights from the PROCAT (Parisian Region Out of hospital Cardiac ArresT) registry. *Circ Cardiovasc Interv*. 2010;3:200–207. doi: 10.1161/CIRCINTERVENTIONS.109.913665.
94. Gorjup V, Radsel P, Kocjancic ST, Erzen D, Noc M. Acute ST-elevation myocardial infarction after successful cardiopulmonary resuscitation. *Resuscitation*. 2007;72:379–385. doi: 10.1016/j.resuscitation.2006.07.013.
95. Bendz B, Eritsland J, Nakstad AR, Brekke M, Kløw NE, Steen PA, Mangschau A. Long-term prognosis after out-of-hospital cardiac arrest and primary percutaneous coronary intervention. *Resuscitation*. 2004;63:49–53. doi: 10.1016/j.resuscitation.2004.04.006.

96. Peberdy MA, Donnino MW, Callaway CW, Dimaio JM, Geocadin RG, Ghaemmaghami CA, Jacobs AK, Kern KB, Levy JH, Link MS, Menon V, Ornato JP, Pinto DS, Sugarman J, Yannopoulos D, Ferguson TB Jr; on behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Impact of percutaneous coronary intervention performance reporting on cardiac resuscitation centers: a scientific statement from the American Heart Association. *Circulation*. 2013;128:762–773. doi: 10.1161/CIR.0b013e3182a15cd2.
97. Booth CM, Boone RH, Tomlinson G, Detsky AS. Is this patient dead, vegetative, or severely neurologically impaired? Assessing outcome for comatose survivors of cardiac arrest. *JAMA*. 2004;291:870–879. doi: 10.1001/jama.291.7.870.
98. Aufderheide TP, Nichol G, Rea TD, Brown SP, Leroux BG, Pepe PE, Kudenchuk PJ, Christenson J, Daya MR, Dorian P, Callaway CW, Idris AH, Andrusiek D, Stephens SW, Hostler D, Davis DP, Dunford JV, Pirrallo RG, Stiell IG, Clement CM, Craig A, Van Ottingham L, Schmidt TA, Wang HE, Weisfeldt ML, Ornato JP, Sopko G; Resuscitation Outcomes Consortium (ROC) Investigators. A trial of an impedance threshold device in out-of-hospital cardiac arrest. *N Engl J Med*. 2011;365:798–806. doi: 10.1056/NEJMoa1010821.
99. Nielsen N, Wetterslev J, al-Subaie N, Andersson B, Bro-Jeppesen J, Bishop G, Brunetti I, Cranshaw J, Cronberg T, Edqvist K, Erlinge D, Gasche Y, Glover G, Hassager C, Horn J, Hovdenes J, Johnsson J, Kjaergaard J, Kuiper M, Langørgen J, Macken L, Martinell L, Martner P, Pellis T, Pelosi P, Petersen P, Persson S, Rundgren M, Saxena M, Svensson R, Stammet P, Thorén A, Undén J, Walden A, Wallskog J, Wanscher M, Wise MP, Wyon N, Aneman A, Friberg H. Target temperature management after out-of-hospital cardiac arrest: a randomized, parallel-group, assessor-blinded clinical trial: rationale and design. *Am Heart J*. 2012;163:541–548. doi: 10.1016/j.ahj.2012.01.013.
100. Friberg H, Cronberg T. Prognostication after cardiac arrest. *Best Pract Res Clin Anaesthesiol*. 2013;27:359–372. doi: 10.1016/j.bpa.2013.06.011.
101. Cronberg T, Brizzi M, Liedholm LJ, Rosén I, Rubertsson S, Rylander C, Friberg H. Neurological prognostication after cardiac arrest: recommendations from the Swedish Resuscitation Council. *Resuscitation*. 2013;84:867–872. doi: 10.1016/j.resuscitation.2013.01.019.
102. Sreedharan J, Gourlay E, Evans MR, Koutroumanidis M. Falsely pessimistic prognosis by EEG in post-anoxic coma after cardiac arrest: the borderland of nonconvulsive status epilepticus. *Epileptic Disord*. 2012;14:340–344. doi: 10.1684/epd.2012.0519.
103. Rothstein TL. Therapeutic hypothermia and reliability of somatosensory evoked potentials in predicting outcome after cardiopulmonary arrest. *Neurocrit Care*. 2012;17:146–149. doi: 10.1007/s12028-012-9696-y.
104. Perman SM, Kirkpatrick JN, Reitsma AM, Gaieski DF, Lau B, Smith TM, Leary M, Fuchs BD, Levine JM, Abella BS, Becker LB, Merchant RM. Timing of neuroprognostication in postcardiac arrest therapeutic hypothermia. *Crit Care Med*. 2012;40:719–724. doi: 10.1097/CCM.0b013e3182372f93.
105. Greer DM, Rosenthal ES, Wu O. Neuroprognostication of hypoxic-ischaemic coma in the therapeutic hypothermia era. *Nat Rev Neurol*. 2014;10:190–203. doi: 10.1038/nrneurol.2014.36.
106. Oddo M, Rossetti AO. Early multimodal outcome prediction after cardiac arrest in patients treated with hypothermia. *Crit Care Med*. 2014;42:1340–1347. doi: 10.1097/CCM.0000000000000211.
107. Crepeau AZ, Rabinstein AA, Fugate JE, Mandrekar J, Wijdicks EF, White RD, Britton JW. Continuous EEG in therapeutic hypothermia after cardiac arrest: prognostic and clinical value. *Neurology*. 2013;80:339–344. doi: 10.1212/WNL.0b013e31827f089d.
108. Benson C, Young GB. Comment: EEG monitoring after cardiac arrest: the cold facts. *Neurology*. 2013;80:343. doi: 10.1212/WNL.0b013e31827f0938.
109. Rossetti AO, Urbano LA, Delodder F, Kaplan PW, Oddo M. Prognostic value of continuous EEG monitoring during therapeutic hypothermia after cardiac arrest. *Crit Care*. 2010;14:R173. doi: 10.1186/cc9276.
110. Mani R, Schmitt SE, Mazer M, Putt ME, Gaieski DF. The frequency and timing of epileptiform activity on continuous electroencephalogram in comatose post-cardiac arrest syndrome patients treated with therapeutic hypothermia. *Resuscitation*. 2012;83:840–847. doi: 10.1016/j.resuscitation.2012.02.015.
111. Rittenberger JC, Popescu A, Brenner RP, Guyette FX, Callaway CW. Frequency and timing of nonconvulsive status epilepticus in comatose post-cardiac arrest subjects treated with hypothermia. *Neurocrit Care*. 2012;16:114–122. doi: 10.1007/s12028-011-9565-0.
112. Bennett KM, Vaslef S, Pappas TN, Scarborough JE. The volume-outcomes relationship for United States Level I trauma centers. *J Surg Res*. 2011;167:19–23. doi: 10.1016/j.jss.2010.05.020.
113. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Chan L. The effect of trauma center designation and trauma volume on outcome in specific severe injuries. *Ann Surg*. 2005;242:512–517.
114. Nathens AB, Jurkovich GJ, Maier RV, Grossman DC, MacKenzie EJ, Moore M, Rivara FP. Relationship between trauma center volume and outcomes. *JAMA*. 2001;285:1164–1171.
115. Cha WC, Lee SC, Shin SD, Song KJ, Sung AJ, Hwang SS. Regionalisation of out-of-hospital cardiac arrest care for patients without prehospital return of spontaneous circulation. *Resuscitation*. 2012;83:1338–1342. doi: 10.1016/j.resuscitation.2012.03.024.
116. Ro YS, Shin SD, Song KJ, Park CB, Lee EJ, Ahn KO, Cho SI. A comparison of outcomes of out-of-hospital cardiac arrest with non-cardiac etiology between emergency departments with low- and high-resuscitation case volume. *Resuscitation*. 2012;83:855–861. doi: 10.1016/j.resuscitation.2012.02.002.
117. Shin SD, Suh GJ, Ahn KO, Song KJ. Cardiopulmonary resuscitation outcome of out-of-hospital cardiac arrest in low-volume versus high-volume emergency departments: an observational study and propensity score matching analysis. *Resuscitation*. 2011;82:32–39. doi: 10.1016/j.resuscitation.2010.08.031.
118. Johnson NJ, Salhi RA, Abella BS, Neumar RW, Gaieski DF, Carr BG. Emergency department factors associated with survival after sudden cardiac arrest. *Resuscitation*. 2013;84:292–297. doi: 10.1016/j.resuscitation.2012.10.013.
119. Callaway CW, Schmicker R, Kampmeyer M, Powell J, Rea TD, Daya MR, Aufderheide TP, Davis DP, Rittenberger JC, Idris AH, Nichol G; Resuscitation Outcomes Consortium (ROC) Investigators. Receiving hospital characteristics associated with survival after out-of-hospital cardiac arrest. *Resuscitation*. 2010;81:524–529. doi: 10.1016/j.resuscitation.2009.12.006.
120. Cudnik MT, Sasson C, Rea TD, Sayre MR, Zhang J, Bobrow BJ, Spaite DW, McNally B, Denninghoff K, Stolz U. Increasing hospital volume is not associated with improved survival in out of hospital cardiac arrest of cardiac etiology. *Resuscitation*. 2012;83:862–868. doi: 10.1016/j.resuscitation.2012.02.006.
121. Carr BG, Kahn JM, Merchant RM, Kramer AA, Neumar RW. Inter-hospital variability in post-cardiac arrest mortality. *Resuscitation*. 2009;80:30–34. doi: 10.1016/j.resuscitation.2008.09.001.
122. Dembitsky WP, Moreno-Cabral RJ, Adamson RM, Daily PO. Emergency resuscitation using portable extracorporeal membrane oxygenation. *Ann Thorac Surg*. 1993;55:304–309.
123. Reichman RT, Joyo CI, Dembitsky WP, Griffith LD, Adamson RM, Daily PO, Overlie PA, Smith SC Jr, Jaski BE. Improved patient survival after cardiac arrest using a cardiopulmonary support system. *Ann Thorac Surg*. 1990;49:101–104.
124. Nagao K, Hayashi N, Kanmatsuse K, Arima K, Ohtsuki J, Kikushima K, Watanabe I. Cardiopulmonary cerebral resuscitation using emergency cardiopulmonary bypass, coronary reperfusion therapy and mild hypothermia in patients with cardiac arrest outside the hospital. *J Am Coll Cardiol*. 2000;36:776–783.
125. Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, Chen WJ, Huang SC, Chi NH, Wang CH, Chen LC, Tsai PR, Wang SS, Hwang JJ, Lin FY. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. *Lancet*. 2008;372:554–561. doi: 10.1016/S0140-6736(08)60958-7.
126. Brooks SC, Anderson ML, Bruder E, Daya MR, Gaffney A, Otto CW, Singer AJ, Thiagarajan RR, Travers AH. Part 6: alternative techniques and ancillary devices for cardiopulmonary resuscitation: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2015;132(suppl 2):S436–S443. doi: 10.1161/CIR.0000000000000260.
127. Rincon F, Mayer SA. Neurocritical care: a distinct discipline? *Curr Opin Crit Care*. 2007;13:115–121. doi: 10.1097/MCC.0b013e32808255c6.
128. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA*. 2002;288:2151–2162.
129. Levy MM, Rapoport J, Lemeshow S, Chalfin DB, Phillips G, Danis M. Association between critical care physician management and patient mortality in the intensive care unit. *Ann Intern Med*. 2008;148:801–809.

130. Garland A, Gershengorn HB. Staffing in ICUs: physicians and alternative staffing models. *Chest*. 2013;143:214–221. doi: 10.1378/chest.12-1531.
131. Varelas PN, Eastwood D, Yun HJ, Spanaki MV, Hacein Bey L, Kessaris C, Gennarelli TA. Impact of a neurointensivist on outcomes in patients with head trauma treated in a neurosciences intensive care unit. *J Neurosurg*. 2006;104:713–719. doi: 10.3171/jns.2006.104.5.713.
132. Elf K, Nilsson P, Enblad P. Outcome after traumatic brain injury improved by an organized secondary insult program and standardized neurointensive care. *Crit Care Med*. 2002;30:2129–2134. doi: 10.1097/01.CCM.0000025893.73582.52.
133. Mirski MA, Chang CW, Cowan R. Impact of a neuroscience intensive care unit on neurosurgical patient outcomes and cost of care: evidence-based support for an intensivist-directed specialty ICU model of care. *J Neurosurg Anesthesiol*. 2001;13:83–92.
134. Varelas PN, Schultz L, Conti M, Spanaki M, Genarrelli T, Hacein-Bey L. The impact of a neuro-intensivist on patients with stroke admitted to a neurosciences intensive care unit. *Neurocrit Care*. 2008;9:293–299. doi: 10.1007/s12028-008-9050-6.
135. Knopf L, Staff I, Gomes J, McCullough L. Impact of a neurointensivist on outcomes in critically ill stroke patients. *Neurocrit Care*. 2012;16:63–71. doi: 10.1007/s12028-011-9620-x.
136. American Heart Association. Mission: Lifeline: STEMI & Cardiac resuscitation ideal system. http://www.heart.org/idc/groups/heart-public/@wcm/@hcm/@ml/documents/downloadable/ucm_439341.pdf. Accessed April 21, 2016.
137. Neumar RW, Barnhart JM, Berg RA, Chan PS, Geocadin RG, Luepker RV, Newby LK, Sayre MR, Nichol G; on behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative, and Resuscitation; Council on Clinical Cardiology; Council on Epidemiology and Prevention; Council on Quality of Care and Outcomes Research; Advocacy Coordinating Committee. Implementation strategies for improving survival after out-of-hospital cardiac arrest in the United States: consensus recommendations from the 2009 American Heart Association Cardiac Arrest Survival Summit. *Circulation*. 2011;123:2898–2910. doi: 10.1161/CIR.0b013e31821d79f3.
138. Kim W, Mauborgne R. *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*. Boston, MA: Harvard Business School Press; 2005.
139. Jollis JG, Al-Khalidi HR, Roettig ML, Berger PB, Corbett CC, Dauerman HL, Fordyce CB, Fox K, Garvey JL, Gregory T, Henry TD, Rokos IC, Sherwood MW, Suter RE, Wilson BH, Granger CB; for the Mission: Lifeline STEMI Systems Accelerator Project. Regional systems of care demonstration project: American Heart Association Mission: Lifeline STEMI Systems Accelerator. *Circulation*. 2016;134:365–374. doi: 10.1161/CIRCULATIONAHA.115.019474.
140. Kern KB, Stickney RE, Gallison L, Smith RE. Metronome improves compression and ventilation rates during CPR on a manikin in a randomized trial. *Resuscitation*. 2010;81:206–210. doi: 10.1016/j.resuscitation.2009.10.015.
141. Hallstrom A, Rea TD, Sayre MR, Christenson J, Anton AR, Mosesso VN Jr, Van Ottingham L, Olsufka M, Pennington S, White LJ, Yahn S, Husar J, Morris MF, Cobb LA. Manual chest compression vs use of an automated chest compression device during resuscitation following out-of-hospital cardiac arrest: a randomized trial. *JAMA*. 2006;295:2620–2628. doi: 10.1001/jama.295.22.2620.
142. Slattery DE, Silver A. The hazards of providing care in emergency vehicles: an opportunity for reform. *Prehosp Emerg Care*. 2009;13:388–397. doi: 10.1080/10903120802706104.
143. Wagner H, Terkelsen CJ, Friberg H, Harnek J, Kern K, Lassen JF, Olivecrona GK. Cardiac arrest in the catheterisation laboratory: a 5-year experience of using mechanical chest compressions to facilitate PCI during prolonged resuscitation efforts. *Resuscitation*. 2010;81:383–387. doi: 10.1016/j.resuscitation.2009.11.006.
144. Werner RM, Bradlow ET. Relationship between Medicare's hospital compare performance measures and mortality rates. *JAMA*. 2006;296:2694–2702. doi: 10.1001/jama.296.22.2694.