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Part 4: CPR Overview

2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Andrew H. Travers, Co-Chair*; Thomas D. Rea, Co-Chair*; Bentley J. Bobrow; Dana P. Edelson; Robert A. Berg; Michael R. Sayre; Marc D. Berg; Leon Chameides; Robert E. O'Connor; Robert A. Swor

Cardiopulmonary resuscitation (CPR) is a series of life-saving actions that improve the chance of survival following cardiac arrest.[1] Although the optimal approach to CPR may vary, depending on the rescuer, the victim, and the available resources, the fundamental challenge remains: how to achieve early and effective CPR. Given this challenge, recognition of arrest and prompt action by the rescuer continue to be priorities for the *2010 AHA Guidelines for CPR and ECC*. This chapter provides an overview of cardiac arrest epidemiology, the principles behind each link in the Chain of Survival, an overview of the core components of CPR (see Table 1), and the approaches of the *2010 AHA Guidelines for CPR and ECC* to improving the quality of CPR. The goal of this chapter is to integrate resuscitation science with real-world practice in order to improve the outcomes of CPR.

Epidemiology

Despite important advances in prevention, cardiac arrest remains a substantial public health problem and a leading cause of death in many parts of the world.[2] Cardiac arrest occurs both in and out of the hospital. In the US and Canada, approximately 350 000 people/year (approximately half of them in-hospital) suffer a cardiac arrest and receive attempted resuscitation.[3–7] This estimate does not include the substantial number of victims who suffer an arrest without attempted resuscitation. While attempted resuscitation is not always appropriate, there are many lives and life-years lost because appropriate resuscitation is not attempted.

The estimated incidence of EMS-treated out-of-hospital cardiac arrest in the US and Canada is about 50 to 55/100 000 persons/year and approximately 25% of these present with pulseless ventricular arrhythmias.[3,8] The estimated incidence of in-hospital cardiac arrest is 3 to 6/1000 admissions[4–6] and similarly, approximately 25% of these present with pulseless ventricular arrhythmias.[7] Cardiac arrest victims who present with ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) have a substantially better outcome compared with those who present with asystole or pulseless electric activity.[1,7,9]

The vast majority of cardiac arrest victims are adults, but thousands of infants and children suffer either an in-hospital or out-of-hospital cardiac arrest each year in the US and Canada.[7,10]

Cardiac arrest continues to be an all-too-common cause of premature death, and small incremental improvements in survival can translate into thousands of lives saved every year.

Key Principles in Resuscitation: Strengthening the Links in the Chain of Survival

Successful resuscitation following cardiac arrest requires an integrated set of coordinated actions represented by the links in the Chain of Survival (see Figure 1).

The links include the following:

- Immediate **recognition** of cardiac arrest and **activation** of the emergency response system
- Early **CPR** with an emphasis on chest compressions
- Rapid **defibrillation**
- Effective **advanced life support**
- Integrated **post–cardiac arrest care**

Emergency systems that can effectively implement these links can achieve witnessed VF cardiac arrest survival of almost 50%.[11–14] In most emergency systems, however, survival is lower, indicating that there is an opportunity for improvement by carefully examining the links and strengthening those that are weak.[3] The individual links are interdependent, and the success of each link is dependent on the effectiveness of those that precede it.

Rescuers have a wide variety of training, experience, and skills. The cardiac arrest victim's status and response to CPR maneuvers, as well as the settings in which the arrests occur, can also be heterogeneous. The challenge is how to encourage early, effective CPR for as many victims as possible, taking

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Table 1. Summary of Key BLS Components for Adults, Children and Infants

	Recommendations		
Component	Adults	Children	Infants
Recognition	Unresponsive (for all ages)		
	No breathing, not breathing normally (eg, only gasping)	No breathing or only gasping	
	No pulse palpated within 10 seconds (HCP Only)		
CPR Sequence	CAB	CAB	CAB
Compression Rate	At least 100/min		
Compression Depth	At least 2 inches (5 cm)	At least 1/3 AP Depth About 2 inches (5 cm)	At least 1/3 AP Depth About 1 $\frac{1}{2}$ inches (4 cm)
Chest Wall Recoil	Allow Complete Recoil Between Compressions HCPs Rotate Compressors Every 2 minutes		
Compression Interruptions	Minimize Interruptions in Chest Compressions Attempt to limit interruptions to less than 10 seconds		
Airway	Head tilt-chin lift (HCP suspected trauma: jaw thrust)		
Compression to Ventilation Ratio (until advanced airway placed)	30:2 (1 or 2 rescuers)	30:2 Single Rescuer 15:2 2 HCP Rescuers	30:2 Single Rescuer 15:2 2 HCP Rescuers
Ventilations: When rescuer Untrained or Trained and Not Proficient	Compressions Only		
Ventilations with advanced airway (HCP)	1 breath every 6–8 seconds (8–10 breaths/min) Asynchronous with chest compressions About 1 second per breath Visible Chest Rise		
Defibrillation	Attach and use AED as soon as available. Minimize interruptions in chest compressions before and after shock, resume CPR beginning with compressions immediately after each shock		

into account the wide range of rescuers, victims, and available resources.

Solutions must be based on rigorous research and careful interpretation whenever possible. As with past guidelines,[15] the process of evidence evaluation for the *2010 AHA Guidelines for CPR and ECC* was comprehensive, systematic, and transparent. The *2010 AHA Guidelines for CPR and ECC* rest on a foundation of previous guidelines, but they are supported by new evidence whenever possible.

The following sections provide an overview of the first three links in the Chain of Survival: immediate recognition of an arrest and activation of the emergency response system, early CPR, and rapid defibrillation. The information is provided in a manner that recognizes the real-world heterogeneity of the rescuer, victim, and resources.

Conceptual Framework for CPR: Interaction of Rescuer(s) and Victim

CPR traditionally has integrated chest compressions and rescue breathing with the goal of optimizing circulation and oxygenation. Rescuer and victim characteristics may influence the optimal application of the components of CPR.

Rescuer

Everyone can be a lifesaving rescuer for a cardiac arrest victim. CPR skills and their application depend on the rescuer's training, experience, and confidence.

Chest compressions are the foundation of CPR (see Figure 2). ***All rescuers, regardless of training, should provide chest compressions to all cardiac arrest victims***. Because of their importance, chest compressions should be the initial CPR action for all victims regardless of age. Rescuers who are able should add ventilations to chest compressions. Highly trained rescuers working together should coordinate their care and perform chest compressions as well as ventilations in a team-based approach.

Victim

Most cardiac arrests in adults are sudden, resulting from a primary cardiac cause; circulation produced by chest compressions is therefore paramount.[16] In contrast, cardiac arrest in children is most often asphyxial, which requires both ventilations and chest compressions for optimal results.[17] Thus rescue breathing may be more important for children than for adults in cardiac arrest.[17]

Early Action: Integrating the Critical Components of CPR

The Universal Adult Basic Life Support (BLS) Algorithm is a conceptual framework for all levels of rescuers in all settings. It emphasizes the key components that any rescuer can and should perform (see Figure 3).

When encountering a victim of sudden adult cardiac arrest, the lone rescuer must first **recognize** that the victim has experienced a cardiac arrest, based on unresponsiveness and lack of normal breathing. After recognition, the rescuer should immediately **activate** the emergency response system, get an AED/defibrillator, if available, and start **CPR** with chest compressions. If an AED is not close by, the rescuer should proceed directly to CPR. If other rescuers are present, the first rescuer should direct them to activate the emergency response system and get

Figure 1. Chain of Survival. The links in this Chain are: Immediate recognition and activation, early CPR, rapid defibrillation, effective advanced life support and integrated post-cardiac arrest care.

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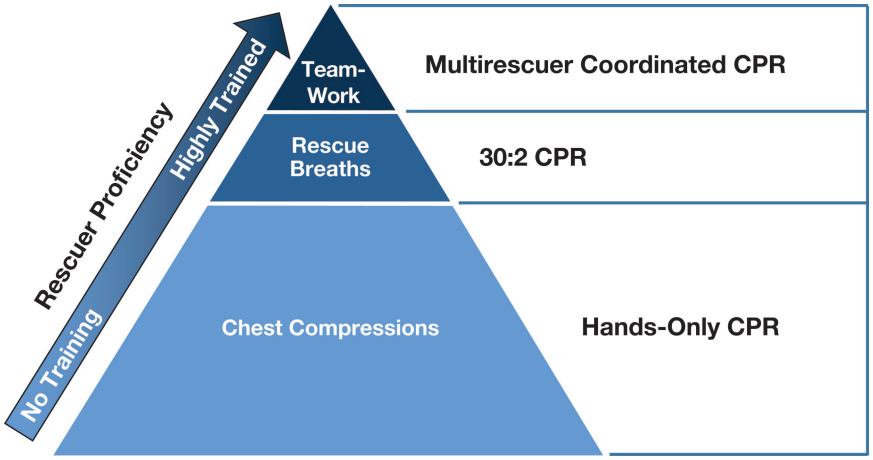

Figure 2. Building Blocks of CPR.

the AED/defibrillator; the first rescuer should start CPR immediately.

When the AED/defibrillator arrives, apply the pads, if possible, without interrupting chest compressions and turn the AED "on." The AED will analyze the rhythm and direct the rescuer either to provide a shock (ie, attempt **defibrillation**) or to continue CPR.

If an AED/defibrillator is not available, continue CPR without interruptions until more experienced rescuers assume care.

Recognition and Activation of Emergency Response

Prompt emergency activation and initiation of CPR requires rapid recognition of cardiac arrest. A cardiac arrest victim is not responsive. Breathing is absent or is not normal.[18,19] Agonal gasps are common early after sudden cardiac arrest and can be confused with normal breathing.[20–23] Pulse detection alone is often unreliable, even when performed by trained rescuers, and it may require additional time.[24–27] Consequently, rescuers should start CPR immediately if the adult victim is unresponsive and not breathing or not breathing normally (ie, only gasping). The directive to "look, listen, and feel for breathing" to aid recognition is no longer recommended.

Emergency dispatchers can and should assist in the assessment and direction to start CPR.[18,28,29] A healthcare professional may incorporate additional information to aid arrest recognition.

Chest Compressions

The prompt initiation of effective chest compressions is a fundamental aspect of cardiac arrest resuscitation. CPR improves the victim's chance of survival by providing heart and brain circulation. Rescuers should perform chest compressions for all victims in cardiac arrest, regardless of rescuer skill level, victim characteristics, or available resources.

Rescuers should focus on delivering high-quality CPR:

- providing chest compressions of adequate rate (at least 100/minute)
- providing chest compressions of adequate depth
  - adults: a compression depth of at least 2 inches (5 cm)
  - infants and children: a depth of least one third the anterior-posterior (AP) diameter of the chest or about 1 ½ inches (4 cm) in infants and about 2 inches (5 cm) in children
- allowing complete chest recoil after each compression
- minimizing interruptions in compressions
- avoiding excessive ventilation

If multiple rescuers are available, they should rotate the task of compressions every 2 minutes.

Airway and Ventilations

Opening the airway (with a head tilt–chin lift or jaw thrust) followed by rescue breaths can improve oxygenation and ventilation. However, these maneuvers can be technically challenging and require interruptions of chest compressions, particularly for a lone rescuer who has not been trained. Thus, the untrained rescuer will provide Hands-Only (compression-only) CPR (ie, compressions without ventilations), and the lone rescuer who is able should open the airway and give rescue breaths with chest compressions. Ventilations should be provided if the victim has a high likelihood of an asphyxial cause of the arrest (eg, infant, child, or drowning victim).

Once an advanced airway is in place, healthcare providers will deliver ventilations at a regular rate 1 breath every 6 to 8 seconds (8 to 10 breaths/minute) and chest compressions can be delivered without interruption.

Defibrillation

The victim's chance of survival decreases with an increasing interval between the arrest and defibrillation.[30,31] Thus early defibrillation remains the cornerstone therapy for ventricular fibrillation and pulseless ventricular tachycardia. Community and hospital strategies should aggressively work to reduce the interval between arrest and defibrillation.[32]

One of the determinants of successful defibrillation is the effectiveness of chest compressions. Defibrillation outcome is improved if interruptions (for rhythm assessment, defibrillation, or advanced care) in chest compressions are kept to a minimum.[11,14,33–39]

Translating Resuscitation Science Into Practice

In a community setting, the sole trained layperson responding to a cardiac arrest victim needs to perform an ordered

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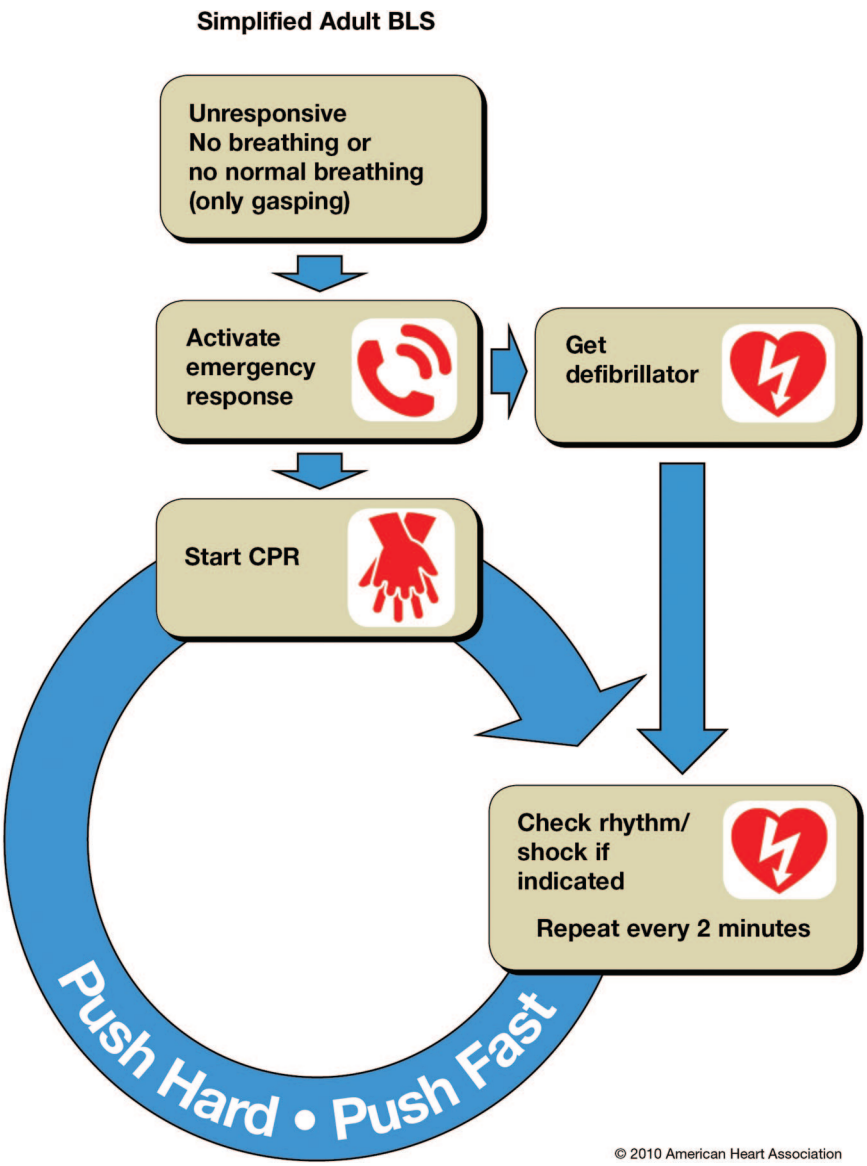

Figure 3. Simplified Adult BLS Algorithm.

sequence of CPR steps. Laypersons can learn these skills online and in courses.

In contrast, in a highly specialized environment, such as a critical care unit of a hospital, many of the individual components of CPR (compression-ventilation-defibrillation) may be managed simultaneously. This approach requires choreography among many highly-trained rescuers who work as an integrated team.

In the prehospital setting, the order of the CPR components performed by the healthcare provider may switch between a sequenced and choreographed model depending on the proficiency of the provider and the availability of resources.

Quality Improvement in Resuscitation Systems, Process, and Outcomes

A Systems Approach

Cardiac arrest is an important public health issue. Resuscitation involves a broad spectrum of individual stakeholders and groups. Individuals include victims, family members, rescuers, and healthcare providers. Key stakeholder groups include the public, emergency medical dispatchers, public safety organizations, EMS systems, hospitals, civic groups, and policy makers at the local, state, and federal levels.

Because the links in the Chain of Survival are interdependent, an effective resuscitation strategy requires these individuals and groups to work in an integrated fashion and function as a *system of care*.[40] Fundamental to a successful resuscitation system of care is the collective appreciation of the challenges and opportunities presented by the Chain of Survival. Thus individuals and groups must work together, sharing ideas and information, to evaluate and improve their resuscitation system. Leadership and accountability are important components of this team approach.

A conceptual appreciation of the system and its working components is only a starting point. Improving care requires assessment of performance. Only when performance is evaluated can participants in a system effectively

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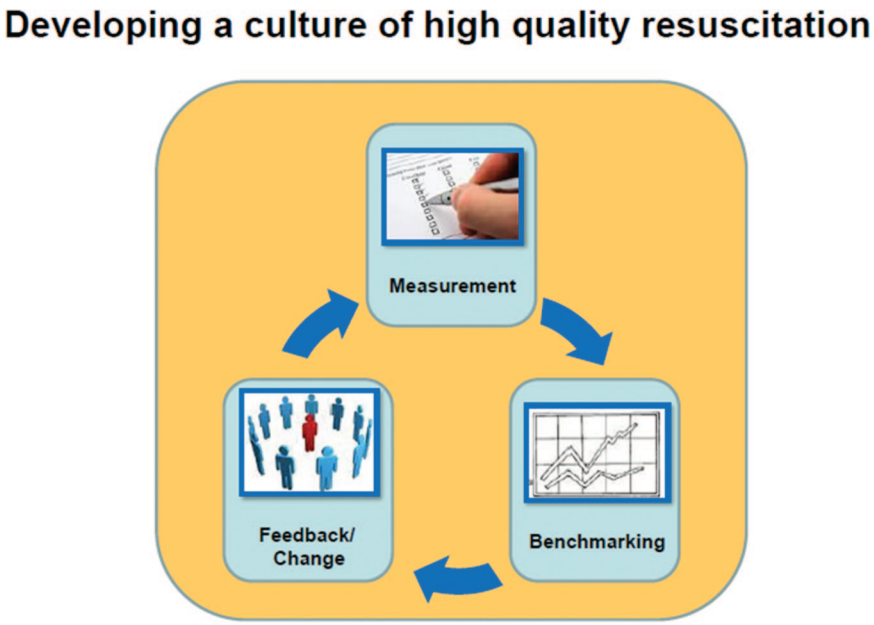

Figure 4. Quality Improvement Elements of a Resuscitation System.

intervene to improve care. This process of quality improvement consists of an iterative and continuous cycle of (1) systematic evaluation of resuscitation care and outcome, (2) benchmarking with stakeholder feedback, and (3) strategic efforts to address identified deficiencies (see Figure 4).

There is wide community and hospital variability in cardiac arrest survival.[3,8,13] High-performing systems have used this continuous quality improvement approach with great success,[41] as have systems that have more recently adopted this strategy.[42] These successes have occurred in a variety of systems, suggesting that all communities and hospitals can substantially improve care and outcomes. Since each system has different characteristics and challenges, there is no single prescriptive strategy for improvement. However, each system has an obligation to address the fundamental principles of quality improvement: measurement, benchmarking, and feedback and change.

Measurement

Quality improvement relies on valid assessment of resuscitation performance and outcome. The Utstein Guidelines provide useful templates for measuring key aspects of resuscitation care and outcome.[43,44] Examples of core performance measures include the rate of bystander CPR, time to defibrillation, and survival to hospital discharge. Such measures are typically assessed based on review of dispatch, EMS, and hospital records, underscoring the importance of information sharing among all the links in the system of care. Additional measures can be incorporated to meet a system's individual quality improvement strategy. For example, individual CPR components can be measured through review of the electronic defibrillator recording and can provide a useful set of metrics for EMS and hospital providers.[45]

Benchmarking and Feedback

These data should be systematically reviewed and compared internally to prior performance and externally to similar systems. Existing cardiac arrest registries can facilitate this benchmarking effort; examples include the Cardiac Arrest Registry to Enhance Survival (CARES)[46] for out-of-hospital cardiac arrest and the National Registry of CardioPulmonary Resuscitation (NRCPR)[47] for in-hospital cardiac arrest. The results of assessments should be regularly interpreted by all stakeholders and can iden-

Table 2. Key Challenges to Improve CPR Quality for Adults, Children, and Infants

CPR Component	Key Challenges to Improving Quality
Recognition	• Failure to recognize gasping as sign of cardiac arrest • Unreliable pulse detection
Initiation of CPR	• Low bystander CPR response rates • Incorrect dispatch instructions
Compression rate	• Slow compression rate
Compression depth	• Shallow compression depth
Chest wall recoil	• Rescuer leaning on the chest
Compression interruptions	• Excessive interruptions for – rhythm/pulse checks – ventilations – defibrillation – intubation – intravenous (IV) access – other
Ventilation	• Ineffective ventilations • Prolonged interruptions in compressions to deliver breaths • Excessive ventilation (especially with advanced airway)
Defibrillation	• Prolonged time to defibrillator availability • Prolonged interruptions in chest compressions pre- and post-shocks
Team Performance	• Delayed rotation, leading to rescuer fatigue and decay in compression quality • Poor communication among rescuers, leading to unnecessary interruptions in compressions

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tify key considerations for directed efforts of improvement (see Table 2).

Change

The process of simply measuring and benchmarking care can positively influence outcome.[48] However, ongoing review and interpretation are necessary to identify areas for improvement. Local data may suggest the need to increase bystander CPR response rates, improve CPR performance, or shorten the time to defibrillation. Useful strategies might include programs targeting citizen awareness, education and training for citizens and professionals, and various technologic solutions. These programs need to be continually re-evaluated to ensure that potential areas for improvement are fully addressed.

Important Lessons from CPR and Summary

The *2010 AHA Guidelines for CPR and ECC* mark the 50th anniversary of modern CPR. There is general agreement that the 1960 Meeting of the Maryland Medical Society in Ocean City, MD, formally introduced the combination of chest compressions and rescue breathing.[49] Two years later (1962) direct-current, monophasic waveform defibrillation was described.[50] In 1966, the American Heart Association developed the first CPR guidelines.[51] Over the past 50 years, these modern-era basic life support fundamentals of early recognition and activation, early CPR, and early defibrillation have saved hundreds of thousands of lives around the world. These lives stand as a testament to the importance of resuscitation research and clinical translation. They give us cause to celebrate this 50th anniversary of CPR.

And yet we still have a long road to travel if we are to fulfill the potential offered by the Chain of Survival. There is a striking disparity in survival across systems of care for cardiac arrest. Survival disparities that were present a generation ago appear to persist.[3,8,52] Although future discoveries will offer opportunities to improve survival, we currently possess the knowledge and tools—represented by the Chain of Survival—to address many of these care gaps.

The challenge is one of real-world translation across diverse systems. Since the *2005 AHA Guidelines for CPR and ECC*, many instructive and encouraging examples have been published, describing ways in which that translation can be accomplished. Each system, whether in the hospital or in the community, must assess its performance and implement a strategy for improving care in cases of cardiac arrest. That strategy should support the building blocks of resuscitation: the BLS links of immediate recognition and emergency activation, early CPR, and rapid defibrillation. If we accept this imperative to act, we can achieve the full potential offered by the Chain of Survival and, in turn, improve public health.

Disclosures

Guidelines Part 4: Overview of CPR Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Andrew H. Travers	Emergency Health Services Nova Scotia–Provincial Medical Director	None	None	None	None	None	None
Thomas D. Rea	University of Washington: Physician, Associate Professor of Medicine; Emergency Medical Services Division - Public Health Seattle & King County–Program Medical Director	*In the past, I have received modest grants from Philips Inc and PhysioControl to evaluate changes in resuscitation protocols. These investigations did not support evaluation of proprietary equipment. I am an investigator in the Resuscitation Outcomes Consortium so participate in studies evaluating dynamic CPR feedback available in a Philips defibrillator and the impedance threshold device which is developed and owned by a private company. These studies are funded primarily by the NIH and I receive no support from private industry related to these research activities. I participate in a trial of chest compression alone versus chest compression plus ventilation supported in part by the Laerdal Foundation. Collectively I receive < 5% of my salary from these research activities.	*We recently completed an AED training study for which Philips and PhysioControl provided equipment. I did not directly receive any equipment as part of the research activity.	None	None	None	*I participate as part of a DSMB in a trial sponsored by Philips Inc to evaluate quantitative VF waveform algorithm to guide care. I receive no financial support as part of the DSMB.
Bentley J. Bobrow	Arizona Department of Health Services–Medical Director, Bureau of EMS and Trauma System; Maricopa Medical Center-Clin. Associate. Professor, Emergency Medicine Department	†AHA. Ultra-Brief CPR Video Study, PI. *Medtronic Foundation. Arizona Statewide Resuscitation System of Care, 2010–2015, PI.	None	None	None	None	None

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Dana P. Edelson	University of Chicago Assistant Professor	†CURRENT RESEARCH GRANTS Pending NHLBI Career Development Award Strategies to Predict and Prevent In-Hospital Cardiac Arrest (1K23HL097157–01) This study is to validate a clinical judgment based tool for predicting impending clinical deterioration of hospitalized floor patients and compare it to previously described physiology-based tools. Role: PI (funds delivered to university). 2009–present Philips Healthcare Research Grant Advancements in CPR and Emergency Care during Hemodynamic Crisis The purpose of this project is to measure capnography and pulse pressure, using a novel plethysmographic sensor, in critically ill patients and correlate quality of CPR with these measures during CA. Role: PI (funds delivered to university) 2008–present Philips Healthcare Research Grant Q-CPR Users & Development Research Alliance The purpose of this project is to establish a multi-center registry of in-hospital resuscitation quality data and a network for clinical trials of resuscitation. Role: PI (funds delivered to university) 2008–present NIH Clinical Research Loan Repayment Granted two years of student loan repayment aims to evaluate the effects of integrated team debriefing using actual performance data to improve CPR quality and patient survival following IHCA.Role: PI (funds delivered to loan servicing program) 2007–present AHA Scientist Development Grant Improving CPR Quality and Patient Outcomes Using a Novel Educational Program This project aims to evaluate the effects of integrated team debriefing using actual performance data to improve CPR quality & patient survival following IHCA. Role: PI (funds delivered to university) 2008–2009 NIH Agency for Healthcare Research and Quality Immersive Simulation Team Training–Impact on Rescue, Recovery and Safety Culture (5U18HS016664–02) The goal is to study the effects of simulation based training for Rapid Response Teams. Consultant (funds to univ.)	*Philips Healthcare, Andover, MA	*Philips Healthcare, Andover, MA	None	*Triage Wireless Inc, San Diego, CA	*Hanna Campbell & Powell LLP, Akron, OH-Hankton Vs Beeson
Robert A. Berg	University of Pennsylvania–Professor		None	None	None	None	None
Michael R. Sayre	The Ohio State University–Associate Professor	None	None	None	None	None	None
Marc D. Berg	University of Arizona - Associate Professor of Clinical Pediatrics Attending Intensivist	None	None	*Travel expenses reimbursed (<$4000 USD) for participation in 13th Asian Australasian Congress of Anesthesiologists, Fukuoka, Japan, June 2010	None	None	None
Leon Chameides	Emeritus–Director, Pediatric Cardiology, Connecticut Children's Hospital, Clinical Professor, University of Connecticut	None	None	None	None	None	None
Robert E. O'Connor	University of Virginia Health System–Professor and Chair of Emergency Medicine	None	None	None	None	None	None
Robert A. Swor	William Beaumont Hospital - Hospital Emergency Physician	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 $ 00 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.

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