State of New Hampshire

Department of Safety

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DATE:	October 3, 2016
TO:	NH EMS Unit Leaders, Providers, EMS Coordinators & EMS Medical Directors
FROM:	Jim Suozzi, EMS Medical Director & Vicki Blanchard, Clinical Systems Coordinator
SUBJECT:	Cardiac Arrest, Team Focused CPR & Double Sequential Defibrillation

As you may have heard the Medical Control Board has approved a new Cardiac Arrest protocol, a Team Focused CPR protocol and a Double Sequential Defibrillation Protocol (see attachment 1) that will change how we manage patients in cardiac arrest. In order to roll out the new protocol in a consistent manner, we have developed an online education module for EMS providers. We will be releasing the training in the upcoming days and wanted to provide you with some information in advancement.

Traditionally, the Medical Control Board does not authorize protocol changes outside of our usual two year cycle, but as these protocols represents such a change in our practice, as well as, advancement in patient care, we felt that it should be released on its own.

Historically, management of patients that had suffered cardiac arrest focused on aggressive airway management CPR, defibrillation and drug therapy. A key focus of the new protocol is high performance CPR.

From the AHA Consensus Statement "CPR Quality: Improving Cardiac Resuscitation Outcomes Both Inside and Outside the Hospital" (see attachment 2) we have learned:

- Every year in the US more than 500,000 adults and children experience a cardiac arrest, and less than 15% survive.
- High-quality CPR is the primary component in influencing survival from cardiac arrest, but there is considerable variation in monitoring, implementation, and quality improvement.
- A large gap exists between current knowledge of CPR quality and its optimal implementation, leading to preventable deaths from cardiac arrest.
- The purpose of this consensus statement is to stimulate transformative change on a large scale by providing healthcare practitioners and healthcare systems a tangible framework with which to maximize the quality of CPR and save more lives.
- Target CPR performance metrics include the following:
  - Chest compression fraction >80%
  - Compression rate of 100-120/min
  - Compression depth of at least 50 mm (2 inches) in adults and at least 1/3 the AP dimension of the chest in infants and children
  - No excessive ventilation (a rate of <12 breaths/min with only minimal chest rise)
- CPR quality monitoring may be based on the resuscitation team's CPR performance or the patient's physiological response to resuscitative efforts, which should be continually adjusted according to the response.
- Resuscitation teams should coordinate efforts to ensure high-quality CPR during cardiac arrest.
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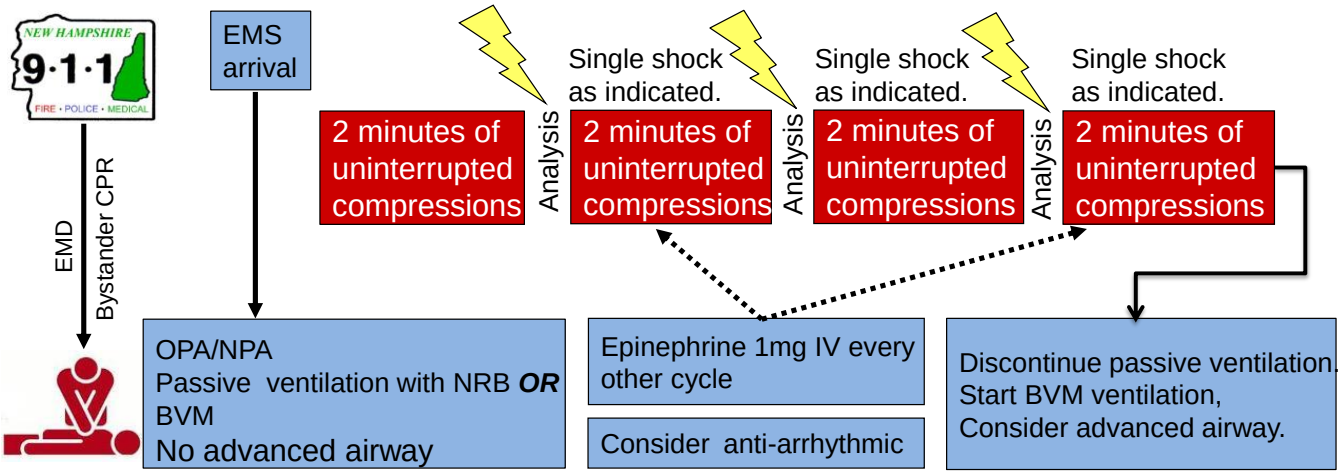
- Every EMS system, hospital, and professional rescuer program should have an ongoing CPR continuous quality improvement program that provides feedback to the director, managers, and providers.
- A national system for standardized reporting of CPR quality metrics should be developed.
- Through better measurement, training, and systems-improvement processes of CPR quality, we can have a significant impact on survival from cardiac arrest and eliminate the gap between current and optimal outcomes.

We are excited about this update and the chance to improve patient outcomes. We will be sending out the instructions and link to the training in the upcoming days. If you have questions in the meantime please do not hesitate to contact either one of us: Dr. Suozzi, JSuozzi@Cheshire-Med.COM or Vicki Blanchard, vicki.blanchard@dos.nh.gov

3.2A Cardiac Arrest – Adult

- Perform 2 minute cycles of uninterrupted chest compressions.
- Interrupt chest compressions only for rhythm/pulse check and defibrillation.
- Ventilation / Oxygenation options:
  - Apply high flow oxygen via non-rebreather mask (NRB) for passive insufflation **OR**
  - BVM ventilation 1 breath every 10 chest compressions without interrupting compressions.
    - For arrests of non-cardiac etiology, including respiratory and trauma, use BVM ventilation.



EMT STANDING ORDERS - ADULT

E

- Routine Patient Care—with focus on CPR
- Immediate chest compressions.
- Use AED as soon as possible, with minimal interruption of chest compressions.
- Continue 2 minute cycles of uninterrupted chest compressions followed by AED analysis and shock for 4 cycles (8 minutes).
- Place an oral or nasal airway.
- Ventilation / oxygenation options during 4 cycles (8 minutes):
  - Apply high flow oxygen via NRB, **OR**
  - BVM ventilation 1 breath every 10 chest compressions during recoil and without interrupting compressions.
  - Consider advanced airway **only** if airway patency cannot be maintained using basic maneuvers and adjuncts.
- If using a BVM, monitor quantitative waveform capnography, if available, throughout resuscitation to assess CPR quality and to monitor for signs of Return of Spontaneous Circulation (ROSC).
- After 4 cycles (8 minutes):
  - Continue 2 minute cycles of uninterrupted chest compressions.
  - If passive insufflation was used, switch to BVM ventilation.
  - Consider placement of a supraglottic airway without interrupting chest compressions.
- Consider treatable causes: hypoxia, overdose/poisoning, hypothermia, hypoglycemia, and hypovolemia—treat as per specific protocol.
- If ROSC occurs see Post Resuscitative Care Protocol 3.5.
- Consider termination of efforts or not attempting resuscitation (see DNR, POLST & Advanced Directives Protocol 8.7 and/or Resuscitation Initiation & Termination Protocol 8.15.

Policy Continues

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Policy Continued

ADVANCED EMT STANDING ORDERS - ADULT

A

- Place IV/IO without interrupting chest compressions.
- After the first 2 minute cycle, administer epinephrine (0.1mg/mL) 1 mg IV; repeat every other cycle.

PARAMEDIC STANDING ORDERS - ADULT

P

- Defibrillate as indicated, per manufacturer's recommendations.
- After 4 cycles (8 minutes):
  - Consider endotracheal intubation without interrupting chest compressions.
- Administer anti-dysrhythmic as indicated.
- Consider tension pneumothorax and treat with needle decompression.
- For suspected pre-existing metabolic acidosis, suspected or known hyperkalemia (dialysis patient), known tricyclic antidepressant overdose, or suspected excited/ agitated delirium consider:
  - Sodium bicarbonate 2mEq/kg IV.
- For suspected or known hyperkalemia (dialysis patient) consider:
  - Calcium gluconate 2 gram IV, **OR**
  - Calcium chloride (10%) 1 gram IV.

EMS agency should use a "pit crew" approach to ensure the most effective and efficient cardiac arrest care, see Team Focused CPR.

Except as indicated in this protocol, follow applicable AHA ACLS and BLS guidelines.

PEARLS:

- It is expected, unless special circumstances are present, resuscitation will be performed on scene until ROSC or termination of efforts. See Resuscitation Initiation and Termination 8.16
- Early CPR and early defibrillation are the most effective therapies for cardiac arrest care.
- Minimize interruptions in chest compression, as pauses rapidly return the blood pressure to zero and stop perfusion to the heart and brain.
- Recognizing the goal of immediate uninterrupted chest compressions, consider delaying application of mechanical CPR devices until after the first four cycles (8 minutes). If applied during the first 4 cycles, the goal is to limit interruptions. Mechanical devices should only be used by services that are practiced and skilled at their application.
- Switch compressors at least every two minutes to minimize fatigue.
- Perform chest compressions while defibrillator is charging and resume compressions immediately after the shock is delivered.

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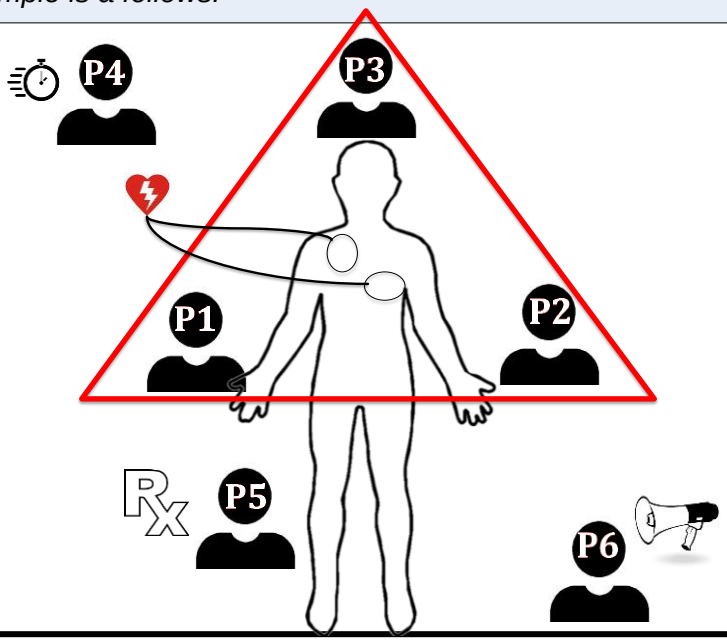
3.7 Team Focused CPR – Adult

EMS agency should use a "pit crew" approach when using this protocol to ensure the most effective and efficient cardiac arrest care. Training should include teamwork simulations integrating BLS, and ALS crew members who regularly work together. EMS systems should practice teamwork using "pit crew" techniques with predefined roles and crew resource management principles. *One Example is a follows:*



POSITION #1-**Compressor 1** (right side of patient):
- Initiates 1 minute of chest compressions at rate of 100-120 / min
- Assists Position 3 with ventilations in off cycle

POSITION #2-**Compressor 2** (left side of patient):
- Sets up defibrillator
- Alternates 1 minute of chest compressions with Position 1
- Assists Position 3 with ventilations in off cycle

POSITION #3-**Airway** (At patient's head):
- Opens airway and inserts OPA
- Assembles NRB or BVM
- If using BVM, provide 2 handed mask seal
- Inserts advanced airway after 8 minutes/4 cycles.

POSITION #4-**Team Leader** (Outside CPR triangle):
- Coaches the metrics
- Calls for compressor change every one minute
- Calls for rhythm analysis every 2 minutes, immediate shock if indicated
- Monitor CPR quality and use of metronome at 100-120 bpm
- Assumes duties of Position 5/6 if limited to four rescuers throughout resuscitation.

POSITION #5-**Vascular/Meds** (Outside CPR triangle):
- Initiates IV/IO access
- Administers medications per protocol

POSITION #6-**Code Commander** (Outside CPR triangle):
- Ideally highest level provider
- Communicates/interfaces with CPR Team Leader
- Coordinates patient treatment decisions
- Communicates with family/loved ones
- Completes Cardiac Arrest Check List

Policy Continues

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Policy Continued

- If feasible and the scene is safe, immediately upon arrival, one member of the crew should rapidly enter the scene without equipment (other than gloves) to begin chest compressions.
- Clear some space to optimize your working environment. Move furniture or get the patient in a position that will allow a rescuer space to kneel on both sides of them, and where there is sufficient room at the head. Effectiveness of chest compressions decrease during patient movement. Therefore resuscitate the patient as close to the scene as operationally feasible.
- Position 1 and 2 are ideally set up on opposite sides of patient's chest and perform continuous chest compressions, alternating after minute to avoid fatigue.
- REMEMBER: Effective chest compressions are one of the most important therapies for the pulseless patient. Effective is defined as:
  - A rate of at least 100 and less than 120 compressions/minute - Use of metronome or CPR feedback device is essential. (e.g. built into monitor or smart phone app)
  - A depth of 2 - 2.4 inches
  - Allow for complete chest recoil (avoid leaning on chest)
  - Do not interrupt compressions to obtain IV access or perform airway management.
  - Do not hyperventilate as it increases intrathoracic pressure and decreases blood return to the heart. Ventilate 1 breath every 10 compressions during recoil without interrupting chest compressions.
- Chest compressions should only be interrupted during rhythm check (AED analysis or manual) and defibrillation shocks. Continue compressions when AED/ defibrillator is charging, if device allows.
- During interruptions compressor's hands should hover over chest.
- Perform pulse check simultaneously with rhythm check.
- With the goal of immediate uninterrupted chest compressions, if a mechanical device is used, it should not lead to delay or interruption in chest compressions; consider delayed applications.
- Pre-charge manual defibrillators prior to rhythm check to ensure rapid defibrillation if a shockable rhythm is present. If no shock is indicated, disarm the device (dump the charge)
- Utilize $ETCO_2$ to assess CPR quality and monitor for signs of ROSC.
- Use of a CPR checklist to ensure that all best practices are followed during CPR.

Example Cardiac Arrest Check List

- ❑ Code commander and pit crew roles identified
- ❑ Chest compression interruptions minimized
- ❑ Compressors rotated at minimum every 2 minutes
- ❑ Metronome set between 100 and 120 beats per minute
- ❑ AED/defibrillator applied
- ❑ O_2 flowing and attached to NRB/BVM
- ❑ $ETCO_2$ waveform present
- ❑ IV/IO access established
- ❑ Possible causes considered
- ❑ Gastric insufflation limited and gastric decompression considered
- ❑ Family present and ongoing communication provided

Consider possible causes

Hypovolemia	Tablets/toxins
Hypoxia	Tamponade
Hydrogen Ions (acidosis)	Tension pneumothorax
Hypothermia	Thrombosis (MI)
Hyper/hypokalemia	Thrombosis (PE)
Hypoglycemia	Trauma

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Double Sequential Defibrillation – Adult

6.1

PARAMEDIC STANDING ORDERS – ADULT

INDICATION: Refractory Ventricular Fibrillation / Tachycardia after 5 unsuccessful shocks

- **Recurrent ventricular fibrillation/tachycardia** is defined as SUCCESSFULLY CONVERTED by standard defibrillation techniques but subsequently returns. It should NOT be treated by double sequential external defibrillation. It is managed by treatment of correctable causes and use of anti-arrhythmic medications in addition to standard defibrillation
- **Refractory ventricular fibrillation/tachycardia** is defined as NOT CONVERTED by standard defibrillation. It is initially managed by treating correctable causes and with antiarrhythmic medications. If these methods fail to produce a response, double sequential external defibrillation may be beneficial.

PROCEDURE:

1. Prior to attempting Double Sequential Defibrillation, at least one shock should be given using a different vector. Change pad placement from anterior-apex to anterior-posterior.
2. Ensure quality CPR and minimally interrupted chest compressions during pad application and procedure.
3. Apply a new set of external defibrillation pads adjacent to, but not touching the pad set currently in use.
4. Assure that controls for the second manual defibrillator are accessible to the team leader
5. Verify that both cardiac manual defibrillators are attached to the patient, that all pads are well adhered, and simultaneously charge both manual defibrillators.
6. When both monitors are charged to maximum energy settings and all persons are clear, push both shock buttons as synchronously as possible.
7. May repeat procedure every 2 minutes as indicated if refractory ventricular fibrillation/tachycardia persists

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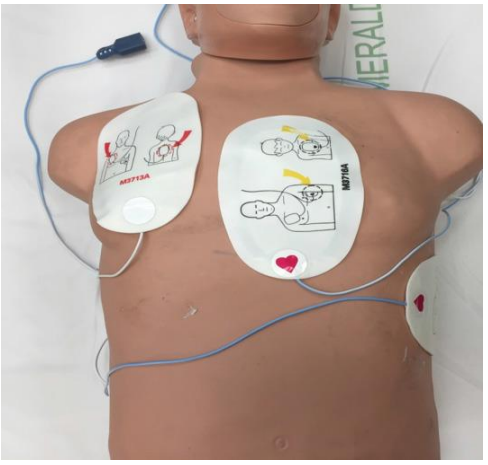

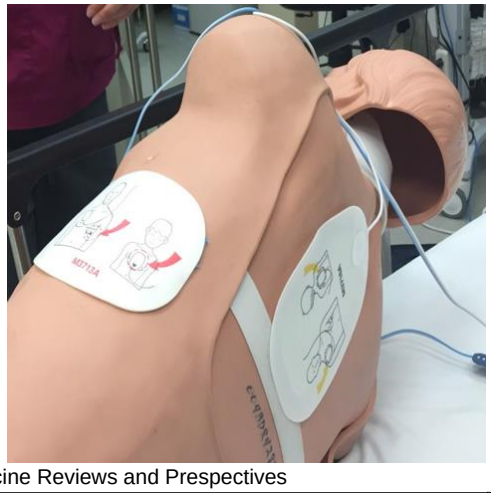

Photo Courtesy of Emergency Medicine Reviews and Prespectives

PEARLS

- Continue compressions when defibrillators are charging.
- During interruptions compressor's hands should hover over chest.
- Pre-charge manual defibrillators prior to rhythm check to ensure rapid defibrillation if a shockable rhythm is present. If no shock is indicated, disarm the device (dump the charge)
- Depending your local hospital resources, some refractory ventricular fibrillation patients may benefit from emergent cardiac catheterization. For this small patient population, transportation (ideally with a mechanical CPR device) may be indicated. Transporting these patient directly to the cath lab should be done in collaboration with on-line medical control and interventional cardiology.

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American Heart Association | American Stroke Association

Top Ten Things To Know
CPR Quality: Improving Cardiac Resuscitation Outcomes Both Inside and Outside the Hospital

1. Every year in the US more than 500,000 adults and children experience a cardiac arrest, and less than 15% survive.
2. High-quality CPR is the primary component in influencing survival from cardiac arrest, but there is considerable variation in monitoring, implementation, and quality improvement.
3. A large gap exists between current knowledge of CPR quality and its optimal implementation, leading to preventable deaths from cardiac arrest.
4. The purpose of this consensus statement is to stimulate transformative change on a large scale by providing healthcare practitioners and healthcare systems a tangible framework with which to maximize the quality of CPR and save more lives.
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   - Chest compression fraction >80%
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6. CPR quality monitoring may be based on the resuscitation team's CPR performance or the patient's physiological response to resuscitative efforts, which should be continually adjusted according to the response.
7. Resuscitation teams should coordinate efforts to ensure high-quality CPR during cardiac arrest.
8. Every EMS system, hospital, and professional rescuer program should have an ongoing CPR continuous quality improvement program that provides feedback to the director, managers, and providers.
9. A national system for standardized reporting of CPR quality metrics should be developed.
10. Through better measurement, training, and systems-improvement processes of CPR quality, we can have a significant impact on survival from cardiac arrest and eliminate the gap between current and optimal outcomes.

For the complete statement, and helpful tools and information please visit:

www.heart.org/cprquality

Meaney PA, et al; on behalf of the CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. CPR quality: improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation. 2013: published online before print June 25, 2013, 10.1161/CIR.0b013e31829d8654.
http://circ.ahajournals.org/lookup/doi/10.1161/CIR.0b013e31829d8654

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CPR Quality: Improving Cardiac Resuscitation Outcomes Both Inside and Outside the Hospital

A Consensus Statement From the American Heart Association

Endorsed by the American College of Emergency Physicians

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Abstract—The "2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" increased the focus on methods to ensure that high-quality cardiopulmonary resuscitation (CPR) is performed in all resuscitation attempts. There are 5 critical components of high-quality CPR: minimize interruptions in chest compressions, provide compressions of adequate rate and depth, avoid leaning between compressions, and avoid excessive ventilation. Although it is clear that high-quality CPR is the primary component in influencing survival from cardiac arrest, there is considerable variation in monitoring, implementation, and quality improvement. As such, CPR quality varies widely between systems and locations. Victims often do not receive high-quality CPR because of provider ambiguity in prioritization of resuscitative efforts during an arrest. This ambiguity also impedes the development of optimal systems of care to increase survival from cardiac arrest. This consensus statement addresses the following key areas of CPR quality for the trained rescuer: metrics of CPR performance; monitoring, feedback, and integration of the patient's response to CPR; team-level logistics to ensure performance of high-quality CPR; and continuous quality improvement on provider, team, and systems levels. Clear definitions of metrics and methods to consistently deliver and improve the quality of CPR will narrow the gap between resuscitation science and the victims, both in and out of the hospital, and lay the foundation for further improvements in the future. (***Circulation*. 2013;128:00-00.**)

Circulation
Journal of the American Heart Association

Key Words: AHA Scientific Statements ■ cardiac arrest ■ CPR ■ CPR quality ■ outcomes ■ resuscitation

Worldwide, there are >135 million cardiovascular deaths each year, and the prevalence of coronary heart disease is increasing.[1] Globally, the incidence of out-of-hospital cardiac arrest ranges from 20 to 140 per 100 000 people, and survival ranges from 2% to 11%.[2] In the United States, >500 000 children and adults experience a cardiac arrest, and <15% survive.[3–5] This establishes cardiac arrest as one of the most lethal public health problems in the United States,

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This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on May 7, 2013. A copy of the document is available at http://my.americanheart.org/statements by selecting either the "By Topic" link or the "By Publication Date" link. To purchase additional reprints, call 843-216-2533 or e-mail kelle.ramsay@wolterskluwer.com.

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claiming more lives than colorectal cancer, breast cancer, prostate cancer, influenza, pneumonia, auto accidents, HIV, firearms, and house fires combined.[6] In many cases, as Claude Beck noted, cardiac arrest victims have "hearts too good to die."[7] In these cases, prompt intervention can result in successful resuscitation. Yet overall survival rates remain low. Why? An increasing body of evidence indicates that even after controlling for patient and event characteristics, there is significant variability in survival rates both across and within prehospital and in-hospital settings. Examples include the following:

- In the prehospital setting, among participating centers in the Resuscitation Outcomes Consortium (ROC) Epistry, survival from out-of-hospital arrest ranged from 3.0% to 16.3%.[3] In the United Kingdom, survival-to-discharge rates within the National Health Service ambulance system ranged from 2% to 12%.[8]
- In the hospital setting, among participating centers in the Get With The Guidelines-Resuscitation quality-improvement program, the median hospital survival rate from adult cardiac arrest is 18% (interquartile range, 12%–22%) and from pediatric cardiac arrest, it is 36% (interquartile range, 33%–49%).
- In a hospital setting, survival is >20% if the arrest occurs between the hours of 7 AM and 11 PM but only 15% if the arrest occurs between 11 PM and 7 AM.[9] There is significant variability with regard to location, with 9% survival at night in unmonitored settings compared with nearly 37% survival in operating room/postanesthesia care unit locations during the day.[9]
- Patient survival is linked to quality of cardiopulmonary resuscitation (CPR). When rescuers compress at a depth of <38 mm, survival-to-discharge rates after out-of-hospital arrest are reduced by 30%.[10] Similarly, when rescuers compress too slowly, return of spontaneous circulation (ROSC) after in-hospital cardiac arrest falls from 72% to 42%.[11]

The variations in performance and survival described in these studies provide the resuscitation community with an incentive to improve outcomes. To maximize survival from cardiac arrest, the time has come to focus efforts on optimizing the quality of CPR specifically, as well as the performance of resuscitation processes in general.

CPR is a lifesaving intervention and the cornerstone of resuscitation from cardiac arrest.[12–14] Survival from cardiac arrest depends on early recognition of the event and immediate activation of the emergency response system, but equally critical is the quality of CPR delivered. Both animal and clinical studies demonstrate that the quality of CPR during resuscitation has a significant impact on survival and contributes to the wide variability of survival noted between and within systems of care.[3,15] CPR is inherently inefficient; it provides only 10% to 30% of normal blood flow to the heart and 30% to 40% of normal blood flow to the brain[16–19] even when delivered according to guidelines. This inefficiency highlights the need for trained rescuers to deliver the highest-quality CPR possible.

Poor-quality CPR should be considered a preventable harm. In healthcare environments, variability in clinician performance has affected the ability to reduce healthcare-associated complications,[20] and a standardized approach has been advocated to improve outcomes and reduce preventable harms.[21] The use of a systematic continuous quality improvement (CQI) approach has been shown to optimize outcomes in a number of urgent healthcare conditions.[22–24] Despite this evidence, few healthcare organizations apply these techniques to cardiac arrest by consistently monitoring CPR quality and outcomes. As a result, there remains an unacceptable disparity in the quality of resuscitation care delivered, as well as the presence of significant opportunities to save more lives.

Today, a large gap exists between current knowledge of CPR quality and its optimal implementation, which leads to preventable deaths attributable to cardiac arrest. Resuscitative efforts must be tailored to each patient. Cardiac arrest occurs in diverse settings with varying epidemiology and resources, yet effective solutions exist to improve CPR quality in each of these settings. The purpose of the present consensus statement is to stimulate transformative change on a large scale by providing healthcare practitioners and healthcare systems a tangible framework with which to maximize the quality of CPR and save more lives. The intent is to fill the gap between the existing scientific evidence surrounding resuscitation (as presented in the "2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" [2010 AHA Guidelines for CPR and ECC]) and the translation of the guidelines into routine clinical practice. The approach taken is the use of expert opinion and interpretation of existing studies to provide a practical hands-on approach to implementing the 2010 AHA Guidelines for CPR and ECC. Although there are many factors—population (eg, neonatal), chain of survival (eg, bystander CPR, postresuscitation care), CPR mechanics (hand position, duty cycle, airway adjuncts), and education (adult learning principles, feedback devices during training)—that impact patient survival, this consensus statement is focused on the critical parameters of CPR that can be enhanced to help trained providers optimize performance during cardiac arrest in an adult or a child.

Four areas related to CPR quality will be addressed:

- Metrics of CPR performance by the provider team
- Monitoring and feedback: options and techniques for monitoring patient response to resuscitation, as well as team performance
- Team-level logistics: how to ensure high-quality CPR in complex settings
- CQI for CPR

In addition, gaps in existing knowledge and technologies will be reviewed and prioritized and recommendations for optimal resuscitation practice made.

Methods

The contributors to this statement were selected for their expertise in the disciplines relevant to adult and pediatric cardiac resuscitation and CPR quality. Selection of participants and contributors was restricted to North America, and other international groups were not represented. After a series of telephone conferences and webinars between the chair and

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program planning committee, members of the writing group were selected and writing teams formed to generate the content of each section. Selection of the writing group was performed in accordance with the AHA's conflict of interest management policy. The chair of the writing group assigned individual contributors to work on 1 or more writing teams that generally reflected their area of expertise. Articles and abstracts presented at scientific meetings relevant to CPR quality and systems improvement were identified through the International Liaison Committee on Resuscitation's "2010 International Consensus on CPR and ECC Science With Treatment Recommendations" statement and the 2010 International Liaison Committee on Resuscitation worksheets, PubMed, Embase, and an AHA master resuscitation reference library. This was supplemented by manual searches of key articles and abstracts. Statements generated from literature review were drafted by the writing group and presented to leaders in CPR quality at a CPR Quality Summit held May 20–21, 2012, in Irving, TX. Participants evaluated each statement, and suggested modifications were incorporated into the draft. Drafts of each section were written and agreed on by members of the writing team and then sent to the chair for editing and incorporation into a single document. The first draft of the complete document was circulated among writing team leaders for initial comments and editing. A revised version of the document was circulated among all contributors, and consensus was achieved. This revised consensus statement was submitted for independent peer review and endorsed by several major professional organizations (see endorsements). The AHA Emergency Cardiovascular Care Committee and Science Advisory and Coordinating Committee approved the final version for publication.

Metrics of CPR Performance by the Provider Team

Oxygen and substrate delivery to vital tissues is the central goal of CPR during the period of cardiac arrest. To deliver oxygen and substrate, adequate blood flow must be generated by effective chest compressions during a majority of the total cardiac arrest time. ROSC after CPR is dependent on adequate myocardial oxygen delivery and myocardial blood flow during CPR.[16–18] Coronary perfusion pressure (CPP, the difference between aortic diastolic and right atrial diastolic pressure during the relaxation phase of chest compressions) is the primary determinant of myocardial blood flow during CPR.[25–27] Therefore, maximizing CPP during CPR is the primary physiological goal. Because CPP cannot be measured easily in most patients, rescuers should focus on the specific components of CPR that have evidence to support either better hemodynamics or human survival.

Five main components of high-performance CPR have been identified: chest compression fraction (CCF), chest compression rate, chest compression depth, chest recoil (residual leaning), and ventilation. These CPR components were identified because of their contribution to blood flow and outcome. Understanding the importance of these components and their relative relationships is essential for providers to improve outcomes for individual patients, for educators to improve the quality of resuscitation training, for administrators to monitor performance to ensure high quality within the healthcare system, and for vendors to develop the necessary equipment needed to optimize CPR quality for providers, educators, and administrators.

Minimize Interruptions: CCF >80%

For adequate tissue oxygenation, it is essential that healthcare providers minimize interruptions in chest compressions and therefore maximize the amount of time chest compressions generate blood flow.[12,28] CCF is the proportion of time that chest compressions are performed during a cardiac arrest. The duration of arrest is defined as the time cardiac arrest is first identified until time of first return of sustained circulation. To maximize perfusion, the 2010 AHA Guidelines for CPR and ECC recommend minimizing pauses in chest compressions. Expert consensus is that a CCF of 80% is achievable in a variety of settings. Data on out-of-hospital cardiac arrest indicate that lower CCF is associated with decreased ROSC and survival to hospital discharge.[29,30] One method to increase CCF that has improved survival is through reduction in preshock pause[31]; other techniques are discussed later in "Team-Level Logistics."

Chest Compression Rate of 100 to 120/min

The 2010 AHA Guidelines for CPR and ECC recommend a chest compression rate of ≥100/min.[28] As chest compression rates fall, a significant drop-off in ROSC occurs, and higher rates may reduce coronary blood flow[11,32] and decrease the percentage of compressions that achieve target depth.[10,33] Data from the ROC Epistry provide the best evidence of association between compression rate and survival and suggest an optimum target of between 100 and 120 compressions per minute.[34] Consistent rates above or below that range appear to reduce survival to discharge.

Chest Compression Depth of ≥50 mm in Adults and at Least One Third the Anterior-Posterior Dimension of the Chest in Infants and Children

Compressions generate critical blood flow and oxygen and energy delivery to the heart and brain. The 2010 AHA Guidelines for CPR and ECC recommend a single minimum depth for compressions of ≥2 inches (50 mm) in adults. Less information is available for children, but it is reasonable to aim for a compression depth of at least one third of the anterior-posterior dimension of the chest in infants and children (≈1½ inches, or 4 cm, in infants and ≈2 inches, or 5 cm, in children).[35,36]

Although a recent study suggested that a depth of ≥44 mm in adults may be adequate to ensure optimal outcomes,[37] the preponderance of literature suggests that rescuers often do not compress the chest deeply enough despite recommendations.[10,37–39] Earlier studies suggested that compressions at a depth >50 mm may improve defibrillation success and ROSC in adults.[40–43] A recent study examined chest compression depth and survival in out-of-hospital cardiac arrest in adults and concluded that a depth of <38 mm was associated with a decrease in ROSC and rates of survival.[10] Confusion may result when a range of depths is recommended and training

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targets differ from operational performance targets. Optimal depth may depend on factors such as patient size, compression rate, and environmental features (such as the presence of a supporting mattress). Outcome studies to date have been limited by the use of mean compression depth of CPR, the impact of the variability of chest compression depth, and the change in chest compliance over time.

Full Chest Recoil: No Residual Leaning

Incomplete chest wall release occurs when the chest compressor does not allow the chest to fully recoil on completion of the compression.[44,45] This can occur when a rescuer leans over the patient's chest, impeding full chest expansion. Leaning is known to decrease the blood flow throughout the heart and can decrease venous return and cardiac output.[46] Although data are sparse regarding outcomes related to leaning, animal studies have shown that leaning increases right atrial pressure and decreases cerebral and coronary perfusion pressure, cardiac index, and left ventricular myocardial flow.[46–48] Human studies show that a majority of rescuers often lean during CPR and do not allow the chest to recoil fully.[49,50] Therefore, the expert panel agrees that leaning should be minimized.

Avoid Excessive Ventilation: Rate <12 Breaths per Minute, Minimal Chest Rise

Although oxygen delivery is essential during CPR, the appropriate timeframe for interventions to supplement existing oxygen in the blood is unclear and likely varies with the type of arrest (arrhythmic versus asphyxial). The metabolic demands for oxygen are also substantially reduced in the patient in arrest even during chest compressions. When sudden arrhythmic arrest is present, oxygen content is initially sufficient, and high-quality chest compressions can circulate oxygenated blood throughout the body. Studies in animals and humans suggest that compressions without ventilations may be adequate early in nonasphyxial arrests.[51–54] When asphyxia is the cause of the arrest, the combination of assisted ventilation and high-quality chest compressions is critical to ensure sufficient oxygen delivery. Animal and human studies of asphyxial arrests have found improved outcomes when both assisted ventilations and high-quality chest compressions are delivered.[55,56]

Providing sufficient oxygen to the blood without impeding perfusion is the goal of assisted ventilation during CPR. Positive-pressure ventilation reduces CPP during CPR,[57] and synchronous ventilation (recommended in the absence of an advanced airway)[35] requires interruptions, which reduces CCF. Excessive ventilation, either by rate or tidal volume, is common in resuscitation environments.[38,57–60] Although chest compression–only CPR by bystanders has yielded similar survival outcomes from out-of-hospital arrest as standard CPR,[38,51,52] there is presently not enough evidence to define when or if ventilation should be withheld by experienced providers, and more data will be required.

Rate <12 Breaths per Minute

Current guideline recommendations for ventilation rate (breaths per minute) are dependent on the presence of an advanced airway (8 to 10 breaths per minute), as well as the patient's age and the number of rescuers present (compression-to-ventilation ratio of 15:2 versus 30:2). When other recommended goals are achieved (ie, compression rate of 100 to 120/min, inflation time of 1 second for each breath), these ratios lead to ventilation rates of between 6 and 12 breaths per minute. Animal studies have yielded mixed results regarding harm with high ventilation rates,[57,61] but there are no data showing that ventilating a patient at a higher rate is beneficial. Currently recommended compression-ventilation ratios are designed as a memory aid to optimize myocardial blood flow while adequately maintaining oxygenation and CO_2 clearance of the blood. The expert panel supports the 2010 AHA Guidelines for CPR and ECC and recommends a ventilation rate of <12 breaths per minute to minimize the impact of positive-pressure ventilation on blood flow.

Minimal Chest Rise: Optimal Ventilation Pressure and Volume

Ventilation volume should produce no more than visible chest rise. Positive-pressure ventilation significantly lowers cardiac output in both spontaneous circulation and during CPR.[57,62–65] Use of lower tidal volumes during prolonged cardiac arrest was not associated with significant differences in Pa_{O_2}[66] and is currently recommended.[67] Additionally, positive-pressure ventilation in an unprotected airway may cause gastric insufflation and aspiration of gastric contents. Lung compliance is affected by compressions during cardiac arrest,[68] and the optimal inflation pressure is not known. Although the conceptual relevance of ventilation pressure and volume monitoring during CPR is well established, current monitoring equipment and training equipment do not readily or reliably measure these parameters, and clinical studies supporting the optimal titration of these parameters during CPR are lacking.

Monitoring and Feedback: Options and Techniques for Monitoring Patient Response to Resuscitation

The adage, "if you don't measure it, you can't improve it" applies directly to monitoring CPR quality. Monitoring the quality and performance of CPR by rescuers at the scene of cardiac arrest has been transformative to resuscitation science and clinical practice. Studies have demonstrated that trained rescuers often had poor CCF ratios, depth of compressions, and compression-ventilation rates,[39,57,58,69] which were associated with worse outcomes.[11,34] With monitoring, there is increased clarity about optimal preshock pause, CCF, and chest compression depth.[10,29,31] With newer technology capable of monitoring CPR parameters during resuscitation, investigators and clinicians are now able to monitor the quality of CPR in real time. Given the insights into clinical performance and discoveries in optimal practice, monitoring of CPR quality is arguably one of the most significant advances in resuscitation practice in the past 20 years and one that should be incorporated into every resuscitation and every professional rescuer program.

The types of monitoring for CPR quality can be classified (and prioritized) into physiological (how the patient is doing)

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and CPR performance (how the rescuers are doing) metrics. Both types of monitoring can provide both real-time feedback to rescuers and retrospective system-wide feedback. It is important to emphasize that types of CPR quality monitoring are not mutually exclusive and that several types can (and should) be used simultaneously.

How the Patient Is Doing: Monitoring the Patient's Physiological Response to Resuscitative Efforts

Physiological data during CPR that are pertinent for monitoring include invasive hemodynamic data (arterial and central venous pressures when available) and end-tidal carbon dioxide concentrations ($ETCO_2$). Abundant experimental literature has established that (1) survival after CPR is dependent on adequate myocardial oxygen delivery and myocardial blood flow during CPR, and (2) CPP during the relaxation phase of chest compressions is the primary determinant of myocardial blood flow during CPR.[17,18,25,26,70,71] CPP during cardiac arrest is the difference between aortic diastolic pressure and right atrial diastolic pressure but may be best conceptualized as diastolic blood pressure–central venous pressure. Although the conceptual relevance of hemodynamic and $ETCO_2$ monitoring during CPR is well established, clinical studies supporting the optimal titration of these parameters during human CPR are lacking. Nevertheless, the opinions and clinical experience of experts at the CPR Quality Summit strongly support prioritizing use of hemodynamic and $ETCO_2$ concentrations to adjust compression technique during CPR when available. Furthermore, the expert panel recommends a hierarchal and situational contextualization of physiological monitoring based on the available data most closely related to myocardial blood flow:

1. Invasive Monitoring: CPP >20 mm Hg

Successful adult resuscitation is more likely when CPP is >20 mm Hg and when diastolic blood pressure is >25 to 30 mm Hg.[16,17,25–27,72–77] Although optimal CPP has not been established, the expert panel agrees with the 2010 AHA Guidelines for CPR and ECC that monitoring and titration of CPP during CPR is reasonable.[13] Moreover, the expert panel recommends that this physiological target be the primary end point when arterial and central venous catheters are in place at the time of the cardiac arrest and CPR. Data are insufficient to make a recommendation for CPP goals for infants and children.

2. Arterial Line Only: Arterial Diastolic Pressure >25 mm Hg

Consistent with these experimental data, limited published clinical studies indicate that the provision of successful adult resuscitation depends on maintaining diastolic blood pressure at >25 mm Hg.[26,75,76] The expert panel recommends that this physiological target be the primary end point when an arterial catheter is in place without a central venous catheter at the time of the cardiac arrest and CPR. The 2010 AHA Guidelines for CPR and ECC recommend "trying to improve quality of CPR by optimizing chest compression parameters or giving vasopressors or both" if diastolic blood pressure is <20 mm Hg.[13] The expert panel recommends that rescuers titrate to a diastolic blood pressure >25 mm Hg for adult victims of cardiac arrest.

3. Capnography Only: $ETCO_2$ >20 mm Hg

$ETCO_2$ concentrations during CPR are primarily dependent on pulmonary blood flow and therefore reflect cardiac output.[78,79] Failure to maintain $ETCO_2$ at >10 mm Hg during adult CPR reflects poor cardiac output and strongly predicts unsuccessful resuscitation.[80–82] The 2010 AHA Guidelines for CPR and ECC recommend monitoring $ETCO_2$ during CPR to assess blood flow in 2 ways: to improve chest compression performance if $ETCO_2$ is <10 mm Hg during CPR and to consider an abrupt sustained increase to a normal value (35 to 40 mm Hg) as an indicator of ROSC.[13] The expert panel recommends that when available, $ETCO_2$ should be the primary physiological metric when neither an arterial nor a central venous catheter is in place at the time of the cardiac arrest and CPR. On the basis of limited animal data and personal experience, the expert panel recommends titrating CPR performance to a goal $ETCO_2$ of >20 mm Hg while not excessively ventilating the patient (rate <12 breaths per minute, with only minimal chest rise).

How the Rescuers Are Doing: Monitoring CPR Performance

Monitors to measure CPR performance are now widely available. They provide rescuers with invaluable real-time feedback on the quality of CPR delivered during resuscitative efforts, data for debriefing after resuscitation, and retrospective information for system-wide CPR CQI programs. Without CPR measurement and subsequent understanding of CPR performance, improvement and optimized performance cannot occur. Providing CPR without monitoring performance can be likened to flying an airplane without an altimeter.

Routinely available feedback on CPR performance characteristics includes chest compression rate, depth, and recoil. Currently, certain important parameters (CCF and preshock, perishock, and postshock pauses) can be reviewed only retrospectively, whereas others (ventilation rate, airway pressure, tidal volume, and inflation duration) cannot be assessed adequately by current technology. Additionally, accelerometers are insensitive to mattress compression, and current devices often prioritize the order of feedback by use of a rigid algorithm in a manner that may not be optimal or realistic (eg, an accelerometer cannot measure depth if there is too much leaning, so the device will prioritize feedback to correct leaning before correcting depth). Although some software (automated algorithms) and hardware solutions currently exist (smart backboard, dual accelerometers, reference markers, and others), continued development of optimal and widely available CPR monitoring is a key component to improved performance.

Human Supervision and Direction of CPR

Visual observation provides qualitative information about depth and rate of chest compressions, as well as rate and tidal volume of ventilations. Although invasive hemodynamic monitoring (via intra-arterial and central venous catheters) provides superior quantitative data about patients' physiology, direct observation can reveal important artifacts (eg, pads were not selected on the monitor/defibrillator, "flat" arterial

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pressure waveform from a turned stopcock obstructed the arterial line tubing), as well as the recognized limitations of feedback technology of CPR performance described above. More rigorous, semiquantitative determination of chest compression depth and rate can be developed by rescuers with increasing experience, especially after effective feedback. Healthcare providers may be accustomed to feel for a pulse as an indication of the adequacy of chest compression, but pulse palpation during CPR is fraught with potential problems[83–85] and is therefore not recommended as a reliable means of monitoring the effectiveness of CPR.[28,35] Observers can quickly identify rescuer-patient mismatch (eg, a 40-kg rescuer versus a 120-kg patient), as well as recommend switching chest compressors if a rescuer manifests early signs of fatigue. In addition, observers can integrate the physiological factors (CPP, arterial relaxation pressure, or $ETCO_2$) with quantitative feedback of CPR quality parameters (depth, rate, leaning) to best achieve optimal CPR delivery.[86]

New methods and technology that accurately monitor both team performance and a patient's physiology during cardiac arrest should be developed. These may include additional markers of perfusion such as ventricular fibrillation waveform analysis, cerebral oximetry, impedance, and near-infrared spectroscopy. We challenge both researchers and industry to provide rescuers with robust solutions to monitor patient and provider performance.

Team-Level Logistics: How to Ensure High-Quality CPR in the Complex Setting of Cardiac Resuscitation

Basic life support skills are generally taught and practiced individually or in pairs.[87] In actual practice, CPR is frequently performed as part of a full resuscitative effort that includes multiple rescuers and advanced equipment. These additional resources allow tasks to be performed in parallel so that CPR can be optimized while the team determines and treats the underlying cause of the arrest. However, the performance of secondary tasks frequently consumes large portions of time and can detract from CPR quality if not managed carefully.[88]

Resuscitation team composition varies widely, depending on location (in hospital versus out of hospital), setting (field, emergency department, hospital ward), and circumstances. Little is known about the optimal number and background of professional rescuers.[89] Examples of high-functioning resuscitation teams for both prehospital and in-hospital cardiac arrest are presented at http://www.heart.org/cprquality. These examples are meant to be descriptive of how to maintain high-quality CPR with varying team size and environment rather than prescriptive if-then rules.

There are, however, data to suggest that resuscitation team leadership training and demonstration of leadership behaviors (eg, setting clear expectations, being decisive, and taking a hands-off approach) are associated with improved CPR performance, especially an increase in CCF.[90–92] As such, it is the recommendation of the expert panel that every resuscitation event should have a designated team leader who directs and coordinates all components of the resuscitation with a central focus on delivering high-quality CPR. The team leader's responsibility is to organize a team of experts into an expert team by directing and prioritizing the essential activities.

Interactions of CPR Performance Characteristics

There are no clear data on the interactions between compression fraction, rate or depth of compressions, leaning while performing compressions, and ventilation. All play a vital role in the transport of substrate to the vital organs during arrest. For instance, characteristics of chest compressions may be interrelated (eg, higher rate may be associated with lower depth, and greater depth may lead to increased leaning), and in practice, the rescuer may need to alter one component at a time, holding the others constant so as not to correct one component at the expense of another. The expert panel proposes that if the patient is not responding to resuscitative efforts (ie, $ETCO_2$ <20 mm Hg), team leaders should prioritize the optimization of individual components of chest compression delivery in the following order: (1) compression fraction, (2) compression rate, (3) compression depth, (4) leaning, and (5) avoidance of excessive ventilation. This order is recommended in part because of the strength of the science as discussed in the prior sections (eg, there is stronger evidence for compression fraction, rate, and depth than leaning) but also for the sake of feasibility, as discussed below.

Maximization of CCF

Prompt initiation of compressions is the first step toward maximizing CCF. However, to achieve a target CCF >80%, careful management of interruptions is critical. The following strategies minimize both the frequency and duration of interruptions.

Choreograph Team Activities

Any tasks that can be effectively accomplished during ongoing chest compressions should be performed without introducing a pause (Table 1). Additional tasks for which a pause in compressions is needed should be coordinated and performed simultaneously in a "pit crew" fashion. The team leader should communicate clearly with team members about impending pauses in compression to enable multiple rescuers to anticipate and then use the same brief pause to achieve multiple tasks.

Table 1. Compression Pause Requirements for Resuscitation Tasks

Pause Requirement	Task
Generally required	Defibrillation Rhythm analysis Rotation of compressors Backboard placement Transition to mechanical CPR or ECMO
Sometimes required	Complicated advanced airway placement in patients who cannot be ventilated effectively by bag-valve-mask Assessment for return of spontaneous circulation
Generally not required	Application of defibrillator pads Uncomplicated advanced airway placement IV/IO placement

CPR indicates cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; and IV/IO, intravenous/intraosseous.

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Minimize Interruptions for Airway Placement

The optimal time for insertion of an advanced airway during management of cardiac arrest has not been established. An important consideration is that endotracheal intubation often accounts for long pauses in performance of chest compressions.[93] Supraglottic airways can be used as an alternative to invasive airways, although a recent large study showed worse outcomes when supraglottic airways were compared with endotracheal intubation.[94] Patients who can be ventilated adequately by a bag-mask device may not need an advanced airway at all.[95] If endotracheal intubation is performed, the experienced provider should first attempt laryngoscopy during ongoing chest compressions. If a pause is required, it should be kept as short as possible, ideally <10 seconds. If a surgical airway is required, a longer pause may be necessary. However, in all such cases, the expert panel recommends performing any portion of the procedure that can be done during ongoing compressions to minimize the pause.

Avoid Unnecessary Pulse Checks

Manual palpation for a pulse can result in unnecessarily long pauses and is often unreliable.[83,85,96–100] These pauses can often be avoided when available monitoring (such as an arterial line or capnography) indicates a level of cardiac output or a rhythm (such as ventricular fibrillation) that is incompatible with organ perfusion.

Minimize Perishock Pauses

The preshock phase may be particularly vulnerable to interruption of chest compressions because of the need to provide a safe environment for the rescuer. It is important to minimize preshock pauses, because outcomes are improved with decreasing duration of pauses before shock delivery, possibly as short as 9 seconds.[31,41,101] A strategy of applying the pads and charging the defibrillator during ongoing chest compressions results in shorter perishock pauses, and this practice is recommended.[33,102] Development of technology that minimizes all interruptions (eg, compression artifact waveform filters that enable rhythm analysis during ongoing chest compressions)[103] in blood flow, particularly around defibrillation, is encouraged. Chest compressions should be restarted without delay after delivery of the shock. In one study, elimination of stacked shocks and extension of the duration of CPR from 1 to 2 minutes before postshock rhythm analyses increased CCF from 48% to 69% and was associated with increased survival.[104]

Tight Regulation of Compression Rate

Once chest compressions have begun, achievement of the target rate is often the easiest parameter to adjust and maintain. Real-time CPR feedback devices, as well as low-cost solutions such as metronomes and music, are known to decrease variability and result in compression rates closer to the target rate of 100 to 120/min.[58,105,106] It is essential to continue to monitor and adjust for degradation in compression rate over time and after modifications to other parameters.

Maximizing Compression Depth

With CCF optimized and compressions ongoing at a rate of 100 to 120/min, focus should turn to ensuring that compression depth is ≥50 mm. This parameter is one of the most difficult to achieve because of the physical force required. However, the following are some strategies to help ensure adequate depth:

1. Ensure a Firm, Hard Surface

The 2010 AHA Guidelines for CPR and ECC recommend performing CPR on a firm, hard surface. Backboards are commonly used to achieve target depths[107–109] and reduce rescuer exertion,[110] but their placement interrupts CPR.[111] For this reason, the expert panel recommends placement of a backboard or firm, hard surface as soon as possible and in coordination with other mandatory pauses in compressions to minimize interruption time.

2. Optimize Provider Mechanics of Compressions

Compression mechanics often degrade over time,[112] and rescuers often do not perceive fatigue before skill deterioration.[113–115] Although the 2010 AHA Guidelines for CPR and ECC recommend rotating chest compressors every 2 minutes,[12] large interindividual differences in chest compression quality exist.[114,116] Some can perform good-quality compressions for up to 10 minutes, whereas inadequate chest compression depths have been observed after only 1 minute of continuous chest compressions[114,116] or even at the initiation of CPR.[114,116] Others have demonstrated that a switch at 2 minutes may be trading optimal compressions for significant leaning after the switch[86] and decreased CCF caused by the frequency of switching.[117] The use of feedback devices, especially visual, can counteract degradation of CPR mechanics to some degree.[118,119] The expert panel recommends that the team leader monitor compressors for signs of fatigue. If there is evidence of inadequate compressions being performed by a rescuer that cannot be corrected with feedback or adjustments in positioning, responsibility for chest compressions should be transferred to another team member as quickly as possible, even if 2 minutes has not passed. With proper communication and preparation for the handoff, the switch can be accomplished in <3 seconds.[86]

Compression mechanics are affected by rescuer positioning, but there is no consensus on the optimal rescuer position for chest compressions. Although there may be no degradation in compression quality over a short duration,[111,120,121] rescuer work appears to increase in the standing position compared with use of a step stool or when kneeling.[122,123] In addition, step stools have been shown to increase compression depth, especially for rescuers of short stature.[124] The expert panel recommends adjustable-height surface (such as a hospital bed), that the height of the surface be lowered, or that a step stool be used to enable rescuers to achieve optimal depth during CPR.

Avoid Leaning

Increasing compression depth is often accompanied by increased leaning. Leaning is a bigger concern for taller rescuers and those using a step stool.[124] The expert panel recommends that as modifications are made to achieve the target depth, rescuers should monitor for leaning and adjust positioning as necessary to ensure adequate depth without residual pressure on the patient's chest between compressions.

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Avoid Excessive Ventilation

Unlike the compression characteristics, which have effects that are intertwined, ventilation is a stand-alone skill that can be optimized in parallel with chest compressions. Methods to decrease ventilation rate, such as use of metronomes, are well established,[106,125] whereas methods to limit excessive tidal volume and inspiratory pressure are less well developed but may include the use of smaller resuscitation bags, manometers, and direct observation.[66,67,126–128]

Additional Logistic Considerations

Incorporation of Mechanical CPR

Trials of mechanical CPR devices to date have failed to demonstrate a consistent benefit in patient outcomes compared with manual CPR.[129–133] The most likely explanation is that inexperienced rescuers underestimate the time required to apply the device,[134] which leads to a significant decrease in CCF during the first 5 minutes of an arrest[135–137] despite increases in CCF later in the resuscitation.[138] There is evidence that pre-event "pit crew" team training can reduce the pause required to apply the device.[139] Three large-scale implementation studies (Circulation Improving Resuscitation Care [CIRC],[140] Prehospital Randomized Assessment of a Mechanical Compression Device in Cardiac Arrest [PARAMEDIC],[141] and LUCAS in Cardiac Arrest [LINC])[142] may provide clarity about the optimal timing and environment for mechanical CPR. In the absence of published evidence demonstrating benefit, the decision to use mechanical CPR may be influenced by system considerations such as in rural settings with limited numbers of providers and/or long transport times.

Patient Transport

Performing chest compressions in a mobile environment has additional challenges and almost uniformly requires that the rescuer be unsecured, thus posing an additional safety concern for providers. Manual chest compressions provided in a moving ambulance are affected by factors such as vehicle movement, acceleration/deceleration, and rotational forces and can compromise compression fraction, rate, and depth.[143,144] There is no consensus on the ideal ambulance speed to address these concerns.[145,146] Studies of mechanical versus manual CPR in a moving ambulance show less effect on CPR quality when a mechanical device is used.[130,147]

CPR and Systematic CQI

Systematic CQI has optimized outcomes in a number of healthcare conditions,[22–24] increases safety, and reduces harm.[21] Review of the quality and performance of CPR by professional rescuers after cardiac arrest has been shown to be feasible and improves outcomes.[40,137,148] Despite this evidence, few healthcare organizations apply these techniques to cardiac arrest by consistently monitoring CPR quality and outcomes. As a result, there remains an unacceptable variability in the quality of resuscitation care delivered.

Debriefing

An effective approach to improving resuscitation quality on an ongoing basis is the use of debriefing after arrest events. In this context, debriefing refers to a focused discussion after a cardiac arrest event in which individual actions and team performance are reviewed. This technique can be very effective for achieving improved performance; CPR quality is reviewed while the resuscitation is fresh in the rescuer's mind. This approach, easily adaptable for either out-of-hospital or in-hospital cardiac arrest, can take a number of forms. One simple approach is represented by a "group huddle" among providers after a resuscitation attempt to briefly discuss their opinions about quality of care and what could have been improved. Similar discussions among providers who actually gave care can be performed on a regularly scheduled basis, and such an approach using weekly debriefing sessions has been shown to improve both CPR performance and ROSC after in-hospital cardiac arrest.[40] Preexisting structures in hospitals and emergency medical services (EMS) systems can be efficiently adapted to debrief

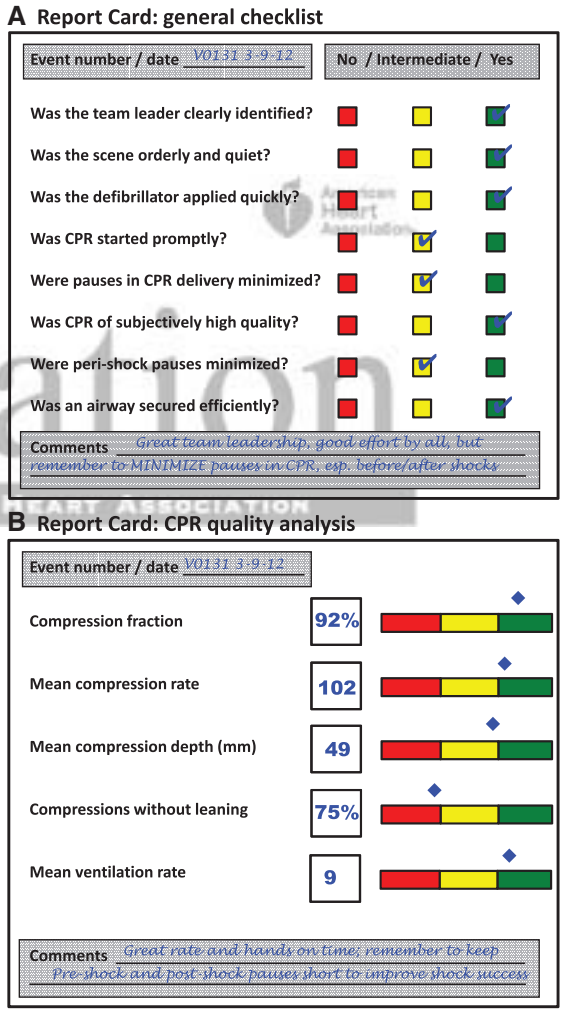

Figure 1. Illustration of proposed resuscitation "report cards." Routine use of a brief tool to document resuscitation quality would assist debriefing efforts and quality improvement efforts for hospital and emergency medical services systems. **A**, General checklist. Example of a general checklist report card that could be completed by a trained observer to a resuscitation event. **B**, CPR quality analysis. Example of a report card that relies on objective recording of CPR metrics. Ideally, both observational (**A**) and objective (**B**) reports could be used together in a combined report. CPR indicates cardiopulmonary resuscitation.

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arrest events. This has also been confirmed by a number of simulation studies among rescuers of both pediatric and adult victims of cardiac arrest.[149,150] If this approach is taken, it is crucial that the actual care providers be present for the discussion.

Use of Checklists

Debriefing can be greatly enhanced by structuring the discussion; that is, basing it on a quality checklist prompted by a short set of questions on quality metrics. Short CPR checklists can provide invaluable feedback directly from multiple sources. Systems should develop or adapt CPR quality checklists as CQI tools. These postevent checklists can be as simple as a short debriefing checklist (Figure 1 ["report card"]) on specific quality metrics that can be easily filled out after arrest events.

Use of Monitoring Data

Inclusion of monitoring data (physiological response of the patient to resuscitative efforts, performance of CPR by the provider) can provide an excellent data set for debriefing, because it allows a more objective approach that avoids perceptions of judgmental feedback. Every EMS system, hospital, and other professional rescuer program should strongly consider acquiring technology to capture CPR quality data for all cardiac arrests. Equipment that measures metrics of CPR performance must be able to provide resuscitation teams with the information necessary to implement immediate review sessions.

Integration With Existing Education

Quality-improvement strategies to improve CPR should include education to ensure optimal resuscitation team performance. Training in basic or advanced life support provides foundational knowledge and skills that can be lifesaving and improve outcomes.[151–153] Unfortunately, skills acquired during these infrequent training programs deteriorate rapidly (within 6–12 months) if not used frequently.[154–160] Recent evidence suggests that frequent short-duration "refreshing" of CPR skills prevents that decay and improves acquisition and retention of skills.[150,161,162] Therefore, there is increasing interest in using this as the foundation for maintenance of competence/certification. Although the various continuous training strategies differ in their advantages, disadvantages, and resource intensiveness, the expert panel recommends that some form of continuous training should be a minimum standard for all CPR CQI programs.

Improved individual healthcare provider and resuscitation team performance can also be achieved through the use of simulated resuscitation exercises, or "mock codes." Use of these kinds of team-training exercises also helps reinforce the importance of human factors in resuscitation team function[163] and may prove to be an important systematic program to improve survival from cardiac arrest.[164] Resuscitation training and education should not be considered a course or a single "event" but rather a long-term progression in the ongoing quest to optimize CPR quality.

Systems Review/Quality Improvement

Every EMS system, hospital, and other professional rescuer program should have an ongoing CPR CQI program that provides feedback to the director, managers, and providers. CPR CQI programs can and should implement systems to acquire and centrally store metrics of CPR performance. System-wide performance (which is optimally linked with survival rate) should be reviewed intermittently, deficiencies identified, and corrective action implemented. Routinely scheduled hospital cardiac arrest committee meetings, departmental "morbidity and mortality" meetings, and EMS quality review meetings can serve as platforms to discuss selected cases of arrest care

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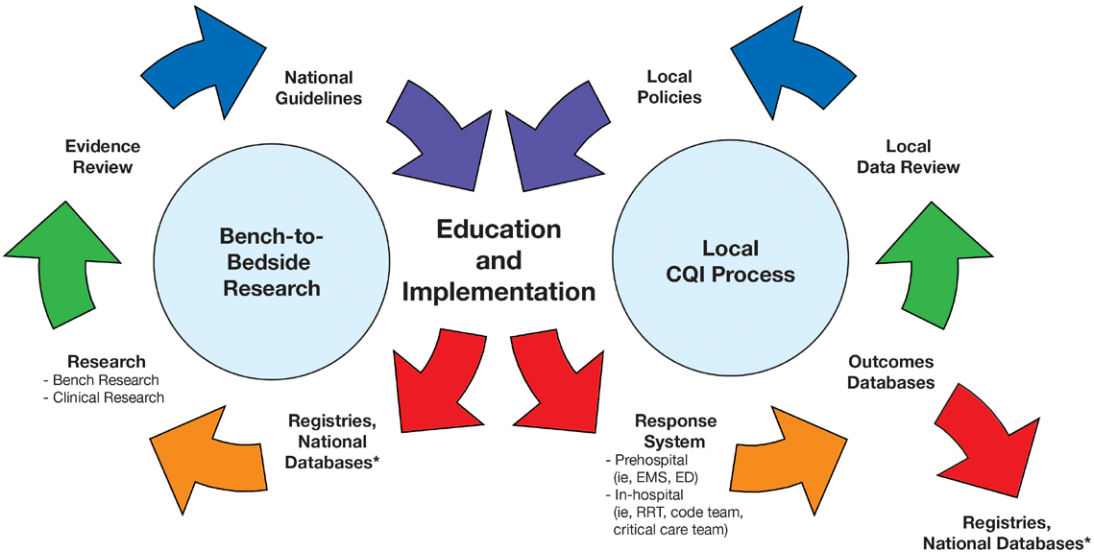

Figure 2. A continuous process evaluates and improves clinical care and generates new guidelines and therapy. Outcome data from cardiac arrest and periarrest periods are reviewed in a continuous quality-improvement (CQI) process. Research and clinical initiatives are reviewed periodically in an evidence-based process. Experts then evaluate new therapy and make clinical and educational recommendations for patient care. The process is repeated, and continual progress and care improvements are generated. ED indicates emergency department; EMS, emergency medical services; and RRT, rapid response team. *This is an overlap point in the cycle. That is, data come from outcomes databases (shown on the right) and go into registries and national databases (shown on the left).

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Table 2. Final Recommendations

1. High-quality CPR should be recognized as the foundation on which all other resuscitative efforts are built. Target CPR performance metrics include
   a. CCF >80%
   b. Compression rate of 100 to 120/min
   c. Compression depth of ≥50 mm in adults with no residual leaning
      i. (At least one third the anterior-posterior dimension of the chest in infants and children)
   d. Avoid excessive ventilation
      i. (Only minimal chest rise and a rate of <12 breaths/min)
2. At every cardiac arrest attended by professional rescuers
   a. Use at least 1 modality of monitoring the team's CPR performance
   b. Depending on available resources, use at least 1 modality of monitoring the patient's physiological response to resuscitative efforts
   c. Continually adjust resuscitative efforts based on the patient's physiological response
3. Resuscitation teams should coordinate efforts to optimize CPR during cardiac arrest by
   a. Starting compressions rapidly and optimizing CPR performance early
   b. Making sure that a team leader oversees the effort and delegates effectively to ensure rapid and optimal CPR performance
   c. Maintaining optimal CPR delivery while integrating advanced care and transport
4. Systems of care (EMS system, hospital, and other professional rescuer programs) should
   a. Determine a coordinated code team response with specific role responsibilities to ensure that high-quality CPR is delivered during the entire event
   b. Capture CPR performance data in every cardiac arrest and use an ongoing CPR CQI program to optimize future resuscitative efforts
   c. Implement strategies for continuous improvement in CPR quality and incorporate education, maintenance of competency, and review of arrest characteristics that include available CPR quality metrics
5. A national system for standardized reporting of CPR quality metrics should be developed:
   a. CPR quality metrics should be included and collected in national registries and databases for reviewing, reporting, and conducting research on resuscitation
   b. The AHA, appropriate government agencies, and device manufacturers should develop industry standards for interoperable raw data downloads and reporting from electronic data collected during resuscitation for both quality improvement and research

AHA indicates American Heart Association; CCF, chest compression fraction; CPR, cardiopulmonary resuscitation; CQI, continuous quality improvement; EMS, emergency medical services.

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in detail and provide opportunities for feedback and reinforcement of quality goals. For example, time to first defibrillation attempt and CCF have both been shown to directly relate to clinical outcomes and are discrete metrics with clear meaning and opportunities for tracking over months or years. Over time, lessons learned from both a system-wide evaluation of performance and individual performance of teams from debriefing can provide invaluable objective feedback to systems to pinpoint opportunities for targeted training. The delivery of these messages needs to be consistent with the culture of the organization.

A number of large data collection initiatives have enriched clinical resuscitation science and represent opportunities to improve CQI processes. Similarly, the integration of local CQI processes, policies, and education through registries and national databases helps determine and drive regional, national, and global agendas (Figure 2). Get With The Guidelines-Resuscitation is an AHA-sponsored registry representing >250 000 in-hospital cardiac arrest events. The Cardiac Arrest Registry to Enhance Survival (CARES), established by the Centers for Disease Control and Prevention, collects national data on out-of-hospital cardiac arrest. The ROC has developed Epistry, a large database of out-of-hospital cardiac arrest events, which includes granular CPR quality metrics. A consortium of the European Resuscitation Council has created EuReCa (European Cardiac Arrest Registry), a multinational, multicultural database for out-of-hospital cardiac arrest. The value of these registries has been demonstrated by numerous research studies using registry data to identify variability in survival, development of standardized mortality ratios for comparing healthcare settings, and specific resuscitation quality deficiencies. In addition, a recent study has suggested that longer participation by hospitals in Get With The Guidelines-Resuscitation is associated with improvements in rates of survival from in-hospital cardiac arrest over time.[165] Hospitals and EMS systems are strongly encouraged to participate in these collaborative registry programs. The costs of participation are modest and the potential benefits large. Not taking advantage of these mechanisms for data collection and benchmarking means that improved quality of care and survival will remain elusive.

Many existing obstacles to a systematic improvement in CPR quality are related to ease of data capture from monitoring systems for systematic review. Currently, most monitors capable of measuring mechanical parameters of CPR provide feedback to optimize performance during cardiac arrest, and some may provide for event review immediately afterward, but none readily lend themselves to systems review. In current practice, for example, most CPR-recording defibrillators require a manual downloading process. A number of challenges remain for CQI tools that are not limited to integration of these data into workflow and processing. Although many devices now exist to capture CPR quality metrics, robust wireless methods to transmit these data need to be less expensive and more widespread. To make CPR quality data collection routine, these processes need to be much more effortless. We

Table 3. Future Directions Needed to Improve CPR Quality: Research and Development

Research
• To determine the optimal targets for CPR characteristics (CCF, compression rate and depth, lean, and ventilation), as well as their relative importance to patient outcome
• To determine the effect of a victim's age and cause of arrest on optimal CPR characteristics (especially initiation and method of ventilation)
• To further characterize the relationships between individual CPR characteristics
• To further characterize which CPR characteristics and relationships between them are time dependent
• To determine the impact of the variability during the arrest of CPR characteristics (especially CCF and depth) on patient outcome
• To clarify whether ventilation characteristics (time-, pressure-, volume-based parameters) during CPR impact patient outcome
• To determine optimal titration of hemodynamic and $ETCO_2$ monitoring during human CPR
• To determine whether $ETCO_2$ monitoring of a noninvasive airway is a reliable and useful monitor of CPR quality
• To determine optimal relationship between preshock CPR characteristics (ie, depth, pause) and ROSC/survival
• To determine the optimal number of rescuers and the effect of rescuer characteristics on CPR quality and patient outcome
• To further characterize the impact of provider fatigue and recovery on patient outcome
• To determine the impact of work environment, training environment, and provider characteristics on CPR performance and patient survival
• To clarify methods of integration of CPR training into advanced courses and continuing maintenance of competency
• To determine the method of education, as well as its timing and location, at a system level to ensure optimal CPR performance and patient outcome
• To develop a global CPR metric that can be used to measure and optimize educational and systems improvement processes
Development
• To standardize the reporting of CPR quality and the integration of these data with existing systems improvement processes and registries
• To develop a device with the ability to measure and monitor CPR quality during training and delivered in real events and integrate it with existing quality improvement and registries
• To develop optimal CPR systems improvement processes that provide reliable, automated reporting of CPR quality parameters with the capacity for continuous CPR quality monitoring in all healthcare systems
• To develop feedback technology that prioritizes feedback in an optimal manner (eg, correct weighting and prioritization of the CPR characteristics themselves)
• To develop a more reliable, inexpensive, noninvasive physiological monitor that will increase our ability to optimize CPR for individual victims of cardiac arrest
• To develop training equipment that provides rescuers with robust skills to readily and reliably provide quality CPR
• To develop improved mechanical systems of monitoring CPR, including consistent and reliable capture of ventilation rate, tidal volume, inspiratory pressure, and duration, as well as complete chest recoil

CCF indicates chest compression fraction; CPR, cardiopulmonary resuscitation; and ROSC, return of spontaneous circulation.

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encourage manufacturers to work with systems to develop seamless means of collecting, transmitting, and compiling resuscitation quality data and linking them to registries to improve future training and survival from cardiac arrest.

Conclusions

As the science of CPR evolves, we have a tremendous opportunity to improve CPR performance during resuscitation events both inside and outside the hospital. Through better measurement, training, and systems-improvement processes of CPR quality, we can have a significant impact on survival from cardiac arrest and eliminate the gap between current and optimal outcomes. To achieve this goal, the expert panel proposes 5 recommendations (Table 2), as well as future directions to close existing gaps in knowledge.

Future Directions

The expert panel expressed full consensus that there is a significant need to improve the monitoring and quality of CPR in all settings. Although there is a much better understanding of CPR, several critical knowledge gaps currently impede the implementation and widespread dissemination of high-quality CPR (Table 3). Research focused on these knowledge gaps will provide the information necessary to advance the delivery of optimal CPR and ultimately save more lives. Additionally, we encourage key stakeholders such as professional societies, manufacturers, and appropriate government agencies to work with systems to develop seamless means of collecting and compiling resuscitation quality data and to link them to registries to improve future training and rates of survival from cardiac arrest.

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Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Peter A. Meaney	The University of Pennsylvania	None	None	None	None	None	Expert witness: Serve as medical expert reviewer for medical issues not pertaining to CPR*
Bentley J. Bobrow	University of Arizona; Arizona Department of Health Services; Maricopa Medical Center	Principal Investigator for institutional grant to the University of Arizona from Medtronic Foundation for implementing statewide system of cardiac care†; NIH funding to study traumatic brain injury: 1R01NS071049-01A1 (Adults) 3R01NS071049-S1 (EPIC4Kids)†	None	None	None	None	None
Benjamin S. Abella	University of Pennsylvania	Medtronic Foundation: project on cardiac arrest outcomes; payment to institution†; Doris Duke Foundation: project on postresuscitation injury; payment to institution†; NIH NHLBI R18: project on CPR training of lay public; payment to institution†; Philips Healthcare: project on CPR hemodynamics and quality; payment to institution†; Stryker Medical: postarrest care; payment to institution†	None	Medivance: honoraria for lectures pertaining to hypothermia after arrest*	Resuscor, a company focused on healthcare provider education in resuscitation science: ownership stake*	HeartSine Corp: advisory board role to evaluate AED development*; Velomedix Corp: postarrest care*	None
Tom P. Aufderheide	Medical College of Wisconsin	NHLBI: Resuscitation Outcomes Consortium; money comes to institution, not to me directly†; NHLBI: Immediate Trial; money comes to institution†; NHLBI: ResQTrial; money comes to institution†; NINDS: Neurological Emergency Treatment Trials (NETT) Network; money comes to institution†	Zoll Medical: software provided directly from Zoll Medical to Milwaukee County Emergency Medical Services to complete research trials for the Resuscitation Outcomes Consortium and Immediate Trials†	None	None	President, Citizen CPR Foundation (volunteer)*; Secretary, Take Heart America (volunteer)*; Medtronic paid consultant; consultant on an acute MI trial; money went to my institution; discontinued consultant position November 2010*	National American Heart Association volunteer on Basic Life Support Subcommittee and Research Working Group*; As a member of the Institute of Medicine (IOM) and a member of the AHA Research Working Group, works with both institutions to generate funding for an IOM report on cardiac arrest (volunteer)*

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Jim Christenson	University of British Columbia, Faculty of Medicine	Resuscitation Outcomes Consortium group grant funded until 2016 on CPR quality; has published a paper on chest compression fraction and its relationship to survival and is coauthor on several papers evaluating various potential aspects of CPR quality†	None	None	None	None	None
Allan R. de Caen	Self-employed	None	None	None	None	None	None
Dana P. Edelson	University of Chicago	Philips Healthcare: funds paid to institution for projects on CPR quality and hemodynamics; Laerdal Medical: funds paid to institution for piloting new Basic Life Support training†; NIH NHLBI: funds paid to institution for strategies to prevent and predict in-hospital cardiac arrests†	None	None	Quant HC: Develops products for risk stratification of hospitalized patients†	CARES Advisory Council: Member*; Sudden Cardiac Arrest Foundation Board of Directors: Member*; FIERCE Certification Advisory Council: Member*	
Monica E. Kleinman	Children's Hospital Anesthesia Foundation	None	None	None	None	None	Expert witness: Review of medical-legal cases on behalf of defendants*
Marion Leary	University of Pennsylvania	None	None	Speaking honoraria a few years ago from Philips Healthcare*	None	Have reviewed devices for Philips Healthcare and Laerdal surrounding CPR quality devices, neither for any money*	Philips Healthcare has given research group QCPR devices to use for research*

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Venu Menon	Cleveland Clinic	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 (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) 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

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Gavin Perkins	Warwick Medical School and Heart of England NHS Foundation Trust, United Kingdom	NIH (money paid to institution)†	None	None	None	None	None	None
Elizabeth H. Sinz	Penn State Hershey Medical Center	None	None	None	None	None	None	AHA, Associate Science Editor (money paid to institution)†
Kjetil Sunde	University of Oslo, Norway	None	None	None	None	None	None	None

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†Significant.

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CPR Quality: Improving Cardiac Resuscitation Outcomes Both Inside and Outside the Hospital: A Consensus Statement From the American Heart Association

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