2005 INTERNATIONAL CONSENSUS ON CARDIOPULMONARY RESUSCITATION (CPR) AND EMERGENCY CARDIOVASCULAR CARE (ECC) SCIENCE WITH TREATMENT RECOMMENDATIONS

DOI: 10.1161/CIRCULATIONAHA.105.170658
Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 75231
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Part 1: Introduction

Toward International Consensus on Science
The International Liaison Committee on Resuscitation (ILCOR) was formed in 1993. Its mission is to identify and review international science and knowledge relevant to cardiopulmonary resuscitation (CPR) and emergency cardiovascular care (ECC) and to offer consensus on treatment recommendations. Emergency cardiovascular care includes all responses necessary to treat sudden life-threatening events affecting the cardiovascular and respiratory systems but with a particular focus on sudden cardiac arrest.

In 1999 the American Heart Association (AHA) hosted the first ILCOR conference to evaluate resuscitation science and develop common resuscitation guidelines. The conference recommendations were published in the international Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care.2–3 Since that time researchers from the ILCOR member councils have continued to evaluate resuscitation science in a process that culminated in the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care With Treatment Recommendations (2005 Consensus Conference). This publication summarizes the conclusions and recommendations of that evidence evaluation process.

The goal of every resuscitation organization and resuscitation expert is to prevent premature cardiovascular death. When cardiac arrest or life-threatening emergencies occur, prompt and skillful response can make the difference between life and death and between intact survival and debilitation. This document summarizes current evidence for the recognition and response to sudden life-threatening events, particularly sudden cardiac arrest in victims of all ages. The broad range and number of topics reviewed and the inevitable limitations of journal space require succinctness in science statements and, where recommendations were appropriate, brevity in treatment recommendations. This is not a comprehensive review of every aspect of resuscitation medicine; some topics were omitted if there was no evidence or no new information.

Evidence Evaluation Process
To begin the current evidence evaluation process, ILCOR representatives established 6 task forces: basic life support, advanced life support, acute coronary syndromes, pediatric life support, neonatal life support, and an interdisciplinary task force to consider overlapping topics such as educational issues. Each task force identified topics requiring evidence evaluation and appointed international experts to review them. To ensure a consistent and thorough approach, a worksheet template was created with step-by-step directions to help the experts document their literature review (Table 1), evaluate studies, determine levels of evidence (Table 2), and develop treatment recommendations. When possible, 2 expert reviewers were recruited to undertake independent evaluations for each topic. In addition, 2 evidence evaluation experts reviewed all worksheets and assisted the worksheet reviewers to ensure that the worksheets met a consistently high standard. This process is described in detail in an editorial in this supplement.4 Two additional task forces were established by the AHA to review evidence about stroke and first aid. These topics were included in the 2005 Consensus Conference and are summarized in this document, but they were not part of the ILCOR process.

A total of 281 experts completed 403 worksheets on 276 topics. Two hundred and forty-nine worksheet authors (141 from the United States and 108 from 17 other countries) attended the 2005 Consensus Conference. In December 2004 the evidence review and summary portions of the evidence evaluation worksheets, with worksheet author conflict of interest statements, were posted on the Internet at http://www.C2005.org. Journal advertisements and e-mails invited public comment. Persons who submitted comments were required to indicate their potential conflicts of interest. Such comments were sent to the appropriate ILCOR task force chair and worksheet author for consideration.

To provide the widest possible dissemination of the science reviews performed for the 2005 Consensus Conference, the worksheets prepared for the conference are linked from the electronic version of this document. Worksheet numbers begin with W to distinguish them from other reference citations. Most worksheet numbers follow headings. Readers of the electronic version of this supplement can access a cited worksheet by clicking on the W# callout, which will take them to the correct “reference” in the Worksheets Cited list at the end of each section. That reference contains an active link to the worksheet. Readers of the print version can identify the complete title and author of a cited worksheet by referring to the numbered worksheet list in Appendix 1 at the end of this supplement. Readers can access the worksheets through the American Heart Association website http://www.C2005.org. Note that any incomplete worksheets have been deleted from the worksheet list and will not be cited in this document.

All 380 participants at the 2005 Consensus Conference received a copy of the worksheets on CD-ROM. Internet
resuscitation medicine. Several papers that were accepted for publication in a peer-reviewed journal before the 2005 Consensus Conference but had not yet been published were circulated, with the permission of the relevant journal editors, to the ILCOR task forces. These papers contributed to the consensus statements.

This manuscript was ultimately approved by all ILCOR member organizations and by an international editorial board (listed on the title page of this supplement). The AHA Science Advisory and Coordinating Committee and the editor of Circulation obtained peer reviews of this document before it was accepted for publication. The document is being published simultaneously in Circulation and Resuscitation, although the version in Resuscitation does not include the sections on stroke and first aid.

Management of Conflict of Interest
The world’s leading experts in resuscitation science establish their expertise by undertaking and publishing research and related scholarly work (eg, presentation of research abstracts and participation in scientific conferences). This work potentially creates financial and intellectual conflicts of interest (COI) for the expert.5,6 Grants and other support for scientific research, speaker fees, and honoraria can also create financial conflicts of interest. Nonfinancial conflicts of interest include in-kind support, intellectual collaboration or intellectual investment in personal ideas, and long-term research agendas in which investigators have invested a substantial amount of time. A robust COI policy was developed to ensure full disclosure of potential conflicts and to protect the objectivity and credibility of the evidence evaluation and consensus development process. This policy is described in detail in an editorial in this supplement.7 Representatives of manufacturers and industry did not participate in this conference.

Potential conflicts of interest of the editorial board are listed in Appendix 3 at the end of this supplement. Potential conflicts of interest of the worksheet authors are noted in the worksheets and can be accessed through the links to the worksheets contained in this document. All 380 attendees were required to complete forms in order to document their potential conflicts of interest. Most attendees were also worksheet authors. The information from the conflict of interest forms completed by all conference attendees, including worksheet authors, can also be accessed at the website http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.105.166471/DC1. Readers of the print version can also access the statements at the AHA website: www.C2005.org.

Applying Science to Improve Survival
From Consensus on Science to Guidelines
This document presents international consensus statements on the science of resuscitation and, wherever possible, treatment recommendations. ILCOR member organizations will subsequently publish resuscitation guidelines that are consistent with the science in this consensus document, but they will also take into account geographic, economic, and system differences in practice and the availability of medical devices and drugs. All ILCOR member organizations strive to mini-
mize international differences in resuscitation practice and to optimize the effectiveness of instructional methods, teaching aids, and training networks.

The recommendations of the 2005 Consensus Conference confirm the safety and effectiveness of some current approaches, acknowledge that other approaches may not be optimal, and introduce new treatments resulting from evidence-based evaluation. New and revised treatment recommendations do not imply that clinical care that involves the use of previously published guidelines is unsafe. ILCOR scientists and member organizations consider these new recommendations to be the most effective and easily learned interventions that can be supported by current knowledge, research, and experience. Implications for education and retention were also considered when developing the final treatment recommendations.

Ischemic heart disease is the leading cause of death in the world. Sudden cardiac arrest is responsible for >60% of the estimated 340,000 annual deaths from coronary heart disease in emergency departments or out-of-hospital in the United States. Most victims die out of hospital without receiving the interventions described in this publication. The actions linking the victim of sudden cardiac arrest with survival are called the adult Chain of Survival. The links in the Chain of Survival are early recognition of the emergency and activation of the emergency medical services (EMS) system, early CPR, early defibrillation, and early advanced life support, including postresuscitation care. The links in the infant and child Chain of Survival are prevention of conditions leading to cardiopulmonary arrest, early CPR, early activation of the EMS system, and early advanced life support.

The most important determinant of survival from sudden cardiac arrest is the presence of a trained rescuer who is ready, willing, able, and equipped to act. Although some advanced life support techniques may improve survival, these improvements are usually less significant than the increased survival rates reported by lay rescuer CPR and automated external defibrillation programs in the community. Thus, our greatest challenge remains the education of the lay rescuer. We must increase the effectiveness and efficiency of instruction, improve skills retention, and reduce barriers to action for both basic and advanced life support providers. The science of resuscitation education is addressed in this publication.

The Universal Algorithm
Several of the new treatment recommendations to emerge from this document are included in the updated ILCOR Universal Cardiac Arrest Algorithm (Figure). This algorithm is intended to apply to attempted resuscitation of infant, child, and adult victims of cardiac arrest (excluding newborns). Every effort has been made to keep this algorithm simple yet make it applicable to cardiac arrest victims of all ages and in most circumstances. Inevitably modification will be required.
in some situations, and these exceptions are highlighted elsewhere in this document. Each resuscitation organization will base its guidelines on this ILCOR algorithm, although there will be subtle regional modifications.

Rescuers begin CPR if the victim is unconscious or unresponsive, not moving, and not breathing (ignoring occasional gasps). A single compression-ventilation ratio of 30:2 is used for the single rescuer of an infant, child, or adult victim (excluding newborns); this applies for the lay rescuer and for all adult CPR. This single ratio is designed to simplify teaching, promote skills retention, increase the number of compressions given, and decrease interruption to compressions.

Once a defibrillator is attached, if a “shockable” rhythm (ie, ventricular fibrillation or rapid ventricular tachycardia) is confirmed, a single shock is delivered. Irrespective of the resultant rhythm, chest compressions and ventilations (5 cycles of 30:2—approximately 2 minutes) are resumed immediately after the shock to minimize the “no flow” time (ie, time during which compressions are not delivered for actions such as rhythm analysis). Advanced life support interventions are outlined in a box at the center of the algorithm. Once an advanced airway (eg, tracheal tube, laryngeal mask airway [LMA] or esophageal-tracheal combitube) has been inserted during 2-rescuer CPR, one rescuer should provide 8 to 10 ventilations/min while the other delivers 100 compressions/min. The rescuer performing the chest compressions should not pause chest compressions for delivery of ventilations. The theme of minimal interruption of chest compressions is emphasized throughout this document; recent evidence indicates that such interruptions occur frequently both in and out of hospital.18–20 Interruptions in chest compressions during CPR must be minimized.

**Future Directions**

The science of resuscitation is evolving rapidly. It would not be in the best interests of patients if we waited 5 or more years to inform healthcare professionals of therapeutic advances in this field. ILCOR members will continue to review new science and, when necessary, publish interim advisory statements to update treatment guidelines so that resuscitation practitioners may provide state-of-the-art treatment. Existing gaps in our knowledge will be closed only by continuing high-quality research into all facets of CPR.

**References**


Part 2: Adult Basic Life Support

The consensus conference addressed many questions related to the performance of basic life support. These have been grouped into (1) epidemiology and recognition of cardiac arrest, (2) airway and ventilation, (3) chest compression, (4) compression-ventilation sequence, (5) postresuscitation positioning, (6) special circumstances, (7) emergency medical services (EMS) system, and (8) risks to the victim and rescuer. Defibrillation is discussed separately in Part 3 because it is both a basic and an advanced life support skill.

There have been several important advances in the science of resuscitation since the last ILCOR review in 2000. The following is a summary of the evidence-based recommendations for the performance of basic life support:

- Rescuers begin CPR if the victim is unconscious, not moving, and not breathing (ignoring occasional gasps).
- For mouth-to-mouth ventilation or for bag-valve–mask ventilation with room air or oxygen, the rescuer should deliver each breath in 1 second and should see visible chest rise.
- Increased emphasis on the process of CPR: push hard at a rate of 100 compressions per minute, allow full chest recoil, and minimize interruptions in chest compressions.
- For the single rescuer of an infant (except newborns), child, or adult victim, use a single compression-ventilation ratio of 30:2 to simplify teaching, promote skills retention, increase the number of compressions given, and decrease interruptions in compressions. During 2-rescuer CPR of the infant or child, healthcare providers should use a 15:2 compression-ventilation ratio.
- During CPR for a patient with an advanced airway (ie, tracheal tube, esophageal-tracheal combitube [Combitube], laryngeal mask airway [LMA]) in place, deliver ventilations at a rate of 8 to 10 per minute for infants (excepting neonates), children and adults, without pausing during chest compressions to deliver the ventilations.

Epidemiology

Incidence

Consensus on Science
Approximately 400,000 to 460,000 people in the United States (LOE 5) and 700,000 people in Europe (LOE 7) experience SCA each year; resuscitation is attempted in approximately two thirds of these victims. Case series and cohort studies showed wide variation in the incidence of cardiac arrest, depending on the method of assessment:

- 1.5 per 1000 person-years based on death certificates (LOE 5)
- 0.5 per 1000 person-years based on activation of emergency medical services (EMS) systems (LOE 5)

In recent years the incidence of ventricular fibrillation (VF) at first rhythm analysis has declined significantly.

Prognosis

Consensus on Science
Since the previous international evidence evaluation process (the International Guidelines 2000 Conference on CPR and ECC), there have been 3 systematic reviews of survival-to-hospital discharge from out-of-hospital cardiac arrest (LOE 5). Of all victims of cardiac arrest treated by EMS providers, 5% to 10% survive; of those with VF, 15% survive to hospital discharge. In data from a national registry, survival to discharge from in-hospital cardiac arrest was 17% (LOE 5). The etiology and presentation of in-hospital arrest differ from that of out-of-hospital arrests.

Risk of cardiac arrest is influenced by several factors, including demographic, genetic, behavioral, dietary, clinical, anatomic, and treatment characteristics (LOE 4 to 7). Recognition

Early recognition is a key step in the early treatment of cardiac arrest. It is important to determine the most accurate method of diagnosing cardiac arrest.

Signs of Cardiac Arrest

Consensus on Science
Checking the carotid pulse is an inaccurate method of confirming the presence or absence of circulation (LOE 3); however, there is no evidence that checking for movement, breathing, or coughing (ie, "signs of circulation") is diagnos-
Airway and Ventilation

The best method of obtaining an open airway and the optimum frequency and volume of artificial ventilation were reviewed.

Airway

Opening the Airway

Consensus on Science
Five prospective clinical studies evaluating clinical (LOE 3)25,26 or radiologic (LOE 3)27–29 measures of airway patency and one case series (LOE 5)30 showed that the head tilt–chin lift maneuver is feasible, safe, and effective. No studies have evaluated the routine use of the finger sweep maneuver to clear an airway in the absence of obvious airway obstruction.

Treatment Recommendation
Rescuers should open the airway using the head tilt–chin lift maneuver. Rescuers should use the finger sweep in the unconscious patient with a suspected airway obstruction only if solid material is visible in the oropharynx.

Devices for Airway Positioning

Consensus on Science
There is no published evidence on the effectiveness of devices for airway positioning. Collars that are used to stabilize the cervical spine can make airway management difficult and increase intracranial pressure (LOE 4)31–33; LOE 5).34

Foreign-Body Airway Obstruction

Like CPR, relief of foreign-body airway obstruction (FBAO) is an urgent procedure that should be taught to laypersons. Evidence for the safest, most effective, and simplest methods was sought.

Consensus on Science
It is unclear which method of removal of FBAO should be used first. For conscious victims, case reports showed success in relieving FBAO with back blows/slaps (LOE 5),35–37 abdominal thrusts (LOE 5),36–44 and chest thrusts (LOE 5).36 Frequently more than one technique was needed to achieve relief of the obstruction.36,45–50 Life-threatening complications have been associated with the use of abdominal thrusts (LOE 5).48,51–72

For unconscious victims, case reports showed success in relieving FBAO with chest thrusts (LOE 5)49 and abdominal thrusts (LOE 5).73 One randomized trial of maneuvers to clear the airway in cadavers (LOE 7)74 and 2 prospective studies in anesthetized volunteers (LOE 7)75,76 showed that higher airway pressures can be generated by using the chest thrust rather than the abdominal thrust.

Case series (LOE 5)68,77,84 reported the finger sweep as effective for relieving FBAO in unconscious adults and children aged >1 year. Four case reports documented harm to the victim’s mouth (LOE 7)77,78 or biting of the rescuer’s finger (LOE 7).29,30

Treatment Recommendation
Chest thrusts, back blows/slaps, or abdominal thrusts are effective for relieving FBAO in conscious adults and children >1 year of age, although injuries have been reported with the abdominal thrust. There is insufficient evidence to determine which should be used first. These techniques should be applied in rapid sequence until the obstruction is relieved; more than one technique may be needed. Unconscious victims should receive CPR. The finger sweep should be used in the unconscious patient with an obstructed airway only if solid material is visible in the airway. There is insufficient evidence for a treatment recommendation for an obese or pregnant patient with FBAO.

Ventilation

Mouth-to-Nose Ventilation

Consensus on Science
A case series suggested that mouth-to-nose ventilation of adults is feasible, safe, and effective (LOE 5).79

Treatment Recommendation
Mouth-to-nose ventilation is an acceptable alternative to mouth-to-mouth ventilation.

Mouth-to-Tracheal Stoma Ventilation

Consensus on Science
There was no published evidence of the safety or effectiveness of mouth-to-stoma ventilation. A single crossover study of patients with laryngectomies showed that a pediatric face mask provided a better seal around the stoma than a standard ventilation mask (LOE 4).80

Treatment Recommendation
It is reasonable to perform mouth-to-stoma breathing or to use a well-sealing, round pediatric face mask.

Tidal Volumes and Ventilation Rates

Consensus on Science
There was insufficient evidence to determine how many initial breaths should be given. Manikin studies (LOE 6)81–83 and one human study (LOE 7)84 showed that when there is no advanced airway (such as a tracheal tube, Combitube, or LMA) in place, a tidal volume of 1 L produced significantly more gastric inflation than a tidal volume of 500 mL. Studies of anesthetized patients with no advanced airway in place showed that ventilation with 455 mL of room air was associated with an acceptable but significantly reduced oxygen saturation when compared with 719 mL (LOE 7).85 There was no difference in oxygen saturation with volumes of
624 mL and 719 mL (LOE 7). A study of cardiac arrest patients compared tidal volumes of 500 versus 1000 mL delivered to patients with advanced airways during mechanical ventilation with 100% oxygen at a rate of 12/min (LOE 2). Smaller tidal volumes were associated with higher arterial PCO2 and worse acidosis but no differences in PaO2.

Reports containing both a small case series (LOE 5) and an animal study (LOE 6) showed that hyperventilation is associated with increased intrathoracic pressure, decreased coronary and cerebral perfusion, and, in animals, decreased return of spontaneous circulation (ROSC). In a secondary analysis of the case series that included patients with advanced airways in place after out-of-hospital cardiac arrest, ventilation rates of >10 per minute and inspiration times >1 second were associated with no survival (LOE 5). Extrapolation from an animal model of severe shock suggests that a ventilation rate of 6 ventilations per minute is associated with adequate oxygenation and better hemodynamics than ≥12 ventilations per minute (LOE 6). In summary, larger tidal volumes and ventilation rates can be associated with complications, whereas the detrimental effects observed with smaller tidal volumes appear to be acceptable.

Treatment Recommendation
For mouth-to-mouth ventilation with exhaled air or bag-valve–mask ventilation with room air or oxygen, it is reasonable to give each breath within a 1-second inspiratory time to achieve chest rise. After an advanced airway (e.g., tracheal tube, Combitube, LMA) is placed, ventilate the patient’s lungs with supplementary oxygen to make the chest rise. During CPR for a patient with an advanced airway in place, it is reasonable to ventilate the lungs at a rate of 8 to 10 ventilations per minute without pausing during chest compressions to deliver ventilations. Use the same initial tidal volume and rate in patients regardless of the cause of the cardiac arrest.

Mechanical Ventilators and Automatic Transport Ventilators

Consensus on Science
Three manikin studies of simulated cardiac arrest showed a significant decrease in gastric inflation with manually triggered, flow-limited, oxygen-powered resuscitators when compared with ventilation by bag-valve mask (LOE 6). One study showed that firefighters who ventilated anesthetized patients with no advanced airway in place produced less gastric inflation and lower peak airway pressure with manually triggered, flow-limited, oxygen-powered resuscitators than with a bag-valve mask (LOE 5). A prospective cohort study of intubated patients, most in cardiac arrest, in an out-of-hospital setting showed no significant difference in arterial blood gas parameters between those ventilated with an automatic transport ventilator and those ventilated manually (LOE 4). Two laboratory studies showed that automatic transport ventilators can provide safe and effective management of mask ventilation during CPR of adult patients (LOE 6).

Treatment Recommendation
There is insufficient data to recommend for or against the use of a manually triggered, flow-limited resuscitator or an automatic transport ventilator during bag-valve–mask ventilation and resuscitation of adults in cardiac arrest.

Chest Compressions
Several components of chest compressions can alter effectiveness: hand position, position of the rescuer, position of the victim, depth and rate of compression, decompression, and duty cycle (see definition, below). Evidence for these techniques was reviewed in an attempt to define the optimal method.

Chest Compression Technique

Hand Position

Consensus on Science
There was insufficient evidence for or against a specific hand position for chest compressions during CPR in adults. In children who require CPR, compression of the lower one third of the sternum may generate a higher blood pressure than compressions in the middle of the chest (LOE 4). Manikin studies in healthcare professionals showed improved quality of chest compressions when the dominant hand was in contact with the sternum (LOE 6). There were shorter pauses between ventilations and compressions if the hands were simply positioned “in the center of the chest” (LOE 6). Treatment Recommendation
It is reasonable for laypeople and healthcare professionals to be taught to position the heel of their dominant hand in the center of the chest of an adult victim, with the nondominant hand on top.

Chest Compression Rate, Depth, Decompression, and Duty Cycle

Consensus on Science
Rate. The number of compressions delivered per minute is determined by the compression rate, the compression-ventilation ratio, the time required to provide mouth-to-mouth or bag-valve–mask ventilation, and the strength (or fatigue) of the rescuer. Observational studies showed that responders give fewer compressions than currently recommended (LOE 5). Some studies in animal models of cardiac arrest showed that high-frequency CPR (120 to 150 compressions per minute) improved hemodynamics without increasing trauma when compared with standard CPR (LOE 6), whereas others showed no effect (LOE 6). Some studies in animals showed more effect from other variables, such as duty cycle (see below). In humans, high-frequency CPR (120 compressions per minute) improved hemodynamics over standard CPR (LOE 4). In mechanical CPR in humans, however, high-frequency CPR (up to 140 compressions per minute) showed no improvement in hemodynamics when compared with 60 compressions per minute (LOE 5).
**Depth.** In both out-of-hospital\textsuperscript{102} and in-hospital\textsuperscript{100} studies, insufficient depth of compression was observed during CPR when compared with currently recommended depths (LOE 5).\textsuperscript{100,102} Studies in animal models of adult cardiac arrest showed that deeper compressions (ie, 3 to 4 inches) are correlated with improved ROSC and 24-hour neurologic outcome when compared with standard-depth compressions (LOE 6).\textsuperscript{107,113,114} A manikin study of rescuer CPR showed that compressions became shallow within 1 minute, but providers became aware of fatigue only after 5 minutes (LOE 6).\textsuperscript{115}

**Decompression.** One observational study in humans (LOE 5)\textsuperscript{88} and one manikin study (LOE 6)\textsuperscript{116} showed that incomplete chest recoil was common during CPR. In one animal study incomplete chest recoil was associated with significantly increased intrathoracic pressure, decreased venous return, and decreased coronary and cerebral perfusion during CPR (LOE 6).\textsuperscript{117} In a manikin study, lifting the hand slightly between compression and release, and decreased coronary and cerebral perfusion during CPR. In one animal study incomplete chest recoil was common during CPR. In one animal study incomplete chest recoil was associated with significantly increased intrathoracic pressure, decreased venous return, and decreased coronary and cerebral perfusion during CPR (LOE 6).\textsuperscript{117} In a manikin study, lifting the hand slightly but completely off the chest during decompression allowed full chest recoil (LOE 6).\textsuperscript{116}

**Duty Cycle.** The term *duty cycle* refers to the time spent compressing the chest as a proportion of the time between the start of one cycle of compression and the start of the next. Coronary blood flow is determined partly by the duty cycle (reduced coronary perfusion with a duty cycle >50%) and partly by how fully the chest is relaxed at the end of each compression (LOE 6).\textsuperscript{118} One animal study that compared duty cycles of 20% with 50% during cardiac arrest chest compressions showed no statistical difference in neurologic outcome at 24 hours (LOE 6).\textsuperscript{109} A mathematical model of mechanical CPR showed significant improvements in pulmonary, coronary, and carotid flow with a 50% duty cycle when compared with compression-relaxation cycles in which compressions constitute a greater percentage of the cycle (LOE 6).\textsuperscript{119} At duty cycles ranging between 20% and 50%, coronary and cerebral perfusion in animal models increased with chest compression rates of up to 130 to 150 compressions per minute (LOE 6).\textsuperscript{104,105,109} In a manikin study, duty cycle was independent of the compression rate when rescuers increased progressively from 40 to 100 compressions per minute (LOE 6).\textsuperscript{120} A duty cycle of 50% is mechanically easier to achieve with practice than cycles in which compressions constitute a smaller percentage of cycle time (LOE 7).\textsuperscript{121}

**Treatment Recommendation**

It is reasonable for lay rescuers and healthcare providers to perform chest compressions for adults at a rate of at least 100 compressions per minute and to compress the sternum by at least 4 to 5 cm (1\textfrac{1}{2} to 2 inches). Rescuers should allow complete recoil of the chest after each compression. When feasible, rescuers should frequently alternate “compressor” duties, regardless of whether they feel fatigued, to ensure that fatigue does not interfere with delivery of adequate chest compressions. It is reasonable to use a duty cycle (ie, ratio between compression and release) of 50%.

**Firm Surface for Chest Compressions**\textsuperscript{W167A}

**Consensus on Science**

When manikins were placed on a bed supported by a pressure-relieving mattress, chest compressions were less effective than those performed when the manikins were placed on the floor. Emergency deflation of the mattress did not improve the efficacy of chest compressions (LOE 6).\textsuperscript{122,123} These studies did not involve standard mattresses or backboards and did not consider the logistics of moving a victim from a bed to the floor.

**Treatment Recommendation**

Cardiac arrest victims should be placed supine on a firm surface (ie, backboard or floor) during chest compressions to optimize the effectiveness of compressions.

**CPR Process Versus Outcome**\textsuperscript{W182A,W182B,W194}

**Consensus on Science**

CPR compression rate and depth provided by lay responders (LOE 5),\textsuperscript{124} physician trainees (LOE 5),\textsuperscript{109} and EMS personnel (LOE 5)\textsuperscript{102} were insufficient when compared with currently recommended methods. Ventilation rates and durations higher or longer than recommended when CPR is performed impaired hemodynamics and reduced survival rates (LOE 6).\textsuperscript{88} It is likely that poor performance of CPR impairs hemodynamics and possibly survival rates.

**Treatment Recommendation**

It is reasonable for instructors, trainees, providers, and EMS agencies to monitor and improve the process of CPR to ensure adherence to recommended compression and ventilation rates and depths.

**Alternative Compression Techniques**

**CPR in Prone Position**\textsuperscript{W166D}

**Consensus on Science**

Six case series that included 22 intubated hospitalized patients documented survival to discharge in 10 patients who received CPR in a prone position (LOE 5).\textsuperscript{125–130}

**Treatment Recommendation**

CPR with the patient in a prone position is a reasonable alternative for intubated hospitalized patients who cannot be placed in the supine position.

**Leg-Foot Chest Compressions**\textsuperscript{W166C}

**Consensus on Science**

Three studies in manikins showed no difference in chest compression depth or rate when leg-foot compressions were used instead of standard chest compressions (LOE 6).\textsuperscript{131–133} Two studies\textsuperscript{132,133} reported that rescuers felt fatigue and leg soreness when using leg-foot chest compressions. One study\textsuperscript{132} reported incomplete chest recoil when leg-foot chest compressions were used.

**“Cough” CPR**\textsuperscript{W166A}

**Consensus on Science**

Case series (LOE 5)\textsuperscript{134–136} show that repeated coughing every 1 to 3 seconds during episodes of rapid VF in supine,
monitored, trained patients in the cardiac catheterization laboratory can maintain a mean arterial pressure >100 mm Hg and maintain consciousness for up to 90 seconds. No data support the usefulness of cough CPR in any other setting, and there is no specific evidence for or against use of cough CPR by laypersons in unsupervised settings.

**Compression-Ventilation Sequence**

Any recommendation for a specific CPR compression-ventilation ratio represents a compromise between the need to generate blood flow and the need to supply oxygen to the lungs. At the same time any such ratio must be taught to would-be rescuers, so that skills acquisition and retention are also important factors.

**Effect of Ventilations on Compressions**

**Interruption of Compressions**

**Consensus on Science**

In animal studies interruption of chest compressions is associated with reduced ROSC and survival as well as increased postresuscitation myocardial dysfunction (LOE 6). A theoretical analysis of the VF waveform, interruption of CPR was associated with a decreased probability of conversion of VF to another rhythm (LOE 5).

**Treatment Recommendation**

Rescuers should minimize interruptions of chest compressions.

**Compression-Ventilation Ratio During CPR**

**Consensus on Science**

An observational study showed that experienced paramedics performed ventilation at excessive rates on intubated patients during treatment for out-of-hospital cardiac arrest (LOE 5). An in-hospital study also showed delivery of excessive-rate ventilation to patients with and without advanced airways in place. Two animal studies showed that hyperventilation is associated with excessive intrathoracic pressure and decreased coronary and cerebral perfusion pressures and survival rates (LOE 6).

Observational studies in humans showed that responders gave fewer compressions than currently recommended (LOE 5).

Multiple animal studies of VF arrests showed that continuous chest compressions with minimal or no interruptions is associated with better hemodynamics and survival than standard CPR (LOE 6).

Results of varying compression-ventilation ratios in intubated animal models and even theoretical calculations have yielded mixed results. In one animal model of cardiac arrest, use of a compression-ventilation ratio of 100:2 was associated with significantly improved neurologic function at 24 hours when compared with a ratio of 15:2 or continuous-compression CPR, but there was no significant difference in perfusion pressures or survival rates (LOE 6).

In an animal model of cardiac arrest, use of a compression-ventilation ratio of 50:2 achieved a significantly greater number of chest compressions than using either 15:2 or 50:5. Carotid blood flow was significantly greater at a ratio of 50:2 compared with 50:5 and not significantly different from that achieved with a ratio of 15:2. Arterial oxygenation and oxygen delivery to the brain were significantly higher with a ratio of 15:2 when compared with a ratio of either 50:5 or 50:2. In an animal model of cardiac arrest, a compression-ventilation ratio of 30:2 was associated with significantly shorter time to ROSC and greater systemic and cerebral oxygenation than with continuous chest compressions (LOE 6).

A theoretical analysis suggests that a compression-ventilation ratio of 30:2 would provide the best blood flow and oxygen delivery.

An animal model of asphyxial arrest showed that compression-only CPR is associated with significantly greater pulmonary edema than both compression and ventilation, with or without oxygenation (LOE 6).

**Treatment Recommendation**

There is insufficient evidence that any specific compression-ventilation ratio is associated with improved outcome in patients with cardiac arrest. To increase the number of compressions given, minimize interruptions of chest compressions, and simplify instruction for teaching and skills retention, a single compression-ventilation ratio of 30:2 for the lone rescuer of an infant, child, or adult victim is recommended. Initial steps of resuscitation may include (1) opening the airway while verifying the need for resuscitation, (2) giving 2 to 5 breaths when initiating resuscitation, and (3) then providing compressions and ventilations using a compression-ventilation ratio of 30:2.

**Chest Compression–Only CPR**

**Consensus on Science**

No prospective studies have assessed the strategy of implementing chest compression–only CPR. A randomized trial of telephone instruction in CPR given to untrained lay responders in an EMS system with a short (mean: 4 minutes) response interval suggests that a strategy of teaching chest compressions alone is associated with similar survival rates when compared with a strategy of teaching chest compressions and ventilations (LOE 7).

Animal studies of nonasphyxial arrest demonstrate that chest compression–only CPR may be as efficacious as compression-ventilation CPR in the initial few minutes of resuscitation (LOE 6). In another model of nonasphyxial arrest, however, a compression-ventilation ratio of 30:2 maintained arterial oxygen content at two thirds of normal, but compression-only CPR was associated with desaturation within 2 minutes (LOE 6). In observational studies of adults with cardiac arrest treated by lay responders trained in standard CPR, survival was better with compression-only CPR than with no CPR but not as good as with both compressions and ventilations (LOE 3; LOE 4).

**Treatment Recommendation**

Rescuers should be encouraged to do compression-only CPR if they are unwilling to do airway and breathing maneuvers or...
if they are not trained in CPR or are uncertain how to do CPR. Researchers are encouraged to evaluate the efficacy of compression-only CPR.

**Postresuscitation Positioning**

**Recovery Position**

Consensus on Science

No studies were identified that evaluated any recovery position in an unconscious victim with normal breathing. A small cohort study (LOE 5)\(^{153}\) and a randomized trial (LOE 7)\(^{154}\) in normal volunteers showed that compression of vessels and nerves occurs infrequently in the dependent limb when the victim’s lower arm is placed in front of the body; however, the ease of turning the victim into this position may outweigh the risk (LOE 5)\(^{155,156}\).

**Treatment Recommendation**

It is reasonable to position an unconscious adult with normal breathing on the side with the lower arm in front of the body.

**Special Circumstances**

**Cervical Spine Injury**

For victims of suspected spinal injury, additional time may be needed for careful assessment of breathing and circulation, and it may be necessary to move the victim if he or she is found face-down. In-line spinal stabilization is an effective method of reducing risk of further spinal damage.

**Airway Opening**

Consensus on Science

The incidence of cervical spine injury after blunt trauma was 2.4% (LOE 5)\(^{157}\) but increased in patients with craniofacial injuries (LOE 4)\(^{158}\), a Glasgow Coma Scale score of <8 (LOE 4)\(^{159}\), or both (LOE 4)\(^{160}\). A large cohort study (LOE 4)\(^{161}\) showed that the following features are highly sensitive (94% to 97%) predictors of spinal injury when applied by professional rescuers: mechanism of injury, altered mental status, neurologic deficit, evidence of intoxication, spinal pain or tenderness, and distracting injuries (ie, injuries that distract the victim from awareness of cervical pain). Failure to stabilize an injured spine was associated with an increased risk of secondary neurologic injury (LOE 4)\(^{162,163}\). A case-control study of injured patients with and without stabilization showed that the risk of secondary injury may be lower than previously thought (LOE 4)\(^{164}\).

All airway maneuvers cause spinal movement (LOE 5)\(^{165}\). Studies in human cadavers showed that both chin lift (with or without head tilt) and jaw thrust were associated with similar, substantial movement of the cervical vertebrae (LOE 6)\(^{165-167}\), (LOE 7)\(^{168,169}\). Use of manual in-line stabilization (MILS)\(^{169}\) or spinal collars (LOE 6)\(^{165}\) did not prevent spinal movement. Other studies have shown that application of MILS during airway maneuvers reduces spinal movement to physiological levels (LOE 5.6)\(^{170,171}\). Airway maneuvers can be undertaken more safely with MILS than with collars (LOE 3, 5)\(^{172-174}\). But a small study of anesthetized paralyzed volunteers showed that use of the jaw thrust with the head maintained in neutral alignment did not improve radiological airway patency (LOE 3)\(^{28}\). No studies evaluated CPR on a victim with suspected spinal injuries.

**Treatment Recommendation**

Maintaining an airway and adequate ventilation is the overriding priority in managing a patient with a suspected spinal injury. In a victim with a suspected spinal injury and an obstructed airway, the head tilt–chin lift or jaw thrust (with head tilt) techniques are feasible and may be effective for clearing the airway. Both techniques are associated with cervical spinal movement. Use of MILS to minimize head movement is reasonable if a sufficient number of rescuers with adequate training are available.

**Face-Down Victim**

Consensus on Science

Head position was an important factor affecting patency (LOE 5)\(^{175}\) and it was more difficult to check for breathing with the victim in a face-down position. Checking for breathing by lay and professional rescuers was not always accurate when done within the recommended 10 seconds (LOE 7)\(^{21,22}\). A longer time to check for breathing will delay CPR and may impair outcome.

**Treatment Recommendation**

It is reasonable to roll a face-down, unresponsive victim carefully into the supine position to check for breathing.

**Drowning**

Drowning is a common cause of death worldwide. The special needs of the drowning victim were reviewed.

**CPR for Drowning Victim in Water**

Consensus on Science

Expired-air resuscitation in the water may be effective when undertaken by a trained rescuer (LOE 5)\(^{176,177}\); (LOE 6)\(^{178}\). Chest compressions are difficult to perform in water and could potentially cause harm to both the rescuer and victim.

**Treatment Recommendation**

In-water expired-air resuscitation may be considered by trained rescuers, preferably with a flotation device, but chest compressions should not be attempted in the water.

**Removing Drowning Victim From Water**

Consensus on Science

Human studies showed that drowning victims without clinical signs of injury or obvious neurologic deficit, a history of diving, use of a waterslide, trauma, or alcohol intoxication are unlikely to have a cervical spine injury (LOE 4)\(^{179,180}\); (LOE 5)\(^{181-185}\).

**Treatment Recommendation**

Drowning victims should be removed from the water and resuscitated by the fastest means available. Only victims with risk factors or clinical signs of injury (history of diving, water slide use, trauma, alcohol) or focal neurologic signs should be treated as a victim with a potential spinal cord injury, with stabilization of the cervical and thoracic spine.
EMS System

Dispatcher Instruction in CPR

Consensus on Science
Observational studies (LOE 4)186,187 and a randomized trial (LOE 2)150 of telephone instruction in CPR by dispatchers to untrained lay responders in an EMS system with a short (mean 4 minutes) response interval showed that dispatcher instruction in CPR increases the likelihood of performance of bystander CPR but may or may not increase the rate of survival from cardiac arrest.

Treatment Recommendation
Providing telephone instruction in CPR is reasonable.

Improving EMS Response Interval

Consensus on Science
Cohort studies (LOE 3)188–191 and a systematic review (LOE 1)12 of cohort studies of patients with out-of-hospital cardiac arrest show that reducing the interval from EMS call to arrival increases survival to hospital discharge. Response time may be reduced by using professional first responders such as fire or police personnel or other methods.

Treatment Recommendation
Administrators responsible for EMS and other systems that respond to patients with cardiac arrest should evaluate their process of delivering care and make resources available to shorten response time intervals when improvements are feasible.

Risks to Victim and Rescuer

Risks to Trainees

Consensus on Science
Few adverse events from training in CPR have been reported by instructors and trainees even though millions of people are trained annually throughout the world. Case series reported the following infrequent adverse occurrences in trainees (LOE 5): infections, including herpes simplex virus (HSV)192; Neisseria meningitidis193; hepatitis B virus (HBV)194; stomatitis195; tracheitis196; and others, including chest pain or near-syncope attributed to hyperventilation197 and fatal myocardial infarction.198 There was no evidence that a prior medical assessment of “at-risk” trainees reduces any perceived risk (LOE 7).199

Commonly used chemical disinfectants effectively removed bacteriologic and viral contamination of the training manikin (LOE 6).200,201 Another study showed that 70% ethanol with or without 0.5% chlorhexidine did not completely eradicate herpes simplex contamination after several hours (LOE 6).202

Treatment Recommendation
Training manikins should be cleaned between trainee ventilation sessions. It is acceptable to clean them with commercially available antiseptic, 30% isopropyl alcohol, 70% alcohol solution, or 0.5% sodium hypochlorite, allowing at least 1 minute of drying time between trainee ventilation sessions.

Risks to Responders

Consensus on Science
Few adverse events resulting from providing CPR have been reported, even though CPR is performed frequently throughout the world. There were only isolated reports of persons acquiring infections after providing CPR, eg, tuberculosis202 and severe acute respiratory distress syndrome (SARS).203 Transmission of HIV during provision of CPR has never been reported. Responders exposed to infections while performing CPR might reduce their risk of becoming infected by taking appropriate prophylactic steps (LOE 7).193 Responders occasionally experienced psychological distress.204–208

No human studies have addressed the safety, effectiveness, or feasibility of using barrier devices during CPR. Laboratory studies showed that nonwoven fiber filters or barrier devices with 1-way valves prevented oral bacterial flora transmission from victim to rescuer during mouth-to-mouth ventilation (LOE 6).209,210 Giving mouth-to-mouth ventilation to victims of organophosphate or cyanide intoxication was associated with adverse effects for responders (LOE 5).211–213 One study showed that a high volume of air transmitting a highly virulent agent (ie, SARS coronavirus) can overwhelm the protection offered by gowns, 2 sets of gloves, goggles, a full face shield, and a non–fit-tested N95 disposable respirator (LOE 5).203

Treatment Recommendation
Providers should take appropriate safety precautions when feasible and when resources are available to do so, especially if a victim is known to have a serious infection (eg, HIV, tuberculosis, HBV, or SARS).

Risks for the Victim

Consensus on Science
The incidence of rib fractures among survivors of cardiac arrest who received standard CPR is unknown. Rib fractures and other injuries are commonly observed among those who die following cardiac arrest and provision of standard CPR (LOE 4).213 One study (LOE 4)214 showed an increased incidence of sternal fractures in an active compression-decompression (ACD)-CPR group when compared with standard CPR alone. The incidence of rib fractures after mechanically performed CPR appeared to be similar to that occurring after performance of standard CPR (LOE 6).215 There is no published evidence of the incidence of adverse effects when chest compressions are performed on someone who does not require resuscitation.

Treatment Recommendation
Rib fractures and other injuries are common but acceptable consequences of CPR given the alternative of death from cardiac arrest. After resuscitation all patients should be reassessed and reevaluated for resuscitation-related injuries. If available, the use of a barrier device during mouth-to-mouth ventilation is reasonable. Adequate protective equipment and administrative, environmental, and quality control measures are necessary during resuscitation attempts in the event of an outbreak of a highly transmittable microbe such as the SARS coronavirus.

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Part 3: Defibrillation

The 2005 Consensus Conference considered questions related to the sequence of shock delivery and the use and effectiveness of various waveforms and energies. These questions have been grouped into the following categories: (1) strategies before defibrillation, (2) use of automated external defibrillators (AEDs), (3) electrode-patient interface, (4) use of the electrocardiographic (ECG) waveform to alter management, (5) waveform and energy levels for the initial shock, (6) sequence after failure of the initial shock (ie, second and subsequent shocks), and (7) other related topics.

The ECC Guidelines 2000 state that defibrillation should be attempted as soon as ventricular fibrillation (VF) is detected, regardless of the response interval (ie, time between collapse and arrival of the AED). If the response interval is >4 to 5 minutes, however, there is evidence that 1½ to 3 minutes of CPR before attempted defibrillation may improve the victim’s chance of survival. The data in support of out-of-hospital AED programs continues to accumulate, and there is some evidence supporting the use of AEDs in the hospital. Analysis of the VF waveform enables prediction of the likelihood of defibrillation success; with this information the rescuer can be instructed to give CPR or attempt defibrillation. This technology was developed by analysis of downloads from AEDs; it has yet to be applied prospectively to improve defibrillation success and is not available outside research programs.

All new defibrillators deliver a shock with a biphasic waveform. There are several varieties of biphasic waveform, but the best variant and the optimal energy level and shock strategy (fixed versus escalating) have yet to be determined. Biphasic devices achieve higher first-shock success rates than monophasic defibrillators. This fact, combined with the knowledge that interruptions to chest compressions are harmful, suggests that a 1-shock strategy (1 shock followed immediately by CPR) may be preferable to the traditional 3-shock sequence for VF and pulseless ventricular tachycardia (VT).

Strategies Before Defibrillation

Precordial Thump

Consensus on Science
No prospective studies have evaluated the use of the precordial (chest) thump. In 3 case series (LOE 5)2–4 VF or pulseless VT was converted to a perfusing rhythm by a precordial thump. The likelihood of conversion of VF decreased rapidly with time (LOE 5).4 The conversion rate was higher for unstable or pulseless VT than for VF (LOE 5).2–6

Several observational studies indicated that an effective thump was delivered by a closed fist from a height of 5 to 40 cm (LOE 5).3,4,5–8 Other observational studies indicated that additional tachyarrhythmias, such as unstable supraventricular tachycardia (SVT), were terminated by precordial thump (LOE 5).9,10 Potential complications of the precordial thump include rhythm deteriorations, such as rate acceleration of VT, conversion of VT into VF, complete heart block, and asystole (LOE 5).3,5,6,8,11,12; LOE 6).13 Existing data does not allow an accurate estimate of the likelihood of these complications.

Treatment Recommendation
One immediate precordial thump may be considered after a monitored cardiac arrest if an electrical defibrillator is not immediately available.

CPR Before Defibrillation

Consensus on Science
In a before–after study (LOE 4)14 and a randomized trial (LOE 2),15 1½ to 3 minutes of CPR by paramedics or EMS physicians before attempted defibrillation improved return of spontaneous circulation (ROSC) and survival rates for adults with out-of-hospital VF or VT when the response interval (ambulance dispatch to arrival) and time to defibrillation was ≥2 to 3 minutes. This contrasts with the results of another trial in adults with out-of-hospital VF or VT, in which 1½ minutes of paramedic CPR before defibrillation did not improve ROSC or survival to hospital discharge (LOE 2).16 In animal studies of VF lasting ≥5 minutes, CPR (often with administration of epinephrine) before defibrillation improved hemodynamics and survival rates (LOE 6).17–21

Treatment Recommendation
A 1½- to 3-minute period of CPR before attempting defibrillation may be considered in adults with out-of-hospital VF or pulseless VT and EMS response (call to arrival) intervals >4 to 5 minutes. There is no evidence to support or refute the use of CPR before defibrillation for in-hospital cardiac arrest.

Use of AEDs

AED Programs

Consensus on Science
A randomized trial of trained lay responders in public settings (LOE 2)22 and observational studies of CPR and defibrillation...
performed by trained professional responders in casinos (LOE 5)\textsuperscript{33} and lay responders in airports (LOE 5)\textsuperscript{24} and on commercial passenger airplanes (LOE 5)\textsuperscript{25,26} showed that AED programs are safe and feasible and significantly increase survival from out-of-hospital VF cardiac arrest if the emergency response plan is effectively implemented and sustained. In some studies defibrillation by trained first responders (eg, firefighters or police officers) has improved survival rates from witnessed out-of-hospital VF sudden cardiac arrest (LOE 2\textsuperscript{27}; LOE 3\textsuperscript{28,29}; LOE 4\textsuperscript{30,31}; LOE 5\textsuperscript{32}). In other studies AED defibrillation by trained first responders has not improved survival.\textsuperscript{14,33}

Approximately 80% of out-of-hospital cardiac arrests occur in a private or residential setting (LOE 4).\textsuperscript{34} However, there is insufficient data to support or refute the effectiveness of home AED programs.

**Treatment Recommendation**
Use of AEDs by trained lay and professional responders is recommended to increase survival rates in patients with cardiac arrest. Use of AEDs in public settings (airports, casinos, sports facilities, etc) where witnessed cardiac arrest is likely to occur can be useful if an effective response plan is in place. The response plan should include equipment maintenance, training of likely responders, coordination with local EMS systems, and program monitoring. No recommendation can be made for or against personal or home AED deployment.

**AED Program Quality Assurance and Maintenance\textsuperscript{W178}**

**Consensus on Science**
No published trials specifically evaluated the effectiveness of AED program quality improvement efforts to further improve survival rates. Case series and reports suggest that potential improvements can be made by reviewing AED function (rhythm analysis and shock), battery and pad readiness, operator performance, and system performance (eg, mock codes, time to shock, outcomes) (LOE 5).\textsuperscript{35–42}

**Treatment Recommendation**
AED programs should optimize AED function (rhythm analysis and shock), battery and pad readiness, operator performance, and system performance (eg, mock codes, time to shock, outcomes).

**AED Use in Hospitals\textsuperscript{W62A}**

**Consensus on Science**
No published randomized trials have compared AEDs with manual defibrillators in hospitals. One study of adults with in-hospital cardiac arrest with shockable rhythms showed higher survival-to–hospital discharge rates when defibrillation was provided through an AED program than with manual defibrillation alone (LOE 4).\textsuperscript{43} In an animal model, use of an AED substantially interrupted and delayed chest compressions compared with manual defibrillation (LOE 6).\textsuperscript{44} A manikin study showed that use of an AED significantly increased the likelihood of delivering 3 shocks but increased the time to deliver the shocks when compared with manual defibrillators (LOE 6).\textsuperscript{45} In contrast, a study of mock arrests in simulated patients showed that use of monitoring leads and fully automated defibrillators reduced time to defibrillation when compared with manual defibrillators (LOE 7).\textsuperscript{46}

**Treatment Recommendation**
Use of AEDs is reasonable to facilitate early defibrillation in hospitals.

**Electrode-Patient Interface**

**Electrode Pad/Paddle Position and Size\textsuperscript{W63A,W63B,W173A,W173B}**

**Consensus on Science**

**Position.** No studies of cardiac arrest in humans have evaluated the effect of pad/paddle position on defibrillation success or survival rates. Most studies evaluated cardioversion (eg, atrial fibrillation [AF]) or secondary end points (eg, transthoracic impedance [TTI]). Placement of paddles or electrode pads on the superior–anterior right chest and the inferior–lateral left chest were effective (paddles studied in AF, LOE 2\textsuperscript{47}; pads studied in AF, LOE 3\textsuperscript{48}; effect of pad position on TTI, LOE 3\textsuperscript{49}). Alternative paddle or pad positions that were reported to be effective were apex–posterior (paddles studied in VF and AF, LOE 4\textsuperscript{50}; effect of pad position on TTI, LOE 3\textsuperscript{44}), and anteroposterior (paddles studied in AF, LOE 2\textsuperscript{51}; pads studied in AF, LOE 2\textsuperscript{52}, LOE 3\textsuperscript{53}; effect of pad position on TTI, LOE 3\textsuperscript{49}). One study showed lower TTI with longitudinal placement of the apical paddle (LOE 3).\textsuperscript{54} Placement of the pad on the female breast increased impedance and may decrease efficacy of defibrillation (LOE 5).\textsuperscript{55} High-voltage alternating current (eg, from high power lines) interfered with AED analysis (LOE 6).\textsuperscript{56}

**Size.** One human study (LOE 3)\textsuperscript{57} and one animal study (LOE 6)\textsuperscript{58} documented higher defibrillation success rates with larger paddles: 12.8-cm paddles were superior to 8-cm paddles. Eight studies (LOE 3\textsuperscript{59,60,61,62,63}; LOE 5\textsuperscript{64}) demonstrated that increased pad size decreased TTI. In one canine study, significantly increased myocardial damage was reported after defibrillation with small (4.3 cm) electrodes compared with larger (8 and 12 cm) electrodes (LOE 6).\textsuperscript{64}

**Treatment Recommendation**
Paddles and electrode pads should be placed on the exposed chest in an anterolateral position. Acceptable alternative positions are anteroposterior (paddles and pads) and apex–posterior (pads). In large-breasted patients it is reasonable to place the left electrode pad (or paddle) lateral to or underneath the left breast. Defibrillation success may be higher with 12-cm electrodes than with 8-cm electrodes. Small electrodes (4.3 cm) may be harmful; myocardial injury can occur.

**Self-Adhesive Defibrillation Pads Versus Paddles\textsuperscript{W71}**

**Consensus on Science**
One randomized trial (LOE 2)\textsuperscript{65} and 2 retrospective comparisons (LOE 4)\textsuperscript{60,66} showed that TTI is similar when either pads or paddles are used. One prospective comparison of pads and paddles (LOE 3)\textsuperscript{67} showed lower TTI when paddles were applied at an optimal force of 8 kg compared with pads. One randomized study of chronic AF showed similar effectiveness for self-adhesive pads and manual paddles when monophasic
damped sinusoidal or BTE waveforms were evaluated separately (LOE 7). Studies showed the practical benefits of pads over paddles for routine monitoring and defibrillation, prehospital defibrillation, and perioperative defibrillation.

**Treatment Recommendation**
Self-adhesive defibrillation pads are safe and effective and are an acceptable alternative to standard defibrillation paddles.

**Waveform Analysis**
VF waveform analysis has the potential to improve the timing and effectiveness of defibrillation attempts; this should minimize interruptions in precordial compressions and reduce the number of unsuccessful high-energy shocks, which cause postresuscitation myocardial injury. The technology is advancing rapidly but is not yet available to assist rescuers.

**Prediction of Shock Success From VF Waveform**

- **Consensus on Science**
  Retrospective analyses of the VF waveform in clinical and animal studies and theoretical models (LOE 4; LOE 6) suggest that it is possible to predict with varying reliability the success of defibrillation from the fibrillation waveform. No studies specifically evaluated whether treatment can be altered by the prediction of defibrillation success to improve survival from cardiac arrest.

- **Initial Shock Waveform and Energy Levels**
  Several related questions were reviewed. Outcome after defibrillation has been studied by many investigators. When evaluating these studies the reviewer must consider the setting (eg, out-of-hospital versus in-hospital), the initial rhythm (eg, VF/pulseless VT), the duration of arrests (eg, out-of-hospital with typical EMS response interval versus electrophysiology study with 15-second arrest interval), and the specific outcome measured (eg, termination of VF at 5 seconds).

- **Biphasic Versus Monophasic Waveforms for Ventricular Defibrillation**
  Studies have shown that biphasic waveform shocks are safe and effective for termination of VF when compared with monophasic waveform shocks.

**Energy Level for Defibrillation**

- **Consensus on Science**
  Eight human clinical studies (LOE 2; LOE 3) described initial biphasic selected shock energy levels ranging from 100 J to 200 J with different devices but without clearly demonstrating an optimal energy level. These human clinical studies also described use of subsequent selected shock energy levels with different devices for shock-refractory VF/VT ranging from 150 J to 360 J but without clearly demonstrating an optimal energy level.
  
  Seven more laboratory studies (LOE 7) in stable patients evaluated termination of induced VF with energy levels of 115 J to 200 J.

- **Treatment Recommendation**
  Biphasic waveform shocks are safe and effective for termination of VF when compared with monophasic waveform shocks.

**First-shock efficacy (termination of VF for 320 J), and high (400 J to 440 J) energy (LOE 2). First-shock efficacy (termination of VF for ≈5 seconds) was 39% for the low-energy group, 58% for the intermediate-energy group, and 56% for the high-energy dose group. These differences did not achieve statistical significance. A study of electrical cardioversion for AF indicated that 360-J MDS shocks were more effective than 120-J or 200-J MDS shocks.

- **Consensus on Science**
  Cardioversion of a well-perfused myocardium, however, is not the same as defibrillation attempted during VF cardiac arrest, and any extrapolation should be interpreted cautiously.

**Treatment Recommendation**
There is insufficient evidence for or against specific selected energy levels for the first or subsequent biphasic shocks. With a biphasic defibrillator it is reasonable to use 150 J to 200 J with BTE waveforms or 120 J with the rectilinear biphasic waveform for the initial shock. With a monophasic waveform defibrillator, an initial shock of 360 J is reasonable.
Sequence 1-Shock Protocol Versus 3-Shock of both short and long duration. Fibrillation can be used safely and effectively to terminate VF.

Treatment Recommendation
Nonescalating- and escalating-energy biphasic waveform defibrillation can be used safely and effectively to terminate VF of both short and long duration.

1-Shock Protocol Versus 3-Shock Sequence

Consensus on Science
No published human or animal studies compared a 1-shock protocol with a 3-stacked shock sequence for any outcome. The magnitude of success of initial or subsequent shocks depended on the specific group of patients, the initial rhythm, and the outcome considered. Shock success was defined as termination of VF for 5 seconds after the shock. Resuscitation success can include ROSC and survival to hospital discharge. Only shock success is cited below.

First-shock success. Six studies of defibrillation in out-of-hospital cardiac arrest reported first-shock success in patients whose initial rhythm was shockable (VF/pulseless VT):

- In studies that used a 200-J MDS waveform, the first-shock success rate was 77% to 91% (LOE 2,94,97; LOE 5,95,99). In studies that used a 200-J MTE waveform, the first-shock success rate was 54% to 63% (LOE 4).97,99
- In studies that used a 150-J BTE waveform 97,99,115,116 and 1 study that used a 200-J BTE waveform,95 the first-shock success rate was 86% to 98%,95,97,99,115,116
- The first-shock success rate with a 120-J rectilinear biphasic waveform was 85% (according to L.J. Morrison, MD, in oral discussion at the 2005 Consensus Conference).94

Although the first-shock success rate was relatively high in patients with out-of-hospital cardiac arrest and an initial rhythm of VF, the average rate of ROSC with the first shock (for MDS, MTE, and BTE waveforms) was 21% (range 13% to 23%) (LOE 5).99

Second- and third-shock success rates. Six studies of defibrillation in out-of-hospital cardiac arrest reported the shock success (defined above) rate of the first shock and subsequent 2 shocks (if the initial shock was unsuccessful) for patients with an initial rhythm of VF/pulseless VT. The figures below refer to only those patients who remained in VF after the first shock, and they represent the proportion of these cases successfully defibrillated by either the second or third shock.

- In 2 studies that used the MDS waveform with increasing energy levels (200 J to 200/300 J to 360 J), the combined shock success of the second and third shocks when the first shock failed was 68% to 72% (LOE 5).94,99
- In 4 studies that used the fixed-energy 150-J BTE waveform, the combined shock success of the second and third shocks when the first shock failed was 50% to 90% (LOE 5).97,99
- In 1 study that used a rectilinear waveform with increasing energy levels (120 J to 150 J to 200 J), the combined success rate of the second and third shocks when the first shock failed was 85% (LOE 5).94

One study of defibrillation for out-of-hospital cardiac arrest in which the initial rhythm was VF reported a 26% rate of ROSC with the initial series of up to 3 shocks (for BTE waveforms) combined with preshock or postshock CPR or both (LOE 5).116

Treatment Recommendation
Priorities in resuscitation should include early assessment of the need for defibrillation (Part 2: “Adult Basic Life Support”), provision of CPR until a defibrillator is available, and minimization of interruptions in chest compressions. Rescuers can optimize the likelihood of defibrillation success by optimizing the performance of CPR, timing of shock delivery with respect to CPR, and the combination of waveform and energy levels. A 1-shock strategy may improve outcome by reducing interruption of chest compressions. A 3-stacked shock sequence can be optimized by immediate resumption of effective chest compressions after each shock (irrespective of the rhythm) and by minimizing the hands-off time for rhythm analysis.

Related Defibrillation Topics

Defibrillator Data Collection

Consensus on Science
Collection of data from defibrillators enables a comparison of actual performance during cardiac arrests and training events. The results of 3 observational studies (LOE 5)117–119 suggest that the rate and depth of external cardiac compressions and ventilation rate were at variance with current guidelines.

Treatment Recommendation
Monitor/defibrillators modified to enable collection of data on compression rate and depth and ventilation rate may be useful for monitoring and improving process and outcomes after cardiac arrest.

Oxygen and Fire Risk During Defibrillation

Consensus on Science
Several case reports (LOE 5)120–125 described instances of fires ignited by sparks from poorly attached defibrillator paddles in the presence of an oxygen-enriched atmosphere. The oxygen-enriched atmosphere rarely extends >0.5 m (1.5 ft) in any direction from the oxygen outflow point, and the oxygen concentration returns quickly to ambient when the source of enrichment is removed (LOE 5; LOE 6).126. The most severe fires were caused when ventilator tubing was disconnected from the tracheal tube and then left adjacent to
Atmosphere.
Defibrillation is not attempted in an oxygen-enriched atmosphere. Rescuers should try to ensure that defibrillation is not attempted in an oxygen-enriched atmosphere.

Treatment Recommendation
Rescuers should take precautions to minimize sparking (by paying attention to pad/paddle placement, contact, etc) during attempted defibrillation. Rescuers should try to ensure that defibrillation is not attempted in an oxygen-enriched atmosphere.

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Part 4: Advanced Life Support

The topics reviewed by the International Liaison Committee on Resuscitation (ILCOR) Advanced Life Support Task Force are grouped as follows: (1) causes and prevention, (2) airway and ventilation, (3) drugs and fluids given during cardiac arrest, (4) techniques and devices to monitor and assist the circulation, (5) periarrest arrhythmias, (6) cardiac arrest in special circumstances, (7) postresuscitation care, and (8) prognostication. Defibrillation topics are discussed in Part 3.

The most important developments in advanced life support (ALS) since the last ILCOR review in 2000 include:

- The emergence of medical emergency teams (METs) as a means of preventing in-hospital cardiac arrest
- Additional clinical data on the use of vasopressin in cardiac arrest
- Several new devices to assist circulation during CPR
- The use of therapeutic hypothermia to improve neurologic outcome after ventricular fibrillation (VF) cardiac arrest
- The potential importance of glucose control after cardiac arrest

For many topics there were insufficient data with which to make firm treatment recommendations. The following interventions in particular need further research:

- The impact of METs on the incidence of cardiac arrest
- Outcome data to define the most appropriate advanced airway adjunct
- Evidence to identify the most effective vasopressor or if any vasopressor is better than placebo for cardiac arrest
- Randomized controlled trials on several new devices to assist circulation during CPR
- Randomized controlled trial data on several postresuscitation care therapies, such as control of ventilation, sedation, and glucose
- The precise role of, and method for implementing, therapeutic hypothermia: patient selection, external versus internal cooling, optimum target temperature, and duration of therapy

### Causes and Prevention

Recuers may be able to identify some noncardiac causes of arrest and tailor the sequence of attempted resuscitation. Most patients sustaining in-hospital cardiac arrest display signs of deterioration for several hours before the arrest. Early identification of these high-risk patients and the immediate arrival of a MET (also known as Rapid Response Team in the United States) to care for them may help prevent cardiac arrest. Hospitals in many countries are introducing early warning systems such as METs.

**Identification of the Etiology of Cardiac Arrest**

Consensus on Science

Very few data address the etiology of cardiac arrest directly. One prospective study (LOE 3) and one retrospective study (LOE 4) suggested that rescuers can identify some noncardiac causes of some arrests.

**Treatment Recommendation**

The physical circumstances, history, or precipitating events may enable the rescuer to determine a noncardiac cause of the cardiorespiratory arrest. Under these circumstances the rescuer should undertake interventions based on the presumed noncardiac etiology.

**Impact of Medical Emergency Teams**

The METs studied were composed generally of a doctor and nurse with critical-care training who were available at all times, responded immediately when called, and had specific, well-defined calling criteria. The MET system normally includes a strategy for educating ward staff about early recognition of critical illness. Variations of the MET system include critical-care outreach teams and patient-at-risk teams; all such variants use early warning scoring (EWS) systems to indicate patients who may be critically ill or at risk of cardiac arrest.

Consensus on Science

Two supportive before-and-after single-center studies (LOE 3) documented significant reductions in cardiac arrest rates and improved outcomes following cardiac arrest (eg, survival and length of stay in the intensive care unit [ICU]) after introduction of a MET. One cluster randomized controlled trial documented no difference in the composite primary outcome (cardiac arrest, unexpected death, unplanned ICU admission) between 12 hospitals in which a MET system was introduced and 11 hospitals that continued to function as normal (LOE 2). In this study, however, the MET system increased significantly the rate of emergency team calling. Two neutral studies documented a trend toward reduction in the rates of adult in-hospital cardiac arrest and overall mortality (LOE 3) and a reduction in unplanned admissions to the ICU (LOE 3). A before-and-after study documented reductions in cardiac arrest and death in children after...
introduction of a MET system for adult hospital in-patients should be considered, with special attention to details of implementation (e.g., composition and availability of the team, calling criteria, education and awareness of hospital staff, and method of activation of the team). Introduction of an EWS system for adult in-hospital patients may be considered.

**Airway and Ventilation**

Consensus conference topics related to the management of airway and ventilation are categorized as (1) basic airway devices, (2) advanced airway devices, (3) confirmation of advanced airway placement, (4) strategies to secure advanced airways, and (5) strategies for ventilation.

**Basic Airway Devices**

**Nasopharyngeal Airway**

Consensus on Science

Despite frequent successful use of nasopharyngeal airways by anesthesiologists, there are no published data on the use of these airway adjuncts during CPR. One study in anesthetized patients showed that nurses inserting nasopharyngeal airways were no more likely than anesthesiologists to cause nasopharyngeal trauma (LOE 7). One LOE 5 study showed that the traditional methods of sizing a nasopharyngeal airway (measurement against the patient’s little finger or anterior nares) do not correlate with the airway anatomy and are unreliable. In one report insertion of a nasopharyngeal airway caused some airway bleeding in 30% of cases (LOE 7). Two case reports involve inadvertent intracranial placement of a nasopharyngeal airway in patients with basal skull fractures (LOE 7).

Treatment Recommendation

In the presence of a known or suspected basal skull fracture, an oral airway is preferred, but if this is not possible and the airway is obstructed, gentle insertion of a nasopharyngeal airway may be lifesaving (i.e., the benefits may far outweigh the risks).

**Advanced Airway Devices**

The tracheal tube has generally been considered the optimal method of managing the airway during cardiac arrest. There is evidence that without adequate training and experience, the incidence of complications, such as unrecognized esophageal intubation, is unacceptably high. Alternatives to the tracheal tube that have been studied during CPR include the bag-valve mask and advanced airway devices such as the laryngeal mask airway (LMA) and esophageal-tracheal combitube (Combitube). There are no data to support the routine use of any specific approach to airway management during cardiac arrest. The best technique depends on the precise circumstances of the cardiac arrest and the competence of the rescuer.

**Tracheal Intubation Versus Ventilation With Bag-Valve Mask**

Consensus on Science

There were no randomized trials that assessed the effect of airway and ventilation management with bag-valve mask (BVM) alone versus airway management that includes tracheal intubation in adult victims of cardiac arrest.

The only published randomized controlled trial identified (LOE 7) that compared tracheal intubation with BVM ventilation was performed in children who required airway management out-of-hospital. In this study there was no difference in survival-to-discharge rates, but it is unclear how applicable this pediatric study is to adult resuscitation. The study had some important limitations, including the provision of only 6 hours of additional training for intubation, limited opportunity to perform intubations, and short transport times. Two studies compared outcomes from out-of-hospital cardiac arrest in adults treated by either emergency medical technicians or paramedics (LOE 3; LOE 4). The skills provided by the paramedics, including intubation and intravenous (IV) cannulation and drug administration, made no difference in survival to hospital discharge.

The reported incidence of unrecognized misplaced tracheal tube is 6% (LOE 5) to 14% (LOE 5). An additional problem common to any advanced airway is that intubation attempts generally require interruptions in chest compressions.

Treatment Recommendation

There is insufficient evidence to support or refute the use of any specific technique to maintain an airway and provide ventilation in adults with cardiopulmonary arrest. Either bag-valve mask alone or in combination with tracheal intubation is acceptable for ventilation during CPR by prehospital providers. Rescuers must weigh the risks and benefits of intubation versus the need to provide effective chest compressions. The intubation attempt will require interruption of chest compressions, but once an advanced airway is in place, ventilation will not require interruption (or even pausing) of chest compressions. To avoid substantial interruptions in chest compressions, providers may defer an intubation attempt until return of spontaneous circulation (ROSC). To ensure competence, healthcare systems that utilize advanced airways should address factors such as adequacy of training and experience and quality assurance. Providers must confirm tube placement and ensure that the tube is adequately secured (see below).

**Tracheal Intubation Versus the Combitube/Laryngeal Mask Airway**

Consensus on Science

In some communities tracheal intubation is not permitted or practitioners have inadequate opportunity to maintain their...
intubation skills. Under these circumstances several studies indicate a high incidence of unrecognized esophageal intubation misplacement and unrecognized dislodgment. Prolonged attempts at tracheal intubation are harmful: the cessation of chest compressions during this time will compromise coronary and cerebral perfusion. Several alternative airway devices have been considered or studied for airway management during CPR; the Combitube and the LMA are the only alternative devices to be studied specifically during CPR. None of the studies of the LMA and Combitube during CPR has been adequately powered to study survival as a primary end point; instead, most researchers have studied insertion and ventilation success rates.

Combitube. Five randomized controlled trials conducted on adult patients undergoing resuscitation (LOE 2)24–28 and 3 additional randomized controlled trials involving patients undergoing anesthesia (LOE 7)29–31 documented successful Combitube insertion and acceptable ventilation when compared with tracheal intubation. Benefits were documented for both experienced and inexperienced healthcare professionals with patients in hospital as well as in out-of-hospital settings.

Six additional studies support the use of the Combitube during CPR (LOE 32; LOE 43; LOE 534–37). Successful ventilation was achieved with the Combitube during CPR in 78.9% to 98% of patients (LOE 236,27,38; LOE 332; LOE 433; LOE 534,35).

LMA. Seven randomized controlled trials involving anesthetized patients (LOE 7)39–45 that compared the LMA with tracheal intubation and another 7 randomized control trials (LOE 7)46–52 that compared the LMA with other airways or ventilation techniques were reviewed. These studies suggested that experienced and inexperienced personnel can insert the device or successfully ventilate the patient’s lungs in a high proportion of cases compared with the tracheal tube or other airway management and ventilation devices.

One randomized crossover study (LOE 2)38 in adults undergoing resuscitation in the prehospital setting compared the Combitube with the LMA and showed that LMA insertion and successful ventilation could be achieved in a high proportion of patients.

Nonrandomized studies (LOE 353–55, LOE 431; LOE 556–61) have also shown high insertion success rates by inexperienced providers both in and out of the hospital. Complication rates in nonrandomized studies (LOE 358; LOE 431; LOE 556) have been extremely low.

Successful ventilation was achieved with the LMA during CPR in 71.5% to 98% of cases (LOE 236; LOE 334; LOE 433; LOE 556.58–60).

Additional airway devices. Use of the laryngeal tube during CPR was described in just a few cases included in 2 LOE 5 studies62,63 and 1 LOE 8 paper.64 There were no studies comparing the laryngeal tube with the tracheal tube in any patient population, although 4 randomized controlled trials compared the laryngeal tube favorably with the LMA in anesthetized patients (LOE 7).65–68

Other devices include the ProSeal LMA, intubating LMA, airway management device, and pharyngeal airway express. There are no published data on the use of these devices during CPR.

Treatment Recommendation
It is acceptable for healthcare professionals to use the Combitube or the LMA as alternatives to the tracheal tube for airway management in cardiac arrest.

Confirming Advanced Airway Placement
Unrecognized esophageal intubation is the most serious complication of attempted tracheal intubation. Routine confirmation of correct placement of the tracheal tube should reduce this risk. There are inadequate data to identify the optimal method of confirming tube placement during cardiac arrest. All devices should be considered adjuncts to other confirmatory techniques. There is no data quantifying the capability of these devices to monitor tube position after initial placement.

Exhaled CO2

Consensus on Science
Evidence from 1 meta-analysis in adults (LOE 1),69 1 prospective controlled cohort study (LOE 3),70 case series (LOE 5),71–79 and animal models (LOE 6)80,81 indicate that exhaled CO2 detectors (waveform, colorimetry, or digital) may be useful as adjuncts to confirm tracheal tube placement during cardiac arrest. Of the 14 references included in this statement, 10 referred to colorimetric assessment,69,71–76,79,81,82 4 to digital,69–71,77 and 4 to waveform.69,70,78,80 There are insufficient data from cardiac arrests to enable any firm recommendations for any particular technique. The range of results obtained from the reviewed papers is as follows:

- Percentage of tracheal placements detected: 33% to 100%
- Percentage of esophageal placements detected: 97% to 100%
- Probability of tracheal placement if test result is positive (exhaled CO2 is detected): 100%
- Probability of esophageal placement if test result is negative (exhaled CO2 is not detected): 20% to 100%

One adult case series (LOE 5)82 shows that in the presence of a perfusing rhythm, exhaled CO2 detection can be used to monitor tracheal tube position during transport.

No studies directly evaluated exhaled CO2 to confirm placement of the Combitube or LMA during cardiac arrest in humans.

Treatment Recommendation
Healthcare providers should recognize that evaluation of exhaled CO2 is not infallible for confirming correct placement of a tracheal tube, particularly in patients in cardiac arrest. Exhaled CO2 should be considered as just one of several independent methods for confirming tracheal tube placement. Continuous capnometry may be useful for early detection of tracheal tube dislodgment during transport.

Esophageal Detector Device

Consensus on Science
Eight studies of at least fair quality evaluated the accuracy of the syringe or self-inflating bulb type of esophageal detector.
device (EDD) (LOE 3$^{11}$,77,83; LOE 5$^{84}$; LOE 7 [noncardiac arrest setting$^{85–88}$], but many suffer from few subjects and lack of a control group.

The EDD was highly sensitive for detection of misplaced tracheal tubes in the esophagus (LOE 5$^{84}$; LOE 7$^{85–88}$). In 2 studies (LOE 3)$^{77,84}$ of patients in cardiac arrest, the EDD had poor sensitivity for confirming tracheal placement of a tracheal tube. In these studies up to 30% of correctly placed tubes may have been removed because the EDD suggested esophageal placement of a tube (LOE 3)$^{78}$.

The EDD had poor sensitivity and specificity in the operating room in 20 children <1 year of age (LOE 2)$^{89}$.

Treatment Recommendation
The use of the EDD should be considered as just one of several independent methods for tracheal tube confirmation.

Strategies to Secure Advanced Airways
Accidental dislodgment of a tracheal tube can occur at any time but may be more likely during resuscitation and during transport. The most effective method for securing the tracheal tube has yet to be determined.

Securing the Tracheal Tube$^{89A,W49B}$

Consensus on Science
There are no studies comparing different strategies for securing the tracheal tube during CPR. Two studies in the intensive care setting (LOE 7)$^{90,91}$ indicated that commercial devices for securing tracheal tubes, backboards, cervical collars, and other strategies provide an equivalent method for preventing accidental tube displacement when compared with the traditional method of securing the tube with tape.

Treatment Recommendation
Either commercially made tracheal tube holders or conventional tapes or ties should be used to secure the tracheal tube.

Strategies for Ventilation
Very few studies address specific aspects of ventilation during ALS. Three recent observational studies report the ventilation rates delivered by healthcare personnel during cardiac arrest (LOE 5)$^{92–94}$; 2 studies$^{92,93}$ show ventilation rates that are much higher than those recommended by the 2000 International Guidelines for CPR and ECC. Automatic transport ventilators (ATVs) might enable delivery of appropriate ventilatory rates, but no data demonstrate clear benefit over bag-valve mask devices.

Disconnection From Ventilation During Cardiac Arrest$^{W54A,W54B}$

Consensus on Science
Eighteen LOE 5 articles involving 31 cases$^{95–112}$ reported unexpected return of circulation (and in some cases prolonged neurologically intact survival) after cessation of resuscitation attempts. One case series suggested that this occurred in patients with obstructive airway disease (LOE 5)$^{100}$. Four studies reported unexpected return of circulation in 6 cases in which resuscitation had ceased and ventilation was shown on repeated occasions (or was highly likely) to result in gas trapping and consequent hemodynamic compromise (LOE 5)$^{100,108–110}$. The authors of all these studies suggested that a period of disconnection from ventilation during resuscitation from PEA may be useful to exclude gas trapping.

Automatic Transport Ventilators$^{W55,W152A}$

Consensus on Science
Research of simulated cardiac arrest with manikins showed a significant decrease in gastric inflation with manually triggered, flow-limited, oxygen-powered resuscitators and masks compared with bag-valve masks (LOE 6)$^{113}$. Anesthetized patients with unprotected airways but not in cardiac arrest who were ventilated by firefighters had less gastric inflation with manually triggered, flow-limited, oxygen-powered resuscitators and masks than with bag-valve masks (LOE 5)$^{114}$. A prospective cohort study of intubated patients, most of whom were in cardiac arrest, in an out-of-hospital urban setting showed no significant difference in arterial blood gas values between those ventilated with an ATV and those ventilated with a bag-valve device (LOE 4)$^{115}$. Two laboratory studies showed that ATVs may provide safe and effective management of mask ventilation during CPR of adult patients with an unprotected airway (LOE 6)$^{116,117}$.

Treatment Recommendation
The use of a manually triggered, flow-limited resuscitator or an ATV by professional healthcare providers is reasonable for ventilation of adults with an advanced airway in place during cardiac arrest. The use of ATVs for adults without an advanced airway in place is discussed in Part 2: “Adult Basic Life Support.”

Drugs and Fluids for Cardiac Arrest
Questions related to the use of drugs during cardiac arrest that were discussed during the 2005 Consensus Conference are categorized as (1) vasopressors, (2) antiarrhythmics, (3) other drugs and fluids, and (4) alternative routes of delivery.

Vasopressors
Despite the widespread use of epinephrine/adrenaline during resuscitation and several studies involving vasopressin, there is no placebo-controlled study that shows that the routine use of any vasopressor at any stage during human cardiac arrest increases survival to hospital discharge. Current evidence is insufficient to support or refute the routine use of any particular drug or sequence of drugs. Despite the lack of human data, it is reasonable to continue to use vasopressors on a routine basis.


Consensus on Science
Despite promising lower-level data (LOE 2)$^{118}$, LOE 5$^{119–121}$ and multiple well-performed animal studies (LOE 6)$^{112,113}$, 2 large randomized controlled human trials of adults in cardiac arrest (LOE 1)$^{122,123}$ were unable to show an increase in the rates of ROSC or survival for vasopressin (40 U, with the dose repeated in 1 study) when compared with epinephrine (1 mg, repeated) as the initial vasopressor. In 1 large multicenter trial
involving out-of-hospital cardiac arrest with all rhythms (LOE 1).\textsuperscript{123} on post hoc analysis the subset of patients with asystole had significant improvement in rate of survival to discharge but not neurologically intact survival when vasopressin 40 U (dose repeated once if necessary) was used as the initial vasopressor compared with epinephrine (1 mg, repeated if necessary). A meta-analysis of 5 randomized trials (LOE 1)\textsuperscript{124} showed no statistically significant differences between vasopressin and epinephrine for ROSC, death within 24 hours, or death before hospital discharge. The subgroup analysis based on initial cardiac rhythm did not show any statistically significant differences in the rate of death before hospital discharge (LOE 1).\textsuperscript{124}

Treatment Recommendation
Despite the absence of placebo-controlled trials, epinephrine has been the standard vasopressor in cardiac arrest. There is insufficient evidence to support or refute the use of vasopressin as an alternative to, or in combination with, epinephrine in any cardiac arrest rhythm.

Alpha-methyl Norepinephrine\textsuperscript{W83B}

Consensus on Science
Preliminary animal studies (LOE 6)\textsuperscript{125–127} have suggested some potential short-term benefits with the use of alpha-methyl norepinephrine in animal models of VF. At this stage no published human studies have been identified.

Endothelin\textsuperscript{W83D,W83I}

Consensus on Science
Evidence from 5 studies of cardiac arrest in animals (LOE 6)\textsuperscript{128–132} documented consistent improvement in coronary perfusion pressure with endothelin-1, but this did not translate into improved myocardial blood flow. No published human studies were available.

Antiarrhythmics
There is no evidence that giving any antiarrhythmic drug routinely during human cardiac arrest increases rate of survival to hospital discharge. In comparison with placebo and lidocaine, the use of amiodarone in shock-refractory VF improves the short-term outcome of survival to hospital admission. Despite the lack of human long-term outcome data, it is reasonable to continue to use antiarrhythmic drugs on a routine basis.

Amiodarone\textsuperscript{W83A,W83I}

Consensus on Science
In 2 blinded randomized controlled clinical trials in adults (LOE 1),\textsuperscript{133,134} administration of amiodarone (300 mg\textsuperscript{133}; 5 mg/kg\textsuperscript{134}) by paramedics to patients with refractory VF/pulseless ventricular tachycardia (VT) in the out-of-hospital setting improved survival to hospital admission when compared with administration of placebo\textsuperscript{133} or lidocaine (1.5 mg/kg).\textsuperscript{134} Additional studies (LOE 7)\textsuperscript{135–139} document consistent improvement in defibrillation response when amiodarone is given to humans or animals with VF or hemodynamically unstable VT.

Treatment Recommendation
In light of the short-term survival benefits, amiodarone should be considered for refractory VF/VT.

Other Drugs and Fluids
There is no evidence that routinely giving other drugs (eg, buffers, aminophylline, atropine, calcium, magnesium) during human cardiac arrest increases survival to hospital discharge. There are several reports on the successful use of fibrinolytics during cardiac arrest, particularly when the arrest was caused by pulmonary embolism.

Aminophylline\textsuperscript{W98A,W98B}

Consensus on Science
One case series (LOE 5)\textsuperscript{140} and 3 small randomized trials (LOE 2)\textsuperscript{141–143} indicate that aminophylline does not increase ROSC when given for bradyasystolic cardiac arrest. No studies have shown an effect of aminophylline on rates of survival to hospital discharge. There is no evidence of harm from giving aminophylline in bradyasystolic cardiac arrest (LOE 2\textsuperscript{144–145}; LOE 5\textsuperscript{140}).

Atropine\textsuperscript{W97A,W97B}

Consensus on Science
Five prospective controlled nonrandomized cohort studies in adults (LOE 3)\textsuperscript{19,144–147} and 1 LOE 4 study\textsuperscript{148} showed that treatment with atropine was not associated with any consistent benefits after in-hospital or out-of-hospital cardiac arrest.

Buffers\textsuperscript{W34,W100A,W100B}

Consensus on Science
There were no published LOE 1, 2, or 3 studies on the use of sodium bicarbonate during CPR. One LOE 2 study\textsuperscript{149} showed no advantage of Tribonate over placebo (neutral), and 5 retrospective analyses of uncontrolled clinical use of sodium bicarbonate were inconclusive (LOE 4).\textsuperscript{150–154} One LOE 4 study\textsuperscript{155} suggested that emergency medical services (EMS) systems using sodium bicarbonate earlier and more frequently had significantly higher rates of ROSC and hospital discharge and better long-term neurologic outcome.

Results of animal studies are conflicting and inconclusive. Sodium bicarbonate was effective for treating the cardiovascular toxicity (hypotension, cardiac arrhythmias) caused by tricyclic antidepressants and other fast sodium channel blockers (see “Drug Overdose and Poisoning,” below). Only 1 LOE 5 publication\textsuperscript{156} reported the successful treatment of VF cardiac arrest caused by tricyclic poisoning using sodium bicarbonate.

Treatment Recommendation
Giving sodium bicarbonate routinely during cardiac arrest and CPR (especially in out-of-hospital cardiac arrest) or after ROSC is not recommended. Sodium bicarbonate may be considered for life-threatening hyperkalemia or cardiac arrest associated with hyperkalemia, preexisting metabolic acidosis, or tricyclic antidepressant overdose.

Magnesium\textsuperscript{W83K,W101A,W101B}

Consensus on Science
Studies in adults in- and out-of-hospital (LOE 2\textsuperscript{157–160}; LOE 3\textsuperscript{161}; LOE 7\textsuperscript{162}) and animal studies (LOE 6)\textsuperscript{163–166} indicated
no increase in the rate of ROSC when magnesium was given during CPR. Results from 1 small case series of 5 patients (LOE 5)\(^{167}\) indicated benefit from giving magnesium in shock-resistant and epinephrine/lidocaine-resistant VF.

**Treatment Recommendation**
Magnesium should be given for hypomagnesemia and torsades de pointes, but there is insufficient data to recommend for or against its routine use in cardiac arrest.

**Fibrinolysis During CPR**\(^{166A,166B,166C}\)

**Consensus on Science**
Adults have been successfully resuscitated following administration of fibrinolytics after initial failure of standard CPR techniques, particularly when the condition leading to the arrest was acute pulmonary embolism or other presumed cardiac cause (LOE 3\(^{169}\); LOE 4\(^{169–171}\); LOE 5\(^{172–176}\)). One large clinical trial (LOE 2)\(^{177}\) failed to show any significant treatment effect from administration of fibrinolytics to out-of-hospital patients with undifferentiated pulseless electrical activity (PEA) cardiac arrest unresponsive to initial interventions. Four clinical studies (LOE 3\(^{168}\); LOE 4\(^{169–171}\)) and 5 case series (LOE 5)\(^{172–176}\) indicated that there is no increase in bleeding complications with fibrinolysis during CPR for nontraumatic cardiac arrest. Two animal studies (LOE 6)\(^{178,179}\) showed positive effects on cerebral reperfusion with fibrinolysis during CPR.

**Treatment Recommendation**
Fibrinolysis should be considered in adult patients with cardiac arrest with proven or suspected pulmonary embolism. There is insufficient data to support or refute the routine use of fibrinolysis in cardiac arrest from other causes.

**Fluids**\(^{105}\)

**Consensus on Science**
There were no published human studies of routine fluid use compared with no fluids during normovolemic cardiac arrest. Four animal studies (LOE 6)\(^{180–183}\) of experimental VF neither support nor refute the use of IV fluids routinely. Fluids should be infused if hypovolemia is suspected.

**Alternative Routes for Drug Delivery**
If IV access cannot be established, intraosseous (IO) delivery of resuscitation drugs will achieve adequate plasma concentrations. Resuscitation drugs can also be given via the tracheal tube, but the plasma concentrations achieved are variable and substantially lower than those achieved when the same drug is given by the IV or IO route.

**Intraosseous Route**\(^{29}\)

**Consensus on Science**
Two prospective trials in adults and children (LOE 3)\(^{184,185}\) and 6 other studies (LOE 4\(^{186}\); LOE 5\(^{187–189}\); LOE 7\(^{190,191}\)) documented that IO access is safe and effective for fluid resuscitation, drug delivery, and laboratory evaluation, and is attainable in all age groups.

**Drugs Given via the Tracheal Tube**\(^{32,W108}\)

**Consensus on Science**

**Atropine and epinephrine.** In 1 historic nonrandomized cohort study (LOE 4)\(^{192}\) in adults, the rate of ROSC (27% vs 15%, \(P=0.01\)) and rate of survival to hospital admission (20% vs 9%, \(P=0.01\)) was significantly higher in the IV drug (atropine and adrenaline) group compared with the tracheal drug group. No patient who received tracheal drugs survived to hospital discharge compared with 5% of those who received IV drugs.

**Epinephrine.** During CPR the equipotent epinephrine dose given endobronchially was approximately 3 to 10 times higher than the IV dose (LOE 5\(^{193}\); LOE 6\(^{194}\)). Endobronchial epinephrine (2 to 3 mg) diluted in 5 to 10 mL 0.9% NaCl achieved therapeutic plasma concentrations (LOE 5)\(^{195}\). Endobronchial epinephrine achieved higher plasma concentrations when diluted with water rather than 0.9% saline (LOE 6)\(^{195}\).

During CPR lung perfusion is only 10% to 30% of the normal value, resulting in a pulmonary epinephrine depot. When cardiac output is restored after a high dose of endobronchial epinephrine, prolonged reabsorption of epinephrine from the lungs into the pulmonary circulation may occur (LOE 6)\(^{194}\), causing arterial hypertension, malignant arrhythmias, and recurrence of VF.

**Lidocaine.** All studies were performed in hemodynamically stable (nonarrest) patients. Therapeutic plasma concentrations of lidocaine were achieved in these patients (LOE 5)\(^{196,197}\) after tracheal tube instillation but in only 40% of similar patients after instillation via an LMA (LOE 5)\(^{197,198}\). In anesthetized healthy adults, endobronchial delivery delayed the increase in lidocaine plasma concentrations (LOE 2)\(^{199}\). In some (LOE 5)\(^{198,200}\) but not all of these studies (LOE 2\(^{199}\); LOE 5\(^{196}\)), deep endobronchial delivery of lidocaine via a catheter achieved lower blood concentrations than when lidocaine was injected directly into the tracheal tube. Endobronchial lidocaine achieved higher plasma concentrations and caused less reduction in PaO\(_2\) when diluted with water instead of 0.9% sodium chloride (LOE 5)\(^{201}\).

**Vasopressin.** Endobronchial vasopressin was more effective in increasing diastolic blood pressure than equivalent doses of endobronchial epinephrine (LOE 6)\(^{202}\). In a small animal study, endobronchial vasopressin was more effective than placebo in increasing coronary perfusion pressure during CPR and improving survival rates (LOE 6)\(^{203}\).

**Treatment Recommendation**
If IV access is delayed or cannot be achieved, IO access should be considered. Give drugs via the tracheal tube if intravascular (IV or IO) access is delayed or cannot be achieved. There are no benefits from endobronchial injection compared with injection of the drug directly into the tracheal tube. Dilution with water instead of 0.9% saline may achieve better drug absorption.

**Monitoring and Assisting the Circulation**
Specific questions related to the use of techniques and devices to (1) monitor the performance of CPR during cardiac arrest or (2) assist the circulation (alternatives to standard
CPR) during cardiac arrest were discussed during the 2005 Consensus Conference. They are listed below.

**Monitoring CPR Performance**
End-tidal CO₂ can be used as an indicator of ROSC. Arterial blood gas analysis may help to guide therapy. Measurement of coronary artery perfusion might be helpful, but because it is technically difficult to measure, it is not available routinely.

**End-Tidal CO₂ Monitoring to Guide Therapy During Cardiac Arrest**

**Consensus on Science**
No studies have addressed this topic directly. The studies published over the past 5 years were consistent with the older literature, which showed that higher end-tidal CO₂ values during CPR correlate with ROSC (LOE 5).

In experimental models, end-tidal CO₂ concentration during ongoing CPR correlated with cardiac output, coronary perfusion pressure, and successful resuscitation from cardiac arrest (LOE 6).

Eight case series have shown that patients who were successfully resuscitated from cardiac arrest had significantly higher end-tidal CO₂ levels than patients who could not be resuscitated (LOE 5). Capnometry can also be used as an early indicator of ROSC (LOE 5).

In case series totaling 744 patients, intubated adults in cardiac arrest receiving CPR who had a maximum end-tidal CO₂ of <10 mm Hg had a poor prognosis even if CPR was optimal (LOE 5). This prognostic indicator may be unreliable immediately after starting CPR because 2 studies (LOE 5) showed no difference in ROSC and survival in those with an initial end-tidal CO₂ of <10 mm Hg. Two additional studies (LOE 5) reported that 5 patients achieved ROSC despite an initial end-tidal CO₂ of <10 mm Hg (1 patient survived).

**Treatment Recommendation**
End-tidal CO₂ monitoring is a safe and effective noninvasive indicator of cardiac output during CPR and may be an early indicator of ROSC in intubated patients.

**Arterial Blood Gas Monitoring During Cardiac Arrest**

**Consensus on Science**
There was evidence from 1 LOE 5 study and 10 LOE 7 studies that arterial blood gas values are an inaccurate indicator of the magnitude of tissue acidosis during cardiac arrest and CPR in both the in-hospital and out-of-hospital settings. The same studies indicate that both arterial and mixed venous blood gases are required to establish the degree of acidosis.

Arterial blood gas analysis alone can disclose the degree of hypoxemia (LOE 5; LOE 6; LOE 7).

Arterial blood gas analysis can also highlight the extent of metabolic acidosis (LOE 5; LOE 6; LOE 7). Arterial CO₂ is an indicator of adequacy of ventilation during CPR (LOE 2; LOE 5; LOE 6; LOE 7). If ventilation is constant, an increase in PaCO₂ is a potential marker of improved perfusion during CPR (LOE 5; LOE 6; LOE 7).

**Treatment Recommendation**
Arterial blood gas monitoring during cardiac arrest enables estimation of the degree of hypoxemia and the adequacy of ventilation during CPR but is not a reliable indicator of the extent of tissue acidosis.

**Coronary Perfusion Pressure to Guide Resuscitation**

**Consensus on Science**
Coronary perfusion pressure (CPP) (aortic relaxation [diastolic] minus the right atrial relaxation phase blood pressure during CPR) correlated with both myocardial blood flow and ROSC (LOE 3). A value ≥15 mm Hg is predictive of ROSC. Increased CPP correlated with improved 24-hour survival in animal studies (LOE 6) and is associated with improved myocardial blood flow and ROSC in studies of epinephrine, vasopressin, and angiotensin II (LOE 6).

**Treatment Recommendation**
Coronary perfusion pressure can guide therapy during cardiac arrest. In an intensive care facility the availability of direct arterial and central venous pressure monitoring makes calculation of CPP potentially useful. Outside the intensive care facility the technical difficulties of invasive monitoring of central arterial and venous pressure make it difficult to calculate CPP routinely during cardiac arrest.

**Techniques and Devices to Assist Circulation During Cardiac Arrest**

Several techniques or adjuncts to standard CPR have been investigated, and the relevant data was reviewed extensively. One multicenter human study (LOE 2) showed poor quality and frequent interruptions in chest compressions delivered during prehospital CPR. In the hands of some groups, novel techniques and adjuncts may be better than standard CPR. The success of any technique depends on the education and training of the rescuers or the resources available (including personnel). Because information about these techniques and devices is often limited, conflicting, or supportive only for short-term outcomes, no recommendations can be made to support or refute their routine use.

**Transcutaneous Pacing for Asystole**

**Consensus on Science**
Three randomized controlled trials (LOE 2) and additional studies (LOE 3) indicate no improvement in the rate of admission to hospital or survival to hospital discharge when pacing was attempted by paramedics or physicians in asystolic patients in the prehospital or the hospital (emergency department) setting.

**Treatment Recommendation**
Pacing is not recommended for patients in asystolic cardiac arrest.

**CPR Prompt Devices**

**Consensus on Science**
Two studies in adults (LOE 5) show that unprompted CPR was frequently of poor quality in the out-of-hospital and
in-hospital settings. One study in adults (LOE 3), one study in children (LOE 3), and animal (LOE 6) and manikin studies (LOE 6) show consistent improvement in end tidal CO$_2$ or quality of CPR performed, or both, when feedback was provided with a variety of formats to guide CPR. In one manikin study (LOE 6), 95% of rescuers reported discomfort in the heels of their hands and wrists when using a CPR prompt applied between their hands and the victim’s chest, but no long-term injuries were noted. A crossover study of paramedic students previously trained in CPR showed that audio feedback significantly improved the proportion of correct inflations, correct compression depth, and duration of compressions (LOE 6). A similar study of nursing students showed improved inflations and depth of compression (LOE 6).

**Treatment Recommendation**

CPR prompt devices may improve CPR performance. See also Part 8: “Interdisciplinary Topics.”

**Interposed Abdominal Compression CPR**

**Consensus on Science**

Two randomized controlled trials (LOE 1; LOE 2) of in-hospital cardiac arrests showed improved ROSC and survival of event when interposed abdominal compression CPR (IAC-CPR) performed by rescuers trained in the technique was compared with standard CPR. One of these studies (LOE 1) also reported improved rates of survival to hospital discharge. This data and that from a crossover study (LOE 3) were combined in 2 meta-analyses (LOE 1). One randomized controlled trial (LOE 2) of out-of-hospital cardiac arrests did not show any survival advantage when IAC-CPR was undertaken by rescuers trained in the technique compared with standard CPR. Some harm was reported in 1 child (LOE 5). Although only a small proportion of patients had postmortem examinations, there was no evidence of significant harm.

**High-Frequency CPR**

**Consensus on Science**

One clinical trial of 9 patients (LOE 4) showed that high-frequency CPR (120 compressions per minute) improved hemodynamics over standard CPR. Three laboratory studies (LOE 6) showed that high-frequency CPR (120 to 150 compressions per minute) improved hemodynamics without increasing trauma. In one additional laboratory study (LOE 6), high-frequency CPR did not improve hemodynamics over standard CPR.

**Active Compression-Decompression CPR**

**Consensus on Science**

Despite initial promising studies suggesting short-term survival benefits (LOE 2; LOE 1) and even intact neurologic survival (LOE 1), a Cochrane meta-analysis (LOE 1) of 10 trials (involving 4162 patients) compared active compression-decompression (ACD) CPR with standard CPR in the out-of-hospital setting and did not show a significant increase in rates of immediate survival or hospital discharge. One meta-analysis (LOE 1) of 2 trials (826 patients) comparing ACD-CPR with standard CPR after in-hospital cardiac arrest did not detect a significant increase in rates of immediate survival or hospital discharge. Although one small study (LOE 4) showed harm with an increased incidence of sternal fractures in the ACD-CPR group when compared with standard CPR alone, the large meta-analysis did not find any increase in complications when ACD-CPR was compared with standard CPR.

**Load Distributing Band CPR**

**Consensus on Science**

The load distributing band (LDB) is a circumferential chest compression device composed of a pneumatically actuated constricting band and backboard. A case control study of 162 adults (LOE 4) documented improvement in survival to the emergency department when LDB-CPR was administered by adequately trained rescue personnel to patients with cardiac arrest in the prehospital setting. The use of LDB-CPR improved hemodynamics in 1 in-hospital study of end-stage patients (LOE 3) and 2 laboratory studies (LOE 6).

**Mechanical (Piston) CPR**

**Consensus on Science**

One prospective randomized study and 2 prospective randomized crossover studies in adults (LOE 2) indicated improvement in end-tidal CO$_2$ and mean arterial pressure when automatic mechanical (piston) CPR was undertaken by medical and paramedical personnel in the hospital or prehospital setting. In several studies in animals (LOE 6), mechanical (piston) CPR improved end-tidal CO$_2$, cardiac output, cerebral blood flow, mean arterial pressure, and short-term neurologic outcome.

**Lund University Cardiac Arrest System CPR**

**Consensus on Science**

The Lund University Cardiac Arrest System (LUCAS) is a gas-driven sternal compression device that incorporates a suction cup for active decompression. There were no published randomized human studies comparing LUCAS-CPR with standard CPR. A single study of pigs with VF showed that LUCAS-CPR improved hemodynamic and short-term survival rates compared with standard CPR (LOE 6). The LUCAS was also used in 20 patients, but incomplete outcome data was reported (LOE 6).

**Phased Thoracic-Abdominal Compression-Decompression CPR**

**Consensus on Science**

Phased thoracic-abdominal compression-decompression (PTACD) CPR combines the concepts of IAC-CPR and ACD-CPR. One modeling study (LOE 7) and one laboratory study (LOE 6) showed that PTACD-CPR improved hemodynamics. One clinical, randomized study in adults (LOE 2) of 108 patients and additional experimental studies (LOE 6; 7) documented no improvement in survival rates for patients with cardiac arrest when PTACD-CPR was used for assistance of circulation during ALS in the prehospital or in-hospital setting. PTACD-CPR did not substantially delay...
starting CPR and had no significant known disadvantages nor caused harm when used correctly.

**Minimally Invasive Direct Cardiac Massage**

**Consensus on Science**

Minimally invasive direct cardiac massage (MIDCM) involves insertion of a plunger-like device through a small incision in the chest wall to enable direct compression of the heart. MIDCM improved ROSC and coronary perfusion pressure compared with standard CPR in one laboratory study (LOE 6) and generated systemic blood flow and myocardial and cerebral flow similar to that produced with open-chest cardiac massage in 2 laboratory studies (LOE 6).

The MIDCM device was placed in patients in the field and generated improved blood pressure over standard CPR in one clinical study (LOE 3). But in this study, use of the MIDCM device caused cardiac rupture in 1 patient. MIDCM increased the defibrillation threshold for standard external defibrillation but reduced the defibrillation threshold if the MIDCM device was used as one of the electrodes in one laboratory study (LOE 6).

**Impedance Threshold Device**

**Consensus on Science**

The impedance threshold device (ITD) is a valve that limits air entry into the lungs during chest recoil between chest compressions. It is designed to reduce intrathoracic pressure and enhance venous return to the heart. A randomized study of 230 adults documented increased admissions to the ICU and 24-hour survival rates (LOE 2) when an ITD was used with standard CPR in patients with cardiac arrest (PEA only) in the prehospital setting. The addition of the ITD improved the hemodynamics during standard CPR in 5 laboratory studies (LOE 6) and 1 clinical study (LOE 2).

A randomized study of 400 adults showed increased ROSC and 24-hour survival rates (LOE 1) when an ITD was used with ACD-CPR in patients with cardiac arrest in the prehospital setting. The addition of the ITD improved the hemodynamics during ACD-CPR in 1 laboratory study (LOE 6) and 1 clinical study (LOE 2). One laboratory study failed to show an improvement in hemodynamics with the use of the ITD during ACD-CPR (LOE 6). Compared with standard CPR, ROSC and 24-hour survival were increased when the ITD was used with ACD in a randomized study of 210 prehospital patients (LOE 1), and hemodynamics were improved in 2 laboratory studies (LOE 6).

**Extracorporeal Techniques and Invasive Perfusion Devices**

**Consensus on Science**

The only adult data comes from 3 case series (LOE 5). One of these indicated that extracorporeal CPR (ECPR) was more successful in postcardiotomy patients than those in cardiac arrest from other causes. The other 2 studies suggested that ECPR is not beneficial for patients presenting to the emergency department in cardiac arrest with the exception of cardiac arrest associated with hypothermia or drug intoxication.

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**Open-Chest CPR**

**Consensus on Science**

No prospective randomized studies of open-chest CPR for resuscitation have been published. Four relevant human studies were reviewed, 2 after cardiac surgery (LOE 4; LOE 5) and 2 after out-of-hospital cardiac arrest (LOE 4; LOE 5). The observed benefits of open-chest cardiac massage included improved coronary perfusion pressure and increased ROSC. Evidence from animal studies indicates that open-chest CPR produces greater survival rates, perfusion pressures, and organ blood flow than closed-chest CPR.

**Treatment Recommendation**

Open-chest CPR should be considered for patients with cardiac arrest in the early postoperative phase after cardiothoracic surgery or when the chest or abdomen is already open.

**Periarrhythmias**

**Narrow-Complex Tachycardia**

There are 4 options for the treatment of narrow-complex tachycardia in the periarrhythm setting: electrical conversion, physical maneuvers, pharmacologic conversion, or rate control. The choice depends on the stability of the patient and the rhythm. In a hemodynamically unstable patient, narrow-complex tachycardia is best treated with electrical cardioversion.

**Drug Therapy for Atrial Fibrillation**

**Consensus on Science**

One randomized controlled trial in adults and 3 additional studies documented improvement in rate control when magnesium (LOE 3), diltiazem (LOE 2), or β-blockers (LOE 2) were given by physicians, nurses, and paramedics in both the out-of-hospital (LOE 3) and hospital settings to patients with atrial fibrillation with a rapid ventricular response.

Two randomized controlled trials in adults and additional studies documented improvement in rhythm when ibutilide, digoxin, clonidine, magnesium, or amiodarone were given by physicians or nurses to patients with atrial fibrillation in the hospital setting.

**Treatment Recommendation**

Magnesium, diltiazem, or β-blockers may be used for rate control in patients with atrial fibrillation with a rapid ventricular response. Amiodarone, ibutilide, propafenone, flecainide, digoxin, clonidine, or magnesium may be used for rhythm control in patients with atrial fibrillation.

**Drug Therapy for Regular Narrow-Complex Tachycardia**

**Consensus on Science**

In one randomized study in the ED, 41 of 148 (28%) patients with paroxysmal supraventricular tachycardia (PSVT) were converted to sinus rhythm with carotid sinus massage or a Valsalva maneuver (LOE 2). One study (LOE 4) showed that stable paroxysmal supraventricular tachycardia (PSVT)
in younger patients may be treated first with vagal maneuvers but will be unsuccessful 80% of the time.

Five prospective controlled nonrandomized cohort studies (LOE 254; LOE 355–358 indicated that adenosine is safe and effective in converting PSVT in the hospital and out-of-hospital settings. Two randomized clinical trials (LOE 255,59) documented no statistical significance in PSVT conversion rate between adenosine and calcium channel blockers, but the effect of adenosine is more rapid, and side effects are less severe than with verapamil. One randomized clinical trial in the ED (LOE 2160 documented no difference in the PSVT conversion rate between infusions of verapamil (99%) and diltiazem (96%). One randomized clinical trial in the ED (LOE 1161 documented significantly better PSVT conversion rates with diltiazem (100%) in comparison with esmolol (25%). One electrophysiologic study (LOE 6)162 documented that amiodarone achieved 100% efficacy in the inhibition of induced sustained reentrant PSVT.

**Treatment Recommendation**

Stable narrow-complex tachycardia (excluding atrial fibrillation or atrial flutter) should be treated first with vagal maneuvers (avoiding carotid sinus massage in the elderly); these will terminate about 20% of PSVTs. If vagal maneuvers are not used or if they fail, give adenosine.

A calcium channel blocker (verapamil or diltiazem) infusion or amiodarone may be used as a second-line treatment for the 10% to 15% of patients who do not respond to adenosine. In unstable PSVT, electrical cardioversion is the treatment of choice; IV rapid bolus adenosine can be tried if electrical cardioversion is not immediately available.

**Broad-Complex Tachycardia**

The stability of the patient determines the choice of treatment for wide-complex (broad-complex) tachycardia. In unstable wide-complex tachycardia, electrical cardioversion is the treatment of choice.

**Drug Therapy for Stable Ventricular Tachycardia**

**Consensus on Science**

Three observational studies (LOE 5)363–365 indicated that amiodarone is effective for the termination of shock-resistant or drug-refractory VT. One randomized parallel study (LOE 2)138 indicated that aqueous amiodarone is more effective than lidocaine in the treatment of shock-resistant VT. One randomized trial (LOE 2)166 indicated that procainamide is superior to lidocaine in terminating spontaneously occurring VT. Three retrospective analyses (LOE 5)367–369 indicated a low rate of termination of VT with lidocaine in patients with and without acute myocardial infarction. One randomized controlled trial (LOE 1)170 indicated that sotalol is significantly more effective than lidocaine for terminating acute sustained VT. One meta-analysis (LOE 1)367 showed that the overall risk of torsades de pointes in patients treated with a single infusion of IV sotalol is approximately 0.1%.

**Treatment Recommendation**

Amiodarone, procainamide, and sotalol are effective in terminating stable sustained VT.

**Drug Therapy for Polymorphic Ventricular Tachycardia**

**Consensus on Science**

One observational study (LOE 5)371 showed that IV magnesium will not terminate polymorphic VT (excluding torsades de pointes) in patients with a normal QT interval. Lidocaine is not effective, but amiodarone may be (LOE 4)372.

**Treatment Recommendation**

For hemodynamically stable polymorphic VT, where electrical therapy is not desirable or is ineffective, treatment with amiodarone may be effective.

**Therapy for Torsades de Pointes**

**Consensus on Science**

Two observational studies (LOE 5)371,373 showed that IV magnesium can effectively terminate torsades de pointes in patients with prolonged QT interval. One adult case series (LOE 5)374 showed that isoproterenol or ventricular pacing can be effective in terminating torsades de pointes associated with bradycardia and drug-induced QT prolongation.

**Treatment Recommendation**

Magnesium, isoproterenol, and ventricular pacing can be used to treat torsades de pointes.

**Bradycardia**

In the periarrest setting, the rescuer should seek and treat reversible causes of bradycardia. In the absence of reversible causes, atropine remains the first-line drug for acute symptomatic bradycardia. Failure to respond to atropine will usually necessitate transcutaneous pacing, although second-line drug therapy with dopamine, epinephrine, isoproterenol, or theophylline may be successful. First pacing may be attempted pending the arrival of an electrical pacing unit.

**Drug Therapy for Symptomatic Bradycardia**

**Consensus on Science**

In 1 randomized clinical trial in adults (LOE 2)375 and 1 historic cohort study in adults and additional reports (LOE 4)376,379 IV atropine improved heart rate, symptoms, and signs associated with bradycardia. An initial dose of 0.5 mg, repeated as needed to a total of 1.5 mg, was effective in both in-hospital and out-of-hospital treatment of symptomatic bradycardia.

In 2 prospective controlled nonrandomized cohort studies in hospitalized adults (LOE 4)376,380 administration of IV theophylline improved heart rate, symptoms, and signs associated with bradycardia that did not respond to atropine.

One case series (LOE 5)379 documented improvement in heart rate, symptoms, and signs associated with bradycardia when IV glucagon (3 mg initially, followed by infusion at 3 mg/h if necessary) was given to hospital patients with drug-induced symptomatic bradycardia not responding to atropine.

One study in 10 healthy volunteers indicated that a 3-mg dose of atropine produces the maximum achievable increase in resting heart rate (LOE 7).381 One study indicated that atropine may paradoxically cause high-degree AV block in patients after cardiac transplantation (LOE 5).382
Fist Pacing in Cardiac Arrest

Consensus on Science

Three case series indicated that fist pacing can be effective. Two of the largest studies have included 100 (LOE 5) and 50 (LOE 5) patients. One study (LOE 5) compared fist pacing with 2 electrical modes in the same patient and found all 3 techniques equally effective. Selected case series indicated that the most effective technique is to deliver serial rhythmic blows (fist pacing) with the closed fist over the left lower edge of the sternum to pace the heart at a physiological rate of 50 to 70 beats per minute (bpm) (LOE 5). There are no prehospital case reports of fist pacing. In virtually all published cases of fist pacing, complete heart block was the underlying bradycardia.

Treatment Recommendation

Fist pacing may be considered in hemodynamically unstable bradycardias until an electrical pacemaker (transcutaneous or transvenous) is available.

Cardiac Arrest in Special Circumstances

In some circumstances modification of the standard resuscitation technique is required to maximize the victim’s chance of survival. In many of these special circumstances recognition of the critically ill patient may enable early treatment to prevent cardiac arrest. The special circumstances reviewed during the consensus process can be categorized as environmental (hypothermia, submersion, electrocution), pregnancy, asthma, and drug overdose/poisoning.

Environmental

Hypothermia

Consensus on Science

Hypothermic patients with pulse. One randomized controlled trial (LOE 1) showed active surface heating to be more effective than metallic foil insulation in an experimental model of accidental hypothermia. Two studies (LOE 4) documented successful active rewarming with external surface, forced air, and warm infusions.

Hypothermic patients with cardiac arrest. Two studies (LOE 4) documented successful resuscitation with prolonged CPR and successful recovery using invasive rewarming (extracorporeal circulation or cardiopulmonary bypass). Successful resuscitation from hypothermic cardiac arrest was reported using active noninvasive rewarming (forced air, warm infusions) (LOE 4). Better outcomes were documented for nonasphyxial versus presumed asphyxial hypothermic arrest (LOE 4). For victims of avalanche, a small air pocket may prevent an asphyxial component of the arrest (LOE 5).

Treatment Recommendation

For hypothermic patients with a perfusing rhythm and without a preceding cardiac arrest, consider active (noninvasive) external warming (with heating blankets, forced air, and warmed infusion). Severely hypothermic patients in cardiac arrest may benefit from invasive warming (cardiopulmonary bypass or extracorporeal circulation).

Drowning

For additional information see “Drowning” in Part 2: “Adult Basic Life Support.”

Consensus on Science

One study indicated that victims of drowning are at risk for cervical spine injury only if they have clinical signs of severe injury (LOE 4). Three single case reports (LOE 5) documented the use of exogenous surfactant for fresh water–induced severe respiratory distress syndrome; 2 victims survived. A case report described the use of noninvasive positive-pressure ventilation in 2 victims of submersion (LOE 5).

There was no evidence to support or refute the use of steroids (LOE 5), nitric oxide (LOE 5), extracorporeal membrane oxygenation (ECMO) rewarming after ROSC (LOE 5), therapeutic hypothermia after ROSC (LOE 5), or vasopressin (LOE 5) after submersion. Case reports documented the use of ECMO in young children with severe hypothermia after submersion (LOE 5).

Treatment Recommendation

Victims of submersion should be removed from the water and resuscitated by the fastest means available. Only victims with risk factors (history of diving, water slide use, trauma, alcohol) or clinical signs of injury or focal neurologic signs should be treated as having a potential spinal cord injury, with stabilization of the cervical and thoracic spine.

Electrocution

Consensus on Science

Case reports (LOE 5) indicated that early BLS and ALS may be lifesaving and may decrease short- and long-term cardiac and neurologic sequelae for victims of electrocution and lightning injuries.

Case studies of victims of lightning and electric injuries emphasize the possible coexistence of multiple injuries and the importance of ensuring initial responder safety. Survivors may have permanent neurologic and cardiac sequelae.

Pregnancy

Etiology of Cardiac Arrest in Pregnancy

Consensus on Science

One large case series (LOE 5) suggested that systematic consideration of the reversible causes of cardiac arrest may
enable skilled rescuers to identify the etiology of cardiac arrest in pregnancy in the hospital setting.

Evidence extrapolated from peri-arrest resuscitation scenarios (LOE 7)\(^{414,415}\) indicated that ultrasound assessment undertaken by trained rescuers may help to identify intra-abdominal hemorrhage as a cause of cardiac arrest in pregnancy in the hospital setting.

**Treatment Recommendation**

Rescuers should try to identify common and reversible causes of cardiac arrest in pregnancy during resuscitation attempts. The use of abdominal ultrasound by a skilled operator should be considered in detecting pregnancy and possible causes of cardiac arrest in pregnancy, but this should not delay other treatments.

**Resuscitation Technique for Pregnancy**\(^{W134}\)

**Consensus on Science**

A case series (LOE 5)\(^{416}\) and numerous case reports (LOE 7)\(^{417; 8418–421}\) documented an improvement in rates of maternal and neonatal survival to discharge when delivery of the fetus was performed within 5 minutes of cardiac arrest in pregnancy if initial resuscitative efforts by skilled rescuers in the hospital setting failed.

Extrapolation from anesthesia (LOE 7)\(^{422}\) and a manikin study (LOE 6)\(^{423}\) suggests that a left lateral tilt of 15 degrees will relieve aortocaval compression in the majority of pregnant women and enable effective chest compressions by rescuers in any setting.

A human volunteer study (LOE 7)\(^{424}\) showed that there was no change in transthoracic impedance during pregnancy. The standard recommended energy levels for adults should be used by rescuers when attempting defibrillation in cardiac arrest during pregnancy in any setting.

**Treatment Recommendation**

If initial resuscitative efforts fail, caesarean delivery of the fetus (hysterotomy) should be performed within 5 minutes of onset of cardiac arrest in pregnancy to improve maternal or fetal survival. A left lateral tilt of 15 degrees is required to relieve inferior vena caval compression in the majority of pregnant women. The energy levels used for defibrillation in adults are appropriate for use in pregnancy.

**Asthma**

**Defibrillation in Asthma**\(^{W133, W133}\)

**Consensus on Science**

One volunteer study in healthy adults (LOE 7)\(^{425}\) documented an increased transthoracic impedance with increasing positive end-expiratory pressure (PEEP) and suggested that increased shock energy may be required if initial defibrillation attempts fail for patients with asthma-induced cardiac arrest in any clinical setting.

**Treatment Recommendation**

If initial attempts at defibrillation fail for the patient with asthma and VF, higher shock energies should be considered.

**Ventilation in Asthma**\(^{W119B}\)

**Consensus on Science**

Evidence extrapolated from a systematic review of patients with noncardiac arrest (LOE 7)\(^{426}\) suggested decreased dynamic hyperinflation (auto-PEEP) when helium/oxygen mixtures were used to ventilate the lungs of asthmatic patients during in-hospital cardiac arrest.

Evidence extrapolated from 3 noncardiac arrest case series (LOE 7)\(^{427–429}\) suggested that asthmatic patients were at risk of gas trapping during cardiac arrest, especially if they were ventilated with higher tidal volumes and rates than recommended. Two small case series (LOE 5)\(^{430,431}\) and anecdotal reports (LOE 8)\(^{432}\) failed to show a consistent benefit from compression of the chest wall, followed by a period of apnea to relieve gas trapping, for patients with asthma-induced cardiac arrest in any clinical setting (see also “Disconnection From Ventilation During Cardiac Arrest,” above).

Evidence extrapolated from a noncardiac arrest case series (LOE 7)\(^{428}\) suggested improved ventilation of the lungs and decreased gastric inflation if the trachea is intubated early by trained rescuers for patients with asthma-induced cardiac arrest in any setting. Evidence from 2 noncardiac arrest case reports (LOE 7)\(^{433; 434}\) neither supported nor refuted the use of open-chest ventilation and cardiac compressions in asthma-induced cardiac arrest.

**Treatment Recommendation**

There are insufficient data to support or refute the use of helium-oxygen mixtures in asthma-related cardiac arrest. Compression of the chest wall or a period of apnea may relieve gas trapping if dynamic hyperinflation occurs. In asthma-related cardiac arrest the patient’s trachea should be intubated early to facilitate ventilation and minimize the risk of gastric inflation.

**Drug Overdose and Poisoning**\(^{W198}\)

**Sodium Bicarbonate for Poisoning and Electrolyte Disturbances**\(^{W197A, W197B, W197C, W197D, W197E}\)

**Consensus on Science**

Evidence from the use of bicarbonate in calcium channel blocker overdose in 2 children (LOE 5)\(^{435}\) with fatal overdoses of nifedipine neither supported nor refuted the value of bicarbonate in calcium channel blocker overdose.

There were no controlled human studies of sodium bicarbonate therapy for arrhythmias or hypotension related to tricyclic antidepressant overdose. However, evidence from case reports (LOE 5)\(^{436,437}\) animal studies (LOE 6)\(^{438–447}\) and in vitro studies (LOE 6)\(^{445,448,449}\) supported the use of sodium bicarbonate to treat tricyclic antidepressant–induced arrhythmias or hypotension.

**Treatment Recommendation**

Sodium bicarbonate is recommended for the treatment of tricyclic antidepressant–induced arrhythmia or hypotension. Although no study has investigated the optimal target pH with bicarbonate therapy, a pH of 7.45 to 7.55 has been commonly accepted and seems reasonable.
Ventilation Before Naloxone in Opioid Overdose

Consensus on Science
Evidence from case series (LOE 5) in adults and extrapolation from LOE 7 studies indicate fewer adverse events when ventilation is provided before administration of naloxone by EMS personnel to patients with opioid-induced respiratory depression in the prehospital setting.

Postresuscitation Care
Rosc is just the first step toward the goal of complete recovery from cardiac arrest. Interventions in the postresuscitation period are likely to significantly influence the final outcome, yet there are relatively few data relating to this phase. In the absence of firm guidelines, approaches to postresuscitation care are heterogeneous. Postresuscitation interventions are categorized into the following areas: (1) ventilation, (2) temperature control (therapeutic hypothermia and prevention and treatment of hyperthermia), (3) seizure control and sedation, and (4) other supportive therapies (blood glucose control, coagulation control, prophylactic antiarrhythmic therapy).

Therapeutic hypothermia improves neurologic outcome in some cardiac arrest survivors, and hyperthermia appears harmful. Tight blood glucose control improves outcome in undifferentiated critically ill patients, but the effect of this therapy in the postresuscitation phase is unknown. Prediction of outcome in comatose survivors of cardiac arrest remains problematic: median nerve somatosensory-evoked potentials measured 72 hours after cardiac arrest may be helpful, but analyses of several serum markers were inconclusive.

Ventilation

Control of Arterial Carbon Dioxide

Consensus on Science
Five studies in adults (LOE 2,458,459, LOE 3,460, LOE 5,461, LOE 7,462) and numerous animal studies (LOE 6) documented harmful effects of hypocapnia (cerebral ischemia) after cardiac arrest. Two studies provide neutral evidence (LOE 5,460, LOE 6,467).

Treatment Recommendation
There are no data to support the targeting of a specific PaCO2 after resuscitation from cardiac arrest. Data extrapolated from patients with brain injury, however, imply that ventilation to normocarbia is appropriate. Routine hyperventilation may be detrimental and should be avoided.

Temperature Control

Therapeutic Hypothermia

Consensus on Science
Two randomized clinical trials (LOE 1,468; LOE 2,469) showed improved outcome in adults who remained comatose after initial resuscitation from out-of-hospital VF cardiac arrest and who were cooled within minutes to hours after ROSC. Patients in these studies were cooled to 33°C or to the range of 32°C to 34°C for 12 to 24 hours. The Hypothermia After Cardiac Arrest (HACA) study included a small subset of patients with in-hospital cardiac arrest.

One study (LOE 2) documented improved metabolic endpoints (lactate and O2 extraction) when comatose adult patients were cooled after ROSC from out-of-hospital cardiac arrest in which the initial rhythm was PEA/asystole. A small study (LOE 4) showed benefit after therapeutic hypothermia in comatose survivors of non-VF arrest.

External or internal cooling techniques can be used to initiate cooling within minutes to hours (LOE 1,468; LOE 2,469,470, LOE 5,472–475). The only studies documenting improved outcome with therapeutic hypothermia after cardiac arrest used external cooling (LOE 1,468; LOE 2,469,470). An infusion of 30 mL/kg of 4°C saline achieved a decrease in core temperature of approximately 1.5°C (LOE 5). Studies (LOE 5,472,473,475) documented that intravascular cooling enables more precise control of core temperature than external methods.

Studies documenting improved outcome with therapeutic hypothermia after cardiac arrest used continuous temperature monitoring (LOE 1,468; LOE 2,469,470).

Multiple studies in animals (LOE 6) documented the importance of initiating cooling as soon as possible and for adequate duration (eg, 12 to 24 hours). Optimal parameters, including onset, depth, and duration of cooling, are unknown.

Seizures or myoclonus occurs in survivors of cardiac arrest (LOE 5,474,485–487). Shivering will necessitate sedation and intermittent or continuous neuromuscular blockade. Use of continuous neuromuscular blockade could mask seizure activity.

Treatment Recommendation
Unconscious adult patients with spontaneous circulation after out-of-hospital cardiac arrest should be cooled to 32°C to 34°C for 12 to 24 hours when the initial rhythm was VF. Cooling to 32°C to 34°C for 12 to 24 hours may be considered for unconscious adult patients with spontaneous circulation after out-of-hospital cardiac arrest from any other rhythm or cardiac arrest in hospital.

Prevention and Treatment of Hyperthermia

Consensus on Science
A period of postarrest hyperthermia is common in the first 48 hours after cardiac arrest (LOE 4,488–490). There were no controlled prospective studies that examined the clinical impact of antipyretics (or physical cooling devices) to prevent hyperthermia after cardiac arrest.

The risk of unfavorable neurologic outcome increased for each degree of body temperature >37°C (LOE 3). Hyperthermia was associated with increased morbidity and mortality in post-stroke patients (LOE 7). Post-stroke pyrexia was not treated effectively by antipyretics such as acetaminophen or ibuprofen (LOE 7), however, antipyretics or physical cooling methods have been associated with decreased infarct volumes in animal models of global ischemia (LOE 7,495,496).

Treatment Recommendation
Hyperthermia should be avoided after cardiac arrest.
Seizure Control and Sedation

Prevention and Control of Seizures

Consensus on Science

There were no studies that directly addressed the use of prophylactic anticonvulsant drugs after cardiac arrest in adults. There are data indicating that seizures can precipitate cardiac arrest (LOE 4), but this has not been shown in post–cardiac arrest patients. Several human studies have documented a strong association between high blood glucose after resuscitation from cardiac arrest and poor neurologic outcome (LOE 4). There was good evidence that persistent hyperglycemia after stroke is an independent predictor of survival (LOE 4). The optimal blood glucose target in critically ill patients has not been determined. Comatose patients were at particular risk from unrecognized hypoglycemia, and the risk of this complication occurring increases as the target blood glucose concentration is lowered (LOE 8). One study in rats has shown that glucose plus insulin improves cerebral outcome after asphyxial cardiac arrest (LOE 6).

Treatment Recommendation

Providers should monitor blood glucose frequently after cardiac arrest and should treat hyperglycemia with insulin but avoid hypoglycemia.

Other Supportive Therapies

Blood Glucose Control

Consensus on Science

Tight control of blood glucose (range 80 to 110 mg/dL or 4.4 to 6.1 mmol/L) with insulin reduces hospital mortality rates in critically ill adults (LOE 8), but this has not been shown in post–cardiac arrest patients. Several human studies have documented a strong association between high blood glucose after resuscitation from cardiac arrest and poor neurologic outcome (LOE 4). There was good evidence that persistent hyperglycemia after stroke is associated with a worse neurologic outcome (LOE 7).

The optimal blood glucose target in critically ill patients has not been determined. Comatose patients were at particular risk from unrecognized hypoglycemia, and the risk of this complication occurring increases as the target blood glucose concentration is lowered (LOE 8). One study in rats has shown that glucose plus insulin improves cerebral outcome after asphyxial cardiac arrest (LOE 6).

Therapeutic hypothermia was associated with hyperglycemia (LOE 2). Comatose patients were at particular risk from unrecognized hypoglycemia, and the risk of this complication occurring increases as the target blood glucose concentration is lowered (LOE 8). One study in rats has shown that glucose plus insulin improves cerebral outcome after asphyxial cardiac arrest (LOE 6).

Sedation and Pharmacologic Paralysis

Consensus on Science

There were no data to support or refute the use of a defined period of ventilation, sedation, and neuromuscular blockade after cardiac arrest. One observational study in adults (LOE 5) documents increased incidence of pneumonia when sedation is prolonged beyond 48 hours after prehospital or in-hospital cardiac arrest.

Prevention and Control of Seizures

Consensus on Science

There were no studies that directly addressed the use of prophylactic anticonvulsant drugs after cardiac arrest in adults. There are data indicating that seizures can precipitate cardiac arrest (LOE 4), but this has not been shown in post–cardiac arrest patients. Several human studies have documented a strong association between high blood glucose after resuscitation from cardiac arrest and poor neurologic outcome (LOE 4). There was good evidence that persistent hyperglycemia after stroke is an independent predictor of survival (LOE 4). The optimal blood glucose target in critically ill patients has not been determined. Comatose patients were at particular risk from unrecognized hypoglycemia, and the risk of this complication occurring increases as the target blood glucose concentration is lowered (LOE 8). One study in rats has shown that glucose plus insulin improves cerebral outcome after asphyxial cardiac arrest (LOE 6).

Treatment Recommendation

Providers should monitor blood glucose frequently after cardiac arrest and should treat hyperglycemia with insulin but avoid hypoglycemia.

Coagulation Control

Consensus on Science

There are no studies evaluating the role of anticoagulation alone to improve outcome after ROSC. In three nonexpe-
studies (LOE 4506,539,562–564; LOE 5512,513,565–568) indicated that neuron-specific enolase (NSE) and protein S-100b may be useful in predicting the outcome of cardiac arrest. But the 95% confidence interval (CI) in these trials was wide, and in many of the trials, return to consciousness (without comment on level of function) was considered a “good” outcome.

The only meta-analysis to look at this topic estimated that to obtain 95% CI with a 5% false-positive rate would require a study population of approximately 600 patients (LOE 1).569 No study this large has been conducted.

Treatment Recommendation
No laboratory analyses (NSE, S-100b, base deficit, glucose, or soluble P-selectin) provide reliable prediction of the outcome after cardiac arrest.

Somatosensory-Evoked Potentials

Consensus on Science
Eighteen prospective studies (LOE 3)568,570–586 and 1 meta-analysis (LOE 1)587 indicated that median nerve somatosensory-evoked potentials in normothermic patients comatose for at least 72 hours after cardiac arrest predict poor outcome with 100% specificity. Bilateral absence of the N20 component of the evoked potentials in comatose patients with coma of hypoxic-anoxic origin is uniformly fatal.

Treatment Recommendation
Median nerve somatosensory-evoked potentials measured 72 hours after cardiac arrest can be used to predict a fatal outcome in patients with hypoxic-anoxic coma.

Electroencephalogram

Consensus on Science
The use of the electroencephalogram (EEG), performed at least 24 to 48 hours after arrest, has been evaluated in case series of humans (LOE 5)578,585,588–598 and animals (LOE 6).599–601 On the modified Hockaday scale, grades I (normal alpha with theta-delta activity), IV (alpha coma, spikes, sharp waves, slow waves with very little background activity), and V (very flat to isoelectric) were most useful prognostically. But the prognosis was unpredictable for those with grade II and III EEGs.

Treatment Recommendation
The use of the EEG performed a minimum of 24 to 48 hours after a cardiac arrest can help define the prognosis in patients with grade I, IV, and V EEGs.

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W58. http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA. 105.170522/DC89
Part 5: Acute Coronary Syndromes

The American Heart Association and the American College of Cardiology,1,2 the European Society of Cardiology3,4 and others5 have developed comprehensive guidelines for the in-hospital management of patients with ST-elevation myocardial infarction (STEMI)2 and for unstable angina (UA) and non–ST-elevation MI (NSTEMI).1 The International Liaison Committee on Resuscitation (ILCOR) Acute Coronary Syndromes (ACS)/Acute Myocardial Infarction (AMI) Task Force reviewed the evidence specifically related to diagnosis and treatment of ACS/AMI in the out-of-hospital setting and the first hours of care in the in-hospital setting, typically in the emergency department (ED).

Much of the research concerning the care of the patient with ACS has been conducted on in-hospital populations rather than in the ED or out-of-hospital settings. By definition, extending the conclusions from such research to the early ED management strategy or the out-of-hospital setting requires extrapolation classified as level of evidence 7.

Diagnostic Tests in ACS and AMI

The sensitivity, specificity, and clinical impact of various diagnostic strategies in ACS/AMI have been evaluated. These include signs and symptoms, cardiac markers, and 12-lead electrocardiogram (ECG). The standard ILCOR/AHA levels of evidence (described in Part 1: "Introduction") pertain largely to therapeutic interventions. For this reason, in the evaluation of evidence for diagnostic accuracy the reviewers used the Centre for Evidence-Based Medicine (CEBM) levels of evidence for diagnostic tests (http://www.cebm.net/levels_of_evidence.asp). The CEBM levels are cited as "levels" and the ILCOR/AHA levels of evidence are designated with "LOE," for "level of evidence."

Neither signs and symptoms nor cardiac markers alone are sufficiently sensitive to diagnose AMI or ischemia in the prehospital setting or the first 4 to 6 hours in the ED. The 12-lead ECG in the ED and out-of-hospital settings is central to the initial triage of patients with possible ACS.

Diagnostic and Prognostic Test Characteristics of Signs and Symptoms of ACS/AMI

Consensus on Science

Diagnosis. Four CEBM level 1B validating cohort studies6–9 and 9 CEBM level 2A-4 studies10–18 do not support the use of any clinical signs and symptoms independent of ECG, cardiac biomarkers, or other diagnostic tests to rule in or rule out ACS/AMI in prehospital or ED settings. Although some signs are more sensitive and specific than others, no sign or symptom evaluated exceeded 92% sensitivity in the higher LOE studies (most reported sensitivity of 35% to 38%) or 91% specificity (range 28% to 91% in highest CEBM levels).7

Prognosis and clinical impact. In 3 CEBM level 1a systematic reviews,10,19,20 10 CEBM level 1b validating cohort studies8–9,21–26 and 21 CEBM level 2a-4 studies,11–13,15–18,27–40 a variety of signs and symptoms assisted in the diagnosis of ACS/AMI and had clinical impact (defined as triage and some treatment and investigational decisions) on the out-of-hospital emergency management and risk assessment for coronary atherosclerosis and unstable syndromes.

Treatment Recommendation

Signs and symptoms of ACS/AMI may be useful in combination with other important information (biomarkers, risk factors, ECG, and other diagnostic tests) in making triage and some treatment and investigational decisions in the out-of-hospital setting and the ED. Signs and symptoms are not independently diagnostic of ACS/AMI.

Diagnostic and Prognostic Test Characteristics of Cardiac Biomarkers for ACS/AMI

Consensus on Science

Diagnosis. All literature reviewed showed that biomarkers (creatinine kinase [CK], creatine kinase myocardial band [CK-MB], myoglobin, troponin I [TnI], troponin T [TnT]) were helpful in the diagnosis of ACS/AMI. But only 6 studies41–44 (CEBM level 445,46; ILCOR LOE 7) showed a sensitivity of >95% within the first 4 to 6 hours of the patient’s arrival in the ED. Multimarker strategies20,41–43,45–61 (CEBM level 1b; ILCOR/AHA LOE 7 [extrapolated from in-hospital setting]), and serial marker testing over time41–43,45–49,51,56,58,60–69 (CEBM level 1b; ILCOR/AHA LOE 7 [extrapolated from in-hospital setting]) improved test performance.Six out-of-hospital studies70–75 (CEBM level 1b) showed consistent lack of support for the use of cardiac biomarkers in diagnosing AMI in the out-of-hospital phase (sensitivity 10% to 25%; specificity 92% to 100%).

Prognosis. Two systematic reviews (CEBM level 1a)76,77 and 21 additional studies78–98 (18 CEBM level 1b and 3 ILCOR/AHA LOE 7) documented consistent ability of cardiac biomarker testing to identify patients at increased risk of adverse outcome. One systematic review (CEBM level 1a)76 suggested that risk assessment cannot be based exclusively on cardiac biomarker results (30-day mortality range for patients with suspected ACS and negative troponin results: 0.7% to 4.4%).
**Treatment Recommendation**

Emergency physicians should obtain cardiac biomarkers for all patients with suspected ACS/AMI. Serial time points (increasing interval from onset of symptoms to testing), and multimarker strategies greatly improve sensitivity for detection of myocardial ischemia or infarction but are insensitive for ruling out these diagnoses in the out-of-hospital setting or within the first 4 to 6 hours of evaluation in the ED.

**ED Interpretation of 12-Lead ECG for STEMI**

**Consensus on Science**

**Diagnostic characteristics—out-of-hospital.** One meta-analysis plus 5 prospective nonrandomized consecutive case series of patients with chest pain (CEBM level 1b–1c) and 5 review articles ILCOR/AHA LOE 711,20,105–107 showed that trained out-of-hospital care providers (paramedics and nurses) could identify ST-segment elevation accurately in the resting out-of-hospital 12-lead ECG of patients with chest pain suspected of having STEMI. The out-of-hospital care providers achieved a specificity of 91% to 100% and sensitivity of 71% to 97% compared with emergency physicians or cardiologists. Of note, left bundle branch block paced rhythm and idioventricular rhythm may affect the diagnostic test accuracy because they were excluded in some studies and not mentioned in others.

**Prognostic characteristics—ED.** ST elevation (>1 mV elevation in 2 or more adjacent limb leads or in 2 or more adjacent precordial leads with reciprocal depression) was the most discriminating single ECG feature for diagnosis of STEMI (likelihood ratio [LR] of 13.1; 95% confidence interval [CI], 8.28–20.6).11 Emergency physicians blinded to biomarker results established the diagnosis of STEMI using admission ECGs with a very high specificity of 99.7% (95% CI, 98%–99.9%; LR + 145; 95% CI, 20.2–1044), although sensitivity was low at 42% (95% CI, 32%–52%) (CEBM 1b–1c; ILCOR/AHA LOE 7).11

**Treatment Recommendation**

**Out-of-hospital.** Trained out-of-hospital personnel can accurately identify acute STEMI in prehospital 12-lead ECGs obtained in patients with ACS. The ECG is used in combination with chest pain symptoms, assessment of risk factors, and other diagnostic tests to rule out alternative diagnoses. Out-of-hospital interpretation of a single 12-lead ECG with stringent inclusion criteria (ie, ST elevation >0.1 mV in 2 or more adjacent precordial leads or 2 or more adjacent limb leads and with reciprocal depression) has a high specificity for the diagnosis of STEMI.

**ED.** In the ED the interpretation of a single 12-lead ECG with rigid inclusion criteria (see above) is discriminating for the diagnosis of STEMI with a relatively low sensitivity but a high specificity for this diagnosis.

**Acute Therapeutic Interventions**

Few studies have been published to guide out-of-hospital interventions for ACS and AMI. Extrapolating from the evidence for many of the adjunctive therapies used in-hospital within 24 to 48 hours may provide some guidance for out-of-hospital and early ED management.

**Adjunctive Therapies**

**Oxygen Therapy**

**Consensus on Science**

Supplementary oxygen should be given to patients with arterial oxygen desaturation (arterial oxygen saturation [Sao2] <90%). Given the safety profile of oxygen in this population and the potential benefit in the patient with unrecognized hypoxia, it is reasonable to give supplementary oxygen to all patients with uncomplicated STEMI during the first 6 hours of emergency management.

**Aspirin (Acetylsalicylic Acid)**

**Consensus on Science**

Eight randomized controlled trials (RCTs) (LOE 1)113–120 showed decreased mortality rates when acetylsalicylic acid (ASA) (75 to 325 mg) was given to hospitalized patients with ACS. The International Study of Infarct Survival (ISIS)-2 trial used 160 mg/day orally (odds reduction=0.23; 95% CI, 0.15–0.30).115

Four RCTs (LOE 1)115,116,120,121 and 3 additional studies (LOE 7)122–124 indicated decreased mortality rates when ASA was given as early as possible.

Two studies (LOE 1)125,126 addressed specific ASA dose, but the standard of 160 mg enteric-coated ASA has still been maintained from ISIS-2. Two studies showed that chewed (LOE 3)127 or soluble (LOE 6)128 ASA provides more rapid bioavailability than swallowed tablets. Two nonblinded studies (LOE 7)124,129 showed that 50 mg of intravenous (IV) ASA was >90% effective in inhibiting thromboxane A2 and inhibits platelets effectively.

One post hoc study suggested decreased mortality rates with out-of-hospital administration of ASA (LOE 7).123

Seven hospital-based RCTs indicated that giving ASA to patients with suspected ACS is safe (LOE 1).113–115,117,118,120,121

**Treatment Recommendation**

It is reasonable for dispatchers to advise the patient with suspected ACS and without a true aspirin allergy to chew a single dose (160 to 325 mg) of ASA. It is also reasonable for EMS providers to administer ASA because there is good evidence that it is safe and that the earlier ASA is given, the greater the reduction in risk of mortality.

Limited evidence from several very small studies suggests that the bioavailability and pharmacologic action of other formulations of ASA (soluble, IV) may be as effective as chewed tablets.

**Heparin**

**Consensus on Science**

**UA/NSTEMI.** Six in-hospital RCTs (LOE 1)130,131 and LOE 2121,132,133 <24 hours; LOE 134 <36 hours) and additional
studies (including 7 meta-analyses, 135–141) documented similar or improved composite outcomes (death, MI or recurrent angina, or recurrent ischemia or revascularization) after giving low-molecular-weight heparin (LMWH) instead of unfractionated heparin (UFH) to patients with UA/NSTEMI within the first 24 to 36 hours after onset of symptoms. No study evaluated the early use of LMWH versus UFH in the first 6 hours of management. Extrapolation (LOE 7) from 1 RCT133 and 1 meta-analysis (LOE 1)135 suggests that changing from one form of heparin to another (crossover of antithrombin therapy) during initial treatment of an acute event may not be safe or effective in patients with UA/NSTEMI. There is no evidence that LMWH is superior to UFH in the group of patients who will receive early percutaneous coronary intervention (PCI).

STEMI. In 2 RCTs (LOE 1142; LOE 2143) and additional studies, including one meta-analysis (LOE 1),144 LMWH (specifically enoxaparin) improved overall TIMI flow145 (coronary reperfusion) and ischemic outcomes better than UFH when given to patients with STEMI within 6 hours of onset of symptoms. TIMI flow grade was defined by investigators from the TIMI study146 as the degree of reperfusion, ranging from 0 for no flow through 3 for complete, brisk flow.

Two studies (LOE 1146; LOE 2147) in the out-of-hospital setting documented improved composite outcomes with LMWH (specifically enoxaparin) in comparison with UFH, when given to patients with STEMI as adjunctive therapy to fibrinolysis. This must be balanced against the increase in intracranial hemorrhage in patients >75 years of age receiving LMWH (enoxaparin) that was observed in one of these RCTs (LOE 2).147

In patients with STEMI proceeding to PCI, there is no evidence in favor of LMWH.

In one RCT (LOE 1148) there was no difference in the incidence of death, reinfarction, or recurrent angina with LMWH (enoxaparin) in comparison with UFH when given to patients who were ineligible for reperfusion therapy.

Treatment Recommendation

UA/NSTEMI. In the ED giving LMWH instead of UFH in addition to aspirin to patients with UA/NSTEMI may be helpful. There is insufficient evidence to identify the optimal time for administration after onset of symptoms. In-hospital administration of UFH is recommended if reperfusion is planned within the first 24 to 36 hours after onset of symptoms. There is insufficient evidence to recommend for or against treatment with LMWH in UA/NSTEMI in the out-of-hospital setting. Changing from one form of heparin to another (crossover of antithrombin therapy) during an acute event is not recommended.

STEMI. LMWH is an acceptable alternative to UFH as ancillary therapy for patients with STEMI who are <75 years of age and receiving fibrinolytic therapy. LMWH should not be given if significant renal dysfunction (serum creatinine >2.5 mg/dL in men or 2 mg/dL in women) is present. UFH is recommended for patients ≥75 years of age as ancillary therapy to fibrinolysis. Heparin may be given to STEMI patients who do not receive reperfusion therapy. These include patients at high risk for cardioembolic events and those on prolonged bedrest. UFH or LMWH may be used. Patients receiving LMWH should have no significant renal dysfunction.

Clopidogrel

Consensus on Science

In 2 in-hospital, randomized, double-blind, controlled trials (LOE 1)149,150 and 4 post hoc analyses (LOE 7),151–154 clopidogrel was effective in reducing the combined event rate (stroke, nonfatal infarction, deaths from cardiovascular causes, refractory ischemia, heart failure, and need for revascularization) in patients with suspected ACS with evidence of ischemia but no infarction. In these studies clopidogrel was given within the first 4 hours of presentation to the hospital in addition to standard care (ASA, heparin) to patients with ACS who had a rise in serum level of cardiac biomarkers or new ECG changes consistent with ischemia but no ST-segment elevation.

One large randomized, double-blind, controlled trial (LOE 7)155 documented no significant increase in risk of bleeding with clopidogrel in comparison with ASA. One large multicenter RCT (LOE 1)156 documented a significant reduction in adverse ischemic events at 28 days after elective PCI when clopidogrel was given at least 6 hours before elective PCI.

One multicenter, randomized, double-blind, controlled trial (LOE 1)157 documented a significant reduction in the composite end point of an occluded infarct-related artery (defined by a TIMI flow grade of 0 or 1) on angiography or death or recurrent MI before angiography when clopidogrel (300 mg oral loading dose) was given at the time of initial management (followed by a 75-mg daily dose for up to 8 days in hospital) to patients up to 75 years of age with STEMI who were treated with fibrinolysis, ASA, and heparin (LMWH or UFH).

In one large prospective STEMI trial (the CURE [Clopidogrel in Unstable angina to prevent Recurrent Events] trial),152 preoperative clopidogrel administration was associated with a trend toward increased postoperative reoperation for bleeding in the 2072 patients who underwent coronary artery bypass graft (CABG) surgery. A second prospective trial (LOE 1)157 failed to show any increase in bleeding in the 136 patients who underwent CABG within 5 to 7 days of receiving clopidogrel. A subsequent risk-to-benefit ratio analysis concluded that the bleeding risk with clopidogrel in patients undergoing CABG was overestimated.154

Treatment Recommendation

Give a 300-mg oral loading dose of clopidogrel in addition to standard care (ASA, heparin) to patients with ACS within 4 to 6 hours of contact if they have

• A rise in serum cardiac biomarkers or new ECG changes consistent with ischemia when a medical approach or PCI is planned in the absence of ST-segment elevation

• STEMI in patients up to 75 years of age receiving fibrinolysis, ASA, and heparin

Although in one large trial152 preoperative clopidogrel administration was associated with increased postoperative reoperation for bleeding, the recent CLARITY TIMI 28 trial157 did not document increased bleeding in patients undergoing CABG within 5 to 7 days of receiving clopidogrel.
Current ACC/AHA recommendations advise withholding clopidogrel for 5 to 7 days before planned CABG. It is reasonable to give clopidogrel 300 mg orally to patients with suspected ACS (without ECG or cardiac marker changes) who have hypersensitivity to or gastrointestinal intolerance of ASA.

**Glycoprotein IIb/IIIa Inhibitors**

**Consensus on Science**

**UA/NSTEMI.** Two studies (LOE 158; LOE 2159) and 2 meta-analyses (LOE 1158,160) showed a reduction in the combined end point of death or recurrent ischemia when glycoprotein (GP) IIb/IIIa inhibitors were added to standard therapy (including ASA and heparin) for patients with high-risk UA/NSTEMI treated with PCI. High-risk features include persistent ongoing pain due to ischemia, hemodynamic or rhythm instability due to ongoing ischemia, acute or dynamic ECG changes, and any elevation in cardiac troponins attributed to ACS.

Two studies (LOE 1158,161 and 3 meta-analyses (LOE 1160,162,163) failed to show a reduction in the combined end point of death or recurrent ischemia in patients with UA/NSTEMI treated with tirofiban or eptifibatide without PCI. Two studies (LOE 1164,165) showed that abciximab given in addition to standard therapy but without PCI in patients with UA/NSTEMI did not reduce the combined end point of death or recurrent ischemia. No published studies evaluated the out-of-hospital use of GP IIb/IIIa inhibitors. Three studies (LOE 1158,160,163) showed the safety (as defined by low incidence of major hemorrhagic complications) of GP IIb/IIIa inhibitors when given to ACS patients within 24 to 48 hours of onset of symptoms.

**STEMI.** In multiple studies (LOE 1166,167,168; LOE 2130,169–174; LOE 4175; LOE 7176) there was no reduction in the combined end point of death or recurrent ischemia when tirofiban or eptifibatide were given in combination with reduced-dose fibrinolitics to patients with STEMI in the absence of PCI.

Two RCTs (LOE 1165,177) in patients with STEMI treated with abciximab and fibrinolitics showed no reduction in the combined end point of death or recurrent ischemia. One meta-analysis (LOE 1178) showed reduction in short-term reinfarction rate when abciximab was given with fibrinolitics or PCI, whereas the benefits in mortality-rate reduction were seen only in patients treated with PCI. One RCT failed to show a benefit with tirofiban in addition to standard therapy when given out-of-hospital (LOE 2).171 Another study demonstrated the feasibility of using abciximab in the out-of-hospital setting (LOE 7).175 A third study showed a trend toward improved patency of infarct-related artery with PCI (LOE 3).179

**Treatment Recommendation**

**High-risk UA/NSTEMI.** If revascularization therapy (PCI or surgery) is planned, it is safe to give GP IIb/IIIa inhibitors in addition to standard therapy (including ASA and heparin) to patients with high-risk UA/NSTEMI in the ED. This therapy may reduce the risk of death or recurrent ischemia. High-risk features of UA/NSTEMI are defined in the consensus on science statement above. If revascularization therapy is not planned, the recommendation for use of GP IIb/IIIa varies by drug. Tirofiban and eptifibatide may be used in patients with high-risk UA/NSTEMI in conjunction with ASA and LMWH if PCI is not planned. But abciximab can be harmful in patients with high-risk UA/NSTEMI if early (eg, 24 hours) PCI is not planned.

**STEMI.** Abciximab is not currently recommended in patients receiving fibrinolitics for STEMI. In patients treated with PCI without fibrinolysis, abciximab may be helpful in reducing mortality rates and short-term reinfarction. There is no evidence documenting a better outcome by giving GP IIb/IIIa inhibitors out of hospital or early in the ED.

**Reperfusion Strategies**

**Out-of-Hospital Fibrinolitics for STEMI**

**Consensus on Science**

One meta-analysis (LOE 1)180 and multiple studies (LOE 1181,182; LOE 2183–185; LOE 3147,186–188; LOE 4189–192; LOE 5193; LOE 7194–196) documented reduced time to injection of fibrinolitics when given by out-of-hospital providers (physicians, nurses, or paramedics) to patients with STEMI and no contraindications to fibrinolysis. In most studies the duration of symptoms was from 30 minutes to 6 hours. Using the same criteria, 1 meta analysis (LOE 1)180 and 8 additional studies (LOE 1184,189; LOE 3197; LOE 4191,192; LOE 5199) documented reduced risk of mortality with out-of-hospital fibrinolysis.

**Treatment Recommendation**

Out-of-hospital administration of fibrinolitics by paramedics, nurses, or physicians using an established protocol is safe and feasible for patients with STEMI and no contraindications. This requires adequate provisions for the diagnosis and treatment of STEMI and its complications, including strict treatment directives, fibrinolitic checklist, ECG acquisition and interpretation, defibrillators, experience in ACLS protocols, and the ability to communicate with medical control. Physicians may give out-of-hospital fibrinolitics to patients with symptoms compatible with ACS and signs of true posterior infarctions (no ST elevation).

**Fibrinolitics in the ED Management of STEMI**

**Consensus on Science**

A prospective cohort study (LOE 3)200 and 11 additional studies (LOE 3201–208; LOE 4209; LOE 5210,211) documented reduced delay to injection of fibrinolitics and some decrease in mortality (LOE 3)200,212 and improved left ventricular function (LOE 3)200 when fibrinolitics were given in the ED to selected patients with STEMI (defined in studies with variable ST-elevation criteria with or without new onset left bundle branch block [LBBB] ≥posterior infarct) and no contraindications.

**Treatment Recommendation**

In the ED patients with symptoms of ACS and ECG evidence of either STEMI (presumably) new LBBB, or true posterior infarction should be given fibrinolitics if fibrinolysis is the treatment of choice and there are no contraindications. The emergency physician should give fibrinolitics as early as possible according to a predetermined protocol.
Primary PCI Compared With ED or Out-of-Hospital Fibrinolysis

Consensus on Science

Six randomized studies (LOE 1),213–218 3 meta-analyses (LOE 1),219–221 and 24 additional studies (LOE 2–4)222–245 compared primary PCI with fibrinolysis in patients with STEMI. These studies documented consistent improvement in the combined end point of death, stroke, and reinfarction when PCI was undertaken by skilled personnel in a high-volume center (ie, >75 procedures per operator annually) with minimal delay. Minimal delay was defined as balloon inflation ≤90 minutes after first medical contact (ie, contact with a healthcare provider who can make a decision to treat or transfer). In these studies the typical additional delay from decision to treat to either PCI or ED fibrinolysis was ≤60 minutes.

One study (LOE 1)217 and a post hoc subgroup analysis (LOE 7)246 of fibrinolysis compared with PCI showed no difference in survival rates when fibrinolysis was initiated within 2 hours246 or 3 hours217 after onset of symptoms.

One RCT and a 1-year follow-up of the same study (LOE 1)216,247 comparing early revascularization (eg, surgery, facilitated PCI, and primary PCI) with medical therapy in patients with cardiogenic shock showed decreased 6-month and 1-year mortality rates, especially for patients <75 years of age. Direct comparison of the outcome of primary PCI patients to patients who received only fibrinolytic therapy was not reported.

Treatment Recommendation

All patients presenting with STEMI within 12 hours of the onset of symptoms should be evaluated for reperfusion therapy (ie, fibrinolysis or PCI).

Primary PCI is the preferred reperfusion strategy in STEMI with symptom duration >3 hours if a skilled team can perform primary PCI in ≤90 minutes after first medical contact with the patient or if there are contraindications to fibrinolysis.

If the duration of symptoms is ≤3 hours, treatment is more time-sensitive, and the superiority of out-of-hospital fibrinolysis, immediate in-hospital fibrinolysis, or transfer for primary PCI is not established (see below for further discussion of transfer).

Early revascularization (ie, surgery, primary or early PCI, defined as PCI ≤24 hours after fibrinolysis) is reasonable in patients with cardiogenic shock, especially for patients <75 years of age.

Primary and Secondary Prevention Interventions

Traditional preventive interventions usually start with the first admission with a confirmed diagnosis of ACS. Therapeutic options include antiarrhythmics, β-blockers, angiotensin-converting enzyme (ACE) inhibitors, and HMG-CoA reductase inhibitors (statins). The current evidence indicates that with the exception of β-blockers, none plays a significant role in the out-of-hospital and ED management of ACS.

Antiarrhythmics

Lidocaine

Consensus on Science

When lidocaine was given by physicians or paramedics for primary prophylaxis within the first 4 hours of a suspected STEMI in the out-of-hospital setting, 4 meta-analyses (LOE 1)248–251 and 2 RCTs (LOE 2)250,252 showed a trend toward increased mortality rates. In addition, 2 meta-analyses253,254 and 15 RCTs (LOE 1255; LOE 2256–269), 1 case series (LOE 5),270 and 1 retrospective trial (LOE 5)271 showed no effect of lidocaine on mortality in this setting. Only one small study (LOE 2)272 showed a decrease in mortality with prophylactic lidocaine. Several trials (LOE 2258,259,262,264,265; LOE 5270) reported more side effects (including paresthesias, tinnitus, confusion, bradycardia requiring treatment, seizures, coma, and respiratory arrest) in patients receiving prophylactic lidocaine.

Magnesium

Consensus on Science

Giving magnesium prophylactically to patients with STEMI has produced mixed results. One study (LOE 2)273 showed a decrease in mortality and symptomatic arrhythmias. One meta-analysis (LOE 1)274 and 2 RCTs (LOE 1275; LOE 2276) showed a decrease in mortality but no reduction in ventricular arrhythmias. One small RCT (LOE 2277) showed that magnesium reduced the incidence of ventricular tachycardia, but it was underpowered to assess mortality. The definitive study on the subject is the ISIS-4 study (LOE 1).278 ISIS-4 enrolled >58 000 patients and showed a trend toward increased mortality when magnesium was given in-hospital for primary arrhythmia prophylaxis to patients within the first 4 hours of known or suspected AMI.

Disopyramide, Mexiletine, and Verapamil

Consensus on Science

One multi-antiarrhythmic meta-analysis (LOE 1)279 and 4 RCTs (LOE 2280–282; LOE 7283) showed no effect on mortality when a variety of antiarrhythmic drugs (disopyramide, mexiletine, and verapamil) were given for primary prophylaxis by paramedics or physicians to patients within the first 4 hours of known or suspected AMI.

Treatment Recommendation for Antiarrhythmics

There is insufficient evidence to support the routine use of any antiarrhythmic drug as primary prophylaxis within the first 4 hours of proven or suspected AMI.

This conclusion does not take into account the potential effect of β-blockers discussed below.

β-Blockers

Consensus on Science

Two in-hospital RCTs (LOE 1)284,285 and 2 supporting studies (LOE 2)286,287 completed before the advent of fibrinolytics documented decreased mortality, reinfarction, ventricular fibrillation, supraventricular arrhythmias, and cardiac rupture in patients treated with β-blockers. In patients with AMI who received fibrinolytics, treatment with IV β-blockade within
24 hours of onset of symptoms reduced rates of reinfarction and cardiac rupture. IV β-blockade may reduce mortality in patients undergoing primary PCI who are not on oral β-blockers (LOE 7). \( ^{288} \) β-Blocker therapy was initiated in the ED for most of these trials; only one included out-of-hospital administration.\( ^{289} \)

One small trial (LOE 2)\(^ {290} \) showed a trend toward decreased mortality when IV β-blockers were given for unstable angina.

**Treatment Recommendation**

In the ED treat ACS patients promptly with IV β-blockers followed by oral β-blockers. β-Blockers are given irrespective of the need for revascularization therapies. Contraindications to β-blockers include hypotension, bradycardia, heart block, moderate to severe congestive heart failure, and reactive airway disease.

**ACE Inhibitors**\(^ {W231} \)

**Consensus on Science**

Seven large clinical trials (LOE 1),\(^ {278,291–296} \) 2 meta-analyses (LOE 1),\(^ {297,298} \) and 11 minor trials (LOE 1)\(^ {296,299–308} \) documented consistent improvement in mortality when oral ACE inhibitors were given to patients with AMI with or without early reperfusion therapy. ACE inhibitors should not be given if hypotension (systolic blood pressure <100 mm Hg or more than 30 mm Hg below baseline) is present or a contraindication to these drugs exists.

One large, randomized, double-blind, placebo-controlled trial (LOE 1)\(^ {309} \) and 2 small randomized trials (LOE 2)\(^ {310,311} \) in adults documented a trend toward a higher mortality rate if an IV ACE inhibitor was started within the first 24 hours after onset of symptoms in the hospital setting. There is no literature evaluating the therapeutic role of ACE inhibitors in the out-of-hospital setting.

**Treatment Recommendation**

Start an oral ACE inhibitor within 24 hours after onset of symptoms in patients with MI whether or not early reperfusion therapy is planned. Do not give an ACE inhibitor if the patient has hypotension (systolic blood pressure <100 mm Hg or more than 30 mm Hg below baseline) or if the patient has a known contraindication to these drugs. ACE inhibitors are most effective in patients with anterior infarction, pulmonary congestion, or left ventricular ejection fraction <40%.

There is no evidence to recommend for or against starting ACE inhibitors in the out-of-hospital setting. Avoid giving IV ACE inhibitors within the first 24 hours after onset of symptoms because they can cause significant hypotension during this phase.

**HMG CoA Reductase Inhibitors (Statins)**\(^ {W233} \)

**Consensus on Science**

Nine RCTs (LOE 7)\(^ {312–320} \) and additional small studies (LOE 3–7)\(^ {321–323} \) documented a consistent decrease in the incidence of major adverse cardiovascular events (reinfarction, stroke, necessary intervention for recurrent angina, and rehospitalization) when statins were given within a few days after onset of ACS. There are few data on patients treated within 24 hours of the onset of symptoms.

One retrospective analysis (LOE 4)\(^ {324} \) and data from one registry (LOE 4)\(^ {325} \) showed that patients presenting with ACS who are already taking statins should continue to take them.

There is no data on the initiation of statin therapy out-of-hospital or in the ED for patients with ACS.

**Treatment Recommendation**

It is safe and feasible to start statin therapy early (within 24 hours) in patients with ACS or AMI; once started, continue statin therapy uninterrupted.

**Healthcare System Interventions for ACS/AMI**

Novel strategies have been developed and evaluated to improve the speed and quality of care delivered to patients with ACS. Many strategies have been shown to be safe, effective, and feasible in the prehospital setting and ED. Such strategies include out-of-hospital 12-lead ECG and advance ED notification, interfacility transfer of the patient for PCI, and a combined strategy of interfacility transfer after fibrinolysis.

**12-Lead Out-of-Hospital ECG and Advance ED Notification**\(^ {W235A,W235B} \)

**Consensus on Science**

Two RCTs (LOE 2),\(^ {326,327} \) 6 nonrandomized controlled trials (LOE 3),\(^ {101,328–332} \) 1 retrospective cross-sectional study (LOE),\(^ {106} \) and extrapolations from 2 feasibility studies (LOE 4\(^ {333} \); LOE 3\(^ {310} \)) showed a reduction of 10 to 60 minutes in the door-to-reperfusion interval for patients with STEMI when a 12-lead out-of-hospital ECG was obtained and interpreted by a physician, nurse, or paramedic and sent to the receiving hospital in advance (cellular ECG transmission or verbal communication).

One RCT (LOE 2)\(^ {326} \) and 5 other studies (LOE 5\(^ {103,334} \); LOE 4\(^ {335} \); LOE 3\(^ {101} \); LOE 5\(^ {335} \)) showed that 12-lead out-of-hospital ECGs with advance notification undertaken by out-of-hospital personnel does not increase on-scene time interval significantly (0.2 to 5.6 minutes) in patients with suspected AMI.

Four studies (LOE 3\(^ {103,334,336} \); LOE 5\(^ {335} \)) showed that out-of-hospital personnel can acquire and transmit diagnostic-quality 12-lead out-of-hospital ECGs.

**Treatment Recommendation**

Routine use of the 12-lead out-of-hospital ECG with advance ED notification may benefit STEMI patients by reducing the time interval to fibrinolysis.

Advance ED notification may be achieved with direct transmission of the ECG itself or verbal report (via telephone) of the ECG interpretation by out-of-hospital personnel.

**Interfacility Transfer for Primary PCI**\(^ {W237A,W237B} \)

**Consensus on Science**

Three RCTs (LOE 2)\(^ {213,217,240} \) and one meta-analysis (LOE 1)\(^ {219} \) documented safety and improved combined event rate (30-day combined rate of death, reinfarction, or stroke) when patients with STEMI from hospitals without the capability for
primary PCI were transferred promptly for primary PCI at a skilled facility. A skilled facility provides access to PCI undertaken by a skilled operator in a high-volume center (ie, >75 procedures per operator annually) with minimal delay.\textsuperscript{214,225,226}

When combined in a meta-analysis (LOE 1),\textsuperscript{219} 5 RCTs (LOE 2)\textsuperscript{213,217,233,240,241} showed reduced mortality rates when patients with STEMI from hospitals without the capability for primary PCI were transferred promptly to a facility with such capability.

In one RCT (LOE 2)\textsuperscript{217} and one post hoc subgroup analysis of an RCT (LOE 7),\textsuperscript{246} it is unclear whether immediate out-of-hospital fibrinolysis, in-hospital fibrinolysis, or transfer for primary PCI is most efficacious for patients presenting with STEMI within 2 to 3 hours of the onset of symptoms.

**Treatment Recommendation**

For patients with STEMI presenting >3 hours but <12 hours from the onset of symptoms, interfacility transfer from hospitals that lack primary PCI capability to centers capable of providing primary PCI is indicated if such a transfer can be accomplished as soon as possible. Optimally PCI should occur ≤90 minutes from first medical contact (ie, contact with a healthcare provider who can make the decision to treat or transfer).

In patients with STEMI presenting ≤3 hours from onset of symptoms, treatment is more time-sensitive, and there is inadequate data to indicate the superiority of out-of-hospital fibrinolysis, immediate hospital fibrinolysis, or transfer for primary PCI.

The time recommendations do not apply to patients in cardiogenic shock. In such patients the evidence supports early revascularization therapy (primary PCI, early PCI, or surgery) compared with medical therapy.\textsuperscript{216}

**Out-of-Hospital Triage for PCI**\textsuperscript{W236A,W236B}

**Consensus on Science**

A single study (LOE 2)\textsuperscript{337} with insufficient power and some methodological concerns and a second post hoc subgroup analysis (LOE 7)\textsuperscript{246} failed to show that out-of-hospital triage for primary PCI was any better than out-of-hospital fibrinolysis, in-hospital fibrinolysis, or transfer for primary PCI.

The time recommendations do not apply to patients in cardiogenic shock. In such patients the evidence supports early revascularization therapy (primary PCI, early PCI, or surgery) compared with medical therapy.\textsuperscript{216}

**Interfacility Transfer for Early PCI**\textsuperscript{W237A,W237B}

**Consensus on Science**

A strategy of fibrinolysis combined with transfer for early PCI (defined as PCI performed ≤24 hours after fibrinolysis) is supported by 6 randomized trials (LOE 1\textsuperscript{223,338,339} and LOE 2\textsuperscript{241,340,341}). The efficacy of this strategy is also supported by a post hoc nonrandomized comparison (LOE 3).\textsuperscript{342} But this strategy is not supported by other RCTs (LOE 1\textsuperscript{343–345}, LOE 2\textsuperscript{2223,240}) and other nonrandomized studies or secondary analyses of the above trials (LOE 7).\textsuperscript{246} Several meta-analyses showed no benefit of early PCI (LOE 1),\textsuperscript{347–349} All but one of these trials were carried out in the 1990s before the era of coronary stenting. These studies did not use modern drugs or contemporary PCI techniques.

The feasibility of fibrinolysis combined with transfer for early PCI is supported by 3 low-level studies. One study is a small trial in which PCI was performed routinely (LOE 7),\textsuperscript{350} one is a randomized trial of low-dose fibrinolitics compared with placebo before immediate cardiac catheterization and PCI as necessary (LOE 7),\textsuperscript{351} and one is a retrospective analysis (LOE 7).\textsuperscript{352}

The efficacy of early PCI for patients with cardiogenic shock was shown in an RCT that showed improved mortality at 6 months and 1 year with early revascularization (LOE 1),\textsuperscript{216} especially in patients <75 years of age. This was supported by a retrospective analysis (LOE 7).\textsuperscript{353}

One RCT (LOE 2) showed improvement in secondary nonfatal outcomes when early PCI was used for patients who did not achieve reperfusion after fibrinolysis.\textsuperscript{354}

All of the above studies involved in-hospital fibrinolysis. The use of prehospital fibrinolysis followed by early PCI has not been studied.

**Treatment Recommendation**

There is inadequate evidence to recommend the routine transfer of patients for early PCI after successful fibrinolysis in community hospital EDs or out of hospital.

Transfer for early PCI is recommended as one strategy for early revascularization for patients with cardiogenic shock, especially patients <75 years of age; or with hemodynamic instability or persistent symptoms of ischemia after fibrinolysis.

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III-62 Circulation  November 29, 2005


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2005 International Consensus Conference


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Part 6: Pediatric Basic and Advanced Life Support

The ILCOR Pediatric Task Force included expert reviewers from Africa, Asia, Australia, Asia, Europe, North America, and South America. These experts reviewed 45 topics related to pediatric resuscitation. Topics were selected from previous recommendations (the ECC Guidelines 20001, 2), emerging science, and newly identified issues. Some well-established topics without controversies or new evidence (eg, adenosine for the treatment of supraventricular tachycardia [SVT]) are not included in this document.

Evidence-based worksheets on some topics were prepared and discussed but are not included here because there was insufficient evidence (eg, fibrinolytics in cardiac arrest3, 4 securing the endotracheal tube in children,5 use of impedance threshold device in children,6 sodium bicarbonate for prolonged resuscitation attempts7, 8 or because no new evidence was found (eg, evaluation of capillary refill,9 ventilation before naloxone,10 delayed volume resuscitation in trauma,11 use of hypertonic saline in shock12). The following is a summary of the most important changes in recommendations for pediatric resuscitation since the last ILCOR review in 2000.1, 2 The scientific evidence supporting these recommendations is summarized in this document:

- Emphasis on the quality of CPR is increased: “Push hard, push fast, minimize interruptions; allow full chest recoil, and don’t hyperventilate”
  - Recommended chest compression-ventilation ratio:
    - For 1 lay rescuer and lone healthcare provider: 30:2
    - For healthcare providers performing 2-rescuer CPR: 15:2
  - Either the 2- or 1-hand technique is acceptable for chest compressions in children
  - 1 initial shock followed by immediate CPR for attempted defibrillation, instead of 3 stacked shocks
- Biphasic attenuated shocks with an automated external defibrillator (AED) are acceptable for children ≥1 year of age.
- Routine use of high-dose epinephrine is no longer recommended.
- Either cuffed or uncuffed tracheal tubes are acceptable in infants and children.
- Exhaled CO₂ monitoring is recommended for confirmation of tracheal tube placement and during transport.
- Consider induced hypothermia for patients who remain comatose following resuscitation.
- Emphasis is increased on intravascular (intravenous [IV] and intraosseous [IO]) rather than tracheal administration of drugs.

The ILCOR Pediatric Task Force reevaluated the definitions of newborn, infant, child, and adult. These definitions are somewhat arbitrary but are important because some recommendations for treatment differ according to patient size and the most likely etiology of arrest. The distinction between child and adult victims has been deemphasized by the recommendation of a universal compression-ventilation ratio for lay rescuers and the same chest compression technique for lay rescuers of children and adults. Some differences in treatment recommendations remain between the newborn and infant and between an infant and child, but those differences are chiefly linked to resuscitation training and practice. They are noted below.

Identified knowledge gaps in pediatric resuscitation include:

- Sensitive and specific indicators of cardiac arrest that lay rescuers and healthcare providers can recognize reliably
- Effectiveness of etiology-based versus age-based resuscitation sequences
- The ideal ratio of chest compressions to ventilations during CPR
- Mechanisms to monitor and optimize quality of CPR during attempted resuscitation
- Best methods for securing a tracheal tube
- Clinical data on the safety and efficacy of automated external defibrillators (AEDs)
- Clinical data on the safety and efficacy of the laryngeal mask airway (LMA) during cardiac arrest
- The benefits and risks of supplementary oxygen during and after CPR
- Clinical data on antiarrhythmic and pressor medications during cardiac arrest
- Data on induced hypothermia in pediatric cardiac arrest
- The identification and treatment of postarrest myocardial dysfunction
- The use of fibrinolytics and anticoagulants in cardiac arrest
- Use of emerging technologies for assessment of tissue perfusion
- Predictors of outcome from cardiac arrest

Initial Steps of CPR

The ECC Guidelines 2000 recommend that lone rescuers of adults victims of cardiac arrest phone the emergency medical services (EMS) system and get an AED (“call first”) before starting CPR. The lone rescuer of an unresponsive infant or child victim was instructed to provide a brief period...
of CPR before leaving the victim to phone for professional help and an AED ("call fast"). These sequence differences were based on the supposition that cardiac arrest in adults is due primarily to ventricular fibrillation (VF) and that a hypoxic-ischemic mechanism is more common in children. But this simplistic approach may be inaccurate and may not provide the ideal rescue sequence for many victims of cardiac arrest. Hypoxic-ischemic arrest may occur in adults, and VF may be the cause of cardiac arrest in up to 7% to 15% of infants and children. Resuscitation results might be improved if the sequence of lay rescuer CPR actions (ie, the priority of phoning for professional help, getting an AED, and providing CPR) is based on the etiology of cardiac arrest rather than age.

The pulse check was previously eliminated as an assessment for the lay rescuer. There is now evidence that healthcare professionals may take too long to check for a pulse and may not accurately determine the presence or absence of the pulse. This may lead to interruptions in chest compressions and affect the quality of CPR.

Experts reviewed the data on the technique of rescue breathing for infants and the 2-thumb–encircling hands versus 2-finger chest compression techniques for infants.

One of the most challenging topics debated during the 2005 Consensus Conference was the compression-ventilation ratio. The scientific evidence on which to base recommendations was sparse, and it was difficult to arrive at consensus. Evidence was presented that the ratio should be higher than 5:1, but the optimal ratio was not identified. The only data addressing a compression-ventilation ratio greater than 15:2 came from mathematical models. The experts acknowledged the educational benefit of simplifying training for lay rescuers (specifically 1-rescuer CPR) by adopting a single ratio for infants, children, and adults with the hope that simplification might increase the number of bystanders who will learn, remember, and perform CPR. On this basis experts agreed that this single compression-ventilation ratio should be 30:2. Healthcare providers will typically be experienced in CPR and practice it frequently. This group of experienced providers will learn 2-person CPR, and for them the recommended compression-ventilation ratio for 2 rescuers is 15:2.

Some laypeople are reluctant to perform mouth-to-mouth ventilation. For treatment of cardiac arrest in infants and children, chest compressions alone are better than no CPR but not as good as a combination of ventilations and compressions.

In the past 1-handed chest compressions were recommended for CPR in children. A review of the evidential basis for this recommendation was conducted. From an educational standpoint, we agree that it will simplify training to recommend a single technique for chest compressions for children and adults.

Activating Emergency Medical Services and Getting the AED

Consensus on Science

Most cardiac arrests in children are caused by asphyxia (LOE 4).3–6 Observational studies of non-VF arrests in children show an association between bystander CPR and intact neurologic outcome (LOE 4).6–8 Animal studies show that in asphyxial arrest, chest compressions plus ventilation CPR is superior to either chest compression-only CPR or ventilation-only CPR (LOE 6).9

Observational studies of children with VF report good (17% to 20%) rates of survival after early defibrillation (LOE 4).5,6,10 The merits of “call first” versus “call fast” CPR sequences have not been adequately studied in adults or children with cardiac arrest of asphyxial or VF etiologies. Three animal studies (LOE 6)9,11,12 show that even in prolonged VF, CPR increases the likelihood of successful defibrillation, and 7 adult human studies (LOE 7)13–19 document improved survival with the combination of CPR with minimal interruptions in chest compression and early defibrillation.

Treatment Recommendation

A period of immediate CPR before phoning emergency medical services (EMS) and getting the AED (“call fast”) is indicated for most pediatric arrests because they are presumed to be asphyxial or prolonged. In a witnessed sudden collapse (eg, during an athletic event), the cause is more likely to be VF, and the lone rescuer should phone for professional help and get the AED (when available) before starting CPR and using the AED, if appropriate. Rescuers should perform CPR with minimal interruptions in chest compressions until attempted defibrillation.

In summary, the priorities for unwitnessed or nonsudden collapse in children are as follows:

- Start CPR immediately.
- Activate EMS/get the AED.
- Attempt defibrillation.

The priorities for witnessed sudden collapse in children are as follows:

- Activate EMS/get the AED.
- Start CPR.
- Attempt defibrillation.

Pulse Check

Consensus on Science

Ten studies (LOE 220–21; LOE 422–26; LOE 527; LOE 628,29) show that lay rescuers23,25,30 and healthcare providers20,21,24,26–29 are often unable to accurately determine the presence of a pulse within 10 seconds. Two studies in infants (LOE 5)31,32 reported that rescuers rapidly detected cardiac activity by direct chest auscultation but were biased because they knew that the infants were healthy.

Treatment Recommendation

Lay rescuers should start chest compressions for an unresponsive infant or child who is not moving or breathing. Healthcare professionals may also check for a pulse but should proceed with CPR if they cannot feel a pulse within 10 seconds or are uncertain if a pulse is present.

Ventilations in Infants

Consensus on Science

One LOE 5 study and 10 LOE 734–43 reports assessed a mouth-to-nose ventilation technique for infants. The LOE 5
study is an anecdotal report of 3 infants ventilated with mouth-to-nose technique. The LOE 7 reports describe post-mortem anatomy, physiology of nasal breathing, related breathing issues, and measurements of infants’ faces compared with the measurement of adult mouths. There is great variation in these measurements, probably because of imprecise or inconsistent definitions.

**Treatment Recommendation**

There is no data to justify a change from the recommendation that the rescuer attempt mouth-to-mouth-and-nose ventilation for infants. Rescuers who have difficulty achieving a tight seal over the mouth and nose of an infant, however, may attempt either mouth-to-mouth or mouth-to-nose ventilation (LOE 5).

**Circumferential Versus 2-Finger Chest Compressions**

**Consensus on Science**

Two manikin (LOE 6) and 2 animal (LOE 6) studies showed that the 2 thumb–encircling hands technique of chest compressions with circumferential thoracic squeeze produces higher coronary perfusion pressures and more consistently correct depth and force of compression than the 2-finger technique.

Case reports (LOE 5) of hemodynamic monitoring in infants receiving chest compressions showed higher systolic and diastolic arterial pressures in the 2-thumb–encircling hands technique compared with the 2-finger technique.

**Treatment Recommendation**

The 2 thumb–encircling hands chest compression technique with thoracic squeeze is the preferred technique for 2-rescuer infant CPR. The 2-finger technique is recommended for 1-rescuer infant CPR to facilitate rapid transition between compression and ventilation and to minimize interruptions in chest compressions. It remains an acceptable alternative method of chest compressions for 2 rescuers.

**One- Versus 2-Hand Chest Compression Technique**

**Consensus on Science**

There are no outcome studies that compare 1- versus 2-hand compressions of the chest in children. One (LOE 6) study reported higher pressures generated in child manikins using the 2-hand technique to compress over the lower part of the sternum to a depth of approximately one third the anterior-posterior diameter of the chest. Rescuers reported that this technique was easy to perform.

**Treatment Recommendation**

Both the 1- and 2-hand techniques for chest compressions in children are acceptable provided that rescuers compress over the lower part of the sternum to a depth of approximately one third the anterior-posterior diameter of the chest. To simplify education, rescuers can be taught the same technique (ie, 2-hand) for adult and child compressions.

**Compression-Ventilation Ratio**

**Consensus on Science**

There is insufficient data to identify an optimal compression-ventilation ratio for CPR in children. Manikin studies (LOE 6) have examined the feasibility of compression-ventilation ratios of 15:2 and 5:1. Lone rescuers cannot deliver the desired number of chest compressions per minute at a ratio of 5:1. A mathematical model (LOE 7) supports compression-ventilation ratios higher than 5:1 for infants and children.

Two animal (LOE 6) studies show that coronary perfusion pressure, a major determinant of success in resuscitation, declines with interruptions in chest compressions. In addition, once compressions are interrupted, several chest compressions are needed to restore coronary perfusion pressure. Frequent interruptions of chest compressions (eg, with a 5:1 compression-ventilation ratio) prolongs the duration of low coronary perfusion pressure. Long interruptions in chest compressions have been documented in manikin studies (LOE 6) and both in- and out-of-hospital adult CPR studies (LOE 7). These interruptions reduce the likelihood of a return of spontaneous circulation (LOE 7).

For ease of teaching and retention, a universal compression-ventilation ratio of 30:2 is recommended for the lone rescuer responding to infants (for neonates see Part 7: “Neonatal Resuscitation”), children, and adults. For healthcare providers performing 2-rescuer CPR, a compression-ventilation ratio of 15:2 is recommended. When an advanced airway is established (eg, a tracheal tube, esophageal-tracheal combitube [Combitube], or laryngeal mask airway [LMA]), ventilations are given without interrupting chest compressions.

**Some CPR Versus No CPR**

**Consensus on Science**

Numerous reports (LOE 5) document survival of children after cardiac arrest when bystander CPR was provided. Bystander CPR in these reports included rescue breathing alone, chest compressions alone, or a combination of compressions and ventilations.

One prospective and 3 retrospective studies of adult VF (LOE 7) and numerous animal studies of VF cardiac arrest (LOE 6) document comparable long-term survival after chest compressions alone or chest compressions plus ventilations, and both techniques result in better outcomes compared with no CPR. In animals with asphyxial arrest (LOE 6), the more common mechanism of cardiac arrest in infants and children, best results are achieved with a combination of chest compressions and ventilations. But resuscitation with either ventilations only or chest compressions only is better than no CPR.

**Bystander CPR is important for survival from cardiac arrest. Trained rescuers should be encouraged to provide both**
ventilations and chest compressions. If rescuers are reluctant to provide rescue breaths, however, they should be encouraged to perform chest compressions alone without interruption.

**Disturbances in Cardiac Rhythm**
Evidence evaluation for the treatment of hemodynamically stable arrhythmias focused on vagal maneuvers, amiodarone, and procainamide. There was no new data to suggest a change in the indications for vagal maneuvers or procainamide. Several case series described the safe and effective use of amiodarone in children, but these studies involved selected patient populations (often with postoperative arrhythmias) treated by experienced providers in controlled settings. Although there is no change in the recommendation for amiodarone as a treatment option in children with stable arrhythmias, providers are encouraged to consult with an expert knowledgeable in pediatric arrhythmias before initiating drug therapy.

There is insufficient evidence to identify an optimal shock waveform, energy dose, and shock strategy (eg, fixed versus escalating shocks, 1 versus 3 stacked shocks) for defibrillation. The new recommendation for the sequence of defibrillation in children is based on extrapolated data from adult and animal studies with biphasic devices, data documenting the high rates of success for first shock conversion of VF with biphasic waveforms, and knowledge that interruption of chest compressions reduces coronary perfusion pressure. Thus, a 1-shock strategy may be preferable to the 3-shock sequence recommended in the ECC Guidelines 2000. For further details, see Part 3: “Defibrillation.”

Many but not all AED algorithms have been shown to be sensitive and specific for recognizing shockable arrhythmias in children. A standard AED (“adult” AED with adult pad-cable system) can be used for children older than about 8 years of age and weighing more than about 25 kg. Many manufacturers now provide a method for attenuating the energy delivered to make the AED suitable for smaller children (eg, use of a pad-cable system or an AED with a key or switch to select a smaller dose).

**Management of Supraventricular Tachycardias**
If the child with SVT is hemodynamically stable, we recommend early consultation with a pediatric cardiologist or other physician with appropriate expertise. This recommendation is common for all of the SVT topics below.

**Vagal Maneuvers for SVT**

**Consensus on Science**
One prospective (LOE 3) and 9 observational studies (LOE 4-5; LOE 5; LOE 7) show that vagal maneuvers are somewhat effective in terminating SVT in children. There are reports of complications from carotid sinus massage and application of ice to the face to stimulate the diving reflex (LOE 5), but virtually none from the Valsalva maneuver.

**Treatment Recommendation**
The Valsalva maneuver and ice application to the face may be used to treat hemodynamically stable VT in infants and children. When performed correctly, these maneuvers can be initiated quickly and safely and without altering subsequent therapies if they fail.

**Amiodarone for Hemodynamically Stable SVT**

**Consensus on Science**
One prospective (LOE 3) and 10 observational (LOE 5) studies show that amiodarone is effective for treating VT in children. A limitation of this evidence is that most of the studies in children describe treatment for postoperative junctional tachycardia.

**Treatment Recommendation**
Amiodarone may be considered in the treatment of hemodynamically stable VT refractory to vagal maneuvers and adenosine. Rare but significant acute side effects include bradycardia, hypotension, and polymorphic VT (LOE 5).

**Procainamide for Hemodynamically Stable SVT**

**Consensus on Science**
Experience with procainamide in children is limited. Twelve LOE 5 and 4 LOE 6 observational studies show that procainamide can terminate SVT that is resistant to other drugs. Most of these reports include mixed adult-pediatric populations. Hypotension following procainamide infusion results from its vasodilator action rather than a negative inotropic effect. (LOE 5; LOE 6).

**Treatment Recommendation**
Procainamide may be considered in the treatment of hemodynamically stable VT refractory to vagal maneuvers and adenosine.

**Management of Stable Wide-QRS Tachycardia**
A child with wide-QRS tachycardia is hemodynamically stable, early consultation with a pediatric cardiologist or other physician with appropriate expertise is recommended. In general, amiodarone and procainamide should not be administered together because their combination may increase risk of hypotension and ventricular arrhythmias.

**Amiodarone**

**Consensus on Science**
One case series (LOE 5) suggests that wide-QRS tachycardia in children is more likely to be supraventricular than ventricular in origin. Two prospective studies (LOE 3) and 13 case series (LOE 5) show that amiodarone is effective for a wide variety of tachyarrhythmias in children. None of these reports specifically evaluates the role of amiodarone in the setting of a stable, unknown wide-complex tachycardia.

**Treatment Recommendation**
Wide-QRS tachycardia in children who are stable may be treated as VT. If the diagnosis of VT is confirmed, amiodarone should be considered.

**Procainamide for Stable VT**

**Consensus on Science**
Twenty (LOE 5) and 2 LOE 6 observational studies primarily in adults but including some children
show that procainamide is effective in the treatment of stable VT.

**Treatment Recommendation**

Procainamide may be considered in the treatment of hemodynamically stable VT.

### Management of Unstable VT

#### Amiodarone

**Consensus on Science**

In small pediatric case series (LOE 3100; LOE 593,95,97,99,147–149) and extrapolation from animal (LOE 6)150,151 and adult (LOE 7)152–165 studies, amiodarone is safe and effective for hemodynamically unstable VT in children.

**Treatment Recommendation**

Synchronized cardioversion remains the treatment of choice for unstable VT. Amiodarone may be considered for treatment of hemodynamically unstable VT.

#### Pediatric Defibrillation

For additional information about consensus on science and treatment recommendations for defibrillation (eg, 1 versus 3 stacked shock sequences and sequence of CPR first versus defibrillation first), see Part 3: “Defibrillation.”

**Manual and Automated External Defibrillation**

**Consensus on Science**

The ideal energy dose for safe and effective defibrillation in children is unknown. Extrapolation from adult data (LOE 1166,167; LOE 2168–170) and pediatric animal studies (LOE 6)171–173 suggests that biphasic shocks are at least as effective as monophasic shocks and produce less postshock myocardial dysfunction. One LOE 5174 and one LOE 6175 study show that an initial monophasic or biphasic shock dose of 2 J/kg generally terminates pediatric VF. Two pediatric case series (LOE 5)176,177,178 report that doses >4 J/kg (up to 9 J/kg) have effectively defibrillated children <12 years of age, with negligible adverse effects.

In 1 animal study (LOE 6)172,173,177–179 large (per kilogram) energy doses caused less myocardial damage in young hearts than in adult hearts. In 3 animal studies (LOE 6)173,179,180 and 1 small pediatric case series (LOE 5),176 a 50-J biphasic dose delivered through a pediatric pad/cable system terminated VF and resulted in survival. One piglet (13 to 26 kg) study (LOE 6)179 showed that pediatric biphasic AED shocks (50/75/86 J) terminated VF and caused less myocardial injury and better outcome than adult AED biphasic shocks (200/300/360 J).

**Treatment Recommendation**

The treatment of choice for pediatric VF/pulseless VT is prompt defibrillation, although the optimum dose is unknown. For manual defibrillation, we recommend an initial dose of 2 J/kg (biphasic or monophasic waveform). If this dose does not terminate VF, subsequent doses should be 4 J/kg.

For automated defibrillation, we recommend an initial pediatric attenuated dose for children 1 to 8 years of age and up to about 25 kg (55 pounds) and 127 cm (50 inches) in length. There is insufficient information to recommend for or against the use of an AED in infants <1 year of age. A variable dose manual defibrillator or an AED able to recognize pediatric shockable rhythms and equipped with dose attenuation are preferred; if such a defibrillator is not available, a standard AED with standard electrode pads may be used. A standard AED (without a dose attenuator) should be used for children ≥25 kg (about 8 years of age) and older adolescent and adult victims.

#### Management of Shock-Resistant VF/Pulseless VT

**Amiodarone**

**Consensus on Science**

Evidence extrapolated from 3 (LOE 1) studies in adults (LOE 7 when applied to pediatrics)154,159,181 shows increased survival to hospital admission but not discharge when amiodarone is compared with placebo or lidocaine for shock-resistant VF. One study in children (LOE 3)100 showed effectiveness of amiodarone for life-threatening ventricular arrhythmias.

**Treatment Recommendation**

IV amiodarone can be considered as part of the treatment of shock-refractory or recurrent VT/VF.

### Airway and Ventilation

Maintaining a patent airway and ventilation are fundamental to resuscitation. Adult and animal studies during CPR suggest detrimental effects of hyperventilation and interruption of chest compressions. For children requiring airway control or ventilation for short periods in the out-of-hospital setting, bag-valve–mask (BVM) ventilation produces equivalent survival rates compared with ventilation with tracheal intubation.

The risks of tracheal tube misplacement, displacement, and obstruction are well recognized, and an evidence-based review led to a recommendation that proper tube placement and patency be monitored by exhaled CO₂ throughout transport. A review also found that cuffed tracheal tubes could be used safely even in infants.

Following the return of spontaneous circulation from cardiac arrest, toxic oxygen byproducts (reactive oxygen species, free radicals) are produced that may damage cell membranes, proteins, and DNA (reperfusion injury). There are no clinical studies in children outside the newborn period comparing different concentrations of inspired oxygen during and immediately after resuscitation, and it is difficult to differentiate “sufficient” from “excessive” oxygen therapy.

#### Bag-Valve–Mask Ventilation

**Consensus on Science**

One out-of-hospital pediatric prospective randomized controlled study (LOE 1)182 in an EMS system with short transport times showed that BVM ventilation compared with tracheal intubation resulted in equivalent survival to hospital discharge rates and neurologic outcome in children requiring airway control, including children with cardiac arrest and trauma.

One study in pediatric cardiac arrest (LOE 4)183 and 4 studies in children with trauma (LOE 3184,185; LOE 4186,187)
found no advantage of tracheal intubation over BVM ventilation.

Treatment Recommendation
In the out-of-hospital setting with short transport times, BVM ventilation is the method of choice for children who require ventilatory support. When transport times are long, the relative benefit versus potential harm of tracheal intubation compared with BVM ventilation is uncertain. It is affected by the level of training and experience of the healthcare professional and the availability of exhale CO₂ monitoring during intubation and transport.

Advanced Airways
Advanced airways include the tracheal tube, the Combitube, and the LMA. Experts at the 2005 Consensus Conference reviewed the available evidence on use of the tracheal tube and LMA in infants and children. There was no data on use of the Combitube in this age group.

Cuffed Versus Uncuffed Tracheal Tubes

Consensus on Science
One randomized controlled trial (LOE 2), 3 prospective cohort studies (LOE 3), and 1 cohort study (LOE 4) document no greater risk of complications for children <8 years of age when using cuffed tracheal tubes compared with uncuffed tubes in the operating room and intensive care unit. Evidence from 1 randomized controlled trial (LOE 2) and 1 small, prospective controlled study (LOE 3) showed some advantage in cuffed over uncuffed tracheal tubes in children in the pediatric anesthesia and intensive care settings, respectively.

Treatment Recommendation
Cuffed tracheal tubes are as safe as uncuffed tubes for infants (except newborns) and children if rescuers use the correct tube size and cuff inflation pressure and verify tube position. Under certain circumstances (eg, poor lung compliance, high airway resistance, and large glottic air leak), cuffed tracheal tubes may be preferable.

Laryngeal Mask Airway

Consensus on Science
There are no studies examining the use of the LMA in children during cardiac arrest. Evidence extrapolated from pediatric anesthesia shows a higher rate of complications with LMAs in smaller children compared with LMA experience in adults. The complication rate decreases with increasing operator experience (LOE 7). Case reports document that the LMA can be helpful for management of the difficult airway.

Treatment Recommendation
There is insufficient data to support or refute a recommendation for the routine use of an LMA for children in cardiac arrest. The LMA may be an acceptable initial alternative airway adjunct for experienced providers during pediatric cardiac arrest when tracheal intubation is difficult to achieve.

Confirmation of Tube Placement

Exhaled CO₂

Consensus on Science
Misplaced, displaced, or obstructed tracheal tubes are associated with a high risk of death. No single method of tracheal tube confirmation is always accurate and reliable. One study (LOE 3) showed that clinical assessment of tracheal tube position (observation of chest wall rise, mist in the tube, and auscultation of the chest) can be unreliable for distinguishing esophageal from tracheal intubation.

In 3 studies (LOE 5), when a perfusing cardiac rhythm was present in infants >2 kg and children, detection of exhaled CO₂ using a colorimetric detector or capnometer had a high sensitivity and specificity for tracheal tube placement. In one study (LOE 5) during cardiac arrest, the sensitivity of exhaled CO₂ detection for tracheal tube placement was 85% and specificity 100%. Both with a perfusing rhythm and during cardiac arrest, the presence of exhaled CO₂ reliably indicates tracheal tube placement, but the absence of exhaled CO₂ during cardiac arrest does not prove tracheal tube misplacement.

Treatment Recommendation
In all settings (ie, prehospital, emergency departments, intensive care units, operating rooms), confirmation of tracheal tube placement should be achieved using detection of exhaled CO₂ in intubated infants and children with a perfusing cardiac rhythm. This may be accomplished using a colorimetric detector or capnometry. During cardiac arrest, if exhaled CO₂ is not detected, tube position should be confirmed using direct laryngoscopy.

Esophageal Detector Device

Consensus on Science Statements
A study in the operating room (LOE 2) showed that the esophageal detector device (EDD) was highly sensitive and specific for correct tracheal tube placement in children weighing >20 kg with a perfusing cardiac rhythm. There have been no studies of the EDD in children during cardiac arrest. A pediatric animal study (LOE 6) showed only fair results with the EDD, but accuracy improved with use of a larger syringe device. The same animal study showed no difference when the tracheal tube cuff was either inflated or deflated.

Treatment Recommendation
The EDD may be considered for confirmation of tracheal tube placement in children weighing >20 kg.

Confirmation of Tracheal Tube Placement During Transport

Consensus on Science
Studies (LOE 1, 2) have documented the high rate of inadvertent displacement of tracheal tubes during prehospital transport. There are no studies to evaluate the frequency of these events during intra- or interhospital transport.

Two studies (LOE 5) show that in the presence of a perfusing rhythm, exhaled CO₂ detection or measurement can confirm tracheal tube position accurately during transport. In
2 animal studies (LOE 6) indicated tracheal tube displacement more rapidly than pulse oximetry. On the basis of one case series (LOE 5), continuous use of colorimetric exhaled CO₂ detectors may not be reliable for long (>30 minutes) transport duration.

**Treatment Recommendation**
We recommend monitoring tracheal tube placement and patency in infants and children with a perfusing rhythm by continuous measurement or frequent intermittent detection of exhaled CO₂ during prehospital and intra- and interhospital transport.

**Oxygen**

**Oxygen During Resuscitation**

Meta-analyses of 4 human studies (LOE 1) showed a reduction in mortality rates and no evidence of harm in newborns resuscitated with air compared with 100% oxygen (see Part 7: “Neonatal Resuscitation”). The 2 largest studies, however, were not blinded, so results should be interpreted with caution. Two animal studies (LOE 6) suggest that ventilation with room air may be superior to 100% oxygen during resuscitation from cardiac arrest, whereas one animal study (LOE 6) showed no difference.

**Treatment Recommendation**
There is insufficient information to recommend for or against the use of any specific inspired oxygen concentration during and immediately after resuscitation from cardiac arrest. Until additional evidence is published, we support healthcare providers’ use of 100% oxygen during resuscitation (when available). Once circulation is restored, providers should monitor oxygen saturation and wean inspired oxygen while ensuring adequate oxygen delivery.

**Vascular Access and Drugs for Cardiac Arrest**

Vascular access can be difficult to establish during resuscitation of children. Review of the evidence showed increasing experience with IO access and resulted in a deemphasis of the tracheal route for drug delivery. Evidence evaluation of resuscitation drugs was limited by a lack of reported experience in children. There was little experience with vasopressin in children in cardiac arrest and inconsistent results in adult patients. In contrast, there was a good study in children showing no benefit and possibly some harm in using high-dose epinephrine for cardiac arrest.

**Routes of Drug Delivery**

**Intraosseous Access**

Two prospective randomized trials in adults and children (LOE 3) and 6 other studies (LOE 4) document that IO access is safe and effective for fluid resuscitation, drug delivery, and blood sampling for laboratory evaluation.

**Treatment Recommendation**
We recommend establishing IO access if vascular access is not achieved rapidly in any infant or child for whom IV drugs or fluids are urgently required.

**Drugs Given via Tracheal Tube**

Consensus on Science

One study in children (LOE 2), 5 studies in adults (LOE 2-4), and multiple animal studies (LOE 6) indicate that atropine, epinephrine, naloxone, lidocaine, and vasopressin are absorbed via the trachea. Administration of resuscitation drugs into the trachea results in lower blood concentrations than the same dose given intravascularly. Furthermore, animal studies (LOE 6) suggest that the lower epinephrine concentrations achieved when the drug is delivered by tracheal route may produce transient β-adrenergic effects. These effects can be detrimental, causing hypotension, lower coronary artery perfusion pressure and flow, and reduced potential for return of spontaneous circulation.

**Treatment Recommendation**

Intravascular, including IO, injection of drugs is preferable to administration by the tracheal route. The recommended tracheal dose of atropine, epinephrine, or lidocaine is higher than the vascular dose and is as follows:

- **Epinephrine 0.1 mg/kg** (multiple LOE 6 studies)
- **Lidocaine 2 to 3 mg/kg** (LOE 3) and multiple LOE 6 studies
- **Atropine 0.03 mg/kg** (LOE 2)

The optimal tracheal doses of naloxone or vasopressin have not been determined.

**Drugs in Cardiac Arrest**

**Dose of Epinephrine for Cardiac Arrest**

Consensus on Science

In 4 pediatric studies (LOE 2-4), there was no improvement in survival rates and a trend toward worse neurologic outcome after administration of high-dose epinephrine for cardiac arrest. A prospective, randomized, controlled trial (LOE 2) comparing high-dose with standard-dose epinephrine for the second and subsequent (“rescue”) doses in pediatric in-hospital cardiac arrest showed reduced 24-hour survival rates in the high-dose epinephrine group. In subgroup analysis, survival rates in asphyxia and sepsis were significantly worse with high-dose rescue epinephrine.

**Treatment Recommendation**

Children in cardiac arrest should be given 10 μg/kg of epinephrine as the first and subsequent intravascular doses. Routine use of high-dose (100 μg/kg) intravascular epinephrine is not recommended and may be harmful, particularly in asphyxia. High-dose epinephrine may be considered in exceptional circumstances (eg, β-blocker overdose).

**Vasopressin in Cardiac Arrest**

Consensus on Science

Based on a small series of children (LOE 5), vasopressin given after epinephrine may be associated with return of
spontaneous circulation after prolonged cardiac arrest. Animal data (LOE 6)\textsuperscript{241,242} indicates that a combination of epinephrine and vasopressin may be beneficial. Adult data is inconsistent. Giving vasopressin after adult cardiac arrest (LOE 7)\textsuperscript{243–247} has produced improved short-term outcomes (eg, return of spontaneous circulation or survival to hospital admission) but no improvement in neurologically intact survival to hospital discharge when compared with epinephrine.

Treatment Recommendation
There is insufficient evidence to recommend for or against the routine use of vasopressin during cardiac arrest in children.

**Magnesium in Cardiac Arrest**\textsuperscript{W15}

Consensus on Science
The relationship between serum magnesium concentrations and outcome of CPR was analyzed in 2 studies in adults (LOE 3\textsuperscript{48}; LOE 4\textsuperscript{49}) and one animal study (LOE 6).\textsuperscript{250} The first 2 studies indicated that a normal serum concentration of magnesium was associated with a higher rate of successful resuscitation, but it is unclear whether the association is causative. Six adult clinical studies (LOE 1\textsuperscript{251}; LOE 2\textsuperscript{252–255}; LOE 3\textsuperscript{256}) and one study in an adult animal model (LOE 6)\textsuperscript{257} indicated no significant difference in any survival endpoint in patients who received magnesium before, during, or after CPR.

Treatment Recommendation
Magnesium should be given for hypomagnesemia and torsades de pointes VT, but there is insufficient evidence to recommend for or against its routine use in cardiac arrest.

**Postresuscitation Care**
Postresuscitation care is critical to a favorable outcome. An evidence-based literature review was performed on the topics of brain preservation and myocardial function after resuscitation from cardiac arrest. It showed the potential benefits of induced hypothermia on brain preservation, the importance of preventing or aggressively treating hyperthermia, the importance of glucose control, and the role of vasoactive drugs in supporting hemodynamic function.

**Ventilation**

**Hyperventilation**\textsuperscript{W27}

Consensus on Science
One study in cardiac arrest patients (LOE 3)\textsuperscript{258} and extrapolation from 12 other studies (LOE 6\textsuperscript{259}; LOE 2\textsuperscript{260}; LOE 3\textsuperscript{261–267}; LOE 4\textsuperscript{268}; LOE 5\textsuperscript{269,270}) suggest that hyperventilation may cause decreased venous return to the heart and cerebral ischemia and may be harmful in the comatose patient after cardiac arrest.

Treatment Recommendation
Hyperventilation after cardiac arrest may be harmful and should be avoided. The target of postresuscitation ventilation is normocapnia. Short periods of hyperventilation may be performed as a temporizing measure for the child with signs of impending cerebral herniation.

**Temperature Control**

**Therapeutic Hypothermia**\textsuperscript{W22B, W22C}

Consensus on Science
Immediately after resuscitation from cardiac arrest, children often develop hypothermia followed by delayed hyperthermia (LOE 5).\textsuperscript{271} Hypothermia (32°C to 34°C) may be beneficial to the injured brain. Although there are no pediatric studies of induced hypothermia after cardiac arrest, support for this treatment is extrapolated from

- Two prospective randomized studies of adults with VF arrest (LOE 1\textsuperscript{272}; LOE 2\textsuperscript{273})
- One study of newborns with birth asphyxia (LOE 2)\textsuperscript{274}
- Numerous animal studies (LOE 6) of both asphyxial and VF arrest
- Acceptable safety profiles in adults (LOE 7)\textsuperscript{272,273} and neonates (LOE 7)\textsuperscript{275–277} treated with hypothermia (32°C to 34°C) for up to 72 hours

Treatment Recommendation
Induction of hypothermia (32°C to 34°C) for 12 to 24 hours should be considered in children who remain comatose after resuscitation from cardiac arrest.

**Treatment of Hyperthermia**\textsuperscript{W22A, W22D}

Consensus on Science
Two studies (LOE 5)\textsuperscript{271,279} show that fever is common after resuscitation from cardiac arrest, and 3 studies (LOE 7)\textsuperscript{280–282} show that it is associated with worse outcome. Animal studies suggest that fever causes a worse outcome. One study (LOE 6)\textsuperscript{283} shows that rats resuscitated from asphyxial cardiac arrest have a worse outcome if hyperthermia is induced within the first 24 hours of recovery. In rats with global ischemic brain injury (which produces endogenous fever), prevention of fever with a nonsteroidal anti-inflammatory drug (NSAID) class of antipyretic attenuated neuronal damage (LOE 6)\textsuperscript{284,285}

Treatment Recommendation
Healthcare providers should prevent hyperthermia and treat it aggressively in infants and children resuscitated from cardiac arrest.

**Hemodynamic Support**

**Vasoactive Drugs**\textsuperscript{W33A, W33B, W33C, W33D}

Consensus on Science
Two studies in children (LOE 5)\textsuperscript{286,287} and multiple studies in adults (LOE 7)\textsuperscript{288–290} indicate that myocardial dysfunction is common after resuscitation from cardiac arrest. Multiple animal studies (LOE 6)\textsuperscript{294–296} document consistent improvement in hemodynamics when selected vasoactive drugs are given in the post–cardiac arrest period. Evidence extrapolated from multiple adult and pediatric studies (LOE 7)\textsuperscript{297–302} of cardiovascular surgical patients with low cardiac output documents consistent improvement in hemodynamics when vasoactive drugs are titrated in the period after cardiopulmonary bypass.
Treatment Recommendation

Vasoactive drugs should be considered to improve hemodynamic status in the post–cardiac arrest phase. The choice, timing, and dose of specific vasoactive drugs must be individualized and guided by available monitoring data.

Blood Glucose Control

Treatment of Hypoglycemia and Hyperglycemia

Consensus on Science

Adults with out-of-hospital cardiac arrest and elevated blood glucose on admission have poor neurologic and survival outcomes (LOE 7). In critically ill children, hypoglycemia (LOE 5) and hyperglycemia (LOE 5) are associated with poor outcome. It is unknown if the association of hyperglycemia with poor outcome after cardiac arrest is causative or an epiphenomenon related to the stress response.

In critically ill adult surgical patients, (LOE 7) strict glucose control improves outcome, but there is currently insufficient data in children showing that the benefit of tight glucose control outweighs the risk of inadvertent hypoglycemia.

Several animal studies (LOE 6) and an adult clinical study (LOE 4) show poor outcome when glucose is given immediately before or during cardiac arrest. It is unknown if there is harm in giving glucose-containing maintenance fluids to children after cardiac arrest.

Hypoglycemia is an important consideration in pediatric resuscitation because

- Critically ill children are hypermetabolic compared with baseline and have increased glucose requirement (6 to 8 mg/kg per minute) to prevent catabolism.
- The combined effects of hypoglycemia and hypoxia/ischemia on the immature brain (neonatal animals) appears more deleterious than the effect of either insult alone.
- Four retrospective studies of human neonatal asphyxia show an association between hypoglycemia and subsequent brain injury (LOE 4; LOE 5).

Treatment Recommendation

Healthcare providers should check glucose concentration during cardiac arrest and monitor it closely afterward with the goal of maintaining normoglycemia. Glucose-containing fluids are not indicated during CPR unless hypoglycemia is present (LOE 7).

Prognosis

One of the most difficult challenges in CPR is to decide the point at which further resuscitative efforts are futile. Unfortunately there are no simple guidelines. Certain characteristics suggest that resuscitation should be continued (eg, ice water drowning, witnessed VF arrest), and others suggest that further resuscitative efforts will be futile (eg, most cardiac arrests associated with blunt trauma or septic shock).

Predictors of Outcome in Children

Consensus on Science

Multiple studies in adults have linked characteristics of the patient or of the cardiac arrest with prognosis following in-hospital or out-of-hospital cardiac arrest. Experience in children is more limited. Six pediatric studies (LOE 5) show that prolonged resuscitation is associated with a poor outcome. Although the likelihood of a good outcome is greater with short duration of CPR, 2 pediatric studies (LOE 3) reported good outcomes in some patients following 30 to 60 minutes of CPR in the in-patient setting when the arrests were witnessed and prompt and presumably excellent CPR was provided. Children with cardiac arrest associated with environmental hypothermia or immersion in icy water can have excellent outcomes despite >30 minutes of cardiac arrest (LOE 5).

One large pediatric study (LOE 4) and several smaller studies (LOE 5) show that good outcome can be achieved when extracorporeal CPR is started after 30 to 90 minutes of refractory standard CPR for in-hospital cardiac arrests. The good outcomes were reported primarily in patients with isolated heart disease. This data shows that 15 or 30 minutes of CPR does not define the limits of cardiac and cerebral viability.

Witnessed events, bystander CPR, and a short interval from collapse to arrival of EMS system personnel are important prognostic factors associated with improved outcome in adult resuscitation, and it seems reasonable to extrapolate these factors to children. At least one pediatric study (LOE 5) showed that the interval from collapse to initiation of CPR is a significant prognostic factor.

Children with prehospital cardiac arrest caused by blunt trauma and in-hospital cardiac arrest caused by septic shock rarely survive.

Treatment Recommendation

The rescuer should consider whether to discontinue resuscitative efforts after 15 to 20 minutes of CPR. Relevant considerations include the cause of the arrest, preexisting conditions, whether the arrest was witnessed, duration of untreated cardiac arrest (“no flow”), effectiveness and duration of CPR (“low flow”), prompt availability of extracorporeal life support for a reversible disease process, and associated special circumstances (eg, icy water drowning, toxic drug exposure).

References


204. Lipinski CA, Hicks SD, Callaway CW. Cardiopulmonary resuscitation with 100% oxygen exacerbates neurological dysfunction following nine minutes of normothermic cardiac arrest in dogs. Resuscitation. 1994;27:159–170.


206. Lipinski CA, Hicks SD, Callaway CW. Cardiopulmonary resuscitation with 100% oxygen exacerbates neurological dysfunction following nine minutes of normothermic cardiac arrest in dogs. Resuscitation. 1994;27:159–170.


Part 7: Neonatal Resuscitation

Approximately 10% of newborns require some assistance to begin breathing at birth, and about 1% require extensive resuscitation. Although the vast majority of newborn infants do not require intervention to make the transition from intrauterine to extrauterine life, the large number of births worldwide means that many infants require some resuscitation. Newborn infants who are born at term, had clear amniotic fluid, and are breathing or crying and have good tone must be dried and kept warm but do not require resuscitation.

All others need to be assessed for the need to receive one or more of the following actions in sequence:

A. Initial steps in stabilization (clearing the airway, positioning, stimulating)
B. Ventilation
C. Chest compressions
D. Medications or volume expansion

Progression to the next step is based on simultaneous assessment of 3 vital signs: respirations, heart rate, and color. Progression occurs only after successful completion of the preceding step. Approximately 30 seconds is allotted to complete one step successfully, reevaluate, and decide whether to progress to the next (Figure).

Since publication of the last International Liaison Committee on Resuscitation (ILCOR) document, several controversial neonatal resuscitation issues have been identified. The literature was researched and a consensus was reached on the role of supplementary oxygen, peripartum management of meconium, ventilation strategies, devices to confirm placement of an advanced airway (eg, tracheal tube or laryngeal mask airway [LMA]), medications, maintenance of body temperature, postresuscitation management, and considerations for withholding and discontinuing resuscitation.

Initial Resuscitation
Supplementary Oxygen

Supplementary Oxygen Versus Room Air

There is growing evidence from both animal and human studies that air is as effective as 100% oxygen for the resuscitation of most infants at birth. There are concerns about potential adverse effects of 100% oxygen on breathing physiology, cerebral circulation, and potential tissue damage from oxygen free radicals.

Consensus on Science

Studies examining blood pressure, cerebral perfusion, and biochemical indicators of cell damage in asphyxiated animals resuscitated with 100% versus 21% oxygen show conflicting results (LOE 6).8–6 One study of preterm infants (<33 weeks of gestation) exposed to 80% oxygen found lower cerebral blood flow when compared with those stabilized with 21% oxygen (LOE 2).7 Some animal data indicates the opposite effect, ie, reduced blood pressure and cerebral perfusion with air versus 100% oxygen (LOE 6).2

Meta-analysis of 4 human studies showed a reduction in mortality and no evidence of harm in infants resuscitated with air compared with those resuscitated with 100% oxygen (LOE 1).8,9 The 2 largest newborn human studies of room air versus oxygen resuscitation were not blinded. In those studies, if there was no response after 90 seconds, those resuscitated with air were switched to supplementary oxygen; a similar proportion who failed to respond while receiving oxygen were not crossed over to room air.10,11 These results require careful interpretation because of significant methodological concerns (regarding patient selection, lack of blinding, randomization methods, and follow-up).

Trials have not examined in sufficient detail infants with a birth weight of <1000 g, those with known congenital pulmonary or cyanotic heart disease, and those without discernible signs of life at birth.10–13 Continuous oximetry studies show that term healthy newborns may take >10 minutes to achieve a preductal oxygen saturation >95% and nearly 1 hour to achieve this postductally (LOE 5).14–16

Treatment Recommendation

There is currently insufficient evidence to specify the concentration of oxygen to be used at initiation of resuscitation. After initial steps at birth, if respiratory efforts are absent or inadequate, lung inflation/ventilation should be the priority. Once adequate ventilation is established, if the heart rate remains low, there is no evidence to support or refute a change in the oxygen concentration that was initiated. Rather the priority should be to support cardiac output with chest compressions and coordinated ventilations. Supplementary oxygen should be considered for babies with persistent central cyanosis. Some have advocated adjusting the oxygen supply according to pulse oximetry measurements to avoid hyperoxia, but there is insufficient evidence to determine the appropriate oximetry goal because observations are confounded by the gradual increase in oxyhemoglobin saturation that normally occurs following birth. Excessive tissue oxygen may cause oxidant injury and should be avoided, especially in the premature infant.
Peripartum Management of Meconium
Management of meconium was examined from 2 perspectives: (1) suctioning of the meconium from the infant’s airway after delivery of the head but before delivery of the shoulders (intrapartum suctioning) and (2) suctioning of the infant’s trachea immediately after birth (tracheal suctioning).

Intrapartum Suctioning

Consensus on Science
Previous studies have yielded conflicting results about the value of intrapartum oropharyngeal and nasopharyngeal suctioning of babies born with meconium-stained fluid (LOE 317; LOE 418,19). A recent large multicenter randomized trial found that intrapartum suctioning of meconium does not reduce the incidence of meconium aspiration syndrome (LOE 1).20

Treatment Recommendation
Routine intrapartum oropharyngeal and nasopharyngeal suctioning for infants born with meconium-stained amniotic fluid is no longer recommended.

Tracheal Suctioning

Consensus on Science
A randomized controlled trial showed that tracheal intubation and suctioning of meconium-stained but vigorous infants at birth offers no benefit (LOE 1).17 The benefit of tracheal suctioning in meconium-stained, depressed infants has not been systematically studied (LOE 5).21–23

Treatment Recommendation
Meconium-stained, depressed infants should receive tracheal suctioning immediately after birth and before stimulation, presuming the equipment and expertise is available. Tracheal suctioning is not necessary for babies with meconium-stained fluid who are vigorous.

Ventilation Strategies
Ventilation strategy was examined from 4 perspectives: (1) the characteristics of the initial assisted breaths, (2) devices to assist ventilation, (3) special considerations for babies born preterm, and the role of positive end-expiratory pressure (PEEP) or continuous positive air pressure (CPAP) during or following resuscitation.

Initial Breaths

Consensus on Science
When performed properly, positive-pressure ventilation alone is effective for resuscitating almost all apneic or bradycardic newborn infants (LOE 5).24 The primary measure of adequate initial ventilation is prompt improvement in heart rate (LOE 6).25–27 The presence or absence of chest wall movement has been described but not assessed adequately (LOE 5).28

In term infants, initial inflations, either spontaneous or assisted, create a functional residual capacity (FRC) (LOE 5).28–33 The optimum pressure, inflation time, and flow required to establish an effective FRC has not been determined. In case series reporting the physiological changes associated with initial ventilation of term human neonates, peak pressures used to initiate ventilation varied widely (18 to 60 cm H2O). Average initial peak inflating pressures of 30 to 40 cm H2O were used to successfully ventilate unresponsive term infants (LOE 5).31–35 In a single small series a sustained inflation pressure of 30 cm H2O for 5 seconds for the first breath was effective in establishing lung volume in term infants requiring resuscitation (LOE 5)31; the risk and benefits of this practice have not been evaluated. Ventilation rates of 30 to 60 breaths per minute are commonly used, but the relative efficacy of various rates has not been investigated (LOE 8).

Treatment Recommendation
Establishing effective ventilation is the primary objective in the management of the apneic or bradycardic newborn infant
in the delivery room. In the bradycardic infant, prompt improvement in heart rate is the primary measure of adequate initial ventilation; chest wall movement should be assessed if heart rate does not improve. Initial peak inflating pressures necessary to achieve an increase in heart rate or movement of the chest are variable and unpredictable and should be individualized with each breath. If pressure is being monitored, an initial inflation pressure of 20 cm H₂O may be effective, but a pressure ≥30 to 40 cm H₂O may be necessary in some term babies. If pressure is not being monitored, the minimal inflation required to achieve an increase in heart rate should be used. There is insufficient evidence to recommend optimal initial or subsequent inflation times.

**Assisted Ventilation Devices**

**Consensus on Science**

Studies on humans and manikins suggest that effective ventilation can be achieved with either a flow-inflating or self-inflating bag or with a T-piece mechanical device designed to regulate pressure (LOE 4).46,47 The pop-off valves of self-inflating bags are flow-dependent, and pressures generated during resuscitation may exceed the target values (LOE 6).39 Target inflation pressures and long inspiratory times are achieved more consistently in mechanical models when using T-piece devices than when using bags (LOE 6),40 although the clinical implications are not clear. To provide the desired pressure, healthcare providers need more training to use flow-inflating bags than they need to use self-inflating bags (LOE 6).41

**Treatment Recommendation**

A self-inflating bag, a flow-inflating bag, or a T-piece mechanical device designed to regulate pressure as needed can be used to provide bag-mask ventilation to a newborn.

**Laryngeal Mask Airway**

**Consensus on Science**

Masks that fit over the laryngeal inlet are effective for ventilating newborn full-term infants (LOE 2); LOE 5).42 There is limited data on the use of these devices in small preterm infants (LOE 5).44,45 There is currently no evidence directly comparing the laryngeal mask airway (LMA) with bag-mask ventilation during neonatal resuscitation. Data from 2 case series shows that use of the LMA can provide effective ventilation in a time frame consistent with current resuscitation guidelines (LOE 5).43,44 A single randomized controlled trial found no significant difference between the LMA and tracheal intubation during resuscitation of babies by experienced providers after cesarean section (LOE 2).42 Case reports suggest that when ventilation via a face mask has been unsuccessful and tracheal intubation is unsuccessful or not feasible, the LMA may provide effective ventilation (LOE 5).47,48

**Treatment Recommendation**

The LMA may enable effective ventilation during neonatal resuscitation if bag-mask ventilation is unsuccessful and tracheal intubation is unsuccessful or not feasible. There is insufficient evidence to recommend use of the LMA as the primary airway device during neonatal resuscitation or in the settings of meconium-stained amniotic fluid, when chest compressions are required, or for the delivery of drugs into the trachea.

**Ventilation Strategies for Preterm Infants**

**Consensus on Science**

There has been little research evaluating initial ventilation strategies in the resuscitation of preterm infants. Animal studies indicate that preterm lungs are more easily injured by large-volume inflations immediately after birth (LOE 6).49 Additional studies in animals indicate that when positive-pressure ventilation is applied immediately after birth, the application of end-expiratory pressure protects against lung injury and improves lung compliance and gas exchange (LOE 6).50,51 Case series in infants indicate that most apneic preterm infants can be ventilated with an initial inflation pressure of 20 to 25 cm H₂O, although some infants who do not respond require a higher pressure (LOE 5).52,53

**Treatment Recommendation**

Providers should avoid creation of excessive chest wall movement during ventilation of preterm infants immediately after birth. Although measured peak inflation pressure does not correlate well with volume delivered in the context of changing respiratory mechanics, monitoring of inflation pressure may help provide consistent inflations and avoid unnecessarily high pressures. If positive-pressure ventilation is required, an initial inflation pressure of 20 to 25 cm H₂O is adequate for most preterm infants. If prompt improvement in heart rate or chest movement is not obtained, then higher pressures may be needed.

**Use of CPAP or PEEP**

**Consensus on Science**

Spontaneously breathing newborns establish functional residual capacity more quickly and with lower transpulmonary pressures than sick neonates (LOE 5).32 In the sick neonate CPAP helps stabilize and improve lung function (LOE 4).54 Excessive CPAP, however, can overdistend the lung, increase the work of breathing, and reduce cardiac output and regional blood flow (LOE 6).55,56 There are no prospective, randomized, controlled clinical trials of sufficient power to compare CPAP and positive-pressure ventilation (via bag-mask or bag–tracheal tube) during resuscitation of either the preterm or term neonate. When compared with historical controls, use of CPAP for extremely premature babies in the delivery room was associated with a decrease in requirement for intubation, days on mechanical ventilation, and use of postnatal steroids (LOE 4).53 A small underpowered feasibility trial of delivery room CPAP/PEEP versus no CPAP/PEEP did not show a significant difference in immediate outcomes (LOE 2).57

**Treatment Recommendation**

There is insufficient data to support or refute the routine use of CPAP during or immediately after resuscitation in the delivery room.
Exhaled CO2 Detectors to Confirm Tracheal Tube Placement

Consensus on Science
After tracheal intubation, adequate ventilation is associated with a prompt increase in heart rate (LOE 5).58-61 Exhaled CO2 detection is a reliable indicator of tracheal tube placement in infants (LOE 5).58-61 A positive test (detection of exhaled CO2) confirms tracheal placement of the tube, whereas a negative test strongly suggests esophageal intubation (LOE 5).58-60,61 Poor or absent pulmonary blood flow may give false-negative results, but tracheal tube placement is identified correctly in nearly all patients who are not in cardiac arrest (LOE 7).62 In critically ill infants with poor cardiac output, a false-negative result may lead to unnecessary extubation.

Exhaled CO2 detectors identify esophageal intubations faster than clinical assessments (LOE 5).58,61 Clinical techniques for confirmation of correct tracheal tube placement (eg, evaluation of condensed humidified gas during exhalation, chest movement) have not been evaluated systematically in neonates.

Treatment Recommendation
Tracheal tube placement must be confirmed after intubation, especially in infants with a low heart rate that is not rising. Exhaled CO2 detection is useful to confirm tracheal tube placement. During cardiac arrest, if exhaled CO2 is not detected, tube placement should be confirmed with direct laryngoscopy.

Medications
The primary considerations about medications focused on which drugs should be used and the route by which they should be given. Medications are rarely needed in neonatal resuscitation. Those that may be used include epinephrine and fluids. Very rarely, a narcotic antagonist, sodium bicarbonate,58,60 or vasopressors may be useful after resuscitation.

Epinephrine

Route and Dose of Epinephrine58-61

Consensus on Science
Despite the widespread use of epinephrine/adrenaline during resuscitation, no placebo-controlled studies have evaluated either the tracheal or intravenous (IV) administration of epinephrine at any stage during cardiac arrest in human neonates. A pediatric study (LOE 7)63 and studies in newborn animals (LOE 6)64,65 showed no benefit and a trend toward reduced survival rates and worse neurologic status after administration of high-dose IV epinephrine (100 µg/kg) during resuscitation. Animal and adult human studies show that when given tracheally, considerably higher doses of epinephrine than currently recommended are required to show a positive effect (LOE 6).66-68

One neonatal animal study using the currently recommended dose of tracheal epinephrine (10 µg/kg) showed no benefit (LOE 6).69 One neonatal cohort study of 9 preterm babies requiring resuscitation showed that tracheal epinephrine was absorbed, but the study used 7 to 25 times the dose recommended currently (LOE 5).70

Treatment Recommendation
Despite the lack of human data, it is reasonable to continue to use epinephrine when adequate ventilation and chest compressions have failed to increase the heart rate to >60 beats per minute. Use the IV route for epinephrine as soon as venous access is established. The recommended IV dose is 0.01 to 0.03 mg/kg. If the tracheal route is used, give a higher dose (up to 0.1 mg/kg). The safety of these higher tracheal doses has not been studied. Do not give high doses of intravenous epinephrine.

Volume Expansion

Crystalloids and Colloids

Consensus on Science
Three randomized controlled trials in neonates showed that isotonic crystalloid is as effective as albumin for the treatment of hypotension (LOE 7).71-73 No studies have compared the relative effectiveness of crystalloid during resuscitation.

Treatment Recommendation
In consideration of cost and theoretical risks, an isotonic crystalloid solution rather than albumin should be the fluid of choice for volume expansion in neonatal resuscitation.

Other Drugs

Naloxone58-61

Consensus on Science
There are no studies examining the use of naloxone in infants with severe respiratory depression from maternal opioids. Vigorous newborns whose mothers received opioids had brief improvement in alveolar ventilation with naloxone without affecting Apgar score, pH, PaCO2, or respiratory rate (LOE 7).74 Compared with intramuscular naloxone, IV naloxone produces higher plasma concentrations but has a shorter half-life (LOE 5).75 Tracheal or subcutaneous administration has not been examined in neonates, nor has the current recommended dose of 0.1 mg/kg been studied.

Naloxone may interfere with critical functions of endogenous opioids and exacerbate long-term neurohistologic injury of cerebral white matter in asphyxiated animals (LOE 6).76,77 Cardiac arrhythmias, hypertension, and noncardiogenic pulmonary edema have been reported in adolescents and adults, especially when high doses have been used (LOE 7).78 Naloxone given to a baby born to an opioid-addicted mother was associated with seizures.79

Treatment Recommendation
Naloxone is not recommended as part of the initial resuscitation of newborns with respiratory depression in the delivery room. Before naloxone is given, providers should restore heart rate and color by supporting ventilation. The preferred route should be IV or intramuscular. Tracheal administration is not recommended. There is no evidence to support or refute the current dose of 0.1 mg/kg.
Supportive Therapy

Temperature Control

**Maintenance of Body Temperature**

**Consensus on Science**
Numerous observational studies showed an association between hypothermia and increased mortality in premature newborns. Premature infants continue to be at risk for hypothermia when treated according to current recommendations (dry the infant, remove wet linens, place the infant on a radiant warmer) (LOE 5).80 Two randomized controlled trials (LOE 2)81,82 and 3 observational studies (LOE 483,84; LOE 585) confirm the efficacy of plastic bags or plastic wrapping (food-grade, heat-resistant plastic) in addition to the customary radiant heat in significantly improving the admission temperature of premature babies of <28 weeks gestation when compared with standard care (LOE 281,82; LOE 483,84; LOE 585). There is no direct evidence that this improves mortality or long-term outcomes. Temperature must be monitored closely because there is a small risk that this technique may produce hyperthermia (LOE 2).82

Other techniques have been used to maintain temperature in the delivery room during stabilization (drying and swaddling, warming pads, placing the newborn skin-to-skin with the mother and covering both, etc) but have not been compared with the plastic wrap technique for premature babies (LOE 8).86,87

**Treatment Recommendation**
Very low birth weight preterm babies remain at risk for hypothermia. Consider the use of plastic bags or plastic wrapping under radiant heat as well as standard techniques to maintain temperature. All initial resuscitation steps, including intubation, chest compression, and insertion of lines, can be performed with these temperature-controlling interventions in place.

Postresuscitation Management

Temperature

**Hyperthermia**

**Consensus on Science**
Babies born to febrile mothers (temperature >38°C) have an increased risk of death, perinatal respiratory depression, neonatal seizures, and cerebral palsy (LOE 4).88,89 During the first 24 hours after adult stroke, fever is associated with a marked increase in neurologic morbidity and mortality (LOE 7).90,91 Adult animal studies indicate that hyperthermia during or after ischemia is associated with a progression of cerebral injury (LOE 6).92,93

**Treatment Recommendation**
The goal is to achieve normothermia and to avoid iatrogenic hyperthermia in babies who require resuscitation.

**Therapeutic Hypothermia**

**Consensus on Science**
A reduction of body temperature by 2°C to 3°C (modest hypothermia) following cerebral hypoxia-ischemia reduces cerebral metabolic and biochemical abnormalities and cerebral injury and improves function in experimental neonatal models (LOE 6).94–96 In adults, induced hypothermia (temperature of 32°C to 34°C) for 12 to 24 hours improves neurologic outcome after cardiac arrest due to ventricular arrhythmias but not after trauma or stroke (LOE 7).97 In a multicenter trial involving newborns with suspected asphyxia (indicated by need for resuscitation at birth, metabolic acidosis, and early encephalopathy), selective head cooling to achieve a rectal temperature of 34°C to 35°C was associated with a nonsignificant reduction in the overall number of survivors with severe disability at 18 months but a significant benefit in the subgroup with moderate encephalopathy (LOE 2).98

Infants with severe electroencephalographic (EEG) suppression and seizures did not benefit from treatment with modest hypothermia (LOE 2).99 A second small controlled pilot study in asphyxiated infants with early induced systemic hypothermia that achieved a rectal temperature of 33°C resulted in fewer deaths and disability at 12 months (LOE 2).99

Moderate hypothermia is associated with bradycardia and elevated blood pressure that do not usually require treatment, but a rapid increase in body temperature may cause hypoten- sion (LOE 5).100 Profound hypothermia (core temperature <33°C) may cause arrhythmia, bleeding, thrombosis, and sepsis, but these complications have not been reported in infants treated with modest hypothermia (LOE 2).98,99,101,102

**Treatment Recommendation**
There is insufficient data to recommend the routine use of systemic or selective cerebral hypothermia after resuscitation of infants with suspected asphyxia. Further clinical trials are needed to confirm that treatment with cooling is beneficial, to identify infants who will benefit most, and to determine the most effective method and timing of cooling.

General Supportive Care

**Glucose**

**Consensus on Science**
Low blood glucose is associated with adverse neurologic outcomes in a neonatal animal model of asphyxia and resuscitation (LOE 6).103 Hypoglycemia in animals at the time of anoxic or hypoxic-ischemic insult resulted in larger areas of cerebral infarction and/or decreased survival rates when compared with controls (LOE 6).104,105 One clinical study showed an association between hypoglycemia (blood glucose <40 mg/dL) measured shortly after resuscitation and poor neurologic outcome following perinatal asphyxia (LOE 4).106

Hyperglycemia induced in neonatal animal models of hypoxia-ischemia had conflicting effects on the extent of brain injury (LOE 6).107,108 No clinical neonatal studies have investigated this topic.

**Treatment Recommendation**
Based on available evidence, the optimal range of blood glucose concentration to minimize brain injury following asphyxia and resuscitation cannot be defined. Infants requir-
ing resuscitation should be monitored and treated to maintain glucose in the normal range.

**Timing of Cord Clamping**

*Consensus on Science*

Although delayed cord clamping (30 to 120 seconds after birth) in premature infants was associated with higher mean blood pressure and hematocrit and less intraventricular hemorrhage, most study subjects did not require resuscitation (LOE 1109; LOE 2110). Delayed cord clamping in term infants not requiring resuscitation resulted in no clinically significant improvement in stability over the first 4 to 6 hours after birth (LOE 3).111,112

**Treatment Recommendation**

No recommendation can be made about the timing of cord clamping when resuscitation is required.

**Withholding or Discontinuing Resuscitative Efforts**

*Consensus on Science*

Mortality and morbidity for newborns varies according to region and availability of resources (LOE 5).113 Social science studies indicate that parents would like a larger role in regional outcomes and societal principles: support when functional survival is highly unlikely. The equivalent, and clinicians should not be hesitant to withdraw sustaining treatment during or after resuscitation are ethically not starting resuscitation and discontinuation of life- obstetric and neonatal teams and parents is an important goal. A consistent and coordinated approach to individual cases by neurodevelopmental disability (LOE 5).117,118

Some data are available to help identify conditions associated with high mortality and poor outcome (LOE 5).80,116 Such conditions may include extreme prematurity and infants with anomalies that predict extreme morbidity or early death. Data from infants without signs of life lasting at least 10 minutes or longer from birth despite continuous and adequate resuscitative efforts document either high mortality or severe neurodevelopmental disability (LOE 5).114,115

**Treatment Recommendation**

A consistent and coordinated approach to individual cases by obstetric and neonatal teams and parents is an important goal. Not starting resuscitation and discontinuation of life-sustaining treatment during or after resuscitation are ethically equivalent, and clinicians should not be hesitant to withdraw support when functional survival is highly unlikely. The following guidelines must be interpreted according to current regional outcomes and societal principles:

- When gestation, birth weight, or congenital anomalies are associated with almost certain early death and an unacceptable high morbidity is likely among the rare survivors, resuscitation is not indicated. Examples from the published literature from developed countries include
  - Extreme prematurity (gestational age <23 weeks or birth weight <400 g)
  - Anomalies such as anencephaly and confirmed trisomy 13 or 18

- In conditions associated with a high rate of survival and acceptable morbidity, resuscitation is nearly always indicated.

- In conditions associated with uncertain prognosis, when there is borderline survival and a relatively high rate of morbidity, and where the burden to the child is high, the parents’ views on starting resuscitation should be supported.

If there are no signs of life after 10 minutes of continuous and adequate resuscitative efforts, it may be justifiable to stop resuscitation.

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Part 8: Interdisciplinary Topics

The Interdisciplinary Task Force discussed topics that applied to several task forces and in particular focused on questions about educational methods, ethics, and outcomes. Some of these topics are discussed in other sections of this document (eg, the topic of medical emergency teams is discussed in Part 4: “Advanced Life Support”).

To maintain consistency with the science statements in other sections, studies using manikins were recorded as LOE 6, irrespective of the study design.

Educational Methods
Acquisition and retention of skills are poor after conventional CPR training.1 Evidence for and against several resuscitation training methods was reviewed, highlighting the need for further research.

Devices
CPR Prompt Devices

Consensus on Science
Twenty-seven randomized studies using models from the motor skills literature (LOE 6)2–28 and one randomized study using manikins (LOE 6)29 showed that the use of audio or visual prompts during motor skills acquisition training improved student skills performance during or immediately after training. These studies and supporting theory from 2 studies (LOE 7)30,31 indicate that the overuse of guiding prompts during training reduced skills retention in the long term.

Treatment Recommendation
Audio and visual prompts and other forms of directive or corrective feedback that guide action sequences and timing of chest compressions and ventilations may help early learning of CPR skills. Training must include ample practice time without prompting devices to optimize skills retention for situations in which prompting devices are not available.

Instructional Methods
Effective AED Instructional Methods

Consensus on Science
Seven studies (LOE 4)32–35; LOE 536,37; LOE 738 showed improved rates of survival from out-of-hospital cardiac arrest when CPR plus automated external defibrillator training (traditional 4-hour course) was made widely available to lay first responders. The prospective randomized trial of lay rescuer automated external defibrillation programs did not specifically evaluate the training provided, but sites where rescuers were trained and equipped to provide CPR or CPR plus automated external defibrillator (AED) use showed higher survival rates compared with national reports (LOE 7).38

Twenty studies (LOE 539; LOE 640–58) document consistent improvement in simulated AED use and skills retention using diverse training methods and durations. Three studies (LOE 6)59–61 show that within a simulated arrest scenario the correct and appropriate use of an AED depends on the AED user interface.

Treatment Recommendation
Community lay responder AED training is recommended. There is insufficient evidence to recommend a specific instructional method for AED training. AED manufacturers should increase the ease of AED user interface to improve efficacy.

Effective BLS Instructional Methods

Consensus on Science
Nineteen randomized manikin studies (LOE 6)48,62–79 and one extrapolated study (LOE 7)80 showed considerable variability in BLS skills acquisition and retention with the use of different instructional formats (video instruction, computer-assisted instruction, and traditional instruction). Four randomized studies using manikins (LOE 6)66–69 indicated that one video instruction program (a self-instructional synchronous “watch-while-you-practice” program) achieved better skills acquisition and retention than other educational formats. One randomized study of adult learners using manikins showed that a brief video self-instruction program produced CPR skills performance equivalent to or better than traditional training (LOE 6).81

Treatment Recommendation
Instruction methods should not be limited to traditional techniques; newer training methods (eg, “watch-while-you-practice” video programs) may be more effective. Training programs should be evaluated to verify that they enable effective skills acquisition and retention.

Instructional Methods for Hand Position in Chest Compressions

Consensus on Science
Six randomized controlled trials (RCTs) using manikins (LOE 6)67,69,82–85 evaluated hand positioning in detail. One
trial compared a simplified message (“place hands in the center of the chest”) versus the standard method (anatomical landmarks) for teaching correct hand placement. Three of the 6 trials compared a staged teaching approach with standard teaching. Two of the trials compared the results of video self-instruction with standard teaching on CPR performance. The likelihood of achieving an acceptable hand position was no different between those who had received detailed instruction on anatomical landmarks and those who were instructed to simply compress the center of the chest.

In 4 manikin RCTs (LOE 6) the use of anatomical landmarks to determine hand placement delayed delivery of the first chest compression after a ventilation; thus, fewer compressions were delivered per minute. Incorrect rescuer hand placement can injure the victim.

Treatment Recommendation
Teaching hand placement for chest compression should be simplified with less attention to anatomical landmarks and emphasis on the importance of minimizing interruption to chest compressions and performing an adequate number of chest compressions per minute.

Retraining Intervals
Retraining Intervals in Advanced and Basic Life Support

Consensus on Science
One prospective cohort study (LOE 3), 1 survey (LOE 5), and 10 manikin studies (LOE 6) documented decay in healthcare provider ALS skills and knowledge after ALS training and retraining from as little as 6 weeks to 2 years. Refresher courses based on knowledge did not prevent the decay in psychomotor skills.

A single randomized manikin study (LOE 6) concluded that retraining at either 3- or 6-month intervals resulted in similar BLS performance at 12 months and providers who were retrained performed significantly better than controls with no retraining.

Treatment Recommendation
Frequent retraining (theory and practice) is required to maintain both BLS and ALS skills. The optimal interval for retraining has not been established.

Media Campaigns
Media Campaigns Targeting Chest Pain

Consensus on Science
One large RCT (LOE 1), a Cochrane systematic review (LOE 1), and 4 additional studies (LOE 4) evaluating the impact of mass media campaigns indicate that they do not reduce the delay to presentation at the hospital following onset of chest pain. Conversely 7 studies (LOE 3) did report reduced delay in the patient’s response to chest pain.

The evidence that mass media campaigns reduce patient delay from the onset of symptoms to presentation at hospital is equivocal and suggests that the impact of such campaigns, particularly on prehospital delay times, may be greater for populations in which the baseline delay time is long.

There is evidence that mass media campaigns can increase the use of ambulance transport (LOE 1) in patients with symptoms that suggest myocardial ischemia. In several studies the number of patients presenting to the emergency department increased in the early stages of the media campaign but soon returned to baseline.

The impact of mass media campaigns on rates of mortality from ischemic heart disease remains inconclusive; however, the inference is that by reducing prehospital delay time, the mortality rate should decrease.

Treatment Recommendation
Given that the data is inconsistent, mass media campaigns should not be considered the only option for reducing patient delay but rather part of an overall system approach to reduce the interval from onset of symptoms of chest pain to hospital presentation.

Educational Evaluation
Although there is considerable literature on the evaluation of educational processes in general, there are few studies of resuscitation education.

Attitude Toward Performing CPR
Barriers to Performing CPR

Consensus on Science
One RCT (LOE 2), 1 prospective controlled cohort study (LOE 3), 2 cohort and case studies (LOE 4), supported by 27 cohort and case studies (LOE 5), and 7 indicate hesitancy or unwillingness to perform CPR, particularly mouth-to-mouth ventilation, on adult patients in and out of hospital, even after CPR training.

Reasons for the hesitancy or unwillingness to perform CPR include, but are not limited to, fear of contracting a disease while performing mouth-to-mouth ventilations, fear of performing the skills incorrectly, and fear of hurting the patient.

Treatment Recommendation
CPR training programs should include discussion of the minimal risk of contracting infectious diseases while performing mouth-to-mouth ventilation. “Chest compression only” resuscitation may be considered when there is a reluctance to perform mouth-to-mouth ventilation (see Part 2: “Adult Basic Life Support”).

Written Test Scores and Skills Competence

Consensus on Science
Do written test scores correlate with competence in CPR skills? None of the studies reviewed was designed specifically to answer this question. In 14 of 17 studies test scores correlated with CPR proficiency. Of the 7 studies with good written test scores (LOE 6 manikin studies), 4 studies were associated with good CPR skills and 3 studies with poor CPR skills.

In 2 manikin studies (LOE 6) mediocre written test scores correlated with mediocre or borderline CPR performance. In 6 manikin studies (LOE
6,147,153–156 poor written test performance was associated with poor CPR capability. In 5 manikin (LOE 6),150–152,157,158 written test scores did not correlate with CPR proficiency.

Treatment Recommendation
A written test score does not always reflect BLS skills competence. Therefore, a written test or questionnaire should not be used as the sole determinant of a person’s acquisition of the skills needed to perform CPR.

Ethics
The ethical issues surrounding resuscitation are dependent on local culture and law. Consideration of the patient’s wishes, the family’s desires, cultural issues, and local laws makes specific recommendations about ethical decisions generally inappropriate.

Impact of DNAR on Resuscitation
Consensus on Science
The emergency medical services (EMS) system is activated for many patients in cardiac arrest who are chronically ill, have a terminal illness, or have do-not-attempt-resuscitation (DNAR) orders (LOE 4).159–161 Studies from the United States and Australia indicate that Caucasians and better-educated persons are more likely to have advance directives (LOE 4;162–165; LOE 7;166–168). There is evidence that out-of-hospital healthcare providers can interpret and use DNAR orders and other documents to limit treatment (LOE 3;169,170; LOE 4;171; LOE 7;172).

The most studied DNAR form is the Physician Orders for Life-Sustaining Treatment (POLST) form,170,171,173–175

Treatment Recommendation
We recommend the use of standardized out-of-hospital physician orders for patients who are chronically ill or have a terminal illness. These must be easily understood by EMS personnel. Additional instructions should indicate whether EMS personnel are to initiate or continue life-sustaining interventions for patients in cardiac arrest and those in near-arrest. Because laws governing the use of DNAR forms and advance directives vary by jurisdiction, providers should be aware of local laws and regulations.176

Family Member Presence During CPR
Consensus on Science
No studies evaluated the effect of the presence of parents during resuscitation of children. Studies on parents’ opinions indicate their preference to be at the side of the child who is dying (LOE 5),177 during CPR (LOE 5),177 or during procedures (LOE 7).177–184 However, 5 studies (LOE 3)185–189 found that staff members were reluctant to allow parents to be present during resuscitation.

Most relatives of adult patients requiring CPR state that they would like to be offered the option of being present in the resuscitation room (LOE 5).190–194 A survey of adult patients indicated that many, but not all, would prefer to have certain family members present (LOE 5).195 Family presence during resuscitation did not impact on self-reported stress among staff (LOE 3),196 nor was it disruptive for staff (LOE 5).191,194 Family members considered their presence to be beneficial (LOE 5)191,193,194,197 and their adjustment to the death of the patient made easier by their presence during the resuscitation attempt (LOE 2;198; LOE 5;191,197).

There are no data to support or refute the importance of having a dedicated staff member available to support family members during resuscitation for either adults or children, but this practice is well described (LOE 2;198; LOE 5;191).

Treatment Recommendation
There is no data indicating that the presence of relatives in the resuscitation room is harmful. Therefore, it is reasonable to give select family members the opportunity to be present during resuscitation unless the adult patient has raised a prior objection.

Outcomes and Cost-Effectiveness
Research about the “quality of life” for survivors of cardiac arrest is plagued by the lack of a consistent definition of quality of life and how best to measure it. Nonetheless, the increasing demand for limited healthcare resources makes it important to measure the effectiveness of CPR in terms of quality of survival and not just the number of survivors.

Outcomes
Quality of Life Outcomes After CPR
Consensus on Science
In 6 nonrandomized prospective cohort studies (LOE 3)144,199–203 and 20 additional studies (LOE 4;204–210; LOE 5;211–223) of long-term survivors of in- and out-of-hospital cardiac arrest, the quality of life among the majority of adult survivors is similar to that of the general population. Cognitive deficits in survivors, such as memory loss and depression, are common. In 2 studies (LOE 4)224,225 neurologic outcomes were poor after cardiac arrest in children. Two studies indicate that the quality of life may not be as good in some cohorts, such as long-term care patients (LOE 5).226,227

Treatment Recommendation

Cost-Effectiveness
Cost-Effectiveness in CPR Training Programs
Consensus on Science
In the single study (LOE 3)148 that considers the cost-effectiveness of CPR training programs, traditional CPR training in an unselected population of laypeople is expensive compared with accepted cost-effectiveness thresholds. Conversely, selective training of laypeople at high risk of witnessing a cardiac arrest (ie, persons living in households with a recent survivor of myocardial infarction) is much more cost-effective.
Treatment Recommendation
It is reasonable for CPR programs to emphasize the enrollment of laypeople with the highest probability of encountering a victim of cardiac arrest. Other potentially more cost-effective methods of training should be considered (see previous sections).

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Introduction
When the International Liaison Committee on Resuscitation (ILCOR) identified priority topics and task forces for the 2005 International Consensus Conference to evaluate CPR and ECC science, stroke and first aid were not chosen. These topics, however, are of great interest to the American Heart Association and the American Stroke Association and their science volunteers. To complete evidence evaluation on these important topics, the American Heart Association hosted the Stroke Task Force and, with the American Red Cross, hosted the National First Aid Science Advisory Board.

The evidence evaluation process used for the stroke and first aid topics was identical to that used for the ILCOR topics and described in Part 1 and in an editorial in this supplement.1 The worksheets completed for evaluation of stroke and first aid topics are linked to the text as online data supplements in the same way as in Section 1 of this supplement.

To ensure transparency in disclosure and management of potential conflicts of interest, the Stroke and First Aid task forces followed the same disclosure policy as that used throughout the 2005 International Consensus Conference.2 The worksheet authors’ conflict of interest statements can be accessed through the online data supplement or the AHA website at http://www.c2005.org.

References
Part 9: Stroke

Stroke experts selected for the Stroke Task Force evidence evaluation process represent a variety of specialties (epidemiology, neurology, emergency medicine) and healthcare settings (community hospitals and medical centers) in the United States and Canada. Conflict of interest statements completed by task force members are linked to the superscript number at the end of this sentence.

The 2005 Consensus Conference evaluated the evidence related to the management of acute stroke. Survival and recovery from acute ischemic stroke requires establishment of systems and programs designed to promote rapid recognition of stroke warning signs, rapid emergency medical service (EMS) transport of stroke victims with prearrival notification to the receiving hospital, and a hospital system capable of providing organized and efficient stroke care. Intravenous (IV) fibrinolytic therapy is effective for reducing morbidity from acute ischemic stroke, but evidence shows that it must be administered within a system of acute stroke care using strict protocols and quality-improvement practices. This chapter separates stroke topics into out-of-hospital management, fibrinolytic therapy, and early in-hospital management.

Out-of-Hospital Setting

Care of the acute stroke patient ideally begins before the patient arrives at the hospital. This section considers the use of supplementary oxygen and out-of-hospital assessment and triage of patients with acute stroke. Oxygen administration is important for hypoxemic patients, but supplementary oxygen administration for all stroke victims has not yet been shown to be effective. Paramedics are able to recognize stroke with more sensitivity and specificity after receiving training in the use of specific stroke scales. Once the stroke victim is identified, transport and triage are important decisions that require the participation of hospitals and community notification. Each receiving hospital should define its capabilities for treating patients with acute stroke and should communicate this information to the EMS system and the community.

Oxygen

Consensus on Science

The combination of poor perfusion and hypoxemia will exacerbate and extend ischemic brain injury, and it has been associated with worse outcome from stroke. Although one small randomized clinical trial (LOE 2) suggested benefit of supplementary oxygen on infarct volume, a much larger trial did not show any clinical benefit (LOE 3) from routine administration of oxygen to all patients with ischemic stroke. In contrast, the administration of supplementary oxygen to the subset of stroke patients who are not hypoxic is indirectly supported by several studies showing improved functional outcomes and survival of stroke patients treated in dedicated stroke units in which higher rates of oxygen supplementation were used (LOE 7).

Treatment Recommendation

Administration of supplementary oxygen to hypoxemic stroke patients by out-of-hospital and in-hospital medical personnel is recommended. Because there is conflicting evidence regarding the benefits of supplementary oxygen administration to normoxemic stroke patients, healthcare professionals may consider giving oxygen to these stroke patients on an individual basis.

Out-of-Hospital Stroke Assessment Tools

EMS systems must provide education and training to minimize delays in prehospital dispatch, assessment, and transport. With training in the use of relatively simple stroke assessment tools, prehospital providers can identify potential victims of stroke with high sensitivity and specificity.

Consensus on Science

When paramedics were given standard training in identification of stroke, sensitivity for identifying patients with stroke ranged from 61% to 66% (LOE 5). After paramedics received training in using a stroke identification tool, sensitivity increased to 66% to 97% (LOE 3; LOE 4; LOE 5).

Treatment Recommendation

Paramedics should be trained in the recognition of stroke with a validated, abbreviated out-of-hospital neurologic evaluation tool such as the Cincinnati Prehospital Stroke Screen or the Los Angeles Prehospital Stroke Screen.

Prehospital Triage

The concept of designating stroke centers and stroke units is a source of contention within communities and among hospitals. Although many high-level studies have shown reduced length of stay and improved outcome from admission of patients to stroke units, more evidence is needed to determine criteria for the designation of stroke centers within a community and to describe time and distance limitations for transport of stroke patients to such units.

Consensus on Science

Evidence from adult case series of fair to good research design (LOE 5) and additional studies of poorer quality
(LOE 716 and LOE 817,18) suggests decreased in-hospital intervals from patient arrival to critical benchmark assessments and decreased patient mortality when triage to specific stroke hospitals for patients with potential stroke occurs in the out-of-hospital setting.

Triage of patients with potential stroke to specific stroke hospitals has not been proven to be safe, feasible, and effective. Clinical trials concerning this issue are ongoing.

**Treatment Recommendation**

Initial low-level evidence indicates a favorable benefit from triage of stroke patients to designated stroke centers, but this concept should be explored using more rigorous levels of evidence.

**Fibrinolytic Therapy**

The National Institute of Neurological Disorders and Stroke (NINDS) trials published in 1995 documented improved neurologic outcome in patients with acute ischemic stroke who received tissue plasminogen activator (tPA) using strict protocols. Since that time the validity of the NINDS trials has been challenged by some who note the higher stroke severity in the placebo group and the 10-fold increase in intracranial hemorrhage (but no increase in mortality) in the tPA group. Some community hospitals and medical centers have reported a higher incidence of intracranial hemorrhage than was reported in the NINDS trials. The experts reviewed the published literature about the reported risks and benefits of tPA for acute ischemic stroke and found more large case series reporting a rate of intracranial hemorrhage equal to or lower than that reported in the NINDS trials when fibrinolytics were administered at centers with institutional commitment, strict use of protocols, and a system of continuous quality improvement.

**IV Fibrinolytics**

**Consensus on Science**

Level 1 studies document a higher likelihood of good to excellent functional outcome when IV tPA is given to adult patients with acute ischemic stroke <3 hours from onset of symptoms when administered by physicians in hospitals with a protocol that adheres to the eligibility criteria and therapeutic regimen of the NINDS protocol (LOE 1).19–24 Evidence from level 1 studies of good to excellent quality in adults also documents greater likelihood of benefit the earlier treatment is begun (LOE 1).19,20,22,23,25 Several studies report high rates of symptomatic intracerebral hemorrhage when tPA is used outside of recommended criteria (LOE 5).26,27

**Treatment Recommendation**

In the setting of a clearly defined protocol, a knowledgeable stroke team, and institutional commitment, IV administration of tPA to patients with acute ischemic stroke who meet the NINDS eligibility criteria is recommended. There is strong evidence to avoid all delays and treat patients as soon as possible.

Although not every hospital is capable of organizing the necessary resources to safely administer fibrinolytic therapy, every hospital with an emergency department should have a written plan describing how patients with acute stroke are to be managed in that institution. The plan should detail the roles of healthcare professionals in the care of patients with acute stroke and define which patients will be treated with fibrinolytic therapy at that facility and when transfer to another hospital with a dedicated stroke unit is appropriate.

Emergent computerized tomography (CT) or magnetic resonance imaging (MRI) scans of patients with suspected acute stroke should be reviewed quickly by a physician who is expert in the interpretation of those studies.

**Intra-arterial Fibrinolytics**

**Consensus on Science**

Evidence from 2 prospective randomized studies in adults (LOE 128 and LOE 229) and additional studies including case series and meta-analysis (LOE 330 and LOE 531–38) document improvement in the National Institutes of Health Stroke Scale scores and modified Rankin Scale score at 1 to 6 months when prourokinase, urokinase, or tPA is administered by the intra-arterial route to patients with acute ischemic stroke in the first 6 hours from onset of symptoms.

**Treatment Recommendation**

For patients with acute ischemic stroke who are not candidates for standard IV fibrinolysis, administration of intra-arterial fibrinolysis in centers that have the resources available may be considered within the first 6 hours after the onset of symptoms.

**In-Patient Care**

In-patient treatment of acute stroke in dedicated units with trained personnel has proved beneficial. Hyperglycemia has been associated with poor neurologic outcome following head injury, resuscitation, and stroke. The question remains if lowering glucose will improve neurologic outcome for patients with acute stroke. Finally, therapeutic or induced hypothermia has been shown to be effective in 2 recent trials for victims of ventricular fibrillation sudden cardiac arrest who had successful return of spontaneous circulation but remained comatose. Investigators have explored the feasibility of hypothermia therapy for acute stroke.

**Stroke Units**

**Consensus on Science**

Evidence from multiple randomized clinical trials and meta-analyses in adults and additional studies document consistent improvement in 1-year survival rates and functional outcomes and reduced costs when care in a dedicated stroke unit is provided by dedicated stroke unit personnel to patients with acute stroke in the hospital setting (LOE 1).39–42

**Treatment Recommendation**

Hospitalized stroke patients experience improved outcomes when cared for by a multidisciplinary team experienced in managing stroke. Thus, when it is available, stroke patients who require hospitalization should be admitted to a stroke unit.

**Glucose Control**

**Consensus on Science**

Prospective, controlled cohort studies (LOE 3)43–46 and additional studies (LOE 447–53; LOE 554; LOE 755) showed
worse clinical outcome in patients with hyperglycemia and acute ischemic stroke. There is no direct evidence that active control of glucose improves clinical outcome in patients with acute ischemic stroke (LOE 2).56,57 There is evidence that treatment of hyperglycemia in other critically ill patients with insulin improves survival rates (LOE 7 for stroke).58

Treatment Recommendation

For consistency with the American Stroke Association59,60 and the European Stroke Initiative Guidelines,61 administration of IV or subcutaneous insulin may be considered for patients with acute ischemic stroke in the in-hospital setting to lower blood glucose when the serum glucose level is >10 mmol/L (about 200 mg/dL).

Therapeutic Hypothermia62,63

Consensus on Science

A Cochrane Database review failed to identify any evidence from prospective, randomized, controlled trials in stroke patients to support the routine use of hypothermia for patients with acute ischemic stroke (LOE 7).64 Two small feasibility studies with concurrent controls (LOE 3)65,66 documented the feasibility of cooling stroke patients to a body temperature of 35.5°C (95.9°F) using a cooling blanket63 or a cooling helmet64 with no increase in complications.

In one open study of 10 patients with a concurrent control group (LOE 3),65 patients with acute ischemic stroke were cooled to 32°C to 33°C (89.6°F to 91.4°F) with minimal complications. But in 2 small case series (LOE 5),66,67 including 1 using endovascular cooling (LOE 5),67 a temperature reduction to ≤33°C (91.4°F) was associated with significant complications. One small case series of 25 patients with severe stroke of the middle cerebral artery and post-ischemic brain edema (LOE 5)68 reported the feasibility of cooling to 33°C (91.4°F) with neutral results, but the patient outcome was poor, and in the absence of control, it is difficult to interpret complication rates. Reported complications of hypothermia in these case series include a rebound increase in intracranial pressure with rewarming, severe coagulopathy, cardiac failure and arrhythmias, pneumonia, and infection. These series were heterogeneous with respect to time between onset of stroke symptoms and cooling, method and degree of cooling, method of rewarming, and associated use of fibrinolytics.

One small series showed the feasibility of maintaining “low normothermic” temperatures (target 36°C to 37°C [96.8°F to 98.6°F]) using a cooling mattress for noncomatose, nonventilated patients with stroke (LOE 5).69

Treatment Recommendation

There is insufficient scientific evidence to recommend for or against the routine use of hypothermia in the treatment of acute ischemic stroke (Class Indeterminate).

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Part 10: First Aid

Introduction
In 2004 the American Heart Association (AHA) and the American Red Cross (ARC) cofounded the National First Aid Science Advisory Board (Table) to review and evaluate the scientific literature on first aid. The goals of the National First Aid Science Advisory Board are to reduce morbidity and mortality due to emergency events and to analyze the scientific evidence that answers the following questions:

- What are the most common emergency conditions that lead to significant morbidity and mortality?
- In which of these emergency conditions can morbidity or mortality be reduced by the intervention of a first aid provider?
- How strong is the scientific evidence that interventions performed by a first aid provider are safe, effective, and feasible?

Members of the National First Aid Science Advisory Board reviewed morbidity data from the US Centers for Disease Control and Prevention and first aid texts to identify common causes of injury and injury fatalities and selected the topics for evidence evaluation that are included in this section. The conflict of interest statements of the Board can be assessed through the website http://www.C2005.org. For further information about the evidence evaluation process, see Part 1: “Introduction.” The information presented here represents a consensus summary of the scientific evidence relevant to common first aid interventions with consensus treatment recommendations.

Definition of First Aid
The National First Aid Science Advisory Board defined first aid as assessments and interventions that can be performed by a bystander (or by the patient/victim) with minimal or no medical equipment. The board defined a first aid provider as someone with formal training in first aid, emergency care, or medicine who provides first aid.

The board agreed that recommended assessments and interventions should be medically sound and based on scientific evidence or, in the absence of such evidence, on scientific consensus. Administration of first aid must not delay activation of the emergency medical services (EMS) system or other medical assistance when such assistance is required. It is recognized that certain conditions that can be treated with first aid may not require EMS involvement or assistance by other medical professionals. The National First Aid Science Advisory Board strongly believes that education in first aid should be universal: everyone can and should learn first aid.

The National First Aid Science Advisory Board recognized that the scope of first aid is not a purely scientific one and is related to both training and regulatory issues. The definition of scope is therefore variable, and it should be defined according to circumstances, need, and local regulatory requirements.

Future Directions
The evidence review by the National First Aid Science Advisory Board confirmed the paucity of scientific evidence on first aid subjects. Many of the following recommendations have been made by extrapolation from the experience of healthcare professionals or evidence derived from healthcare settings. Research is needed to ensure that future guidelines are based on a larger body of scientific evidence.

Overview
This document summarizes current evidence for evaluation and first aid interventions for medical, injury, and environmental emergencies. The broad range and number of topics reviewed and limitations of journal space require succinctness and brevity in science statements and treatment recommendations. This is not intended as a comprehensive review of every aspect of first aid. Rather, it is intended to evaluate the evidence available to support management of common problems.

Medical Emergencies
The experts reviewed published evidence to support the first aid use of oxygen and to support assistance with the use of asthma inhalers and epinephrine autoinjectors. Although there was no published information on the first aid application of any of these common adjuncts, some recommendations could be made to support assistance with asthma inhalers and epinephrine autoinjectors based on extrapolated evidence from use by laypersons.

Oxygen Administration

Consensus on Science
Although oxygen administration is a basic healthcare provider procedure, the reviewers found no studies that evaluated emergency oxygen administration by first aid providers. Many studies included oxygen as a professional treatment modality, but all identified studies were confounded by the heterogeneity of subject disease states and condition, diverse equipment needs, and multiple adjunctive treatments. These

From the 2005 First Aid Science Advisory Board Evidence Evaluation Conference, hosted by the American Heart Association and the American Red Cross in Dallas, Texas, January 23–24, 2005.
(Circulation. 2005;112:III-115-III-125.)
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This special supplement to Circulation is freely available at http://www.circulationaha.org DOI: 10.1161/CIRCULATIONAHA.105.166480
Organizations Represented on the National First Aid Science Advisory Board

- Academy of Orthopaedic Surgeons
- American Academy of Pediatrics
- American Association of Poison Control Centers
- American Burn Association
- American College of Emergency Physicians
- American College of Occupational and Environmental Medicine
- American College of Surgeons
- American Heart Association
- Army Medical Command
- The American Pediatric Surgical Association
- American Red Cross
- American Safety and Health Institute
- Australian Resuscitation Council
- Canadian Red Cross
- International Association of Fire Chiefs
- International Association of Fire Fighters
- Medic First Aid International
- Military Training Network
- National Association of EMS Educators
- National Association of EMS Physicians
- National Association of EMTs
- National Safety Council
- Occupational Safety and Health Administration
- Save a Life Foundation

Variables prevent extrapolation of the results of any of the reviewed studies to first aid applications.

Treatment Recommendation
There is insufficient evidence to recommend for or against the use of oxygen by the first aid provider.

Assistance With Use of Inhalers

Consensus on Science
Severe asthma and deaths from asthma are increasing, so it is likely that first aid responders will be asked to help victims with respiratory distress caused by asthma. Patients with asthma often use prescribed bronchodilator inhalers, but the reviewers found no studies evaluating the efficacy of first aid providers assisting patients in the use of these inhalers for breathing difficulty. Nonrandomized studies documented the ability of adults to appropriately self-administer bronchodilator medications (LOE 4) and the ability of parents to correctly administer metered-dose inhalers to their children (LOE 4). An important difference in the first aid situation, however, is that the first aid provider may not know the victim, the victim’s medical history, or what medications the victim takes. Thus the studies regarding parents constitute LOE 7 (extrapolated) information applied to first aid.

Treatment Recommendation
Because the frequency and mortality from severe asthma is increasing and bronchodilator therapy is safe and can be effective during episodes of severe asthma, the first aid rescuer should assist with administration of bronchodilator therapy.

Epinephrine Autoinjector

Consensus on Science
A severe allergic reaction (anaphylaxis) can cause life-threatening airway edema and obstruction, vasodilatation, and cardiovascular collapse. Although administration of epinephrine is a cornerstone of emergency management of severe allergic reactions, the reviewers found no studies of the safety, efficacy, or feasibility of first aid providers assisting with administration of epinephrine autoinjectors. Many adults and children with a history of anaphylaxis carry a prescribed epinephrine autoinjector.

Evidence from one small retrospective study (LOE 7) reported that parents who administer epinephrine to their children via an autoinjector can do so safely and effectively. Evidence from other studies (LOE 7) highlighted the need for additional education and retraining of parents and health-care providers in the use of epinephrine autoinjectors.

Treatment Recommendation
Given the widespread use of epinephrine autoinjectors and their documented efficacy in the rapid delivery of epinephrine, first aid providers may be trained to assist with the use of an epinephrine autoinjector for a victim of anaphylaxis when the victim has a prescribed autoinjector and the victim is unable to use it.

Recovery Position

Consensus on Science
Although the recovery position is widely used in healthcare settings, the reviewers found no studies evaluating the safety, effectiveness, or feasibility of this position in unresponsive, breathing victims in the out-of-hospital setting. All identified studies of specific recovery positions used healthy, responsive adult volunteers (LOE 3–5), so results are at best extrapolated (LOE 7) to unresponsive victims.

Any recovery position used for the patient with known or suspected spinal injury should maintain a patent airway, stabilize the spine, and minimize movement of the victim. Two human prospective cohort studies in healthy adult volunteers (extrapolated from LOE 3) suggest that the modified HAINES position results in more neutral position of the cervical spine than the traditional lateral recovery position. HAINES is an acronym for High Arm IN Endangered Spine: the rescuer extends the victim’s arm above the head and rolls the victim to the side, onto that arm, and then bends the victim’s knees. The subjects in these studies were responsive (with presumably normal muscle tone), however, and had no head, neck, or cervical spine injury. In addition, the study of the HAINES position did not include study of the movement of patients to that position.

The recovery position was also reviewed by the Basic Life Support Task Force. For additional information see Part 2: Adult Basic Life Support” and the associated worksheets.

Treatment Recommendation
The use of the recovery position with the victim lying on his or her side with the dependent hand placed in front of the
body is recommended for the unconscious victim with an intact airway, spontaneous respiration, and signs of circulation. This position is easy to teach, but conscious volunteers who were placed in the position developed some vessel and nerve compression (LOE 3).13,14 Nerve and vessel injury can develop, particularly if the victim remains in the position for a long period of time.

The preferred position for the victim with known or suspected spinal injury is to stabilize the spine in the supine position and minimize movement of the victim. Use of the recovery position may be necessary if it is difficult to maintain a patent airway in the supine position, if the victim has secretions or emesis, or if the rescuer must leave the victim and there is no provider trained in spinal stabilization. If use of the recovery position is absolutely necessary, use the HAINES recovery position: extend the victim’s arm above the head and roll the victim to the side so that the victim’s head rests on that arm. Bend both legs to stabilize the victim.

**Injury Emergencies**

There was little published evidence about common first aid maneuvers to stabilize the cervical spine; control bleeding; and treat wounds, abrasions, burns, and musculoskeletal injuries. Because the consequences of spinal cord injury are severe, the experts developed consensus treatment recommendations for stabilization of the cervical spine based on extrapolation from healthcare provider experiences. Treatment of bleeding in the battlefield provided evidence regarding the use of pressure and tourniquets by trained lay rescuers and healthcare providers. But these results must be applied with caution to the first aid setting when medical assistance may be available within minutes.

The experts found that many “common sense” treatments for wounds, burns, musculoskeletal injuries, and dental and environmental injuries are supported by only low levels of evidence.

**Cervical Spine Injuries**

**Cervical Spine Stabilization**W256,W257,W265,W266,W269,W150A,W150B

**Consensus on Science**

Approximately 2% of adult victims of blunt trauma evaluated in the emergency department suffer a spine injury (LOE 3),15,16 and this risk is tripled in patients with craniofacial injury (LOE 4)17 or a Glasgow Coma Scale score of <8 (LOE 4).18

EMS and emergency department personnel can correctly identify injury mechanisms that may produce spinal injury in adults (LOE 315,19,20; LOE 421) and in children.22 EMS personnel can properly apply spinal immobilization devices in such circumstances (LOE 3),23–25 although they may not accurately detect signs and symptoms of actual spinal injury (LOE 326–28; LOE 429,30). Results of these healthcare provider studies constitute only extrapolated evidence (LOE 7) for first aid actions. There are no studies showing that first aid providers can recognize potential or actual spinal injury.

There is no evidence that first aid rescuers can correctly use spinal immobilization devices. Although the failure to detect and immobilize cervical spine injury in hospitalized patients is associated with a 7-fold to 10-fold risk of secondary neurologic injury (LOE 331; LOE 432), it is not clear if the secondary injuries occur in the prehospital setting and can be prevented by spinal immobilization devices. A 5-year retrospective chart review (LOE 4)33 with a multivariate analysis compared all patients with blunt traumatic spine or spinal cord injuries admitted to a trauma hospital in Malaysia with patients with similar injuries admitted to a US trauma hospital. Physicians blinded to hospital origin found less evidence of neurologic disability in the Malaysian patients, who were transported without spinal immobilization, than in the US patients, who were transported with spinal immobilization devices in place.

There is some evidence that spinal immobilization devices can be harmful. A retrospective chart review (LOE 4)44 found that spinal immobilization devices masked life-threatening injuries. In addition, immobilization on a spine board restricted pulmonary function in healthy adults (LOE 3)35 and children (LOE 3).36 Application of a cervical collar increased intracranial pressure in healthy patients (LOE 3)37 and patients with traumatic brain injury.38

Spine immobilization was also reviewed by the Basic Life Support Task Force. For additional information see Part 2: “Adult Basic Life Support” and the associated worksheets.W150A,W150B

**Treatment Recommendation**

Considering the serious consequences of spinal cord injury, most experts agree that spinal motion restriction should be the goal of early treatment of all patients at risk for spinal injury. The first aid provider should restrict spinal motion by manual spinal stabilization if there is any possibility of spinal injury.

In the absence of any evidence supporting the first aid use of immobilization devices and with some evidence suggesting potential harm even when these devices are used by healthcare providers, the first aid provider should refrain from use of spinal immobilization devices.

**Severe Bleeding**

**Application of Pressure and Tourniquets**W254,W255

**Consensus on Science**

Direct pressure. Although bleeding is a common first aid emergency and control of hemorrhage can be lifesaving, only 2 studies reported the efficacy of direct pressure to control hemorrhage in the prehospital or field hospital settings, and in both studies the pressure was applied by trained medical personnel. One retrospective case series (LOE 5)29 described the technique of hemorrhage control by highly trained ambulance workers. Hemorrhage control was achieved by wrapping an adhesive elastic bandage applied directly over a collection of 4 × 4-inch gauze pads placed on the wound surface. The roll was wrapped around the body surface over the bleeding site until ongoing hemorrhage ceased. The pressure was effective in stopping bleeding in all cases with no complications. A second nonrandomized observational case series from a field hospital (LOE 4)40 compared the efficacy of direct pressure applied by trained providers with an elastic bandage to control hemorrhage in 50 successive victims of traumatic amputations to the effectiveness of tourniquets used for 18 previous victims with traumatic amputations from mine explosions. Less ongoing bleeding,
higher survival rates, and higher admission hemoglobin were observed in the 50 victims for whom bleeding was controlled with direct pressure compared with the 18 earlier victims who had bleeding controlled with a tourniquet. Four studies from cardiac catheterization experience (LOE 7, extrapolated from LOE 1 and 2),41–44 one animal study (LOE 6),45 and clinical experience document that direct pressure is an effective and safe method of controlling bleeding. The efficacy, feasibility, and safety of use of pressure points to control bleeding have never been subjected to any reported study, and there have been no published studies to determine if elevation of a bleeding extremity helps to control bleeding or causes harm.

Tourniquets. The use of tourniquets by a first aid provider to control bleeding is controversial. Tourniquets are routinely and safely used to obtain extremity ischemia for orthopedic and vascular surgical procedures in operating rooms where applied pressure and occlusion time are strictly measured and controlled and on the battlefield when occlusion time is carefully documented. But these results cannot be extrapolated to the first aid setting. Two studies illustrate the contradictory evidence reported about the effectiveness and safety of tourniquet use in the first aid setting. In a retrospective military field case series (LOE 5),46 110 tourniquets were applied to 91 soldiers by medical (47%) or nonmedical (53%) personnel. The tourniquets controlled bleeding in most (78%) of the victims, typically within 15 minutes. Penetrating trauma was the most common mechanism of injury, and ischemic time was 83 ± 52 minutes (range of 1 to 305 minutes). The rate of success was higher for medical staff compared with soldiers and for upper limbs (94%) compared with lower limbs (71%, P < .01). Neurologic complications of the tourniquet were reported in 7 limbs of 5 patients (5.5%) who had an ischemic time of 109 to 187 minutes. Complications included bilateral peroneal and radial nerve paralysis, 3 cases of forearm peripheral nerve damage, and 1 case of paresthesia and weakness of the distal foot. In the nonrandomized report (LOE 5)47 of victims of traumatic amputation from mine explosions cited in the previous section, tourniquet use resulted in more bleeding, lower survival rates, and lower admission hemoglobin than direct pressure with an elastic bandage. Complications following tourniquet use in the operating room are well documented. Tourniquet use during surgical procedures has produced temporary (LOE 5)47 or permanent (LOE 7)48 injury to the underlying nerves and muscles (LOE 5)49 and limb ischemia with resulting systemic complications, including acidemia and hyperkalemia (LOE 2).50 Complications can include reperfusion injury (LOE 2)51 and limb loss. These complications are related to the pressure applied (LOE 5)52 and occlusion time (LOE 2).50

Treatment Recommendation
The first aid provider should try to control external bleeding by applying direct pressure.

There is insufficient evidence to recommend for or against the first aid use of pressure points or extremity elevation to control bleeding.

Tourniquets may be useful under some unique conditions (eg, battlefield conditions when rapid evacuation is required and ischemic time is carefully monitored). Additional studies are needed to identify those conditions and the indications and procedures for use. The method of application and best design of tourniquets is still under investigation.53 There is insufficient evidence about the effectiveness, feasibility, and safety of tourniquets to recommend for or against their use by first aid providers to control bleeding.

Wounds and Abrasions

Wound Irrigation

Consensus on Science
Wound irrigation is often used in the prehospital and hospital setting to clean wounds. There is strong evidence from human and animal studies that wound irrigation using clean running tap water is at least as effective as wound irrigation with normal saline. In 1 Cochrane meta-analysis (LOE 1),54 1 small randomized human study (LOE 2),55 and 1 human case series (LOE 5),56 irrigation with running tap water was more effective than irrigation with saline in improving wound healing and lowering infection rates. In 1 small randomized human study (LOE 2),57 irrigation with tap water produced wound infection rates equivalent to that observed after irrigation with normal saline. Although many of these studies were performed in healthcare settings, running tap water is readily available to lay rescuers in the out-of-hospital setting.

Treatment Recommendation
Superficial wounds and abrasions should be irrigated with clean tap water.

Use of Antibiotic Ointment

Consensus on Science
Two prospective, randomized controlled studies compared the effectiveness of triple antibiotic ointment with single antibiotic ointment or no ointment in conditions comparable to first aid situations. In one human volunteer study (LOE 1)58 of the effects of applied ointment to intradermal chemical blisters inoculated with a single organism (Staphylococcus aureus), contaminated blisters treated with triple antibiotic ointment healed significantly faster and with a lower infection rate than blisters treated with either single antibiotic ointment or no ointment. Both triple and single antibiotic ointments were superior to no treatment in promoting healing of the contaminated blisters. In a study (LOE 1)59 of 59 children in a rural day care center, application of triple antibiotic ointment to minor skin trauma (eg, mosquito bites, abrasions) resulted in lower rates of one skin infection, streptococcal pyoderma, than the rates of that infection observed in children who received applications of placebo ointment (15% versus 47%).

Extrapolation of results from studies of surgically created wounds supports the use of antibiotic ointments. In 2 studies involving human volunteers with wounds that were created under sterile conditions (ie, dermabrasion or split-thickness skin graft donor sites), triple antibiotic ointment was superior to no ointment in minimizing pigment changes50 and scarring.51 These reports may not be relevant to the treatment of nonsurgical and probably nonsterile wounds in the first aid setting. Triple antibiotic ointment can eliminate coagulase-negative staphylococci underlying the skin surface (LOE 7),62 but its impact on wound contamination and healing cannot be extrapolated from these studies.
Treatment Recommendation
Lay rescuers should apply antibiotic ointment or cream to cutaneous abrasions and wounds to promote faster healing with less risk of infection. The use of triple antibiotic ointment may be preferable to double- or single-agent antibiotic ointment or cream.

Thermal Burns
Cooling With Water

Consensus on Science
Immediate cooling of thermal burns with cold tap water is supported by a large number of observational clinical studies and controlled experiments in animals. Cooling may provide pain relief and reduce formation of edema, infection rates, depth of injury, and need for grafting and may promote more rapid healing. One small, controlled human volunteer study (LOE 3)43 several large retrospective human studies (LOE 464; LOE 565–67), and multiple animal studies (LOE 668–72 document consistent improvement in wound healing and reduced pain when burns are cooled with cold water (10°C to 25°C [50°F to 77°F]). Several studies (LOE 6)69,73 indicate that cooling of burns should begin as early as possible and continue at least until pain is relieved (LOE 5).74 There is limited (LOE 5) evidence that brief application of ice or ice water may be safe and effective for small burns in adults,64,68,74,75 but prolonged application of ice or ice water may result in additional tissue injury (necrosis)67 (LOE 576; LOE 67). Evidence from animal studies (LOE 6)78 suggests that cooling of large burns (≥20% of total body surface area) with ice or ice water for ≥10 minutes can result in hypothermia.

Treatment Recommendation
Cooling of burns with cold water as soon as possible is safe, feasible, and effective as a first aid treatment. First aid providers should avoid cooling burns with ice or ice water for >10 minutes, especially if burns are large (>20% total body surface area).

First Aid for Burn Blisters

Consensus on Science
There is no clear, evidence-based consensus on the treatment of burn blisters. Many treatment recommendations are based on level 5 or lower studies and common practice. Although many first aid guidelines recommend that burn blisters be left intact, some researchers suggest that burn blister fluid may retard healing, particularly when blisters are large (>2.5 cm) and thin-walled. One case control study (LOE 4)79 looked at wound healing rates for intact blisters versus those in which fluid was drained and found that removal of burn blister fluid enhanced healing. In contrast, most animal data (LOE 6)80–82 documents faster healing rates, significantly lower infection rates, and less scar tissue formation in animals with burn blisters left intact compared with those with debrided burn blisters.

Treatment Recommendation
Because the need for blister debridement is controversial and requires equipment and skills that are not consistent with first aid training, first aid providers should leave burn blisters intact and cover them loosely.

Musculoskeletal Injuries (Fractures, Sprains, and Contusions)

Stabilization

Consensus on Science
There are numerous reports of the benefits of stabilization of extremities by trained providers, but it is impossible to extrapolate this data to the first aid provider. There is no evidence to support the hypothesis that realignment of a fractured extremity bone by a lay first aid provider is safe, effective, or feasible.

Treatment Recommendation
The first aid provider should assume that any injury to an extremity can include a potential bone fracture. The first aid provider may manually stabilize the injured extremity but should not attempt to straighten it.

Compression

Consensus on Science
The reviewers found no data to support the hypothesis that compression of an injured extremity is safe, effective, and feasible when performed by a first aid provider. Although it is widely accepted (LOE 7)83 that compression of an injured extremity decreases edema, this concept has not been subjected to randomized trials. One small study (LOE 7)84 with Doppler evaluation of blood flow to the toes of 10 healthy female volunteers suggests that moderate circumferential compression may compromise distal (toe) blood flow, but this information must be extrapolated to the first aid arena.

Treatment Recommendation
There is inadequate evidence to recommend for or against the use of a circumferential bandage to compress a closed soft-tissue injury and reduce formation of edema (Class Indeterminate).

Application of Cold

Consensus on Science
The basic principle in first aid for soft-tissue injuries is to decrease hemorrhage, edema, and pain. Cold therapy has been shown to reduce edema in animal85,86 and human87,88 studies. Cold therapy has been shown experimentally to reduce the temperature of various tissues, including muscles and joints in healthy89–92 and postoperative93 subjects. Ice therapy also contributes to reductions in arterial and soft-tissue blood flow along with bone metabolism as shown in nuclear medicine imaging studies.94 It appears to be time dependent.95

The application of ice is effective for reducing pain, swelling, and duration of disability87,96 after soft-tissue injury. There is good evidence to suggest that cold therapy reduces edema.86,87,97 One postoperative study evaluating anterior cruciate ligament reconstruction suggested that cold therapy contributed to no objective benefit in the postoperative period related to length of hospital stay, range of motion, use of pain medication, and drain output.93 However, there was a trend
for a decrease in oral pain medication in the group of patients treated with ice bags. Other types of cold therapy, including cold gel,98 frozen pea bags,89 and other cold therapy delivery systems,85,91 may also be beneficial. Some studies85,89,99 showed that refreezable gel packs are inefficient. Cold therapy modalities that undergo a phase change seem to be more efficient in decreasing tissue temperature.91

**Treatment Recommendation**

Cooling is generally safe, effective, and feasible in first aid for a sprained joint and soft-tissue injury. Cold applied for >20 minutes may be detrimental, although there are several reports that suggest that longer application may continue to cool the joint without additional complications.91

There is insufficient information to make recommendations on optimal frequency, duration, and initial timing of cryotherapy after an acute injury.100,101 Many textbooks are not consistent in their recommendations related to duration, frequency, and length of ice treatment.100

To prevent cold injury to the skin and superficial nerves, it is best to limit ice to periods ≤20 minutes at a time with a protective barrier.102,103 A damp cloth or plastic bag barrier may be ideal, whereas cold is not conducted as well through padded elastic bandages.100 Caution should be exercised when applying ice to an injury in a person with little subcutaneous fat, especially over areas of superficial peripheral nerves.102,104

**Dental Injuries**

**Tooth Avulsion**

The evidence reviewed included an expert opinion review article (LOE 7)105 and extrapolated evidence from a study of survival of lip fibroblasts in various media (LOE 7).106 Expert opinion and a study of tissue survival in mild versus salt solutions or other storage media supported placement of avulsed teeth in milk until reimplantation or other definitive care can be provided.

**Treatment Recommendation**

The consensus of the experts is that the potential harm from attempted reimplantation of an avulsed tooth outweighs the potential benefit, and that avulsed teeth should be stored in milk and transported with the injured victim to a dentist as quickly as possible.

**Environmental Injuries**

Relatively good animal data is available to evaluate the treatment of snakebite, but little evidence is available on which to base specific treatment recommendations for cold injuries.

**Snakebite**

The consensus of the experts is that the potential harm from attempted reimplantation of an avulsed tooth outweighs the potential benefit, and that avulsed teeth should be stored in milk and transported with the injured victim to a dentist as quickly as possible.

**Consensus on Science**

Although some first aid texts recommend that rescuers must remove venom from a snakebite, a controlled animal study (LOE 6)107 showed no clinical benefit and earlier death in animals with snakebites that were treated with suction compared with animals with snakebites treated without suction. Two subsequent studies (LOE 5108, LOE 6109) showed that the application of suction resulted in the removal of some injected venom, but these reports did not examine clinical outcome. The use of a suction device on rattlesnake envenomation in a porcine model (LOE 6)110 showed no benefit and suggested injury may occur with suction. A simulated snakebite study in human volunteers (LOE 5)111 determined that a suction device recovered virtually no mock venom.

If a snakebite is from an elapid (eg, coral) snake, first aid treatment includes application of pressure immobilization. The landmark article by Sutherland (LOE 6)112 showed that pressure immobilization after elapid snakebites retarded venom uptake in monkeys. In a human study Howarth (LOE 3)113 showed that lymphatic flow and mock venom uptake can be safely reduced by proper application of pressure (40 to 70 mm Hg for upper limbs, 55 to 70 mm Hg for lower limbs) and immobilization and that either alone is insufficient. Pressure bandages should not be applied too tightly because they will restrict blood flow. A recent study in pigs (LOE 6)114 documented improved survival rates with application of moderate pressure and immobilization.

**Treatment Recommendation**

First aid providers should not apply suction to snakebite envenomation sites.

Properly performed pressure immobilization is recommended for first aid treatment of elapid snakebites. The first aid provider creates this pressure by applying a snug bandage that allows a finger to slip under the bandage.

**Cold Injuries**

**Hypothermia**

**Consensus on Science**

The goals of care for the victim of hypothermia are to stop the fall in core temperature, establish a steady, safe rewarming rate, and support cardiorespiratory function.115 Although there is a general belief that hypothermic patients should be rewarmed, there is very little data to support any specific method or timing of rewarming in the out-of-hospital setting.

One small in-hospital study116 of adult patients with hypothermia randomized to warming with forced-air convective covers plus warmed IV fluids versus cotton blankets plus warmed IV fluids documented that forced-air rewarming (using an air-filled blanket) raised the core temperature faster than passive rewarming and produced no additional complications. In a prospective randomized study117 of 8 healthy volunteers who were anesthetized and cooled to 33°C (91.4°F) (shivering was prevented with administration of meperidine) core temperature increased more rapidly with active rewarming using a resistive heating blanket than with passive rewarming using reflective foil. It is difficult to extrapolate these results to all victims of hypothermia in the first aid setting. The need for lay rescuers to institute fast or active rewarming in the prehospital setting has not been established.

In a retrospective chart review (LOE 4),118 prehospital rewarming strategies did not affect outcome of hypothermic patients admitted through the emergency department. Active prehospital rewarming may lead to increased complications...
such as the “afterdrop phenomenon,” in which vasodilation results in increased perfusion of cold extremities and delivery of acidic blood to the central circulation.119

This topic was also reviewed by the Basic Life Support Task Force. For additional information see Part 2: “Adult Basic Life Support,” and the related worksheet.W162A

Treatment Recommendation
The first aid provider should provide passive warming (using blankets) as feasible for victims of hypothermia. Victims should be transported to a facility where active rewarming can be initiated. If the victim is in a remote location far from medical help, the first aid rescuer may initiate active rewarming.

FrostbiteW267

Consensus on Science
There is little published evidence about the first aid treatment of frostbite. One opinion review with a case report120 suggests that the frostbitten body part should be rewarmed in the prehospital setting only if there is no chance of refreezing. Other consensus opinion reviews121 suggest that the frostbitten part should not be rubbed or massaged because this can increase tissue damage.

Treatment Recommendation
The first aid provider should rewar a frostbitten body part unless there is a possibility that it might refreeze.

Poisoning
Poisoning can be caused by solids, liquids, gases, and vapors. Solids and liquids are ingested or absorbed through the skin, whereas gases and vapors are typically inhaled (vapors can also be absorbed through the skin). This evidence evaluation process did not review the evidence surrounding first aid for inhaled toxins.

Water irrigation was shown to be effective for topical chemical or caustic burns. Some common first aid treatments for ingested poisons, such as drinking water or administration of syrup of ipecac, are not supported by evidence and may be harmful, so they are not recommended. There was inadequate evidence to recommend for or against the use of activated charcoal in the first aid setting.

Toxic Exposure and Chemical Burns

Water IrrigationW258,W259

Consensus on Science
Irrigation of the skin and eye after exposure to caustic agents can reduce the severity of tissue damage. Evidence from multiple studies examining alkali and acid exposure to both the eye (LOE 1–8)22–127 and the skin (LOE 4–6)128–134 document improved outcome when water irrigation is rapidly administered in first aid treatment. One nonrandom case series (LOE 5)134 of immediate (first aid) versus delayed (healthcare provider) skin irrigation documented a lower incidence of full-thickness burns and 50% reduction in length of hospital stay with immediate and copious irrigation of skin chemical burns. Animal evidence (LOE 6) also supports water irrigation to reduce toxic exposure from acid burns to the skin124,130 and eye.122,123 In a study of rats with acid skin burns,130 water irrigation within 1 minute of the burn prevented any drop in tissue pH, whereas delayed irrigation allowed a progressively more significant fall in tissue pH.

Treatment Recommendation
To treat skin or eye exposure to acid or alkali, the first aid provider should immediately irrigate the skin or eye with copious amounts of tap water.

Ingested Poisons

Water and Gastrointestinal DecontaminationW249,W250,W251

Consensus on Science
As noted in the ECC Guidelines 2000,135 there is no human evidence to support the administration of water or milk after the ingestion of a poison. Although animal studies of caustic (acid or alkali) ingestions have documented reduced esophageal tissue injury following lavage with or ingestion of saline, cola, orange juice, water or milk, outcome data was limited to tissue pH studies or tissue injury and did not evaluate survival rates. In addition, these studies did not address ingestion of noncaustic substances. Because the poisoned patient may have an altered level of consciousness that compromises airway protective reflexes, expert opinion suggests that administration of anything by mouth may be harmful.

Three randomized clinical trials (LOE 2) in children136 and adults137,138 have shown no benefit and possible harm from the administration of syrup of ipecac after toxic ingestion. In 2 studies136,138 administration of ipecac delayed the use of activated charcoal and in 1 trial138 increased charcoal emesis and length of stay. One prospective, randomized clinical trial (LOE 2)139 of 200 adults treated for ingestion in the emergency department with either ipecac plus activated charcoal or ipecac alone documented higher complication rates and higher incidence of aspiration pneumonia among adults who received ipecac alone. A large retrospective study of 752 602 children in the American Association of Poison Control Center Toxic Exposure Surveillance System Database (LOE 4)40 was unable to document improvement in outcome or reduction in healthcare use related to administration of syrup of ipecac for potentially toxic ingestions. Administration of syrup of ipecac has been associated with harm in case reports (LOE 5)141–144 and clinical studies (LOE 2).139

Administration of activated charcoal to animals immediately after drug ingestion can reduce the amount of drug absorbed, but effectiveness varies and decreases over time.145,146 The published experience pertaining to first aid administration of activated charcoal is limited. Although 1 prospective uncontrolled study (LOE 4)147 and 2 retrospective case series(LOE 5)148,149 suggest that activated charcoal may be safely administered to children at home and can reduce the time to activated charcoal administration, activated charcoal was rarely recommended for childhood poisonings and was successfully administered to only two thirds of the victims.147 Studies in healthy children document that children will not take the recommended dose of activated charcoal.150 Although a retrospective chart review (LOE 5)151 of 878 patients who received multiple doses of activated charcoal in the hospital documented a low incidence of complications,
aspiration did occur in this study, and the results are likely to be worse in the prehospital setting with no healthcare providers in attendance. Some reports of aspiration of activated charcoal were identified, but the precise incidence of this complication is unknown.

Treatment Recommendation
The administration of water or milk to the victim of ingested poison is not recommended.

Based on lack of evidence of benefit and documentation of potential harm, syrup of ipecac is not recommended.

There is insufficient evidence to recommend for or against the use of activated charcoal in first aid.

References


International Collaboration in Resuscitation Medicine

Richard O. Cummins, MD, MPH, MSc; Douglas Chamberlain, MD; William H. Montgomery, MD; Walter G.J. Kloock, MD, BCh; Vinay M. Nadkarni, MD

“Researchers from many countries, publishing in multiple languages, are building the scientific foundation for resuscitation practice. Universal guidelines will follow if we can find a way to gather all this information in one location and decide what it all means.” —Richard O. Cummins and Douglas Chamberlain, founding cochairs of the International Liaison Committee on Resuscitation

For more than a decade an international collaboration of clinicians and researchers has tried to identify, evaluate, and interpret the most valid resuscitation science. This supplement to Circulation (simultaneously published in Resuscitation) presents these collaborators’ latest attempts to reach consensus on what the science means and what resuscitation practices should follow. We have not reached our goal of universal resuscitation guidelines, but we have made a worthy attempt. Building on the International Guidelines 2000 Conference on CPR and ECC,1 in January 2005 a total of 380 experts reviewed 276 resuscitation topics, digested countless peer-reviewed publications, and participated in 6 days of almost continuous discussion and debate. Particular attention was paid to disclosure of potential conflicts of interest and identification of topics that lacked good evidence to support current practice.

We can trace the pedigree of these efforts over half a century. The original reports of rescue breathing2 and closed-chest compressions3 and the effective combination of the two4 created an immediate demand for CPR training and performance guidelines. In 1966 the Institute of Medicine convened the first conference to specifically review the evidence and recommend standard CPR and ECC techniques.5 The American Heart Association sponsored subsequent conferences in 1973 and 1979.6,7 Parallel efforts occurred internationally as other resuscitation councils faced a growing demand for training in this strange new technique of compressing the victim’s chest and blowing into the victim’s mouth.8 Inevitably variations in resuscitation techniques and training methods began to emerge from one country to another.

With continued development of new drugs and medical devices, resuscitation leaders identified many questions that needed answers. At numerous small national conferences they asked whether answers might already exist in other countries, published in both English and non-English language scientific journals. Increasing awareness of variations in resuscitation practices between countries sparked interest about gathering international experts at a single location. The AHA convened such a meeting in 1985, inviting resuscitation leaders from many countries to observe the AHA’s review of standards and guidelines for CPR and ECC.9 Passive observation by these international guests lasted only through opening introductions; these multinational experts, passionately devoted to improving resuscitation outcomes, soon demonstrated an ability to generate both heat and light.

By 1992, when the AHA convened the next Guidelines Conference, more than 40% of the participants were from outside the United States.10 During this 1992 conference a panel on international cooperation on CPR and ECC endorsed the need to foster a multinational base of evidence for resuscitation practices. What was lacking, however, was a focused mechanism with which to capture and assess this growing body of evidence. That panel strongly recommended that an expanded group of international experts initiate a systematic review of the world’s resuscitation literature. In 1993, under the leadership of many of these panel members, including Richard O. Cummins, Douglas Chamberlain, William Montgomery, and Walter Kloock, the International Liaison Committee on Resuscitation (ILCOR) was formed. The founding member organizations of ILCOR were the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, the Resuscitation Council of Southern Africa, and the Australian Resuscitation Council. These organizations were later joined by the Consejo Latino-Americanico de Resuscitacion (which now forms part of the Inter-American Heart Foundation) and the New Zealand Resuscitation Council.

With the shared vision of international cooperation, ILCOR began to assess systematically the supportive evidence for resuscitation standards and guidelines. During this project ILCOR experts identified numerous national differences in the practices of basic life support, advanced life support, and pediatric and newborn resuscitation. As of 2005, ILCOR published 18 scientific advisory statements with the goal of explaining, eliminating, or reducing these international variations while endorsing mainly evidence-based resuscitation guidelines.11

The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.

From the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations, hosted by the American Heart Association in Dallas, Texas, January 23–30, 2005.

This article has been copublished in Circulation. (Circulation. 2005;112:III-126-III-127.)

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This special supplement to Circulation is freely available at http://www.circulationaha.org

DOI: 10.1161/CIRCULATIONAHA.105.170811
Between 1993 and 2005 ILCOR has convened 22 official meetings. Guiding these ILCOR meetings was a belief that evaluation of international science by a common group of experts should lead to “the single best set” for evidence-based resuscitation guidelines and practices. This belief permeated the international CPR and ECC evidence evaluation conferences held in 2000 and 2005, as well as several international consensus statements. The 2000 Guidelines Conference, the first major assembly under the auspices of ILCOR, adopted a sophisticated process for gathering and assessing evidence; this process evolved further in 2005. With practical insight, conference participants determined how to incorporate different levels of evidence into consensus treatment recommendations, with identification of key gaps in knowledge.

The experience of developing evidence-based guidelines forced a reluctant conclusion on the ILCOR leadership: the goal of a single “best set” of international CPR and ECC guidelines was not yet achievable. It was recognized that universal science consensus was achievable but that localization of the treatment recommendations using regional guidelines and training tools is necessary. Undoubtedly international cooperation has enabled a more thorough collection and analysis of the evidence. Nevertheless, review and debate of that evidence has not always led to standard training and practice. Some obstacles were encountered in the pursuit of universal guidelines.

1. The available evidence may present an inconsistent, contradictory, or less definitive picture that fails to support universal guidelines. CPR ventilation is one example of this obstacle: fine-tuning the details of ventilation consumed considerable time and energy at the 2000 Guidelines Conference. The experts debated numerous ventilation variables, such as rate, inspiratory pressure, inspiratory duration, inspiratory/expiratory ratios, and optimal airway devices for field and hospital and lay rescuers and professionals. At the 2005 Consensus Conference many of these same resuscitation experts argued that compression-only CPR may be more effective and that perhaps ventilations should be eliminated completely from initial resuscitation actions.

2. For many questions, high-level evidence, preferably in the form of randomized controlled clinical trials, is simply not available and probably never will be, preventing the identification of definitive answers to many questions. For example, what is the best way to train lay rescuers so that they will make a vital intervention, undertake it properly and effectively, and retain the skill for years?

ILCOR and international collaboration has continued to mature. In retrospect, the goal of a single set of universal guidelines is idealistic and premature. Many problems in resuscitation require local modifications and solutions. The common goals of the resuscitation community are more important: reducing rates of morbidity and mortality from cardiovascular disease and stroke. The treatment recommendations in this publication are based on the best science known, and they have been achieved by effective international collaboration. Exponential improvements in communication technology are making international collaborative research and topic review a reality, and when indicated, will enable urgent revisions to current guidelines. We look forward to this continual review and update of the science and the year 2010, when another international collaborative conference will be convened.

Our problems in resuscitation are similar the world over, but none of us has a monopoly of wisdom, knowledge, or experience. We must therefore continue to work effectively together for the good of all.

—Douglas Chamberlain

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The Evidence Evaluation Process for the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations

Arno Zaritsky, MD; Peter T. Morley, MD

“In God we trust. All others must bring data.”
—Robert Hayden, Plymouth State College

Evidence-based medicine is described as “the conscientious, explicit and judicious use of current best evidence in making decisions about individual patients.”1 The evidence evaluation process summarized in this supplement was designed to ensure the review of all available evidence pertaining to resuscitation. Many aspects of the resuscitation process create unique challenges for the design of experimental protocols and data analysis and have not been evaluated by randomized controlled human studies. Exclusion of studies other than controlled human studies would eliminate a wealth of information that could help guide resuscitation management; for this reason, lower levels of evidence, including nonhuman studies, were included in the review.

To begin the review process, international experts (worksheet reviewers) were assigned questions to evaluate. The questions were selected from a survey of each of the International Liaison Committee on Resuscitation (ILCOR) specialty task forces (eg, basic life support, advanced life support, pediatrics) and from the ILCOR member resuscitation councils and their training networks. The evaluation of each question was completed on a structured evidence evaluation worksheet developed for the 2005 Consensus Conference. Because many of the worksheet reviewers had never conducted a structured evidence-based review, instructional sessions were held at the twice-yearly ILCOR meetings and an instructional CD-ROM was created, demonstrating how to conduct an efficient search for evidence, complete the worksheet, and use citation management software. Two worksheet experts (Arno Zaritsky and Peter Morley) were appointed to provide further quality assurance; they reviewed all submitted worksheets. Comments, emendations, and queries were provided to the worksheet reviewers in an iterative process until the worksheets were deemed complete by the worksheet experts.

The worksheets completed for the 2005 Consensus Conference are linked from the electronic version of this document as online data supplements. Most superscript worksheet numbers are located adjacent to headings and begin with the letter W to distinguish them from other reference citations. Readers of the electronic version of this supplement can access a cited worksheet by clicking on the linked worksheet callout. This will link the reader to the Worksheets Cited list at the end of each section. This list contains active links to the individual worksheets cited. Readers of the printed publication can identify the complete title and author of a cited worksheet by referring to the numbered worksheet list at the end of this supplement (See Appendix 1) and then accessing that worksheet on the conference website at www.C2005.org. In the discussion below, a blank worksheet is cited and can be accessed for reference.

Steps for Evidence Evaluation

The following steps correspond with the major steps listed in the evidence evaluation worksheets.

Step 1. State the Proposal (1A) and Gather and Select the Evidence (1B)2

All reviewers were instructed to search their allocated questions broadly. Reviewers documented their search strategies to ensure reproducibility of the search. The minimum electronic databases to be searched included the Cochrane database for systematic reviews and the Central Register of Controlled Trials [http://www.cochrane.org/], MEDLINE [http://www.ncbi.nlm.nih.gov/PubMed/], EMBASE (www.embase.com), and the master reference library collated by the American Heart Association (AHA). To identify the largest possible number of relevant articles, reviewers were also encouraged to perform hand searches of journals, review articles, and books as appropriate.

The reviewers documented the mechanism by which studies relevant to the hypothesis were selected. Specific study inclusion and exclusion criteria and study limitations were documented. Inclusion of all relevant evidence (from animal and manikin/model studies as well as human studies) was encouraged.

DOI: 10.1161/CIRCULATIONAHA.105.170812
Step 2. Assess the Quality of Evidence

In this step reviewers were asked to determine the level of evidence of relevant studies (Step 2A), assess the quality of study research design and methods (Step 2B), determine the direction of results (Step 2C), and cross-tabulate assessed studies (Step 2D).

The levels of evidence used for the 2005 consensus process (see Part 1 of this supplement) were modified from those used in 2000. In many situations summary conclusions were based on lower levels of evidence because human clinical trial data was not available.

The reviewers assessed the quality of research design and methods and allocated each study to 1 of 5 categories: excellent, good, fair, poor, or unsatisfactory. Studies graded as poor or unsatisfactory were excluded from further analysis.

Reviewers evaluated the direction of the study results as supportive, neutral, or opposed and then depicted the data in 1 of 2 grids. The grids were 2-dimensional, showing quality and levels of evidence. The reviewers completed a Supporting Evidence grid and a Neutral or Opposing Level of Evidence grid.

Step 3. Recommendation for Class of Recommendation

The 2005 AHA Guidelines for CPR and ECC use a class of recommendation system to indicate the overall strength of recommendations. These classes of recommendation were not used in the ILCOR 2005 CPR Consensus document contained in this supplement.

In this step reviewers were invited to offer an opinion on the overall strength of a specific treatment recommendation for the AHA or other council-specific guidelines. Statements contained in this section of the worksheet reflect the reviewer’s opinion and may or may not be consistent with consensus conclusions from the 2005 Consensus Conference or the final recommendations in the 2005 AHA Guidelines for CPR and ECC or guidelines from other resuscitation councils.

Step 4. Reviewer’s Perspective and Potential Conflict of Interest

All reviewers completed a conflict-of-interest disclosure form and also listed potential conflicts of interest on the worksheets. This ensured transparency of the review process. More details of the conflict-of-interest disclosure process are described in another editorial in this supplement.

Step 5. Summary of the Science

Worksheet reviewers created a summary of the science. In the summary format reviewers were encouraged to provide a detailed discussion of the evidence, including the outcomes evaluated and the strengths and limitations of the data.

The final step in the science summary process was the creation of draft consensus on science statements and treatment recommendations. Statement templates were provided to standardize the comprehensive summary of information. Elements of the consensus on science statement template included the specific intervention or assessment tool, number of studies, levels of evidence, clinical outcome, population studied, and the study setting. Elements of the treatment recommendation template included specific intervention or assessment tool, population and setting, and strength of recommendation.

The statements drafted by the reviewers in the worksheets reflect the recommendations of the reviewers and may or may not be consistent with the conclusions of the 2005 Consensus Conference.

Step 6. References

Worksheet reviewers were asked to provide a database file containing the references that were used. The submitted references were added to the master reference library collated by the AHA.

Step 7. Posting on the Internet

Completed worksheets were posted on the Internet for further review. The initial process involved posting the worksheet to a password-protected area of the AHA Intranet (accessible to worksheet reviewers). In December 2004 the completed worksheets were posted on an Internet site that could be accessed by the public for further review and feedback before the 2005 Consensus Conference in Dallas (www.C2005.org).

Controversies Encountered

Studies on Related Topics (LOE 7)

Many reviewers identified studies that answered related questions but did not specifically address the reviewer’s initial hypothesis. Examples include the extrapolation of adult data for pediatric worksheets and extrapolation of the results of glucose control in critically ill patients to the postresuscitation setting. Worksheet reviewers were instructed to clearly designate evidence that represented extrapolations. Reviewers could designate such studies as LOE 7, or they could assign a level of evidence based on the study design but include terms such as “extrapolated from” with specific relevant details in the draft consensus on science statements to indicate clearly that these were extrapolations from data collected for other purposes.

Animal Studies and Mechanical Models

Animal studies can be performed under highly controlled experimental conditions using extremely sophisticated methodology. Irrespective of methodology, all animal studies and all studies involving mechanical models (eg, manikin studies) were classified as LOE 6. Specific details about these studies (including methodology) are included in the summary of science where appropriate.

Studies Evaluating Diagnosis or Prognosis

The default levels of evidence used for the 2005 consensus process were not designed for the review of studies that evaluate diagnosis or prognosis. For these studies other methods of assigning levels of evidence were considered (such as those proposed by the Oxford Centre for Evidence-Based Medicine [http://www.cebm.net/]). Worksheet reviewers planning to include alternative levels of evidence were asked to define such levels clearly and to retain the default levels of evidence.
Summary
The 2005 consensus process provided a large number of detailed literature reviews published on the Internet and summarized in this supplement. This review suggests that the evidence evaluation process for resuscitation literature will continue to evolve, providing a comprehensive process for collating data, summarizing the science, and facilitating its translation into treatment recommendations.

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Worksheet Cited
W277. http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.105.170522/DC450
Conflict of Interest Management Before, During, and After the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations

John E. Billi, MD; David A. Zideman, MD; Brian Eigel, PhD; Jerry P. Nolan, MD; William H. Montgomery, MD; Vinay M. Nadkarni, MD; from the International Liaison Committee on Resuscitation and the American Heart Association

To preserve the public trust and integrity of the International Liaison Committee on Resuscitation (ILCOR) evidence evaluation process, in 2004 ILCOR established a conflict of interest (COI) policy1,E1 to manage any real or potential conflicts of interest in an open and effective manner. Readers of the electronic version of this supplement can access the online documents by clicking on the E# callout, which will take them to the hyperlink in the Online Documents Cited list at the end of this editorial. Readers of the print version can access the documents at the URLs listed or by clicking the links found at http://www.C2005.org. This editorial explains the ILCOR and American Heart Association (AHA) COI policies and their application throughout the 2005 evidence evaluation process. ILCOR and the AHA also welcome readers’ questions and feedback on this process.

The value of the ILCOR evidence evaluation process depends on rigorous expert review of published science. Therefore, it is essential that any potential professional conflict of interest be fully disclosed and managed effectively during the planning and conduct of the evidence evaluation process, especially when issues arise. Because many of the world’s most qualified scientific experts may have professional relationships that could pose a real or perceived conflict of interest, it is not always possible to avoid all involvement by such persons. It is necessary, however, to limit and manage their involvement in areas of potential conflict, especially to minimize their influence over consensus statements or recommendations in such areas. ILCOR COI procedures applied to all ILCOR delegates, 2005 Consensus Conference participants, observers, worksheet experts, worksheet authors, editors of the ILCOR 2005 CPR Consensus document (published in this supplement), and all others working on ILCOR projects.

As host of the 2005 Consensus Conference, the AHA also required every participant to complete an AHA COI disclosure questionnaire and to comply with all AHA COI policies. The purpose of the AHA COI policies and procedures2,E2 is to protect the integrity of the AHA’s decision-making processes and the 2005 AHA Guidelines for CPR and ECC, as well as to protect the public’s trust in the AHA and AHA volunteers and staff.

Summary of COI Procedures

Each participant in the 2005 evidence evaluation process completed and submitted both an ILCOR and an AHA COI disclosure form before attending the 2005 Consensus Conference.E3 Late registrants were required to complete the COI disclosure forms when they registered on-site. AHA staff reviewed the forms and ensured that completed versions of both forms were submitted by each conference participant and worksheet author. ILCOR task force cochairs (eg, cochairs of the Basic Life Support, Advanced Life Support, and Pediatric Resuscitation Task Forces) reviewed the forms for potential conflicts of interest. COI-related questions or concerns were submitted to the ILCOR COI cochairs (John Billi and David Zideman) for resolution. Corrective actions included reassigning topics or moderator roles to persons without a significant conflict of interest or limiting persons with a significant conflict of interest to the role of reviewer of the evidence. In the latter instance, panelists with no conflict of interest made any final judgments based on the evidence and drafted any consensus statements or summaries. The AHA and ILCOR have retained all disclosure forms together with written records of actions taken.

Each evidence evaluation worksheet (see the editorial on evidence evaluation in this supplement) included a section for the author to disclose potential conflicts of interest. Worksheets without a completed COI section were not accepted. The COI information submitted for each worksheet was cross-referenced for accuracy and consistency with the COI information on file with the AHA and ILCOR.

At the start of the 2005 Consensus Conference each participant was given a printed COI disclosure booklet listing each

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From the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations, hosted by the American Heart Association in Dallas, Tex, January 23–30, 2005.

This article has been copublished in Circulation. (Circulation. 2005;112:III-131-III-132.)
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This special supplement to Circulation is freely available at http://www.circulationaha.org

DOI: 10.1161/CIRCULATIONAHA.105.170813
attendee’s name and institution and the basic details of any declared professional relationship that could pose a potential conflict of interest (see COI listing at http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.105.166471/DC1). Each participant was assigned a participant number. COI information for each participant was listed numerically in the COI booklet, which was updated daily with additional COI disclosure information from late registrants.

Throughout the 2005 Consensus Conference, continuous COI disclosure for all speakers (scheduled or unscheduled) was provided without interruption or delay in the proceedings. Every speaker, whether moderator, presenter, panelist, or someone making comments from the floor, was required to state his or her name and participant number. A slide listing the speaker’s institution and COI disclosure information was projected on a designated screen for the duration of the speaker’s comments. This provided conference participants with immediate and continuous information on any relationships the speaker had that could pose a COI issue. Participant numbers enabled participants to immediately crosscheck disclosures in the conference COI disclosure booklet. Late registrants were required to make verbal disclosures until their information could be posted on a slide.

All moderated sessions, questions from the audience, comments, and statements were audiorecorded for future reference. All speakers stated their participant numbers each time they spoke, making the task of identifying recorded speakers easier and assessment of the impact of potential conflicts of interest possible.

A COI monitor was assigned to each session to ensure that policies were followed and to record any irregularities. The monitors’ reports were reviewed and retained as part of the AHA COI documentation file. Conference participants were repeatedly reminded to raise COI issues with COI monitors, moderators, or cochairs. Participants were also given the number of a confidential COI telephone “hotline” to enable them to report issues anonymously if they did not wish to make their comments in person. The methods through which participants could raise potential COI issues were displayed on the screens in the plenary sessions several times each day.

During the conference any new COI problems or questions that could not be resolved by the session moderators were referred to the ILCOR COI cochairs for rapid resolution. If an issue was deemed sufficiently challenging, it was referred to the Ad Hoc COI Committee (see results, below). The Ad Hoc COI Committee was composed of the 2005 Consensus Conference coordinator (William Montgomery), conference cochairs (Vinay Nadkarni and Jerry Nolan), and COI cochairs (John Billi and David Zideman). Moderators were instructed to stop discussion immediately if they believed that the session should not continue until a specific COI issue was resolved and to go on to the next presentation to enable the COI cochairs time to resolve the issue. After resolution the panel was permitted to resume the earlier presentation and discussion.

Results of COI Policy Implementation

All 380 participants in the 2005 Consensus Conference completed COI disclosure forms, most before the conference. Staff added information from late registrants to daily updates of the COI disclosure booklet and slides. Although a few reminders were needed on the first day of the conference, all conference participants quickly adopted the habit of giving their name and participant number whenever they spoke.

COI cochairs investigated and recommended resolution for 8 concerns before the conference and 12 concerns during the conference. One COI issue required that the Ad Hoc COI Committee convene. On another occasion a discussion was stopped when a floor debate appeared centered on a detail of interest to device manufacturers and the debaters had potential or perceived links with the manufacturers as disclosed on the COI slides. In this instance the COI monitor and session moderators conferred, then asked all participants to send any further written comments to the Task Force for consideration. The comments included the authors’ participant numbers so that their COI disclosures could be considered when their input was weighed. Throughout the poster sessions a COI policy/rationale poster was displayed and attended by one of the COI cochairs. This stimulated much discussion, raising awareness of the importance of good COI management.

No anonymous calls were received on the COI hotline. Twelve participants voluntarily revised their COI disclosure forms once they observed the comprehensive level of disclosure of their peers or were reminded of relationships that might pose a potential conflict. In two instances one participant was aware of a potentially conflicting, undisclosed relationship of another participant. In both instances a COI cochair investigated the issue, and the disclosure forms, booklet, and slides were updated.

A participant survey conducted after the 2005 Consensus Conference indicated almost uniform support for the COI disclosure method. The common responses were “very effective” and “nonintrusive.” A few participants indicated that the disclosure was too continuous, but several others thought it did not go far enough. Ninety percent of the 120 respondents “strongly agreed” or “agreed” that speakers’ relationships with commercial entities were clearly disclosed during the 2005 Consensus Conference. One unintended benefit of the simultaneous projection of the COI slide was that the audience always knew who was speaking, something that can be difficult to discern in a large meeting with floor microphones.

Readers are welcome to provide feedback on any aspect of the ILCOR or AHA COI policies and implementation. Please contact any of the authors at www.C2005.org.

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E3. http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.105.170813/DC3
Controversial Topics From the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations

Mary Fran Hazinski, RN, MSN; Jerry P. Nolan, MD; Lance B. Becker, MD; Petter A. Steen, MD

Cardiopulmonary resuscitation (CPR) and emergency cardiovascular care (ECC) constitute a relatively young field of medicine concerned literally with issues of life and death. The scientific evidence is scant and opinions are strong. It is difficult to perform clinical intervention studies with sufficient power, and this has been compounded by the severe restrictions on research created by consent legislation in North America and Europe. There is very little high-level evidence for resuscitation therapies, and many traditional treatment recommendations such as the use of epinephrine/adrenaline, are based on animal studies and reluctance to change an existing treatment recommendation until it is proven ineffective or less effective than a novel therapy.

A rigorous evidence evaluation worksheet process, full disclosure and management of potential conflicts of interest, and focus on science rather than treatment guidelines enabled the 380 international participants at the 2005 Consensus Conference ultimately to achieve consensus constructively and transparently. Participants agreed to focus on the few factors known to have the greatest impact on outcome, specifically recommendations most likely to improve survival rates without adding to the complexity of rescuer training. It was feared that complexity of training could have a negative impact by reducing attention to the most important factors.

There was unanimity about the need for increased emphasis on the quality of CPR, particularly the quality and number of chest compressions provided and the need to minimize interruptions in chest compressions. Participants also considered the need for altering the sequence of actions (ie, compression first or shock delivery first) based on the interval from collapse of the victim to the arrival of rescuers (ie, on the phase of resuscitation).

Selection and Debate of Controversial Topics During the 2005 Consensus Conference

Plenary sessions were scheduled daily for presentation and additional debate on the most controversial issues from the previous day. Controversial topics were identified by panel moderators, conference participants, and the International Liaison Committee on Resuscitation (ILCOR) task force cochairs. During the final day of the conference the entire group of experts focused on the most controversial issue of the conference: selection and sequence of the critical actions needed to treat sudden cardiac arrest (SCA). This session crystallized discussion of controversial topics that had been debated daily and enabled the group to reach consensus on these topics. The topics included the relative merits of a compression-first sequence versus a shock-first sequence for treatment of ventricular fibrillation (VF) SCA, the compression-ventilation ratio, and the concept of a 1-shock strategy (followed by immediate CPR) versus the 3-shock strategy for treatment of VF/pulseless ventricular tachycardia (VT), and other topics (see below).

Summary of Debate and Decision About the Most Controversial Topics

Compression First Versus Shock First for VF SCA

Recent data challenges the standard practice of providing defibrillation first to every victim with VF, particularly when 4 to 5 minutes or longer has elapsed from collapse to rescuer intervention. Only 3 human studies plus a somewhat larger body of animal data were available for experts to consider.

If the emergency medical services (EMS) response interval (interval between call to 911 [EMS] and EMS arrival) for out-of-hospital VF arrest is more than 4 to 5 minutes, a period of CPR before attempted defibrillation may improve outcome. If all of the human evidence had been positive, there would have been no debate. But one randomized study (LOE 2) failed to show any effect of CPR before defibrillation at any collapse-to-response or collapse-to-defibrillation interval. An added factor is the realization that rescuers may not know the interval since collapse of the victim.

Some conference participants proposed a treatment recommendation for rescuers to “perform CPR for 3 minutes (or some specified interval or number of CPR cycles) before the first shock if more than 4 to 5 minutes had elapsed since arrest.” Animal evidence suggests that ventilation is unnecessary for the first few minutes after primary VF cardiac arrest. But ventilation is
important in asphyxial arrest (eg, most arrests in children and many noncardiac arrests, such as drowning and drug overdose). Some conference participants suggested that recommendations provide the option of omitting ventilation for the first few minutes unless the victim is a child or the possibility of asphyxial cardiac arrest exists (eg, drowning). To simplify lay rescuer education, the consensus among conference participants was to strive for a universal sequence of resuscitation by lay rescuers that would be identical for all victims.

Because the improvement in survival rates associated with provision of CPR before defibrillation was observed only in the subset of victims for whom EMS response intervals were 4 to 5 minutes or longer, the consensus was that there was insufficient data to justify recommending CPR before defibrillation for all victims of VF SCA. The experts wanted the treatment recommendations to allow rescuers the option of providing CPR first, particularly for out-of-hospital cardiac arrest in settings where the EMS response interval is >4 to 5 minutes. Therefore, the final decision was that 1 1/2 to 3 minutes of CPR before attempting defibrillation may be considered for treatment of out-of-hospital VF or pulseless VT when the EMS response interval is typically >4 to 5 minutes.

There was insufficient data to determine (1) whether this recommendation should be applied to in-hospital cardiac arrest, (2) the ideal duration of CPR before attempted defibrillation, or (3) the duration of VF at which rescuers should switch from defibrillation first to CPR first.

**Compression-Ventilation Ratio**

The compression-ventilation ratio was one of the most controversial topics of the conference. The experts began the conference acknowledging that rates of survival to hospital discharge from witnessed out-of-hospital VF SCA are low, averaging ≤6% internationally (LOE 5), and that survival rates have not increased substantially in recent years. The North American Public Access Defibrillation trial showed that lay rescuer AED programs produced higher survival than lay rescuer CPR programs without AEDs and that organized lay rescuer AED and CPR programs improved survival for witnessed VF SCA over the international average of 6%. High (49% to 74%) survival rates for out-of-hospital witnessed VF SCA have been reported in some lay rescuer programs using CPR plus automated external defibrillation (AED) in casinos (LOE 5), airports (LOE 5), and commercial passenger planes (LOE 5) and in some first responder AED programs (LOE 2A; LOE 3; and LOE 5). Typically the higher rates were associated with provision of both early CPR and early (within 3 to 5 minutes of collapse) defibrillation.

No human data has identified an optimal compression-ventilation ratio for CPR in victims of any age. Compelling animal data indicates that frequent and prolonged interruption of chest compressions is deleterious. Recent clinical data showed frequent periods without chest compressions even for advanced CPR providers in both out-of-hospital and in-hospital settings, and laypersons require intervals of 14 to 16 seconds (during which chest compressions are interrupted) to give 2 rescue breaths.

In animal models better results were achieved with a compression-ventilation ratio higher than 15:2. In animals with sudden VF cardiac arrest and open airways, good results were achieved with continuous compressions without any ventilatory support. One study of dispatcher-assisted CPR with apparent cardiac arrest and short (4-minute) EMS call-to-ambulance response intervals had good results with chest compressions only. However, it is difficult to determine the relevance of these studies to victims of out-of-hospital arrest with no patent airway, victims of asphyxial arrest, and victims in areas where EMS response intervals are longer than 4 minutes.

There was substantial evidence that the current practice of CPR provides too much ventilation to victims of cardiac arrest. Participants agreed that fewer ventilations are needed during CPR than previously recommended. One observational study showed that experienced paramedics provided ventilations at excessive rates to intubated patients during treatment for out-of-hospital cardiac arrest and that these excessive rates of ventilation persisted despite intensive retraining (LOE 5). An in-hospital study also showed delivery of ventilation at excessive rates during CPR to patients with and without an advanced airway in place. Although no human outcome studies were identified, 2 animal studies showed that hyperventilation is associated with excessive intrathoracic pressure, decreased coronary and cerebral perfusion pressures, and decreased rates of survival.

The obvious challenge was how to translate the need to increase chest compressions into recommendations that would be simple and appropriate for both asphyxial and VF cardiac arrest. There was agreement that continuous chest compressions could be appropriate in the first minutes of VF arrest, but ventilations would be more important for asphyxial arrest and all forms of prolonged arrest. There was also agreement that it would be too complicated to teach lay rescuers different sequences of CPR for different circumstances. For simplicity, a universal compression-ventilation ratio of 30:2 for lone rescuers of victims from infancy (excluding neonates) through adulthood was agreed on by consensus based on integration of the best human, animal, manikin, and theoretical models available. For 2-rescuer CPR in children, a compression-ventilation ratio of 15:2 was recommended.

Oxygenation and ventilation are crucial for the newborn infant, and a few newborn infants require chest compressions. No new data was discussed to support a higher compression-ventilation ratio in newborns. For this reason the 3:1 compression-ventilation ratio was retained for newborns.

**1- Versus 3-Shock Sequence for Attempted Defibrillation**

The ECC Guidelines 2000 recommended the use of a stacked sequence of up to 3 shocks without interposed chest compressions if VF/VT persists after the first or second shock. The 2005 Consensus Conference participants challenged this strategy, partly because the 3 shocks require prolonged interruption of compressions that is likely to be needless in the face of relatively high first-shock efficacy.
will need to determine the role of vasopressin in their

38 In 2 studies therapeutic hypothermia improved neurologic outcome among initially comatose survivors from out-of-hospital VF cardiac arrest, but the role of

References


### Appendix 1: Worksheet Topics and Authors

Note: Worksheet topics without authors’ names were reviewed but not completed.

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<td>Impedance threshold valve in pediatric CPR</td>
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<td>15:2 vs. 5:1 compression:ventilation ratio</td>
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<td>The age-based sequence (“phone fast” for infants and children, “phone first” for children &gt;8 years old and adults) was retained (Class Indeterminate).</td>
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<td>Lay rescuers are instructed to assess for signs of circulation rather than attempt to check a pulse (Class IIa).</td>
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(Circulation. 2005;112:B1-B14.)

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DOI: 10.1161/CIRCULATIONAHA.105.170522
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<td>When should we commence ventilation during cardiac arrest?</td>
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<td>Does chest compression before defibrillation improve outcome?</td>
<td>Raul J. Gazmuri, MD, PhD</td>
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<td>Edison Ferreira de Paiva, MD</td>
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<td>Does the use of up to 3 shocks for subsequent shocks improve outcome compared with single shock?</td>
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<td>Does the presence of supplementary oxygen in the immediate vicinity increase the risks of fire during defibrillation?</td>
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<td>Does High-Frequency CPR improve outcome from cardiac arrest when compared with standard CPR?</td>
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<td>Does ACD-CPR improve outcome from cardiac arrest when compared with standard CPR?</td>
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<td>Does Phased Thoracic-Abdominal Compression-Decompression CPR improve outcome from cardiac arrest when compared with standard CPR?</td>
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<td>Does Open Chest CPR improve outcome from cardiac arrest when compared with standard CPR?</td>
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<td>82.</td>
<td>Do extracorporeal techniques or invasive perfusion devices improve outcome from cardiac arrest when compared with standard CPR?</td>
<td>Octavio A. Falcucci, MD</td>
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<td>116.</td>
<td>Does the use of <strong>thrombolytics</strong> in the management of the patient following cardiac arrest improve outcome?</td>
<td>Bernd W. Böttiger, MD</td>
<td>W116_Boettiger.doc</td>
</tr>
<tr>
<td>117.</td>
<td>Does the use of <strong>anticoagulation</strong> in the management of the patient after a cardiac arrest improve outcome?</td>
<td>Steven Kronick, MD, MS</td>
<td>W118A_Kronick.doc</td>
</tr>
<tr>
<td>118.</td>
<td>Does the use of <strong>prophylactic antiarrhythmics</strong> in the management of the patient after a cardiac arrest improve outcome?</td>
<td>Nabil El Sanadi, MD, MBA</td>
<td>W118B_El Sanadi.doc</td>
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<td>119.</td>
<td>Can the rescuer identify the etiology of the cardiac arrest during the cardiac arrest (eg, asphyxia-induced cardiac arrest, drug/toxin-induced VT/VF [cocaine], drug-induced PEA, hypothermia, drowning, trauma, electrolytes, anaphylaxis, asthma, pulmonary)?</td>
<td>Arlo Weltge, MD, MPH</td>
<td>W119A_Weltge.doc</td>
</tr>
<tr>
<td>120.</td>
<td>Does the identification of the etiology during the cardiac arrest allow tailored cardiac arrest management (BLS/ALS)?</td>
<td>Arlo Weltge, MD, MPH</td>
<td>W120_Weltge.doc</td>
</tr>
<tr>
<td>121.</td>
<td>Does the identification of the etiology and tailored cardiac arrest management during the cardiac arrest improve outcome?</td>
<td>Arlo Weltge, MD, MPH</td>
<td>W121_Weltge.doc</td>
</tr>
<tr>
<td>122.</td>
<td>Can neurological examination, eg, pupil dilation, allow the rescuer to predict the likely outcome of the cardiac arrest during the cardiac arrest?</td>
<td>Steven Kronick, MD, MS</td>
<td>W122A_Kronick.doc</td>
</tr>
<tr>
<td>123.</td>
<td>Can any stat laboratory analyses or other investigations allow the rescuer to predict the likely outcome of the cardiac arrest during the cardiac arrest?</td>
<td>Octavio A. Falcucci, MD</td>
<td>W124A_Falcucci.doc</td>
</tr>
<tr>
<td>124.</td>
<td>Can the use of somatosensory evoked potentials allow the rescuer to predict the likely outcome of the cardiac arrest after the cardiac arrest?</td>
<td>Douglas Franzen</td>
<td>W126_Franzen_Christiansen.doc</td>
</tr>
<tr>
<td>125.</td>
<td>Can the use of EEG allow the rescuer to predict the likely outcome of the cardiac arrest after the cardiac arrest?</td>
<td>Douglas Franzen</td>
<td>W126_Franzen_Christiansen.doc</td>
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<td>126.</td>
<td>Can the use of serum analyses allow the rescuer to predict the likely outcome of the cardiac arrest after the cardiac arrest?</td>
<td>Douglas Franzen</td>
<td>W126_Franzen_Christiansen.doc</td>
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<td>127.</td>
<td>Can the use of CSF analyses allow the rescuer to predict the likely outcome of the cardiac arrest after the cardiac arrest?</td>
<td>Douglas Franzen</td>
<td>W126_Franzen_Christiansen.doc</td>
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<tr>
<td>128.</td>
<td>Can the use of early warning scoring systems reduce the number of in-hospital cardiac arrests?</td>
<td>Mary Ann Peberdy, MD</td>
<td>W128A_Peberdy.doc</td>
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<td>129.</td>
<td>Does the use of a Medical Emergency Team reduce the number of in-hospital cardiac arrests?</td>
<td>Mary Ann Peberdy, MD</td>
<td>W129A_Peberdy.doc</td>
</tr>
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<td>130.</td>
<td>Does the use of a Medical Emergency Team improve outcome from in-hospital cardiac arrest?</td>
<td>Mary Ann Peberdy, MD</td>
<td>W130A_Peberdy.doc</td>
</tr>
<tr>
<td>131.</td>
<td>What modifications are applicable to resuscitation technique for: Hypothermia?</td>
<td>Arlo Weltge, MD, MPH</td>
<td>W131_Weltge.doc</td>
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<td>132.</td>
<td>What modifications are applicable to resuscitation technique for: Drowning?</td>
<td>Arlo Weltge, MD, MPH</td>
<td>W132_Weltge.doc</td>
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<td>133.</td>
<td>What modifications are applicable to resuscitation technique for: Asthma?</td>
<td>Jasmeet Soar, MD</td>
<td>W133_Soar.doc</td>
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<td>134.</td>
<td>What modifications are applicable to resuscitation technique for: Pregnancy?</td>
<td>Jasmeet Soar, MD</td>
<td>W134_Soar.doc</td>
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<td>135.</td>
<td>What modifications are applicable to resuscitation technique for: Electrocuton?</td>
<td>Nabil El Sanadi, MD, MBA</td>
<td>W135_El Sanadi.doc</td>
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<tr>
<td>136.</td>
<td>What modifications are applicable to resuscitation technique for: Anaphylaxis?</td>
<td>Nabil El Sanadi, MD, MBA</td>
<td>W135_El Sanadi.doc</td>
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<td>Topic No.</td>
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<td>137.</td>
<td>What is the incidence, prevalence, and etiology of cardiopulmonary</td>
<td>Tom Rea</td>
<td>W137_Rea.doc</td>
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<td></td>
<td>arrest?</td>
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<td></td>
<td>What are the independent predictors of outcomes after CPA?</td>
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<td>139.</td>
<td>What interventions are feasible, safe, and effective in individuals</td>
<td>N. Clay Mann, PhD, MS</td>
<td>Jennifer Dennett</td>
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<td></td>
<td>at risk of impending CPA (ie, within 24 h)?</td>
<td>W139A_Mann.doc, W139B_Mann.doc</td>
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<td>140.</td>
<td>What are adverse effects for the patient who receives cardiopulmonary</td>
<td>Graham Nichol, MD</td>
<td>W140A_Nichol.doc</td>
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<td></td>
<td>resuscitation?</td>
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<td>141.</td>
<td>What are the adverse effects for the responder who performs</td>
<td>Graham Nichol, MD</td>
<td>W141A_Nichol.doc, W141B_Nichol.doc</td>
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<td></td>
<td>cardiopulmonary resuscitation (including infection control)?</td>
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<td>142.</td>
<td>What is the sensitivity, specificity, and clinical impact of signs</td>
<td>Wanchun Tang, MD</td>
<td>Ian Jacobs, RN, PhD</td>
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<td></td>
<td>of need for resuscitation, including agonal respirations, shaking,</td>
<td>W142A_Tang.doc, W142B_Jacobs.doc</td>
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<td></td>
<td>and signs of circulation?</td>
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<td>143.</td>
<td>What is the sensitivity, specificity, and clinical signs of need</td>
<td>Mike Jacobs, EMT-P</td>
<td>Jeff Wassertheil, MD</td>
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<td></td>
<td>for resuscitation in facedown victim? in suspected neck injury?</td>
<td>W143A_Jacobs.doc, W143B_Wassertheil.doc</td>
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<td>144.</td>
<td>(For above, consider any differences in S, E, and F according to</td>
<td>Lei Huang</td>
<td>Tony Walker</td>
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<td></td>
<td>age of victim and availability of responders.)</td>
<td>W146A_Huang_Tang.doc</td>
<td>W146B_Walker.doc</td>
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<td>145.</td>
<td>(For above, consider etiology, eg, trauma, drowning, intubation,</td>
<td>Ting Yu, MD</td>
<td>Jeff Wassertheil, MD</td>
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<td></td>
<td>arrhythmia, respiratory arrest.)</td>
<td>W147A_Yu_Tang.doc, W147B_Wassertheil.doc</td>
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<td>146.</td>
<td>What is the feasibility, safety, and effectiveness of</td>
<td>Wanchun Tang, MD</td>
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<td></td>
<td>repositioning a victim?</td>
<td>W146A_Huang_Tang.doc</td>
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<td>147.</td>
<td>What is the sensitivity, specificity, and clinical impact of</td>
<td>Ting Yu, MD</td>
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<td></td>
<td>interruption of CPR to check circulation?</td>
<td>W147A_Yu_Tang.doc, W147B_Wassertheil.doc</td>
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<td>148.</td>
<td>What is the safety, effectiveness, and feasibility of improving</td>
<td>Lynn J. White, MS</td>
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<td></td>
<td>response time?</td>
<td>W148A_White.doc</td>
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<td>149.</td>
<td>Which methods for opening the airway are feasible, safe, and</td>
<td>Gavin Perkins, MD</td>
<td>W149_Perkins.doc</td>
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<td></td>
<td>effective?</td>
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<td>150.</td>
<td>What interventions are safe, effective, and feasible when</td>
<td>Edward Crosby, MD</td>
<td>Gavin Perkins, MD</td>
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<td></td>
<td>performing CPR in victims with suspected cervical spine injury?</td>
<td>W150A_Crosby.doc, W150B_Perkins.doc</td>
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<td></td>
<td>For above, consider over the head position for CPR? body position</td>
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<td>of victim? body positions of responder?</td>
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<td>151.</td>
<td>Are methods for removal of FBAO feasible, safe, and effective?</td>
<td>Thomas A. Barnes, EdD, RRT</td>
<td>Gavin Perkins, MD</td>
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<td>- For above, consider chest compression/finger sweep or</td>
<td>W151A_Barnes.doc, W151B_Perkins.doc</td>
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<td></td>
<td>alternatives</td>
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<td>- For above, consider Heimlich, chest thrust?</td>
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<td>- Consider responsive and unresponsive victim?</td>
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<td>- Consider obese, pregnant?</td>
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<td>152.</td>
<td>Are mechanical ventilators used by basic-trained rescuers (first</td>
<td>Thomas A. Barnes, EdD, RRT</td>
<td>Richard Branson</td>
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<td></td>
<td>responders) and professional healthcare providers safe and effective</td>
<td>W152A_Barnes_Branson.doc</td>
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<td>for ventilating unintubated adult patients during cardiac arrest?</td>
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<td>153.</td>
<td>Are devices/adjuncts for airway positioning and ventilation</td>
<td>Andrea Gabrielli, MD</td>
<td>Peter Fenici, MD</td>
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<td></td>
<td>feasible, safe, and effective?</td>
<td>W154_Gabrielli_Fenici.doc</td>
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<td>154.</td>
<td>Which compression-ventilation ratio is feasible, safe, and effective</td>
<td>Andrea Gabrielli, MD</td>
<td>Peter Fenici, MD</td>
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<td></td>
<td>for which etiology, condition, and age group?</td>
<td>W154_Gabrielli_Fenici.doc</td>
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<td>155.</td>
<td>What recovery positions are feasible, safe, and effective?</td>
<td>Anthony J. Handley, MD</td>
<td>E. Brooke Lerner, PhD</td>
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<td>W155_Handley_Lerner.doc</td>
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<td>156</td>
<td>Which tidal volume and ventilation rate are feasible, safe, and effective using MMV/BVM/with or without O₂ for which etiology, condition, and age group?</td>
<td>Andrea Gabrielli, MD</td>
<td>E. Brooke Lerner, PhD</td>
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<tr>
<td>157</td>
<td>Is MNV safe, effective, and feasible compared with MMV?</td>
<td>E. Brooke Lerner, PhD</td>
<td>Benno Wolcke, MD</td>
</tr>
<tr>
<td>158</td>
<td>Which methods of ventilation are feasible, safe, and effective in MSV?</td>
<td>E. Brooke Lerner, PhD</td>
<td>Benno Wolcke, MD</td>
</tr>
<tr>
<td>159</td>
<td>What is the safety, effectiveness, and feasibility of protective devices to protect a rescuer while performing CPR? Including barrier devices.</td>
<td>Andrea Gabrielli, MD</td>
<td>E. Brooke Lerner, PhD</td>
</tr>
<tr>
<td>160</td>
<td>What is the safety, effectiveness, and feasibility of performing CPR on a near-drowning victim in the water? (Consider C-spine injury, VF, call first/call fast.)</td>
<td>Jane G. Wigginton, MD</td>
<td>Ahamed H. Idris, MD</td>
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<td>David Szpilman, MD</td>
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<td>161</td>
<td>What is the safest, most feasible, and effective intervention for removing a near-drowning victim from the water?</td>
<td>Jane G. Wigginton, MD</td>
<td>Ahamed H. Idris, MD</td>
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<td>David Szpilman, MD</td>
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<td>162</td>
<td>What interventions are safe, effective, and feasible for immersion, exposure, or accidental hypothermia? Consider active rewarming.</td>
<td>Benjamin S. Abella, MD, MPhil</td>
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<tr>
<td>164</td>
<td>Is compression-only CPR safe, effective, and feasible? When should ventilation begin?</td>
<td>Vincent N Mosesso, Jr, MD</td>
<td>E. Brooke Lerner, PhD</td>
</tr>
<tr>
<td>165</td>
<td>Is dispatcher-assisted CPR safe, effective, and feasible?</td>
<td>Lynn Roppolo, MD</td>
<td>Ahamed H. Idris, MD</td>
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<tr>
<td>166</td>
<td>Alternative methods of CPR including cough CPR and precordial thump</td>
<td>Ahamed H. Idris, MD</td>
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<td>167</td>
<td>What hand position/depth of chest compression is safe, effective, and feasible?</td>
<td>Andrea Gabrielli, MD</td>
<td>Peter Fenici, MD</td>
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<td>168</td>
<td>What compression-decompression method is safe, effective, and feasible?</td>
<td>Jane G. Wigginton, MD</td>
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<td>169</td>
<td>Are rectilinear first-phase biphasic waveform shocks with escalation to 200 J or nonescalating 150–200 J biphasic shocks safer, more effective, and feasible?</td>
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<td>170</td>
<td>Are rectilinear first-phase biphasic waveform shocks with escalation to 200 J or 200–360 J escalating energy biphasic shocks safer, more effective, and feasible?</td>
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<td>171.</td>
<td>Escalating-energy biphasic waveform shocks delivering energy in the range of 200–360 J are safer, more effective, and more feasible than are non–escalating-energy biphasic waveforms delivering 200 J or less.</td>
<td>Karl B. Kern, MD</td>
<td>Ian G. Stiell, MD</td>
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<td>172.</td>
<td>Biphasic waveforms for use in transthoracic defibrillation of VF cardiac arrest are more efficacious (higher rates of VF termination, ROSC, and survival) as well as safer (fewer adverse effects) than monophasic waveforms.</td>
<td>Karl B. Kern, MD</td>
<td>Colin Robertson, MD</td>
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<td>W172_Kern_Robertson.doc</td>
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<td>173.</td>
<td>What pad position is safe, effective, and feasible for AED use?</td>
<td>Vincent N Mosesso, Jr, MD</td>
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<td>174.</td>
<td>What is the safety, effectiveness, and feasibility of AED programs?</td>
<td>Keith Lurie, MD</td>
<td>Rudolph W. Koster, MD, PhD</td>
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<td>W174_Lurie_Koster.doc</td>
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<td>175.</td>
<td>(For above, consider defibrillation by EMS, first responder, public access, home use, wearable cardioverter-defibrillators.)</td>
<td>Keith Lurie, MD</td>
<td>Rudolph W. Koster, MD, PhD</td>
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<td>W175_Lurie_Koster.doc</td>
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<td>176.</td>
<td>What algorithms should be recommended for AED users? One shock or three?</td>
<td>Vincent N Mosesso, Jr, MD</td>
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<td>177.</td>
<td>Is CPR before defibrillation safe, effective, and feasible?</td>
<td>Vincent N Mosesso, Jr, MD</td>
<td>Edison Ferreira de Paiva, MD</td>
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<td>W177A_Okamoto.doc</td>
<td>Raúl J. Gazmuri, MD, PhD</td>
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<td>W177B_Okamoto.doc</td>
<td>Leo Bossaert, MD, PhD</td>
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<td>W177C_Gazmuri_Mosesso_de Paiva_Bossaert.doc</td>
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<td>178.</td>
<td>What quality assurance is appropriate for AED users? Does the collection of data from the AED affect quality control and education?</td>
<td>Vincent N Mosesso, Jr, MD</td>
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<td>179.</td>
<td>What is the impact of “advanced directives,” “living wills,” and “do-not-resuscitate orders” in directing resuscitative efforts?</td>
<td>Deems Okamoto, MD</td>
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<td>W179C_Schmidt_Iserson.doc</td>
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<td>180.</td>
<td>Should family members be present during resuscitation?</td>
<td>Douglas S. Diekema, MD, MPh</td>
<td>Dominique Biarent</td>
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<td>W180A_Diekema.doc</td>
<td>W180B_Biarent.doc</td>
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<td>181.</td>
<td>Ethical issues in pediatric resuscitation</td>
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<td>182.</td>
<td>What are the outcomes associated with resuscitation after CPA (including health-related quality of life)?</td>
<td>David Rodgers, EdS, NREMT-P</td>
<td>Judith Finn, PhD, RN</td>
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<td>W182A_Rodgers.doc</td>
<td>W182B_Finn.doc</td>
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<td>183.</td>
<td>What is the cost-effectiveness of lay-responder training in CPR?</td>
<td>Peter Cram, MD, MBA</td>
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<td>W183_Cram.doc</td>
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<td>184.</td>
<td>Are people who are trained in CPR willing to perform it? (Chest compression only)</td>
<td>Judy Young, RN, MSN, Lt Col, USAF, Ret (Ret)</td>
<td>Jennifer Dennett</td>
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<td>W184A_Young.doc</td>
<td>W184B_Dennett.doc</td>
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<td>185.</td>
<td>What instructional methods are most effective in BLS skill acquisition and retention at 6 months?</td>
<td>David Rodgers, EdS, NREMT-P</td>
<td>Ana Paula Quilici</td>
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<td>W185A_Rodgers.doc</td>
<td>Marcello Ricardo Paulista</td>
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<td>Markus, PhD</td>
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<td>186.</td>
<td>How frequently are ACLS/BLS retraining/update sessions required in order to maintain skills in (a) laypersons and (b) health professionals?</td>
<td>Jennifer Dennett</td>
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<td>187.</td>
<td>Does the use of audio/visual CPR performance aids during training improve the acquisition of CPR psychomotor skills?</td>
<td>Cheryl Hamel, PhD</td>
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<td>188.</td>
<td>Does a written test score reflect BLS skill competence?</td>
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<td>Jane G. Wigginton, MD W190B_Wigginton.doc</td>
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<td>191.</td>
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<td>Michelle Cretikos, MBBS, MPH W195C_Cretikos.doc</td>
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<td>Myra H. Wyckoff, MD</td>
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<td>220</td>
<td>Intravenous high-dose epinephrine during DR resuscitation</td>
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<td>221</td>
<td>What is the sensitivity, specificity, and clinical impact on signs and symptoms in prehospital and emergency department management of ACS and AMI?</td>
<td>David Lendrum, MD</td>
<td>Andrzej Okreglicki, MD</td>
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<td>What is the sensitivity, specificity, and clinical impact on protein markers in the prehospital and emergency department management of ACS and AMI?</td>
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<td>Brian Steinhart</td>
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<td>What is the sensitivity, specificity, and clinical impact of prehospital and emergency department 12-lead ECG interpretation on the prehospital and emergency department management of ACS AMI?</td>
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<td>What is the safety, efficacy, and feasibility of oxygen vs room air in prehospital and emergency department management of ACS and AMI?</td>
<td>Dave Hostler, PhD, NREMT-P</td>
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<td>What is the safety, efficacy, and feasibility of ASA in prehospital and emergency department ACS and AMI?</td>
<td>Ivy Cheng</td>
<td>Bjug Borgundvaag MD, PhD</td>
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<td>What is the safety, efficacy, and feasibility of heparin UF vs LMW in prehospital and emergency department management of ACS and AMI?</td>
<td>Jane Lukins, MD</td>
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<td>What is the safety, efficacy, and feasibility of fibrinolytics in prehospital and emergency department management of ACS and AMI?</td>
<td>Monica Gope</td>
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<td>What is the safety, efficacy, and feasibility of IIB/IIIA inhibitors in prehospital and emergency department management of ACS and AMI?</td>
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<td>What is the safety, efficacy, and feasibility of prophylactic</td>
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<td>What is the safety, efficacy, and feasibility of PTCA vs fibrinolytics in prehospital and emergency department management of ACS and AMI?</td>
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<td>What is the most appropriate first aid of the burn blister?</td>
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<td>David Markenson, MD</td>
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<td>What is the safety and feasibility of assisting the victim in the administration of the victim’s own self-administered epinephrine (adrenaline) in first aid management of a severe allergic reaction?</td>
<td>Jonathan L. Epstein, MEMS, NREMT-P</td>
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<td>James A. Judge II, CEM, BPA, EMT-P</td>
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<td>Jonathan L. Epstein, MEMS, NREMT-P</td>
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<td>261.</td>
<td>What is the safety, efficacy, and feasibility of compression in the first aid management of an injured extremity joint?</td>
<td>Rita Ann Herrington</td>
<td>Ryan C. Fringer, MD</td>
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<td>262.</td>
<td>What is the safety, efficacy, and feasibility of cooling in the first aid management of an injured extremity joint?</td>
<td>Thomas W. Zoch, MD</td>
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<td>263.</td>
<td>What is the safety, efficacy, and feasibility of psychological first aid (may also need to define psychological first aid)?</td>
<td>James A. Judge II, CEM, BPA, EMT-P</td>
<td>Bill Clendenen, MBA</td>
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<td>James A. Judge II, CEM, BPA, EMT-P</td>
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<td>264.</td>
<td>What is the safety, efficacy, and feasibility of oxygen administration in the first aid management of the dyspneic patient?</td>
<td>Mary Fry Davis, RN</td>
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<td>265.</td>
<td>What is the most appropriate first aid management of the cutaneous abrasion, including safety, efficacy, and feasibility of antibiotic ointment?</td>
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<td>Arthur Cooper, MD, MS</td>
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<td>What is the most appropriate first aid management of the cutaneous abrasion, including safety, efficacy, and feasibility of tap water?</td>
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<td>What are the risk factors for possible spinal injury that can be used by the lay rescuer?</td>
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<td>What is the incidence of spinal injury?</td>
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<td>What is the safety, efficacy, and feasibility of compressive wrapping for coral snake (elapid) envenomation?</td>
<td>Naomi Gauthier, MD</td>
<td>Donald J. Gordon, PhD</td>
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<td>What is the safety, efficacy, and feasibility of incision-mediated wound suctioning for pit viper envenomation?</td>
<td>Stephen H. Thomas, MD, MPH</td>
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<td>272.</td>
<td>What is the best first aid treatment for burns: wet or dry dressings?</td>
<td>Christopher P. Holstege, MD</td>
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<td>What is the safety, efficacy, and feasibility of straightening angulated long bone fractures?</td>
<td>Michael Bosse, MD</td>
<td>Rick Murray, EMT-P</td>
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<td>What is the safety, efficacy, and feasibility of the left lateral recumbent position or the recovery position?</td>
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<td>Is it safe, feasible, and effective to place the avulsed tooth in milk until definitive therapy can be provided?</td>
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Appendix 2: Previous “Giants” Honorees

The American Heart Association began the tradition of honoring “giants” in resuscitation science at the 1985 conference establishing new resuscitation guidelines. ILCOR joined this tradition in 2000. “Giants” honorees are selected based on ongoing landmark contributions to cardiopulmonary resuscitation and emergency cardiovascular care in general; authorship of books, articles, and education and teaching materials in the field of emergency cardiovascular care; national and international recognition for their contributions to the field; and development of innovative technological and scientific breakthroughs. The 2005 Honorees are listed in the front of this supplement. Past honorees are listed here:

1985
James Elam, MD
Archer Gordon, MD
James Jude, MD
Guy Knickerbocker, PhD
Peter Safar, MD

1992
Stephen Carveth, MD
Leonard Cobb, MD
Frank Pantridge, MD
Joseph Redding, MD
Paul Zoll, MD

2000
Douglas Chamberlain, MD
Leon Chameides, MD
Mickey Eisenberg, MD, PhD
Gordon Ewy, MD
Laerdal Foundation represented by Tore Laerdal
Richard Kerber, MD
William Montgomery, MD
Joseph Ornato, MD
Leonard Scherlis, MD
Max Harry Weil, MD, PhD

(Circulation. 2005;112:B15.)
This special supplement to Circulation is freely available at http://www.circulationaha.org  DOI: 10.1161/CIRCULATIONAHA.105.171078 B15
### Appendix 3: Conflict of Interest for Editors, Editorial Board, Special Contributors and Reviewers, and Honorees

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<td>Vanderbilt Children’s Hospital</td>
<td>Served as uncompensated principle investigator for Medtronic Physio-Control sponsored study of AEDs in children (1996–99, published in 2003).</td>
<td>None</td>
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<td>Senior Science Editor, American Heart Association; consultation fees for AHA ECC programs</td>
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<td>Part-time consultant, Laerdal Sophus, Copenhagen; Executive member, Resuscitation Council, London</td>
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DOI: 10.1161/CIRCULATIONAHA.105.171079

(Circulation. 2005;112:B16-B18.)
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