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Pediatrics. Author manuscript; available in PMC 2013 September 26.

Published in final edited form as:
Pediatrics. 2010 November ; 126(5): e1261–e1318. doi:10.1542/peds.2010-2972A.

Special Report—Pediatric Basic and Advanced Life Support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations

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Keywords

arrhythmia; cardiopulmonary resuscitation; pediatrics; resuscitation

The 2010 ILCOR Pediatric Task Force experts developed 55 questions related to pediatric resuscitation. Topics were selected based on the 2005 Consensus on Science and Treatment Recommendations (CoSTR) document,[1,2] emerging science, and newly identified issues. Not every topic reviewed for the 2005 International Consensus on Science was reviewed in the 2010 evidence evaluation process. In general, evidence-based worksheets were assigned to at least 2 authors for each topic. The literature search strategy was first reviewed by a "worksheet expert" for completeness. The expert also approved the final worksheet to ensure that the levels of evidence were correctly assigned according to the established criteria. Worksheet authors were requested to draft CoSTR statements (see Part 3: Evidence Evaluation Process). Each worksheet author or pair of authors presented their topic to the Task Force in person or via a webinar conference, and Task Force members discussed the available science and revised the CoSTR draft accordingly. These draft CoSTR summaries were recirculated to the International Liaison Committee on Resuscitation (ILCOR) Pediatric Task Force for further refinement until consensus was reached. Selected controversial and critical topics were presented at the 2010 ILCOR International Evidence Evaluation conference in Dallas, Texas, for further discussion to obtain additional input and feedback. This document presents the 2010 international consensus on the science, treatment, and knowledge gaps for each pediatric question.

The most important changes or points of emphasis in the recommendations for pediatric resuscitation since the publication of the *2005 ILCOR International Consensus on CPR and ECC Science With Treatment Recommendations*[1,2] are summarized in the following list. The scientific evidence supporting these changes is detailed in this document.

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Note From the Writing Group: Throughout this article, the reader will notice combinations of superscripted letters and numbers (eg, "Family Presence During Resuscitation[Peds-003]"). These callouts are hyper linked to evidence-based worksheets, which were used in the development of this article. An appendix of worksheets, applicable to this article, is located at the end of the text. The worksheets are available in PDF format and are open access.

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- Additional evidence shows that healthcare providers do not reliably determine the presence or absence of a pulse in infants or children.
- New evidence documents the important role of ventilations in CPR for infants and children. However, rescuers who are unable or unwilling to provide ventilations should be encouraged to perform compression-only CPR.
- To achieve effective chest compressions, rescuers should compress at least one third the anterior-posterior dimension of the chest. This corresponds to approximately 1½ inches (4 cm) in most infants and 2 inches (5 cm) in most children.
- When shocks are indicated for ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) in infants and children, an initial energy dose of 2 to 4 J/kg is reasonable; doses higher than 4 J/kg, especially if delivered with a biphasic defibrillator, may be safe and effective.
- More data support the safety and effectiveness of cuffed tracheal tubes in infants and young children, and the formula for selecting the appropriately sized cuffed tube was updated.
- The safety and value of using cricoid pressure during emergency intubation are not clear. Therefore, the application of cricoid pressure should be modified or discontinued if it impedes ventilation or the speed or ease of intubation.
- Monitoring capnography/capnometry is recommended to confirm proper endotracheal tube position.
- Monitoring capnography/capnometry may be helpful during CPR to help assess and optimize quality of chest compressions.
- On the basis of increasing evidence of potential harm from exposure to high-concentration oxygen after cardiac arrest, once spontaneous circulation is restored, inspired oxygen concentration should be titrated to limit the risk of hyperoxemia.
- Use of a rapid response system in a pediatric inpatient setting may be beneficial to reduce rates of cardiac and respiratory arrest and inhospital mortality.
- Use of a bundled approach to management of pediatric septic shock is recommended.
- The young victim of a sudden, unexpected cardiac arrest should have an unrestricted, complete autopsy, if possible, with special attention to the possibility of an underlying condition that predisposes to a fatal arrhythmia. Appropriate preservation and genetic analysis of tissue should be considered; detailed testing may reveal an inherited “channelopathy” that may also be present in surviving family members.

Systems

Medical emergency teams (METs) or rapid response teams (RRTs) have been shown to be effective in preventing respiratory and cardiac arrests in selected pediatric inpatient settings.

Family presence during resuscitations has been shown to be beneficial for the grieving process and in general was not found to be disruptive. Thus, family presence is supported if it does not interfere with the resuscitative effort.

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Medical Emergency or Rapid Response Team[Peds-025A, Peds-025B]

Consensus on Science—The introduction of METs or RRTs was associated with a decrease in pediatric hospital mortality in 1 LOE 3 metaanalysis[3] and 3 pediatric LOE 3 studies with historic controls.[4–6] The introduction of a MET or RRT was associated with

- a decrease in respiratory but not cardiac arrest in 1 LOE 3[7] study with historic controls
- a decrease in preventable total number of arrests in 1 LOE 3 study compared with a retrospective chart review[8]
- a decrease in total number of arrests in 2 LOE 3[4,8] studies
- a decrease in preventable cardiac arrests in 1 LOE 3[6] study
- a decrease in cardiac arrest and non–pediatric intensive care unit (PICU) mortality in 1 LOE 3[9] pediatric cohort study using historical controls

Treatment Recommendations—Pediatric RRT or MET systems may be beneficial to reduce the risk of respiratory and/or cardiac arrest in hospitalized pediatric patients outside an intensively monitored environment.

Knowledge Gaps—Is it the team or the staff education associated with MET or RRT implementation that leads to improved patient outcomes? Is the team effectiveness due to validated team activation criteria or specific team composition? Do the benefits attributed to these teams extend to children in a community hospital setting?

Family Presence During Resuscitation[Peds-003]

Consensus on Science—Ten studies (LOE 2[10]; LOE 3[11]; LOE 4[12–19]) documented that parents wish to be given the option of being present during the resuscitation of their children. One LOE 2,[10] 1 LOE 3,[11] 2 LOE 4,[13,19] and 1 LOE 5[20] studies confirmed that most parents would recommend parent presence during resuscitation.

One LOE 2,[10] 1 LOE 3,[11] 6 LOE 4,[12,14,19,21–23] and 2 LOE 5[20,24] studies of relatives present during the resuscitation of a family member reported that they believed their presence was beneficial to the patient.

One LOE 2,[10] 1 LOE 3,[11] 6 LOE 4,[12,13,16 –19] and 1 LOE 5[24] studies reported that most relatives present during the resuscitation of a family member benefited from the experience. One LOE 3,[11] 4 LOE 4,[12,13,20,21] and 2 LOE 5[24,25] studies reported that being present during the resuscitation helped their adjustment to the family member's death.

One LOE 2[10] and 2 LOE 4[12,13] studies observed that allowing family members to be present during a resuscitation in a hospital setting did them no harm, whereas 1 LOE 4[26] study suggested that some relatives present for the resuscitation of a family member experienced short-term emotional difficulty.

One LOE 2,[10] 1 LOE 3,[27] 3 LOE 4,[12,23,28] and 3 LOE 5[20,24,29] studies showed that family presence during resuscitation was not perceived as being stressful to staff or to have negatively affected staff performance. However, 1 survey (LOE 4[30]) found that 39% to 66% of emergency medical services (EMS) providers reported feeling threatened by family members during an out-of-hospital resuscitation and that family presence interfered with their ability to perform resuscitations.

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Treatment Recommendations—In general, family members should be offered the opportunity to be present during the resuscitation of an infant or child. When deciding whether to allow family members to be present during an out-of-hospital resuscitation, the potential negative impact on EMS provider performance must be considered.

Knowledge Gaps—How does the presence of a dedicated support person help family members and, potentially, healthcare providers during the resuscitation of an infant or child? What training is appropriate for staff who may serve as support persons for family members during resuscitation of an infant or child? Why is family presence during resuscitation perceived more negatively by out-of-hospital care providers than by in hospital staff?

Assessment

Many healthcare providers find it difficult to rapidly and accurately determine the presence or absence of a pulse. On the basis of available evidence, the Task Force decided to deemphasize but not eliminate the pulse check as part of the healthcare provider assessment. The Task Force members recognized that healthcare providers who work in specialized settings may have enhanced skills in accurate and rapid pulse checks, although this has not been studied.

There are considerable data regarding use of end-tidal carbon dioxide (P_{ETCO_2}) measurement, capnography and capnometry, during cardiopulmonary resuscitation (CPR) as an indicator of CPR quality and as a predictive measure of outcome. Although capnography/capnometry may reflect the quality of CPR, there is insufficient evidence of its reliability in predicting resuscitation success in infants and children.

Pulse Check Versus Check for Signs of Life[Peds-002A]

Consensus on Science—Thirteen LOE 5 studies[31–43] observed that neither laypersons nor healthcare providers are able to perform an accurate pulse check in healthy adults or infants within 10 seconds. In 2 LOE 5 studies in adults[44,45] and 2 LOE 3 studies in children with nonpulsatile circulation,[46,47] blinded healthcare providers commonly assessed pulse status inaccurately and their assessment often took >10 seconds. In the pediatric studies, healthcare professionals were able to accurately detect a pulse by palpation only 80% of the time. They mistakenly perceived a pulse when it was nonexistent 14% to 24% of the time and failed to detect a pulse when present in 21% to 36% of the assessments. The average time to detect an actual pulse was approximately 15 seconds, whereas the average time to confirm the absence of a pulse was 30 seconds. Because the pulseless patients were receiving extracorporeal membrane oxygenation (ECMO) support, one must be cautious in extrapolating these data to the arrest situation; all pulseless patients did have perfusion and therefore had signs of circulation as evidenced by warm skin temperature with brisk capillary refill. All patients evaluated were in an intensive care unit (ICU) setting without ongoing CPR.

Treatment Recommendations—Palpation of a pulse (or its absence) is not reliable as the sole determinant of cardiac arrest and need for chest compressions. If the victim is unresponsive, not breathing normally, and there are no signs of life, lay rescuers should begin CPR. In infants and children with no signs of life, healthcare providers should begin CPR unless they can definitely palpate a pulse within 10 seconds.

Knowledge Gaps—Is there an association between the time required to successfully detect a suspected cardiac arrest victim's pulse and resuscitation outcome? Is there a

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difference in outcome when the decision to start chest compressions is based on the absence of signs of life as opposed to absence of a pulse?

Focused Echocardiogram to Detect Reversible Causes of CardiacArrest[Peds-006B]

Consensus on Science—In 1 small LOE 4 pediatric case series[48] cardiac activity was rapidly visualized by echocardiography without prolonged interruption of chest compressions, and this cardiac activity correlated with the presence or absence of a central pulse. In 1 pediatric LOE 4 case report,[49] echocardiography was useful for diagnosing pericardial tamponade as the cause of cardiac arrest and was useful in guiding treatment.

In 8 LOE 5 adult case series,[50–57] echocardiographic findings correlated well with the presence or absence of cardiac activity in cardiac arrest. These reports also suggested that echocardiography may be useful in identifying patients with potentially reversible causes for the arrest.

Treatment Recommendations—There is insufficient evidence to recommend for or against the routine use of echocardiography during pediatric cardiac arrest. Echocardiography may be considered to identify potentially treatable causes of an arrest when appropriately skilled personnel are available, but the benefits must be carefully weighed against the known deleterious consequences of interrupting chest compressions.

Knowledge Gaps—Can echocardiography be performed during cardiac arrest in infants and children without significant interruptions in chest compressions? How often does echocardiography during cardiac arrest provide information that can affect treatment and outcome?

End-tidal CO_2 (P_{ETCO_2}) and Quality of CPR[Peds-005A, Peds-005B]

Consensus on Science—Three LOE 5 animal studies,[58–60] 4 LOE 5 adult,[61–64] and 1 LOE 5 pediatric series[65] showed a strong correlation between P_{ETCO_2} and interventions that increase cardiac output during resuscitation from shock or cardiac arrest. Similarly 3 LOE5animal models[66–68] showed that measures that markedly reduce cardiac output result in a fall in P_{ETCO_2}.

Two LOE 5 adult out-of-hospital studies[69,70] supported continuous P_{ETCO_2} monitoring during CPR as a way of determining return of spontaneous circulation (ROSC), particularly if the readings during CPR are >15 mm Hg (2.0 kPa). In 1 LOE 4[71] and 2 LOE 5 adult case series,[72,73] an abrupt and sustained rise in P_{ETCO_2} often preceded identification of ROSC.

Two LOE 4 pediatric cases series,[65,74] 8 LOE 5 adult,[70,75–81] and 1 LOE 5 animal study[59] showed that a low P_{ETCO_2} (<10 mm Hg [1.33 kPa] to <15 mm Hg [2.0 kPa]) despite 15 to 20 minutes of advanced life support (ALS) is strongly associated with failure to achieve ROSC. On the basis of 2 LOE 5 animal studies[71,82] and 2 adult LOE 5 case series,[70,78] P_{ETCO_2} after at least 1 minute of CPR may be more predictive of outcome than the initial value because the initial P_{ETCO_2} is often increased in patients with asphyxial cardiac arrest.

The wide variation for initial P_{ETCO_2} during resuscitation limits its reliability in predicting outcome of resuscitation and its value as a guide to limiting resuscitation efforts. Two LOE 5 animal studies[71,82] and 2 large LOE 5 adult trials[70,78] suggested that the initial P_{ETCO_2} is higher if the etiology of the cardiac arrest is asphyxial rather than if it is a primary cardiac arrest.

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Interpretation of the end-tidal CO_2 during resuscitation is affected by the quality of the measurement, the minute ventilation delivered during resuscitation, the presence of lung disease that increases anatomic dead space, and the presence of right-to-left shunting.[83–85]

In 1 LOE 5 adult study,[86] sodium bicarbonate transiently increased end tidal CO_2, and in 3 LOE 5 adult[87–89] and 2 LOE 5 animal[90,91] studies, epinephrine (and other systemic vasoconstrictive agents) transiently decreased P_{ETCO_2}.

Treatment Recommendations—Continuous capnography or capnometry monitoring, if available, may be beneficial by providing feedback on the effectiveness of chest compressions. Whereas a specific target number cannot be identified, if the P_{ETCO_2} is consistently <15 mm Hg, it is reasonable to focus efforts on improving the quality of chest compressions and avoiding excessive ventilation.

Although a threshold P_{ETCO_2} may predict a poor outcome from resuscitation and might be useful as a guide to termination of CPR, there are insufficient data to establish the threshold and the appropriate duration of ALS needed before such evaluation in children. The P_{ETCO_2} must be interpreted with caution for 1 to 2 minutes after administration of epinephrine or other vasoconstrictive medications because these medications may decrease the P_{ETCO_2}.

Knowledge Gaps—Does P_{ETCO_2} monitoring during CPR improve quality of chest compressions and/or outcome of pediatric resuscitation? During CPR, can P_{ETCO_2} be reliably measured via a laryngeal mask airway (LMA)? Is there a threshold P_{ETCO_2} that predicts ROSC or low likelihood of ROSC during resuscitation from pediatric cardiac arrest? Can the initial P_{ETCO_2} distinguish asphyxial from cardiac etiology of pediatric cardiac arrest? Is detection of ROSC using P_{ETCO_2} monitoring more accurate than palpation of a pulse? Are P_{ETCO_2} targets during CPR different for subgroups of infants and children with alterations in pulmonary blood flow or high airway resistance?

Airway and Ventilation

Opening and maintaining a patent airway and providing ventilations are fundamental elements of pediatric CPR, especially because cardiac arrest often results from, or is complicated by, asphyxia. There are no new data to change the 2005 ILCOR recommendation to use manual airway maneuvers (with or without an oropharyngeal airway) and bag-mask ventilation (BMV) for children requiring airway control or positive-pressure ventilation for short periods in the out-of-hospital setting. When airway control or BMV is not effective, supraglottic airways may be helpful when used by properly trained personnel.

When performing tracheal intubation, data suggest that the routine use of cricoid pressure may not protect against aspiration and may make intubation more difficult.

Routine confirmation of tracheal tube position with capnography/capnometry is recommended with the caveat that the P_{ETCO_2} in infants and children in cardiac arrest may be below detection limits for colorimetric devices.

Following ROSC, toxic oxygen byproducts (reactive oxygen species, free radicals) are produced that may damage cell membranes, proteins, and DNA (reperfusion injury). Although there are no clinical studies in children (outside the newborn period) comparing different concentrations of inspired oxygen during and immediately after resuscitation, animal data and data from newborn resuscitation studies suggest that it is prudent to titrate inspired oxygen after return of a perfusing rhythm to prevent hyperoxemia.

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Supplementary Oxygen[Peds-015]

Consensus on Science—There are no studies comparing ventilation of infants and children in cardiac arrest with different inspired oxygen concentrations. Two LOE 5 meta-analyses of several randomized controlled trials comparing neonatal resuscitation initiated with room air versus 100% oxygen[92,93] showed increased survival when resuscitation was initiated with room air.

Seven LOE 5 animal studies[94–100] suggested that ventilation with room air or an F_{IO2} of <1.0 during cardiac arrest may be associated with less neurologic deficit than ventilation with an F_{IO2} of 1.0, whereas 1 LOE 5 animal study[101] showed no difference in outcome. In 5 LOE 5 animal studies[95,97–99,102] ventilation with 100% oxygen during and following resuscitation contributed to free radical–mediated reperfusion injury to the brain.

Treatment Recommendations—There is insufficient evidence to recommend any specific inspired oxygen concentration for ventilation *during* resuscitation from cardiac arrest in infants and children. Once circulation is restored, it is reasonable to titrate inspired oxygen to limit hyperoxemia.

Knowledge Gaps—Does the use of any specific concentration of supplementary oxygen during resuscitation from cardiac arrest in infants and children improve or worsen outcome? What is the appropriate target oxygen saturation for the pediatric patient after achieving ROSC?

Cuffed Versus Uncuffed Tracheal Tube[Peds-007]

Consensus on Science—There are no studies that compare the safety and efficacy of cuffed versus uncuffed tubes in infants and children who require emergency intubation.

Two LOE 5 randomized controlled studies[103,104] and 1 LOE 5 cohort-controlled study[105] in a pediatric anesthesia setting showed that the use of cuffed tracheal tubes was associated with a higher likelihood of selecting the correct tracheal tube size (and hence a lower reintubation rate) with no increased risk of perioperative or airway complications. Cuff pressures in these 3 studies were maintained at <25 cm H_2O. Two perioperative LOE 5 cohort-controlled pediatric studies[105,106] similarly showed that cuffed tubes were not associated with an increased risk of perioperative airway complications.

One LOE 5 pediatric case series[107] observed that the use of cuffed tracheal tubes was not a risk factor for developing subglottic stenosis in patients having corrective surgery for congenital cardiac defects. In the intensive care setting, 2 LOE 5 prospective cohort-controlled studies[108,109] and 1 LOE 5 retrospective cohort-controlled study[110] documented no greater risk of complications for children. >8 years of age who were intubated with cuffed compared with uncuffed tracheal tubes.

One small LOE 5 case-controlled study[111] showed that cuffed tracheal tubes decreased the incidence of aspiration in the PICU, and 1 LOE 5 case series[105] of children with burns undergoing general anesthesia showed a significantly higher rate of excessive air leak requiring immediate reintubation in patients initially intubated with an uncuffed tracheal tube.

Treatment Recommendations—Both cuffed and uncuffed tracheal tubes are acceptable for infants and children undergoing emergency intubation. If cuffed tracheal tubes are used, avoid excessive cuff pressures.

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Knowledge Gaps—What is the best technique to determine cuff pressure and/or the presence of an air leak when using cuffed tracheal tubes in infants and children? What is the optimal cuff or leak pressure for children of different ages? Does optimal cuff pressure vary based on the type of cuffed tube (eg, Microcuff®) used?

Are the data generated in elective operating room studies applicable to emergency resuscitation scenarios? Are there select populations of pediatric patients whose outcomes are improved by the use of cuffed tracheal tubes during resuscitation?

Tracheal Tube Size[Peds-057A, Peds-057B]

Consensus on Science—Evidence from 1 LOE 2 prospective randomized trial of elective intubation in a pediatric operating room[103] was used to support the existing formula for estimation of appropriate cuffed tracheal tube internal diameter (ID): ID (mm) = (age in years/4) +3, also known as the Khine formula. Detailed analysis of this paper, however, reveals that the aggressive rounding up of age employed by the authors in their calculations commonly resulted in selection of a tube with an ID 0.5 mm larger than the size derived from the formula.

Evidence from 1 LOE 2 prospective randomized multicenter study,[104] 1 LOE 2,[112] and 3 LOE 4 prospective observational studies of elective intubation in the pediatric operating room[113–115] supported use of 3-mm ID cuffed tracheal tubes for newborns and infants (3.5 kg to 1 year of age) and 3.5-mm ID cuffed tracheal tubes for patients 1 to 2 years of age.

One LOE 2 prospective randomized multi-center study[104] and 3 LOE 4 prospective observational studies of elective intubation in the pediatric operating room[113–115] using Microcuff® tracheal tubes support the use of the following formula for cuffed endotracheal tubes in children: ID (mm) = (age/4) + 3.5. One LOE 2 prospective observational study of elective intubation in the pediatric operating room[112] found that formula acceptable but associated with a marginally greater reintubation rate than with the Khine formula (ID [mm] = [age in years/4] + 3).

Treatment Recommendations—If a cuffed tracheal tube is used in infants ≥3.5 kg and <1 year of age, it is reasonable to use a tube with an ID of 3.0 mm. If a cuffed tracheal tube is used in children between 1 and 2 years of age, it is reasonable to use a tube with an ID of 3.5 mm.

After the age of 2, it is reasonable to estimate the cuffed tracheal tube size with the formula ID (mm) = (age in years/4) + 3.5. If the tracheal tube meets resistance during insertion, a tube with an ID 0.5 mm smaller should be used. If there is no leak around the tube with the cuff deflated, reintubation with a tube ID 0.5 mm smaller may be beneficial when the patient is stable.

Knowledge Gaps—Are the formulas for estimation of tracheal tube size that are used for elective intubation in the operating room setting applicable during resuscitation? Is there an upper age limit for the validity of the formula to estimate tube size? Are length-based formulas more accurate compared withage- or weight-based formulas for estimating tracheal tube size in infants and children?

Bag-Mask Ventilation Versus Intubation[Peds-008]

Consensus on Science—One LOE 1 study[116] compared paramedic out-of-hospital BMV with intubation for children with cardiac arrest, respiratory arrest, or respiratory failure in an EMS system with short transport intervals and found equivalent rates of

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survival to hospital discharge and neurologic outcome. One LOE 1 systematic review that included this study[117] also reached the same conclusion.

One LOE 2 study of pediatric trauma patients[118] observed that out-of-hospital intubation is associated with a higher risk of mortality and postdischarge neurologic impairment compared with in-hospital intubation. These findings persisted even after stratification for severity of trauma and head trauma.

In 1 LOE 2 (nonrandomized) prehospital pediatric study,[119] if paramedics provided BMV while awaiting the arrival of a physician to intubate the patient, the risk of cardiac arrest and overall mortality was lower than if the patient was intubated by the paramedics. These findings persisted even after adjusting for Glasgow Coma Scale score.

Four LOE 4 studies[120–123] showed a significantly greater rate of failed intubations and complications in children compared with adults in the out-of-hospital and emergency department settings. Conversely 1 LOE 3 out-of-hospital study[124] and 1 LOE 4 out-of-hospital study[125] failed to demonstrate any difference in intubation failure rates between adults and children.

Treatment Recommendations—BMV is recommended over tracheal intubation in infants and children who require ventilatory support in the out-of-hospital setting when transport time is short.

Knowledge Gaps—For the experienced airway specialist, does tracheal intubation improve outcomes in comparison with BMV for pediatric resuscitation? Does the use of neuromuscular blocking drugs improve the outcome of children undergoing intubation during resuscitation? What is the minimal initial training and ongoing experience needed to improve success rate and reduce complications of emergent intubation of infants and children?

Bag-Mask Ventilation Versus Supraglottic Airway[Peds-009]

Consensus on Science—No studies have directly compared BMV to the use of supraglottic airway devices during pediatric resuscitation other than for the newly born in the delivery room. Nine LOE 5 case re-ports[126–134] demonstrated the effectiveness of supraglottic airway devices, primarily the LMA, for airway rescue of children with airway abnormalities.

One LOE 5 out-of-hospital adult study[135] supports the use of LMAs by first responders during CPR, but another LOE 5 out-of-hospital adult cardiac arrest study[136] of EMS personnel providing assisted ventilation by either bag-mask device or LMA failed to show any significant difference in ventilation ($PaCO_2$). Six LOE 5 studies during anesthesia[137–142] demonstrated that complication rates with LMAs increase with decreasing patient age and size.

In 2 LOE 5 manikin studies[143,144] trained nonexpert providers successfully delivered positive-pressure ventilation using the LMA. Tracheal intubations resulted in a significant incidence of tube misplacement (esophageal or right mainstem bronchus), a problem not present with the LMA, but time to effective ventilation was shorter and tidal volumes were greater with BMV.

In 2 LOE 5 studies of anesthetized children[145,146] suitably trained ICU and ward nurses placed LMAs with a high success rate, although time to first breath was shorter in the BMV

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group. In a small number of cases ventilation was achieved with an LMA when it proved impossible with BMV.

Treatment Recommendations—BMV remains the preferred technique for emergency ventilation during the initial steps of pediatric resuscitation. In infants and children for whom BMV is unsuccessful, use of the LMA by appropriately trained providers may be considered for either airway rescue or support of ventilation.

Knowledge Gaps—Are the data regarding use of supraglottic airways for elective airway management in the operating room applicable to emergency resuscitation scenarios? With an LMA in place, is it necessary to pause chest compressions to provide effective ventilations? Is the combination of an oropharyngeal airway with BMV more or less effective than supraglottic airways?

Minute Ventilation[Peds-013A]

Consensus on Science—There are no data to identify the optimal minute ventilation (tidal volume or respiratory rate) for infants or children with an advanced airway during CPR, regardless of arrest etiology.

Three LOE 5 animal studies[147–149] showed that ventilation during CPR after VF or asphyxial arrest resulted in improved ROSC, survival, and/or neurologic outcome compared with no positive-pressure breaths.

Evidence from 4 LOE 5 adult studies[150–153] showed that excessive ventilation is common during resuscitation from cardiac arrest. In 1 LOE 5 animal study[150] excessive ventilation during resuscitation from cardiac arrest decreased cerebral perfusion pressure, ROSC, and survival compared with lower ventilation rates. One good LOE 5 animal study[149] found that increasing respiratory rate during conditions of reduced cardiac output improved alveolar ventilation but not oxygenation, and it reduced coronary perfusion pressure.

In 1 LOE 5 prospective, randomized adult study[154] constant-flow insufflation with oxygen compared with conventional mechanical ventilation during CPR did not change outcome (ROSC, survival to admission, and survival to ICU discharge). In another LOE 5 adult study,[155] adults with witnessed VF arrest had improved neurologically intact survival with passive oxygen insufflation compared with BMV, whereas there was no difference in survival if the VF arrest was unwitnessed.

Two LOE 5 animal studies showed that ventilation or continuous positive airway pressure (CPAP) with oxygen compared with no ventilation improved arterial blood gases[156] but did not change neurologically intact survival.[157] One good-quality LOE 5 animal study[158] showed that reducing tidal volume by 50% during CPR resulted in less excessive ventilation without affecting ROSC.

Treatment Recommendations—Following placement of a secure airway, avoid excess ventilation of infants and children during resuscitation from cardiac arrest, whether asphyxial or due to VF. A reduction in minute ventilation to less than baseline for age is reasonable to provide sufficient ventilation to maintain adequate ventilation-to-perfusion ratio during CPR while avoiding the harmful effects of excessive ventilation. There are insufficient data to identify the optimal tidal volume or respiratory rate.

Knowledge Gaps—What is the optimal minute ventilation to achieve ventilation-perfusion matching during pediatric CPR? Is it preferable to reduce tidal volume or respiratory rate to achieve optimal minute ventilation during pediatric CPR? Does

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hypoventilation (ie, hypercarbia) during resuscitation affect outcome from pediatric cardiac arrest? Does passive oxygen insufflation or CPAP during cardiac arrest in infants and children provide adequate gas exchange or improve outcome from resuscitation?

Devices to Verify Advanced Airway Placement Peds004

Consensus on Science—No single assessment method accurately and consistently confirms tracheal tube position. Three LOE 4 studies[71,159,160] showed that when a perfusing cardiac rhythm is present in infants (>2 kg) and children, detection of exhaled CO_2 using a colorimetric detector or capnometer has a high sensitivity and specificity for confirming endotracheal tube placement. One of these studies[71] included infants and children in cardiac arrest. In the cardiac arrest population the sensitivity of exhaled CO_2 detection was only 85% (ie, false-negatives occurred), whereas the specificity remained at 100%.

One neonatal LOE 5 study[161] of delivery room intubation demonstrated that detection of exhaled CO_2 by capnography was 100% sensitive and specific for detecting esophageal intubation and took less time than clinical assessment to identify esophageal intubation. Two additional neonatal LOE 5 studies[162,163] showed that confirmation of tracheal tube position is faster with capnography than with clinical assessment.

Two pediatric LOE 4 studies[164,165] showed that in the presence of a perfusing rhythm, exhaled CO_2 detection or measurement can confirm tracheal tube position accurately during transport, while 2 LOE 5 animal studies[166,167] showed that tracheal tube displacement can be detected more rapidly by CO_2 detection than by pulse oximetry.

One LOE 2 operating room study[168] showed that the esophageal detector device (EDD) is highly sensitive and specific for correct tracheal tube placement in children >20 kg with a perfusing cardiac rhythm; there have been no studies of EDD use in children during cardiac arrest. An LOE 4 operating room (ie, non-arrest) study[169] showed that the EDD performed well but was less accurate in children <20 kg.

Treatment Recommendations—Confirmation of tracheal tube position using exhaled CO_2 detection (colorimetric detector or capnography) should be used for intubated infants and children with a perfusing cardiac rhythm in all settings (eg, out-of-hospital, emergency department, ICU, inpatient, operating room).

In infants and children with a perfusing rhythm, it may be beneficial to monitor continuous capnography or frequent intermittent detection of exhaled CO_2 during out-of-hospital and intra-/interhospital transport.

The EDD may be considered for confirmation of tracheal tube placement in children weighing >20 kg when a perfusing rhythm is present.

Knowledge Gaps—Which technique for CO_2 detection (colorimetric versus capnography) is more accurate during pediatric resuscitation? For infants and children in cardiac arrest, what is the most reliable way to achieve confirmation of tracheal tube position?

Cricoid Pressure Peds-039A, Peds-039B

Consensus on Science—There are no data to show that cricoid pressure prevents aspiration during rapid sequence or emergency tracheal intubation in infants or children. Two LOE 5 studies[170,171] showed that cricoid pressure may reduce gastric inflation in

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children. One LOE 5 study in children[172] and 1 LOE 5 study in adult cadavers[173] demonstrated that esophageal reflux is reduced with cricoid pressure.

In 1 LOE 5 adult systematic review[174] laryngeal manipulation enhanced BMV or intubation in some patients while impeding it in others. One LOE 5 study in anesthetized children[175] showed that cricoid pressure can distort the airway with a force of as low as 5 newtons.

Treatment Recommendations—If cricoid pressure is used during emergency intubations in infants and children it should be discontinued if it impedes ventilation or interferes with the speed or ease of intubation.

Knowledge Gaps—Can cricoid pressure reduce the incidence of aspiration during emergent intubation of infants or children? How much cricoid pressure should be applied, and what is the best technique to reduce gastric inflation during BMV?

Chest Compressions

The concept of chest compression-only CPR is appealing because it is easier to teach than conventional CPR, and immediate chest compressions may be beneficial for resuscitation from sudden cardiac arrest caused by VF or pulseless VT. Animal studies showed that conventional CPR, including ventilations and chest compressions, is best for resuscitation from asphyxial cardiac arrest. In a large study of outof-hospital pediatric cardiac arrest,[176] few children with asphyxial arrest received compression-only CPR and their survival was no better than in children who received no CPR.

To be effective, chest compressions must be deep, but it is difficult to determine the optimal depth in infants and children; should recommended depth be expressed as a fraction of the depth of the chest or an absolute measurement? How can this be made practical and teachable?

Compression-Only CPR[Peds-012A]

Consensus on Science—Evidence from 1 LOE 2 large out-of-hospital pediatric prospective observational investigation[176] showed that children with cardiac arrest of noncardiac etiology (asphyxial arrest) had a higher 30-day survival with more favorable neurologic outcome if they received standard bystander CPR (chest compressions with rescue breathing) compared with chest compression only CPR. Standard CPR and chest compression-only CPR were similarly effective and better than no bystander CPR for pediatric cardiac arrest from cardiac causes. Of note, the same study showed that more than 50% of children with out-of-hospital cardiac arrest did not receive any bystander CPR. Compression-only CPR was as ineffective as no CPR in the small number of infants and children with asphyxial arrest who did not receive ventilations.

Two LOE 5 animal studies[148,177] demonstrated improved survival rates and favorable neurologic outcome with standard CPR compared with no CPR. One LOE 5 animal study[178] showed that blood gases deteriorated with compression-only CPR compared with standard CPR in asphyxial arrests.

Data from 1 LOE 5 animal study[177] indicated that compression-only CPR is better than no CPR for asphyxial arrest but not as effective as standard CPR, and 7 LOE 5 clinical observational studies in adults[179–184] showed that compression-only CPR can result in successful resuscitation from an asphyxial arrest. Moreover, in 10 LOE 5 animal studies[185–194] and 7 LOE 5 adult clinical observational studies[179–184,195] compression-only

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bystander CPR was generally as effective as standard 1-rescuer bystander CPR for arrests from presumed cardiac causes.

Treatment Recommendations—Rescuers should provide conventional CPR (rescue breathing and chest compressions) for in-hospital and out-of-hospital pediatric cardiac arrests. Lay rescuers who cannot provide rescue breathing should at least perform chest compressions for infants and children in cardiac arrest.

Knowledge Gaps—Does teaching compression-only CPR to lay rescuers increase the likelihood that CPR will be performed during out-of-hospital pediatric cardiac arrest?

One- Versus 2-Hand Chest Compression in Children[Peds-033]

Consensus on Science—There are no outcome studies comparing 1- versus 2-hand chest compressions for children in cardiac arrest. Evidence from 1 LOE 5 randomized crossover child manikin study[196] showed that higher chest-compression pressures are generated by healthcare professionals using the 2-hand technique. Two LOE 5 studies[197,198] report no increase in rescuer fatigue comparing 1-hand with 2-hand chest compressions delivered by healthcare providers to a child-sized manikin.

Treatment Recommendations—Either a 1- or 2-hand technique can be used for performing chest compressions in children.

Knowledge Gaps—Does the use of 1-hand compared with 2-hand chest compressions during pediatric cardiac arrest affect quality of CPR or outcome?

Circumferential Chest Squeeze inInfants[Peds-034]

Consensus on Science—There are no studies that compare the 2-thumb chest compression technique with and without a “circumferential squeeze” in infants.

Treatment Recommendations—There are insufficient data for or against the need for a circumferential squeeze of the chest when performing the 2-thumb technique of external chest compression for infants.

Knowledge Gaps—Does the addition of a circumferential squeeze to 2-thumb compression in infants provide more effective chest compressions or improve resuscitation outcome?

Chest Compression Depth[Peds-040A, Peds-040B]

Consensus on Science—Evidence from anthropometric measurements in 3 good-quality LOE 5 case series[199–201] showed that in children the chest can be compressed to one third of the anterior-posterior chest diameter without causing damage to intrathoracic organs. One LOE 5 mathematical model based on neonatal chest computed tomography scans[202] suggests that one third anterior-posterior chest compression depth is more effective than one fourth compression depth and safer than one half anterior-posterior compression depth.

A good-quality LOE 5[152] adult study found that chest compressions are often inadequate, and a good-quality LOE 4 pediatric study[200] showed that during resuscitation of patients >8 years of age, compressions are often too shallow, especially following rescuer changeover. Evidence from 1 pediatric LOE 4 systematic review of the literature[203] showed that rib fractures are rarely associated with chest compressions.

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Treatment Recommendations—In infants, rescuers should be taught to compress the chest by *at least* one third the anterior-posterior dimension or approximately 1½ inches (4 cm). In children, rescuers should be taught to compress the chest by *at least* one third the anterior-posterior dimension or approximately 2 inches (5 cm).

Knowledge Gaps—Can lay rescuers or healthcare providers reliably perform compressions to the recommended depth during pediatric cardiac arrest? Is there harm from compressions that are "too deep" in infants?

Compression-Ventilation Ratio

The ILCOR Neonatal Task Force continues to recommend a compression ventilation ratio of 3:1 for resuscitation of the newly born in the delivery room, with a pause for ventilation whether or not the infant has an advanced airway. The Pediatric Task Force reaffirmed its recommendation for a 15:2 compression-ventilation ratio for 2-rescuer infant CPR, with a pause for ventilation in infants without an advanced airway, and continuous compressions without a pause for ventilation for infants with an advanced airway.

No previous recommendations were made for hospitalized newborns cared for in areas other than the delivery area or with primary cardiac rather than asphyxial arrest etiology. For example, consider the case of a 3-week old infant who has a cardiac arrest following cardiac surgery. In the neonatal intensive care unit such an infant would be resuscitated according to the protocol for the newly born, but if the same infant is in the PICU, resuscitation would be performed according to the infant guidelines. A resolution to this dilemma is suggested on the basis of the arrest etiology and ease of training.

Optimal Compression-Ventilation Ratio for Infants and Children[Peds-011B]

Consensus on Science—There are insufficient data to identify an optimal compression-ventilation ratio for CPR in infants and children. In 4 LOE 5 manikin studies[204–207] examining the feasibility of compression-ventilation ratios of 15:2 and 5:1, lone rescuers could not deliver the desired number of chest compressions per minute at a ratio of 5:1. In 5 LOE 5 studies[208–212] using a variety of manikin sizes comparing compression-ventilation ratios of 15:2 with 30:2, a ratio of 30:2 yielded more chest compressions with no, or minimal, increase in rescuer fatigue. One LOE 5 study[213] of volunteers recruited in an airport to perform 1-rescuer layperson CPR on an adult-sized manikin observed less "no flow time" with the use of a 30:2 ratio compared with a 15:2 ratio.

One LOE 5 observational human study[214] comparing resuscitations by firefighters before and after the change from a recommended 15:2 to 30:2 compression-ventilation ratio reported more chest compressions per minute with the 30:2 ratio, but the rate of ROSC was unchanged. Three LOE 5 animal studies[192,215,216] showed that coronary perfusion pressure, a major determinant of success in resuscitation, rapidly declines when chest compressions are interrupted; once compressions are resumed, several chest compressions are needed to restore coronary perfusion pressure to preinterruption levels. Thus, frequent interruptions of chest compressions prolong the duration of low coronary perfusion pressure and flow and reduce the mean coronary perfusion pressure. Three LOE 5 manikin stud ies[213,217,218] and 3 LOE 5[151,152,219] in- and out-of-hospital adult human studies documented long interruptions in chest compressions during simulated or actual resuscitations. Three LOE 5 adult studies[220–222] demonstrated that these interruptions reduced ROSC.

In 5 LOE 5 animal studies[191,192,194,215–216] chest compressions without ventilations were sufficient to resuscitate animals with VF-induced cardiac arrest. Conversely in 2 LOE 5

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animal studies[223,224] decreasing the frequency of ventilation was detrimental in the first 5 to 10 minutes of resuscitation of VF-induced cardiac arrest.

One LOE 5 mathematical model[225] suggested that the compression-ventilation ratio in children should be lower (more ventilations to compressions) than in adults and should decrease with decreasing weight. Two LOE 5 studies of asphyxial arrest in pigs[148,177] showed that ventilations added to chest compressions improved outcome compared with compressions alone. Thus, ventilations are more important during resuscitation from asphyxia-induced arrest than during resuscitation from VF. But even in asphyxial arrest, fewer ventilations are needed to maintain an adequate ventilation-perfusion ratio in the presence of the low cardiac output (and consequently low pulmonary blood flow) produced by chest compressions.

Treatment Recommendations—For ease of teaching and retention, a compression-ventilation ratio of 30:2 is recommended for the lone rescuer performing CPR in infants and children, as is used for adults. For healthcare providers performing 2-rescuer CPR in infants and children, a compression-ventilation ratio of 15:2 is recommended. When a tracheal tube is in place, compressions should not be interrupted for ventilations.

Knowledge Gaps—What is the optimal compression-ventilation ratio to improve outcome for neonates, infants, and children in cardiac arrest?

Newborns (Out of the Delivery Area) Without an Endotracheal Airway[Peds-027A]

Consensus on Science—There are insufficient data to identify an optimal compression-ventilation ratio for all infants in the first month of life. One LOE 5 animal study[192] showed that coronary perfusion pressure declined with interruptions in chest compressions; after each interruption, several chest compressions were required to restore coronary perfusion pressure to preinterruption levels. One LOE 5 adult human study[221] and 2 LOE 5 animal studies[215,222] showed that interruptions in chest compression reduced the likelihood of ROSC in VF cardiac arrest.

One LOE 5 1-rescuer manikin study[207] showed that more effective ventilation was achieved with a 3:1 ratio than with a 5:1, 10:2, or 15:2 ratio. One LOE 5 mathematical study of cardiovascular physiology[226] suggested that blood flow rates in neonates are best at compression rates of >120/min.

Treatment Recommendations—There are insufficient data to recommend an optimal compression-ventilation ratio during CPR for all infants in the first month of life (beyond the delivery room). The limited data available suggest that if the etiology of the arrest is cardiac, a 15:2 ratio (2 rescuers) may be more effective than a 3:1 ratio.

Knowledge Gaps—Do healthcare providers perform better CPR if they learn 1 rather than 2 compression-ventilation ratios based on etiology of the arrest (cardiac or asphyxial)?

Newborns (Out of Delivery Area) With a Tracheal Tube[Peds026A]

Consensus on Science—There is insufficient evidence to determine if an intubated neonate has a better outcome from cardiac arrest using a 3:1 compression-ventilation ratio and interposed ventilations compared with continuous chest compressions without pause for ventilations (asynchronous compressions and ventilations).

Two LOE 5 adult[220,222] and 2 LOE 5 animal[191,192] studies demonstrated that interruptions in chest compressions reduced coronary perfusion pressure, a key determinant of successful

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resuscitation in adults, and decreased ROSC. There are no equivalent studies evaluating the impact of interrupted chest compressions in asphyxiated neonates or neonatal animal models.

In 1 LOE 5 piglet study[227] of VF arrest, myocardial blood flow increased using simultaneous chest compressions and high–airway pressure ventilations in a 1:1 ratio as compared with conventional CPR at a 5:1 ratio. Another LOE 5 VF piglet study[228] demonstrated equivalent cardiac output but worsened gas exchange using a 1:1 compression-ventilation ratio (ie, simultaneous compressions and ventilations) with high airway pressures compared with conventional CPR at a 5:1 ratio.

One LOE 5[148] study in nonintubated asphyxiated piglets resuscitated with a 5:1 compression-ventilation ratio showed that ventilations are important for successful resuscitation. One LOE 5 study in intubated asphyxiated piglets[178] showed that the addition of ventilations resulted in lower arterial CO_2 tension ($PaCO_2$) without compromising hemodynamics when compared with compressions alone. One LOE 5 manikin study[229] found that healthcare providers were unable to achieve the recommended rate of ventilations during infant CPR at a 3:1 compression-ventilation ratio, with 20% delivering a net rate of 40 breaths per minute after 5 minutes of resuscitation. There are no studies that evaluate the impact of continuous compressions on minute ventilation, gas exchange, or the outcome of resuscitation during CPR for intubated neonates.

Treatment Recommendations—For ease of training, providers should use the compression-ventilation ratio and resuscitation approach that is most commonly used in their practice environment for intubated term or near-term newborns within the first month of life. Intubated newborns (ie, those with an advanced airway) who require CPR in non-neonatal settings (eg, prehospital, emergency department, PICU, etc) or those with a cardiac etiology of cardiac arrest, regardless of location, should receive CPR according to infant guidelines (continuous chest compressions without pause for ventilations).

Knowledge Gaps—In intubated infants in cardiac arrest, can effective ventilations be performed during continuous chest compressions with asynchronous ventilations? Do pauses for ventilations during CPR affect the outcome from cardiac arrest in intubated infants?

Vascular Access and Drug Delivery

There is no new evidence to change the 2005 ILCOR recommendations on vascular access, including the early use of intraosseous (IO) access and de-emphasis of the tracheal route of drug delivery. Epidemiological data, largely from the National Registry of CPR (NRCPR), reported an association between vasopressin, calcium, or sodium bicarbonate administration and an increased likelihood of death. These data, however, cannot be interpreted as a cause-and-effect relationship. The association may be due to more frequent use of these drugs in children who fail to respond to standard basic and advanced life support interventions. These and other data in adults question the benefit of intravenous (IV) medications during resuscitation and reemphasize the importance of high quality CPR.

Intraosseous Access[Peds-035]

Consensus on Science—There are no studies comparing IO with IV access in children with cardiac arrest. In 1 LOE 5 study of children in shock[230] IO access was frequently more successful and achieved more rapidly than IV access. Eight LOE 4 case series[231–238] showed that providers with many levels of training could rapidly establish IO access with minimal complications for children with cardiac arrest.

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Treatment Recommendations—IO cannulation is an acceptable route of vascular access in infants and children with cardiac arrest. It should be considered early in the care of critically ill children whenever venous access is not readily attainable.

Knowledge Gaps—Does the use of IO compared with IV vascular access improve outcome of pediatric cardiac arrest? Does the use of newer IO devices (eg, bone injection guns and drills) compared with conventional IO needles affect outcome in pediatric cardiac arrest?

Tracheal Drug Delivery[Peds036]

Consensus on Science—One LOE 3 study of children with in-hospital cardiac arrest[239] demonstrated similar ROSC and survival rates, whereas 2 LOE 5 studies of adults in cardiac arrest[240,241] demonstrated reduced ROSC and survival to hospital discharge rates when tracheal instead of IV epinephrine was given. One LOE 5 case series of neonatal asphyxial bradycardia[242] demonstrated similar rates of ROSC whether IV or tracheal epinephrine was administered, whereas another LOE 5 study[243] demonstrated a lower rate of ROSC in neonates given tracheal as opposed to IV epinephrine. Many of the human studies used tracheal epinephrine doses of <0.1 mg/kg.

In some animal studies[244–249] lower doses of tracheal epinephrine (0.01 to 0.05 mg/kg) produced transient deleterious β-adrenergic vascular effects resulting in lower coronary artery perfusion. One LOE 5 study[250] of animals in VF cardiac arrest demonstrated a higher rate of ROSC in those treated with tracheal vasopressin compared with IV placebo.

Four LOE 5 studies of animals in cardiac arrest[251–254] demonstrated similar ROSC and survival rates when either tracheal or IV routes were used to deliver epinephrine. These studies also demonstrated that to reach an equivalent biological effect, the tracheal dose must be up to 10 times the IV dose.

Treatment Recommendations—The preferred routes of drug delivery for infants and children in cardiac arrest are IV and IO. If epinephrine is ad ministered via a tracheal tube to infants and children (not including the newly born) in cardiac arrest, the recommended dose is 0.1 mg/kg.

Knowledge Gaps—What is the optimal dose of tracheal epinephrine during pediatric cardiac arrest?

Defibrillation

The Pediatric Task Force evaluated several issues related to defibrillation, including safe and effective energy dosing, stacked versus single shocks, use of automated external defibrillators (AEDs) in infants <1 year of age and paddle/pad type, size, and position. There were a few new human and animal studies on these topics, and the level of evidence (LOE) was generally 3 to 5. No new data are available to support a change in drug treatment of recurrent or refractory VF/pulseless VT. There were several human and animal publications on defibrillation energy dose, but the data are contradictory and the optimal safe and effective energy dose remains unknown.

The new recommendation of an initial dose of 2 to 4 J/kg is based on cohort studies showing low success in termination of VF in children with 2 J/kg. However, these studies do not provide data on success or safety of higher energy doses. The reaffirmation of the recommendation for a single initial shock rather than stacked shocks (first made in 2005) is extrapolated from the ever-increasing adult data showing that long pauses in chest

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compressions required for stacked shocks are associated with worse resuscitation outcomes and that the initial shock success rate is relatively high with biphasic defibrillation.

No changes are recommended in pad/paddle size or position. Although the safety of AEDs in infants <1 year is unknown, case reports have documented successful defibrillation using AEDs in infants. A manual defibrillator or an AED with pediatric attenuation capabilities is preferred for use in infants and small children.

Paddle Size and Orientation[Peds029]

Consensus on Science—One LOE 5 study in adults[255] demonstrated that shock success increased from 31% to 82% when pad size was increased from 8 × 8 cm to 12 × 12 cm. Three pediatric LOE 4,[256–258] 3 adult LOE 5[255,259,260] and 3 LOE 5 animal[261–263] studies demonstrated that transthoracic impedance decreases with increasing pad size. Decreased transthoracic impedance increases transthoracic current and, thus, presumably, transmyocardial current.

Pad Position

Consensus on Science—One pediatric LOE 4 study[264] observed no difference in the rate of ROSC between antero-lateral and anterior-posterior electrode positions for shock delivery. One pediatric LOE 2 study,[256] 2 adult LOE 5 studies,[265,266] and 1 LOE 5 animal study[263] demonstrated that transthoracic impedance is not dependent on pad position. Transthoracic impedance was increased in 1 adult LOE 5[267] study by placing the pads too close together and in 1 LOE 5[260] study when the pads were placed over the female breast. Additionally, 1 adult LOE 5[268] study showed that placing the apical pad in a horizontal position lowers transthoracic impedance.

Treatment Recommendation—There is insufficient evidence to alter the current recommendations to use the largest size paddles/pads that fit on the infant or child's chest without touching each other or to recommend one paddle/pad position or type over another.

Self-Adhesive Pads Versus Paddles[Peds-043A, Peds-043B]

Consensus on Science—There are limited studies comparing self-adhesive defibrillation pads (SADPs) with paddles in pediatric cardiac arrest. One pediatric LOE 4[264] study demonstrated equivalent ROSC rates when paddles or SADPs were used. One LOE 5[269] adult out-of-hospital cardiac arrest study suggested improved survival to hospital admission when SADPs rather than paddles were used.

One adult LOE 5[270] study showed a lower rate of rhythm conversion, and 1 small adult LOE 5[271] study showed at least equivalent success with the use of SADPs in comparison with paddles in patients undergoing cardioversion for atrial fibrillation. Two adult LOE 5[272,273] studies showed equivalent transthoracic impedance with SADPs or paddles. One adult LOE 5[266] and 2 LOE 5 animal[274,275] studies showed that SADPs had a higher transthoracic impedance than paddles.

One LOE 4[276] study described difficulty with fitting self-adhesive pads onto the thorax of a premature infant without the pads touching. One LOE 5[277] study demonstrated the improved accuracy of cardiac rhythm monitoring following defibrillation using SADPs compared with the combination of paddles and gel pads.

Using standard resuscitation protocols in simulated clinical environments, 1 LOE 5[278] study found no significant difference in the time required to deliver shocks using either SADPs or

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paddles, and 1 LOE 5[279] study found no significant difference in time without compressions when SADPs or paddles were used.

Treatment Recommendations—Either self-adhesive defibrillation pads or paddles may be used in infants and children in cardiac arrest.

Knowledge Gaps—Is the use of hands-on defibrillation safe for rescuers and does it improve outcome for infants and children in cardiac arrest (eg, by presumably reducing interruptions in chest compressions)?

Number of Shocks[Peds-022A]

Consensus on Science—There are no randomized controlled studies examining a single versus sequential (stacked) shock strategy in children with VF/pulseless VT. Evidence from 7 LOE 5 studies in adults with VF[221,280–285] supported a single-shock strategy over stacked or sequential shocks because the relative efficacy of a single biphasic shock is high and the delivery of a single shock reduces duration of interruptions in chest compressions.

Treatment Recommendations—A single-shock strategy followed by immediate CPR (beginning with chest compressions) is recommended for children with out-of-hospital or in-hospital VF/pulseless VT.

Knowledge Gaps—Are there circumstances during which the use of stacked or multiple shocks can improve outcome from pediatric cardiac arrest?

Energy Dose[Peds-023A, Peds-023B]

Consensus on Science—Two LOE 4[264,286] studies reported no relationship between defibrillation dose and survival to hospital discharge or neurologic outcome from VF/pulseless VT. Evidence from 3 LOE 4 studies in children in out-of-hospital and in-hospital settings[264,287,288] observed that an initial dose of 2 J/kg was effective in terminating VF 18% to 50% of the time. Two LOE 4 studies[286,289] reported that children often received more than 2 J/kg during out-of hospital cardiac arrest, with many (69%) requiring ≥3 shocks of escalating energy doses. One in-hospital cardiac arrest LOE 4 study[264] reported that the need for multiple shocks with biphasic energy doses of 2.5 to 3.2 J/kg was associated with lack of ROSC.

Evidence from 2 LOE 5 animal studies[290,291] observed that 0% to 8% of episodes of long-duration VF were terminated by a 2 J/kg monophasic shock and up to 32% were terminated by biphasic shocks. Animals in these studies received both fixed and escalated doses, and most required 2 or more shocks to terminate VF. In 1 LOE 5 animal study[263] the defibrillation threshold for short-duration VF was 2.4 J/kg, whereas in another[291] it was 3.3 J/kg.

In 4 LOE 5 animal studies[290, 292–294] of AED shocks delivered using a pediatric attenuator, 50 J and 50→76→86 J (2.5to 4 J/kg) escalating doses were effective at terminating long-duration VF but required multiple shocks. In 1 LOE 5 animal study[295] 10 J/kg shocks were more effective at terminating long-duration VF (6 minutes) with 1 shock than 4 J/kg shocks.

In 2 LOE 4 pediatric studies[264,286] and 4 LOE 5 animal studies,[290,292–294] energy doses of 2 to 10 J/kg for short- or long-duration VF resulted in equivalent rates of survival. Myocardial damage, as assessed by hemodynamic or biochemical measurements, was less when a pediatric attenuator was used with an adult energy dose compared with a full adult AED dose, but the degree of myocardial damage was not associated with any difference in 4- or

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72-hour survival. An LOE 5 animal study[295] found no difference in hemodynamic parameters or biochemical measurements of myocardial damage comparing biphasic 150 J (4 J/kg) with monophasic 360 J/kg (10 J/kg) shocks.

In 2 LOE 5 animal studies[290,291] biphasic waveforms were more effective than monophasic waveforms for treatment of VF/pulseless VT. There areno human data that directly compare monophasic to biphasic waveforms for pediatric defibrillation.

Treatment Recommendations—An initial dose of 2 to 4 J/kg is reasonable for pediatric defibrillation. Higher subsequent energy doses may be safe and effective.

Knowledge Gaps—What is the minimum effective and maximum safe defibrillation energy dose for pediatric VF/pulseless VT? What is the optimal parameter (eg, weight or length) on which to base de fibrillation energy doses for infants and children? Should the energy dose for defibrillation be escalated for shock-refractory VF?

Does the use of biphasic waveforms when compared to monophasic waveforms improve outcome from pediatric cardiac arrest?

Amiodarone Versus Lidocaine for Refractory VF/Pulseless VT[Peds-019]

Consensus on Science—In 2 LOE 5 prospective out-of-hospital adult trials IV amiodarone improved ROSC and survival to hospital admission but not hospital discharge when compared with placebo[296] or lido\caine[297] for treatment of shock-refractory VF/pulseless VT. Evidence from 2 LOE 5 case series in children[298,299] supported the effectiveness of amiodarone for the treatment and acute conversion of life-threatening (nonarrest) ventricular arrhythmias. There are no pediatric data investigating the efficacy of lidocaine for shock refractory VF/pulseless VT.

Treatment Recommendations—Amiodarone may be used for the treatment of shock-refractory or recurrent VF/pulseless VT in infants and children; if amiodarone is not available, lidocaine may be considered.

Knowledge Gaps—Does the use of amiodarone compared with lidocaine improve outcome from shock-refractory or recurrent VF/pulseless VT in infants and children? Is lidocaine effective for the treatment of VF/pulseless VT in children?

AED Use in Infants[Peds-001A, Peds-001B]

Consensus on Science—One LOE 4[300] and 2 LOE 5[288,301] studies showed that infants in cardiac arrest (in- and out-of-hospital) may have shockable rhythms. Evidence from 3 LOE 5[302–304] studies showed that many AED devices can safely and accurately distinguish between a shockable and nonshockable rhythm in infants and children.

The optimal energy dose for defibrillation in infants has not been established, but indirect data from 5 LOE 5 animal studies[287,294,305–307] showed that the young myocardium may be able to tolerate high-energy doses. In 3 LOE 5 animal studies a pediatric attenuator used with an adult-dose biphasic AED shock was as effective and less harmful than monophasic weight-based doses[290] or biphasic adult doses.[292,293]

Two LOE 4 case reports[308,309] described survival of infants with out-of-hospital cardiac arrest when AED use was coupled with bystander CPR and defibrillation using an AED. Two pediatric LOE 5 case reports[310,311] noted successful defibrillation with minimal myocardial damage and good neurologic outcome using an AED with adult energy doses.

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Treatment Recommendations—For treatment of out-of-hospital VF/pulseless VT in infants, the recommended method of shock delivery by device is listed in order of preference below. If there is any delay in the availability of the preferred device, the device that is available should be used. The AED algorithm should have demonstrated high specificity and sensitivity for detecting shockable rhythms in infants. The order of preference is as follows:

1. Manual defibrillator
2. AED with dose attenuator
3. AED without dose attenuator

Knowledge Gaps—Is there a lower limit of infant size or weight below which an AED should not be used?

Arrhythmia Therapy[Peds-030]

The evidence on emergency treatment of arrhythmias was reviewed and the only change was the addition of procainamide as possible therapy for refractory supraventricular tachycardia (SVT).

Unstable VT

Consensus on Science—There is insufficient evidence to support or refute the efficacy of electric therapy over drug therapy or the superiority of any drug for the emergency treatment of unstable VT in the pediatric age group. In 2 LOE 5 adult case series,[312,313] early electric cardioversion was effective for treatment of unstable VT.

In 4 small LOE 4 pediatric case se-ries[298,299,314,315] amiodarone was effective in the management of VT. One prospective randomized multicenter safety and efficacy LOE 2 trial evaluating amiodarone for the treatment of pediatric tachyarrhythmias[316] found that 71% of children treated with amiodarone experienced cardiovascular side effects. Both efficacy and adverse events were dose-related.

Treatment Recommendation—It is reasonable to use synchronized electric cardioversion as the preferred first therapy for pediatric VT with hypotension or evidence of poor perfusion. If drug therapy is used to treat unstable VT, amiodarone may be a reasonable choice, with careful hemodynamic monitoring performed during its slow delivery.

Knowledge Gaps—What is the optimal dose of energy for synchronized cardioversion during treatment of unstable VT in pediatric patients?

Drugs for Supraventricular Tachycardia[Peds-031]

Consensus on Science—Twenty-two LOE 4 studies in infants and children[317–338] demonstrated the effectiveness of adenosine for the treatment of hemodynamically stable or unstable SVT. One LOE 4 study[339] and 4 larger LOE 5 studies involving teenagers and adults[340–343] also demonstrated the efficacy of adenosine, although frequent but transient side effects were reported.

One LOE 2 study[344] showed highly successful (approximately 90%) treatment of SVT in infants and children using adenosine or verapamil and superiority of these drugs to digitalis (61% to 71%). One LOE 5 randomized prospective adult study[345] and 1 LOE 5 meta-analysis, primarily involving adults but including some children,[346] demonstrated the effectiveness of verapamil and adenosine in treating SVT and highlighted the cost-effectiveness of verapamil over adenosine.

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One LOE 4 randomized, prospective study[316] and 15 LOE 4 small case series and observational studies in infants and children[298, 299, 314, 315, 347–357] showed that amiodarone was effective in the treatment of supraventricular tachyarrhythmias. Generalization to pediatric SVT treatment with amiodarone may be limited, however, since most of these studies in children involved postoperative junctional tachycardia.

Rare but significant side effects have been reported in association with rapid administration of amiodarone. Bradycardia and hypotension were reported in 1 prospective LOE 4 study,[316] cardiovascular collapse was reported in 2 LOE 5 case reports,[358,359] and polymorphic VT was reported in 1 small LOE 4 case se ries.[360] Other LOE 5 case reports describe late side effects of pulmonary toxicity[359] and hypothyroidism.[362]

In 1 LOE 2 pediatric comparison control study[363] procainamide had a significantly higher success rate and an equal incidence of adverse effects when compared with amiodarone for treating refractory SVT. In 5 LOE 4 observational studies[364 –368] and 5 LOE 5 case reports[369–373] procainamide effectively suppressed or slowed the rate in children with SVT. A wide variety of arrhythmias were studied, including ectopic atrial tachycardia, atrial flutter, and orthodromic reciprocating tachycardia.

In LOE 5 studies in children,[374] adults,[375,376] and animals,[377] hypotension from procainamide infusion resulted from vasodilation and not decreased myocardial contractility. Initial observational LOE 4 reports[378–380] and 1 LOE 4 case series[381] described successful treatment of pediatric SVT with verapamil. However, multiple small LOE 4 case series[344,382] and LOE 5 case reports[383,384] documented severe hypotension, bradycardia, and heart block causing hemodynamic collapse and death following IV administration of verapamil for SVT in infants. Two small LOE 4 pediatric case series[385,386] described esmolol and dexmedetomidine in the treatment of SVT.

Treatment Recommendations—For infants and children with SVT with a palpable pulse, adenosine should be considered the preferred medication. Verapamil may be considered as alternative therapy in older children but should not be routinely used in infants. Procainamide or amiodarone given by a slow IV infusion with careful hemodynamic monitoring may be considered for refractory SVT.

Knowledge Gaps—Does the use of alternate medications (eg, esmolol, dexmedetomidine) in the treatment of SVT in infants and children improve outcome? What is the role of vagal maneuvers in the treatment of SVT?

Shock

The Task Force reviewed evidence related to several key questions about the management of shock in children. There is ongoing uncertainty about the indications for using colloid versus crystalloid in shock resuscitation. One large adult trial suggested that normal saline (isotonic crystalloid) is equivalent to albumin, although subgroup analysis suggested harm associated with the use of colloid in patients with traumatic brain injury. There were insufficient data to change the 2005 recommendations.

The optimal timing for intubation of children in shock remains unclear, although reports of children and adults with septic shock suggested potential beneficial effects of early intubation (before signs of respiratory failure develop) combined with a protocol driven management approach. When children in septic shock were treated with a protocol that included therapy directed to normalizing central venous oxygen saturation, patient outcome appeared to improve.

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Performing rapid sequence induction and tracheal intubation of a child with shock can cause acute cardiovascular collapse. Etomidate typically causes less hemodynamic compromise than other induction drugs and is therefore often used in this setting. However, data suggest that the use of this drug in children and adults with septic shock is associated with increased mortality that may be secondary to etomidate's inhibitory effects on corticosteroid synthesis. Administering stress-dose corticosteroids in septic shock remains controversial, with recent adult trials failing to show a beneficial effect.

Graded Volume Resuscitation for Hemorrhagic Shock[Peds-032]

Consensus on Science—There are no pediatric studies of the timing or extent of volume resuscitation in hemorrhagic shock with hypotension. Nine LOE 5 adult[387–395] studies reported conflicting results with regard to the effect of timing and extent of volume resuscitation on outcome of hemorrhagic shock with hypotension.

Treatment Recommendations—There is insufficient evidence as to the best timing or quantity for volume resuscitation in infants and children with hemorrhagic shock following trauma.

Knowledge Gaps—What is the appropriate clinical indicator for volume resuscitation during treatment of hemorrhagic shock in infants and children?

Early Ventilation in Shock[Peds-038B]

Consensus on Science—There are no studies investigating the role of intubation and assisted ventilation before the onset of respiratory failure in infants and children with shock. Two LOE 5 animal studies in septic shock[396,397] and 1 LOE 5 animal study in pericardial tamponade[398] showed improved hemodynamics and select organ perfusion with intubation before the onset of respiratory failure. One report of 2 adult patients[399] (LOE 5) described cardiac arrest following intubation of 1 adult patient with tamponade due to penetrating trauma and improvement in hemodynamics during spontaneous breathing in 1 mechanically ventilated adult patient with post–cardiac surgery tamponade.

One LOE 5 study of septic shock in adults[400] suggested a reduced mortality with early ventilation compared with historic controls who only received ventilation for respiratory failure. One LOE 5 study of animals in septic shock[401] showed that early assisted ventilation does not reduce oxygen extraction or prevent the development of lactic acidosis.

Treatment Recommendations—There is insufficient evidence to support or refute the use of endotracheal intubation of infants and children in shock before the onset of respiratory failure.

Knowledge Gaps—Does the timing of respiratory support in infants and children with shock affect outcome?

Colloid Versus Crystalloid Fluid Administration[Peds-044A, Peds-044B]

Consensus on Science—Evidence from 3 randomized blinded LOE 1 controlled trials in children with dengue shock syndrome[402–404] and 1 LOE 1 open randomized trial in children with septic shock[405] suggested no clinically important differences in survival from therapy with colloid versus therapy with isotonic crystalloid solutions for shock.

In 1 large LOE 5 randomized controlled trial of fluid therapy in adult ICU pa-tients[406] and in 6 good-quality LOE 5 meta-analyses, predominantly of adults,[407–412] no mortality

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differences were noted when colloid was compared with hypertonic and isotonic crystalloid solutions, and no differences were noted between types of colloid solutions.

Three LOE 5 studies comparing the use of crystalloids and colloids for adults in shock suggested that crystalloid may have an associated survival benefit over colloid in subgroups of patients with shock, including general trauma,[409] traumatic brain injury,[413] and burns.[414] One randomized controlled LOE 5 study of children with severe malaria suggested better survival with colloid than with crystalloid infusion.[415]

Treatment Recommendations—Isotonic crystalloids are recommended as the *initial* resuscitation fluid for infants and children with any type of shock. There is insufficient evidence to identify the superiority of any specific isotonic crystalloid over others.

Knowledge Gaps—Does the use of any specific crystalloid solution (Ringer's lactate, normal saline, hypertonic saline) improve outcome for pediatric shock? Are there subgroups of children in shock whose outcome is improved with the use of colloid compared with crystalloid?

Vasoactive Agents in Distributive Shock[Peds-045A, Peds-045B]

Consensus on Science—One LOE 4 observational study[416] suggested that the course of pediatric septic shock physiology is dynamic and that serial assessments are required to titrate the type and dose of inotropes or vasopressor therapy to achieve optimal hemodynamic results. Evidence from 4 LOE 1 pediatric randomized controlled studies,[417–420] 3 LOE 5 adult randomized controlled studies,[421–423] and 1 LOE 5 adult systematic review[424] showed that no inotrope or vasopressor is superior in reducing mortality from pediatric or adult distributive shock.

Two LOE 1 pediatric randomized controlled studies[417,418] showed that children with “cold” (ie, low cardiac index) septic shock improved hemodynamically with brief (4-hour) administration of milrinone (bolus and infusion). One LOE 1 pediatric randomized controlled study[420] of vasodilatory shock compared the addition of vasopressin versus placebo to standard vasoactive agents and showed no change in duration of vasopressor infusion but observed a trend toward increased mortality.

Eleven small LOE 4 pediatric case se ries[425–435] showed improved hemodynamics but not survival when vasopressin or terlipressin was administered to children with refractory, vasodilatory, septic shock.

Treatment Recommendations—There is insufficient evidence to recommend a specific inotrope or vasopressor to improve mortality in pediatric distributive shock. Selection of an inotrope or vasopressor to improve hemodynamics should be tailored to each patient's physiology and adjusted as clinical status changes.

Knowledge Gaps—Does the use of any specific vasoactive agent improve outcome for infants and children with distributive shock?

Vasoactive Agents in Cardiogenic Shock[Peds-046A]

Consensus on Science—One LOE 4 pediatric case series[436] showed that critically ill children requiring inotropic support have wide variability in hemodynamic responses to different infusion rates of dobutamine. One LOE 2 blinded crossover study[437] found dopamine and dobutamine had equal hemodynamic effects in infants and children requiring

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post–cardiac surgical inotropic support but that dopamine at an infusion rate of >7 mcg/kg per minute increased pulmonary vascular resistance.

Six LOE 3 studies[438–443] showed that both dopamine and dobutamine infusions improve hemodynamics in children with cardiogenic shock.

Evidence from 1 LOE 1 pediatric placebo controlled trial[444] showed that milrinone is effective in preventing low cardiac output syndrome in infants and children following biventricular cardiac repair. One LOE 4 study[445] showed that milrinone improved cardiac index in neonates with low cardiac output following cardiac surgery.

One small LOE 1 study[446] showed that children had better hemodynamic parameters and shorter ICU stays if they received milrinone compared with low-dose epinephrine plus nitroglycer in for inotropic support following repair of tetralogy of Fallot.

In 2 LOE 4 small case series,[447,448] when children with heart failure secondary to myocardial dysfunction were given levosimendan, they demonstrated improved ejection fraction, required a shorter duration of catecholamine in fusions,[447] and showed a trend toward improved hemodynamics and reduced arterial lactate levels.[448]

In subgroup analysis from 1 LOE 5 randomized controlled trial in adults,[449] patients with cardiogenic shock treated with norepinephrine versus dopamine had an improved survival at 28 days. When all causes of shock were included, patients treated with norepinephrine also had fewer arrhythmias than those treated with dopamine (12% versus 24%).

Treatment Recommendations—The catecholamine dose for inotropic support in cardiogenic shock must be individually titrated because there is a wide variability in clinical response. It is reasonable to use epinephrine, levosimendan, dopamine, or dobutamine for inotropic support in infants and children with cardiogenic shock. Milrinone may be beneficial for the prevention and treatment of low cardiac output following cardiac surgery.

There are insufficient data to support or refute the use of norepinephrine in pediatric cardiogenic shock.

Knowledge Gaps—Does the use of any specific vasoactive agent improve outcome for infants and children with cardiogenic shock who have not undergone cardiac surgery?

Etomidate for Intubation in Hypotensive Septic Shock[Peds-047A, Peds-047B]

Consensus on Science—One LOE 4 study of children with septic shock[450] showed that adrenal suppression occurred after the administration of a single dose of etomidate and persisted for at least 24 hours. Evidence from 2 LOE 4[451,452] studies and 1 LOE 5[453] study showed that etomidate can be used to facilitate tracheal intubation in infants and children with minimal hemodynamic effect, but very few of these reports included patients with hypotensive septic shock. One LOE 4 study[450] suggested an association with mortality when etomidate is used to facilitate the intubation of children with septic shock.

One adult LOE 5 study[454] observed an increased mortality associated with the use of etomidate for intubation of patients in septic shock, even with steroid supplementation. Conversely, 1 underpowered adult LOE 5 study[455] in septic patients did not show an increase in mortality.

One multicenter adult LOE 5 comparative trial of etomidate versus ketamine for intubation[456] found no difference in organ failure over the first 72 hours and no mortality

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difference, but this study included only a small number of patients with shock. Adrenal insufficiency was more common in etomidate-treated patients.

Treatment Recommendations—Etomidate should not be routinely used when intubating an infant or child with septic shock. If etomidate is used in infants and children with septic shock, the increased risk of adrenal insufficiency should be recognized.

Knowledge Gaps—If etomidate is used, does steroid administration improve outcome for infants and children with septic shock?

Corticosteroids in Hypotensive Shock[Peds-049A, Peds-049B]

Consensus on Science—In 6 LOE 5 randomized controlled trials in adults with septic shock[454,457–461] the addition of low-dose hydrocortisone decreased the time to shock reversal. Three LOE 5 randomized controlled trials in adults with vasopressor-dependent septic shock[457,462,463] showed that survival was improved when low-dose hydrocortisone was administered, while 1 small adult LOE 5 randomized controlled trial[464] showed a trend toward increased survival.

One fair-quality, small LOE 1 study in children with septic shock[465] found that low-dose hydrocortisone administration resulted in no survival benefit. One fair-quality LOE 1 study of administration of low-dose hydrocortisone to children with septic shock[466] demonstrated earlier shock reversal. Data from 1 LOE 4 hospital discharge database[467] noted the association between the use of steroids in children with severe sepsis and decreased survival.

In 1 LOE 5 study in adults with septic shock[457] survival improved significantly with the use of low-dose hydro cortisone and fludrocortisone compared with placebo. Conversely 4 LOE 5 adult trials in septic shock[454,459–461] showed no survival benefit with low dose corticosteroid therapy. In 1 large LOE 5 randomized controlled trial of adults in septic shock,[454] corticosteroid administration was associated with an increased risk of secondary infection.

Treatment Recommendations—There is insufficient evidence to support or refute the routine use of stress-dose or low-dose hydrocortisone and/or other corticosteroids in infants and children with septic shock. Stress-dose corticosteroids may be considered in children with septic shock unresponsive to fluids and requiring vasoactive support.

Knowledge Gaps—What is the appropriate “stress dose” of hydrocortisone for hypotensive septic shock? Should the dose of hydrocortisone be titrated to the degree of shock? Should an adrenocorticotrophin (ACTH) stimulation test be performed to determine if an infant or child in septic shock has adrenal insufficiency?

Diagnostic Tests as Guide to Management of Shock[Peds-050A, Peds-050B]

Consensus on Science—In 1 LOE 1 randomized controlled trial in children with severe sepsis or fluid-refractory septic shock,[468] protocol-driven therapy that included targeting a superior vena caval oxygen saturation >70%, coupled with treating clinical signs of shock (prolonged capillary refill, reduced urine output, and reduced blood pressure), improved patient survival to hospital discharge in comparison to treatment guided by assessment of clinical signs alone.

Two LOE 5 studies of adults with septic shock, one a randomized controlled trial[469] and the other a cohort study,[470] documented improved survival to hospital discharge following implementation of protocol-driven early goal directed therapy, including titration to a central

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venous oxygen saturation (S_{vco_2}) ≥70%. In 1 large multicenter LOE 5 adult study[471] evaluating the "Surviving Sepsis" bundle, early goal-directed therapy to achieve an S_{vco_2} ≥70% was not associated with an improvement in survival, but venous oxygen saturations were measured in <25% of participants.

There are insufficient data on the utility of other diagnostic tests (eg, pH, lactate) to help guide the management of infants and children with shock.

Treatment Recommendations—A protocol-driven therapy, which includes titration to a superior vena caval oxygen saturation ≥70%, may be beneficial for infants and children (without cyanotic congenital heart disease) with fluid-refractory septic shock. No treatment recommendations can be made to target S_{vco_2} saturation in the management of fluid-refractory septic shock in pediatric patients with cyanotic congenital heart disease or for other forms of pediatric shock.

Knowledge Gaps—What is the optimal diagnostic test (ie, lactate, S_{vco_2}) to guide management of pediatric shock? Does continuous versus intermittent S_{vco_2} monitoring affect outcome?

Medications in Cardiac Arrest and Bradycardia

The Task Force reviewed and updated evidence to support medications used during cardiac arrest and bradycardia, but no new recommendations were made. It was again emphasized that calcium and sodium bicarbonate should not be routinely used in pediatric cardiac arrest (ie, should not be used without specific indications).

Calculating Drug Dose[Peds017B]

Consensus on Science—Eight LOE 5 studies[472–479] concluded that length-based methods are more accurate than age-based or observer (parent or provider) estimate-based methods in the prediction of body weight. Four LOE 5 studies[472,474,480,481] suggested that the addition of a category of body habitus to length may improve prediction of body weight.

Six LOE 5 studies[482–487] attempted to find a formula based on drug pharmacokinetics and physiology that would allow the calculation of a pediatric dose from the adult dose.

Treatment Recommendations—In nonobese pediatric patients, initial resuscitation drug doses should be based on actual body weight (which closely approximates ideal body weight). If necessary, body weight can be estimated from body length.

In obese patients the initial doses of resuscitation drugs should be based on ideal body weight that can be estimated from length. Administration of drug doses based on actual body weight in obese patients may result in drug toxicity.

Subsequent doses of resuscitation drugs in both nonobese and obese patients should take into account observed clinical effects and toxicities. It is reasonable to titrate the dose to the desired therapeutic effect, but it should not exceed the adult dose.

Knowledge Gaps—What is the most accurate method for calculating resuscitation drug doses for children? Does the accuracy of the estimated weight used to calculate drug dose affect patient outcome? Do specific resuscitation drugs require different adjustments for estimated weight, maturity and/or body composition?

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Are formulas for scaling drug doses with formulas from adult doses superior to existing weight-based methods?

Epinephrine Dose[Peds-018]

Consensus on Science—No studies have compared epinephrine versus placebo administration for pulseless cardiac arrest in infants and children. One LOE 5 randomized controlled adult study[488] of standard drug therapy compared with no drug therapy during out-of-hospital cardiac arrest showed improved survival to hospital admission with any drug delivery but no difference in survival to hospital discharge.

Evidence from 1 LOE 1 prospective, randomized, controlled trial,[489] 2 LOE 2 prospective trials,[490,491] and 2 LOE 2 case series with concurrent controls[492,493] showed no increase in survival to hospital discharge or improved neurologic outcome when epinephrine doses of >10 mcg/kg IV were used in out-of-hospital or in-hospital pediatric cardiac arrest. In 1 LOE 1 prospective trial[489] of pediatric in-hospital cardiac arrest comparing high-dose (100 mcg/kg) with standard-dose epinephrine administered if cardiac arrest persisted after 1 standard dose of epinephrine, 24-hour survival was reduced in the high-dose epinephrine group.

Evidence extrapolated from adult prehospital or in-hospital studies, including 9 LOE 1 randomized trials,[494–502] 3 LOE 2 trials,[503–505] and 3 LOE 3 studies,[506–508] showed no improvement in survival to hospital discharge or neurologic outcome when doses >1 mg of epinephrine were given.

Treatment Recommendations—In infants and children with out-of-hospital or in-hospital cardiac arrest, the appropriate dose of IV epinephrine is 10 mcg/kg per dose (0.01 mg/kg) for the first and for subsequent doses. The maximum single dose is 1 mg.

Knowledge Gaps—Does epinephrine administration improve outcome from cardiac arrest in infants and children? Are there specific patients or arrest types (eg, prolonged arrest, asphyxial arrest, VF arrest) for which epinephrine is more effective?

Sodium Bicarbonate During Cardiac Arrest[Peds-028]

Consensus on Science—There are no randomized controlled studies in infants and children examining the use of sodium bicarbonate as part of the management of pediatric cardiac arrest. One LOE 2 multicenter retrospective in-hospital pediatric study[509] found that sodium bicarbonate administered during cardiac arrest was associated with decreased survival, even after controlling for age, gender, and first documented cardiac rhythm.

Two LOE 5 randomized controlled studies have examined the value of sodium bicarbonate in the management of arrest in other populations: 1 adult out-of-hospital cardiac arrest study[510] and 1 study in neonates with respiratory arrest in the delivery room.[511] Both failed to show an improvement in overall survival.

Treatment Recommendations—Routine administration of sodium bicarbonate is not recommended in the management of pediatric cardiac arrest.

Knowledge Gaps—Are there circumstances under which sodium bicarbonate administration improves outcome from pediatric cardiac arrest?

Vasopressin[Peds-020A, Peds-020B]

Consensus on Science—In 1 pediatric LOE 3 study[512] vasopressin was associated with lower ROSC and a trend toward lower 24-hour and discharge survival. In 3 pediatric LOE

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4[513–515] and 2 adult LOE 5[516,517] case series/reports (9 patients) vasopressin[513] or its long-acting analogue, terlipressin,[514,515] administration was associated with ROSC in patients with refractory cardiac arrest (ie, standard therapy failed).

Extrapolated evidence from 6 LOE 5 adult studies[518–523] and 1 LOE 1 adult meta-analysis[524] showed that vasopressin used either by itself or in combination with epinephrine during cardiac arrest does not improve ROSC, hospital discharge, or neurologic outcome. Evidence from 1 LOE 5 animal study[525] of an infant asphyxial arrest model showed no difference in ROSC when terlipressin was administered alone or in combination with epinephrine as compared with epinephrine alone.

Treatment Recommendations—There is insufficient evidence for or against the administration of vasopressin or its long-acting analogue, terlipressin, in pediatric cardiac arrest.

Knowledge Gaps—Are there patient subgroups who might benefit from vasopressin (with or without other vasopressors) for pediatric cardiac arrest? Does the use of “early” versus “late” (ie, rescue) vasopressin affect outcome in pediatric cardiac arrest? Is vasopressin effective when administered via a tracheal tube?

Calcium in Cardiac Arrest[Peds-021A, Peds-021B]

Consensus on Science—Evidence from 3 LOE 2[509,526,527] studies in children and 5 LOE 5 adult studies[528–532] failed to document an improvement in survival to hospital admission, hospital discharge, or favorable neurologic outcome when calcium was administered during cardiopulmonary arrest in the absence of documented hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia. Four LOE 5 animal studies[533–536] showed no improvement in ROSC when calcium, compared with epinephrine or placebo, was administered during cardiopulmonary arrest.

Two studies investigating calcium for in-hospital pediatric cardiac arrest suggested a potential for harm. One LOE 2 study examining data from the NRCPR[526] observed an adjusted odds ratio of survival to hospital discharge of 0.6 in children who received calcium, and 1 LOE 3 multicenter study[509] showed an odds ratio for increased hospital mortality of 2.24 associated with the use of calcium. One LOE 2 study of cardiac arrest in the PICU setting[527] suggested a potential for harm with the administration of calcium during cardiac arrest; the administration of 1 or more boluses was an independent predictor of hospital mortality.

Treatment Recommendations—Routine use of calcium for infants and children with cardiopulmonary arrest is not recommended in the absence of hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia.

Knowledge Gaps—Are there indications for calcium administration that may be associated with improved outcome from pediatric cardiac arrest? Does the increased mortality risk associated with calcium administration reflect harm from calcium or does it simply identify patients who failed to respond to other ALS interventions and therefore were at a higher risk of death?

Atropine Versus Epinephrine for Bradycardia[Peds-052A]

Consensus on Science—Evidence from 1 LOE 3 study of in-hospital pediatric cardiac arrest[537] observed an improved odds of survival to discharge for those patients who received atropine based on multivariate analysis, whereas the use of epinephrine was associated with

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decreased odds of survival. Another large LOE 3 study[538] demonstrated no association between atropine administration and survival.

In 1 LOE 5 adult case series,[539] 6 of 8 patients in cardiac arrest who did not respond to epinephrine did respond to atropine with a change to a perfusing rhythm; 3 survived to hospital discharge. An LOE 5 retrospective adult review[540] observed that a small number of asystolic patients who failed to respond to epinephrine did respond to atropine, but none survived to hospital discharge.

Four LOE 5 adult studies[541–544] showed a benefit of atropine in vagally mediated bradycardia. One small LOE 4 pediatric case series[545] showed that atropine is more effective than epinephrine in increasing heart rate and blood pressure in children with post–cardiac surgical hypotension and bradycardia (Bezold-Jarisch reflex mediated bradycardia).

Four LOE 5 adult[542,546–548] and 4 LOE 5 animal[549–552] studies showed no benefit from atropine used to treat bradycardia or cardiac arrest. One LOE 5 animal study[553] did show a benefit of atropine when used with epinephrine in cardiac arrest.

Treatment Recommendations—Epinephrine may be used for infants and children with bradycardia and poor perfusion that is unresponsive to ventilation and oxygenation. It is reasonable to administer atropine for bradycardia caused by increased vagal tone or cholinergic drug toxicity. There is insufficient evidence to support or refute the routine use of atropine for pediatric cardiac arrest.

Knowledge Gaps—What is the optimal dose of epinephrine for pediatric bradycardia? Is there a role for titrated doses? Does the use of epinephrine versus atropine improve outcome from pediatric bradycardia? Are there circumstances under which atropine administration improves outcome from pediatric cardiac arrest?

Extracorporeal Cardiac Life Support[peds014, Peds-014b]

There is increasing evidence that extracorporeal cardiac life support (ECLS) can act as a bridge to maintain oxygenation and circulation in selected infants and children with cardiac arrest if they are transplant candidates or have a self-limited or treatable illness. When ECLS is initiated for the treatment of cardiac arrest, it is referred to as ECPR (extracorporeal CPR). ECPR can only be employed if the cardiac arrest occurs in a monitored environment with protocols and personnel for rapid initiation.

Consensus on Science

One LOE 2[554] and 26 LOE 4 studies[555–580] reported favorable early outcome after ECPR in children with primary cardiac disease who were located in an ICU or other highly supervised environment using ECPR protocols at the time of the arrest.

One LOE 2[554] and 2 LOE 4[555,564] studies indicated poor outcome from ECPR in children with noncardiac diseases.

In 1 LOE 4 study[556] survival following ECPR in children was associated with shorter time interval between arrest and ECPR team activation and shorter CPR duration. Two LOE 4 studies[560,581] found insignificant improvements in outcome after ECPR in children following protocol changes leading to shorter durations of CPR. One LOE 2[554] and 3 LOE 4[555,559,565] studies found no relationship between CPR duration and outcome after ECPR in children.

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Three small LOE 4 studies,[582–584] including a total of 21 children, showed favorable outcome with ECPR following outof-hospital cardiac arrest associated with environmentally induced severe hypothermia (temperature <30°C).

Treatment Recommendations

ECPR may be beneficial for infants and children with cardiac arrest if they have heart disease amenable to recovery or transplantation and the arrest occurs in a highly supervised environment such as an ICU with existing clinical protocols and available expertise and equipment to rapidly initiate ECPR. There is insufficient evidence for any specific threshold for CPR duration beyond which survival with ECPR is unlikely. ECPR may be considered in cases of environmentally induced severe hypothermia (temperature <30°C) for pediatric patients with out-of-hospital cardiac arrest if the appropriate expertise, equipment, and clinical protocols are in place.

Knowledge Gaps

What are the long-term neurologic outcomes of pediatric patients treated with ECPR? Is there an upper limit for the duration of standard CPR beyond which using ECPR will be of no benefit?

Post-Resuscitation Care

The Task Force reviewed evidence regarding hypothermia for pediatric patients who remain comatose following resuscitation from cardiac arrest. There is clear benefit for adult patients who remain comatose after VF arrest, but there is little evidence regarding effectiveness for infants (ie, beyond the neonatal period) and young children who most commonly have asphyxial arrest.

Some patients with sudden death without an obvious cause have a genetic abnormality of myocardial ion channels (ie, a channelopathy), which presumably leads to a fatal arrhythmia. Because this is an inherited abnormality, family members might be affected, but special tests are required for the detection of this inherited genetic defect.

Hypothermia[Peds-010A, Peds-010B]

Consensus on Science—There are no randomized pediatric studies on induced therapeutic hypothermia following cardiac arrest.

Two prospective randomized LOE 5 studies of adults with VF arrest[585,586] and 2 prospective randomized LOE 5 studies of newborns with birth asphyx-ia[587,588] showed that therapeutic hypothermia (32° to 34°C) up to 72 hours after resuscitation has an acceptable safety profile and may be associated with better long-term neurologic outcome.

One LOE 2 observational study[589] neither supports nor refutes the use of therapeutic hypothermia after resuscitation from pediatric cardiac arrest. However, patients in this study were not randomized, and the cooled patients were much sicker and younger than those not cooled.

Treatment Recommendations—Therapeutic hypothermia (to 32°C to 34°C) may be beneficial for adolescents who remain comatose following resuscitation from sudden witnessed out-of-hospital VF cardiac arrest. Therapeutic hypothermia (to 32°C to 34°C) may be considered for infants and children who remain comatose following resuscitation from cardiac arrest.

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Knowledge Gaps—Does therapeutic hypothermia improve outcome following pediatric cardiac arrest? Is there a difference in effectiveness for VF arrest versus asphyxial arrest? What is the optimal protocol for cooling after pediatric cardiac arrest (timing, duration, goal temperature, rate of rewarming)?

Vasoactive Drugs[Peds-024A, Peds-024B]

Consensus on Science—There are no studies evaluating the role of vasoactive medications after ROSC in children. Evidence from 2 LOE 3 studies in children,[590,591] 2 LOE 5 studies in adults,[592,593] and 2 LOE 5 animal studies[594,595] documented that myocardial dysfunction and vascular instability are common following resuscitation from cardiac arrest.

Evidence from 6 LOE 5 animal stud ies[594–599] documented hemodynamic improvement when vasoactive medications (dobutamine, milrinone, levosimendan) were given in the post–cardiac arrest period. Evidence from 1 large LOE 5 pediatric[444] and 4 LOE 5 adult[600–603] studies of patients with low cardiac output or at risk for low cardiac output following cardiac surgery documented consistent improvement in hemodynamics when vasoactive medications were administered.

Treatment Recommendations—It is reasonable to administer vasoactive medications to infants and children with documented or suspected cardiovascular dysfunction after cardiac arrest. These vasoactive medications should be selected and titrated to improve myocardial function and/or organ perfusion while trying to limit adverse effects.

Knowledge Gaps—What is the optimal vasoactive drug regimen for postarrest myocardial dysfunction in infants and children?

Glucose[Peds-016]

Consensus on Science—There is insufficient evidence to support or refute any specific glucose management strategy in infants and children following cardiac arrest. Although there is an association of hyperglycemia and hypoglycemia with poor outcome following ROSC after cardiac arrest, there are no studies that show causation and no studies that show that the treatment of either hyperglycemia or hypoglycemia following ROSC improves outcome.

Two studies of adult survivors of cardiac arrest, including 1 LOE 5 prospective observational study[604] and 1 LOE 5 randomized controlled trial comparing tight with moderate glucose con trol[605] observed no survival benefit with tight glucose control. Two studies of tight glucose control in adult surgical ICU patients, including 1 LOE 1 prospective randomized controlled trial[606] and 1 LOE 1 meta-analysis[607] observed reduced mortality with tight glucose control. Two LOE 5 meta-analyses comparing tight with moderate glucose control in adult ICU patients[608,609] and 1 LOE 5 randomized controlled trial comparing tight with moderate glucose control in adult medical ICU patients[610] observed no differences in survival. Three LOE 5 studies of tight glucose control in adult ICU patients, including 1 randomized controlled trial in cardiac surgical patients,[611] 1 multicenter randomized controlled trial in medical and surgical ICU patients,[612] and 1 cohort-controlled study of medical and surgical ICU patients[613] demonstrated increased mortality with tight glucose control.

One LOE 5 randomized controlled trial of critically ill children[614] observed an improvement in inflammatory biochemical markers and reduced ICU length of stay with tight glucose control. One study of tight glucose control of critically ill neonates[615] was terminated early

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for reasons of futility. Significant rates of hypoglycemia are widely reported with the use of tight glucose control without explicit methodology or continuous glucose monitoring in critically ill neonates,[615] children,[614] and adults.[607,608,612]

Evidence from LOE 5 animal studies of neonatal cerebral ischemia[616] and critically ill adults[617,618] suggest that hypoglycemia combined with hypoxia and ischemia is harmful and associated with higher mortality. Evidence from 3 LOE 5 animal studies[619–621] showed that prolonged hyperglycemia after resuscitation is harmful to the brain. One LOE 5 animal study[622] showed that glucose infusion with associated hyperglycemia after resuscitation worsened outcome, whereas another LOE 5 animal study[623] showed that moderate hyperglycemia managed with insulin improved neurologic outcome.

Treatment Recommendations—It is appropriate to monitor blood glucose levels and avoid hypoglycemia as well as sustained hyperglycemia following cardiac arrest. There is insufficient evidence to recommend specific strategies to manage hyperglycemia in infants and children with ROSC following cardiac arrest. If hyperglycemia is treated following ROSC in children, blood glucose concentrations should be carefully monitored to reduce episodes of hypoglycemia.

Knowledge Gaps—Does the use of “tight” glucose control improve outcome following pediatric cardiac arrest?

Channelopathy[Peds-048A, Peds-048B]

Consensus on Science—In 4 LOE 4 studies[624–627] 14% to 35% of young patients with sudden, unexpected death had no abnormalities found at autopsy.

In 7 LOE 3 studies[628–634] mutations causing channelopathies occurred in 2% to 10% of infants with sudden infant death syndrome noted as the cause of death. In 1 LOE 3[635] and 2 LOE 4[636,637] studies 14% to 20% of young adults with sudden, unexpected death had no abnormalities on autopsy but had genetic mutations causing channelopathies. In 4 LOE 4 studies,[638–641] using clinical and laboratory (electrocardiographic, molecular-genetic screening) investigations, 22% to 53% of first- and second-degree relatives of patients with sudden, unexplained death had inherited, arrhythmogenic disease.

Treatment Recommendation—When sudden unexplained cardiac arrest occurs in children and young adults, a complete past medical and family history (including a history of syncopal episodes, seizures, unexplained accidents/drownings, or sudden death) should be obtained and any available previous ECGs should be reviewed. All infants, children, and young adults with sudden, unexpected death should, if possible, have an unrestricted, complete autopsy, preferably performed by pathologists with training and expertise in cardiovascular pathology. Consideration should be given to preservation and genetic analysis of tissue to determine the presence of a channelopathy. It is recommended that families of patients whose cause of death is not found on autopsy be referred to a healthcare provider or center with expertise in cardiac rhythm disturbances.

Knowledge Gaps—What is the population-based incidence of inherited arrhythmic deaths in patients with sudden, unexpected death and a negative autopsy? What are the most effective strategies (eg, for emergency medicine physician, primary care provider, coroner, or others) to identify families at risk?

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Special Situations

New topics introduced in this document include resuscitation of infants and children with certain congenital cardiac abnormalities, namely single ventricle following stage I procedure and following the Fontan or bidirectional Glenn procedures (BDGs) as well as resuscitation of infants and children with cardiac arrest and pulmonary hypertension.

Life Support for Trauma[Peds-041A, Peds-041B]

Consensus on Science—Cardiac arrest (out-of-hospital and in-hospital) due to major (blunt or penetrating) injury (out-of-hospital and in-hospital) in children has a very high mortality rate.[642–645] In 1 LOE 4[645] and 1 LOE 5[117] study there was no survival advantage to intubating child victims of traumatic cardiac arrest in the out-of-hospital setting. One LOE 2[646] and 4 LOE 4[647–650] studies suggested that there is minimal survival advantage associated with resuscitative thoracotomy with or without internal cardiac massage for blunt trauma–induced cardiac arrest in children. Two LOE 4 studies[648,649] suggested that survival in children with cardiac arrest from penetrating trauma is improved by thoracotomy if time from event to hospital is short and signs of life are restored in the field.

Treatment Recommendations—There is insufficient evidence to make a recommendation for modification of standard resuscitation for infants and children suffering cardiac arrest due to major trauma, although consideration should be given to selectively performing a resuscitative thoracotomy in children with penetrating injuries who arrive at the hospital with a perfusing rhythm.

Knowledge Gaps—What is the role of open-chest CPR for nontraumatic etiologies of pediatric cardiac arrest?

Single-Ventricle Post Stage I Repair[Peds-059]

Consensus on Science—In 1 LOE 4 case series[651] cardiac arrest occurred frequently (in 20% of 112 patients) in infants following stage I repair for single-ventricle anatomy. Two LOE 5 case series of mechanically ventilated, chemically paralyzed patients with a single ventricle in the pre operative period[652,653] showed that excessive pulmonary blood flow may be attenuated in the short term by increasing the inspired fraction of CO_2 to achieve a $PaCO_2$ of 50 to 60 mm Hg. In the same population, decreasing the fraction of inspired oxygen below 0.21 did not appear to improve systemic oxygen delivery. Three LOE 4 studies[654–656] showed that clinical identification of the prearrest state in patients with a single ventricle is difficult and may be aided by monitoring systemic oxygen extraction using superior vena caval oxygen saturation or near infrared spectroscopy of cerebral and splanchnic circulations.

One LOE 3 prospective, crossover design study[657] of infants following stage I repair showed that inspired carbon dioxide increased systemic oxygen delivery. Evidence from 3 LOE 4 studies of infants following stage I repair[658–660] showed that reducing systemic vascular resistance with agents such as phenoxybenzamine improved systemic oxygen delivery,[659] reduced the risk for cardiovascular collapse,[658] and improved survival.[660]

There is no evidence for or against any specific modification of standard resuscitation practice for cardiac arrest in infants with single-ventricle anatomy following stage I repair.

Five LOE 4 pediatric studies[555,558,578,661,662] showed that survival to hospital discharge for patients with single-ventricle anatomy following ECPR (see ECPR above) is comparable to that of other neonates undergoing cardiac surgery. In 1 LOE 4 study[578] survival following

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ECPR initiated as a consequence of systemic-to-pulmonary artery shunt block after stage I repair was consistently higher than for other etiologies of cardiac arrest.

Treatment Recommendations—Standard resuscitation (prearrest and arrest) procedures should be followed for infants and children with single-ventricle anatomy following stage I repair. Neonates with a single ventricle before stage I repair who demonstrate shock caused by elevated pulmonary to systemic flow ratio (Qp-to-Qs ratio) might benefit from inducing mild hypercarbia ($PaCO_2$ to 50 to 60 mm Hg); this can be achieved during mechanical ventilation by reducing minute ventilation, adding CO_2 to inspired air, or administering opioids with or without chemical paralysis.

Neonates in a prearrest state following stage I repair may benefit from α-adrenergic antagonists to treat or ameliorate excessive systemic vasoconstriction in order to improve systemic blood flow and oxygen delivery and reduce the likelihood of cardiac arrest. Assessment of systemic oxygen extraction by monitoring S_{vco_2} or near infrared spectroscopy monitoring of cerebral and splanchnic circulation may help identify evolving hemodynamic changes in infants following stage I procedures; such hemodynamic changes may herald impending cardiac arrest.

Knowledge Gaps—Is there benefit in using heparin or thrombolytics during cardiac arrestto open a potentially occluded systemic-to-pulmonary artery (PA) or right ventricle to pulmonary artery (RV-PA) shunt following stage I repair? What is the role of monitoring near infrared spectroscopy/S_{vco_2} to guide resuscitation following stage I repair? Is there a potential benefit from the administration of milrinone during the prearrest state in infants with a single ventricle? Is it better to use a pure β-adrenergic agonist (isoproterenol) or an α- and β-agonist (epinephrine) to achieve ROSC after cardiac arrest following stage I repair? Does P_{ETCO_2} reflect pulmonary blood flow in single-ventricle physiology and can it be used to guide resuscitative procedures? Should the inspired oxygen concentration (100% versus room air) be different in infants with single-ventricle physiology during resuscitation from cardiac arrest? How does the Sano modification of Stage I repair (RV-PA conduit instead of a systemic-pulmonary artery shunt) affect response to therapies for cardiac arrest?

Single-Ventricle Post-Fontan and Bidirectional Glenn Procedures[Peds-055B]

Consensus on Science—In 1 LOE 4 case series[663] ECLS was useful in resuscitating patients with Fontan circulation but was not successful in hemi-Fontan/BDG patients. One LOE 4 case report[664] described manual external abdominal compressions with closed chest cardiac compressions as an alternative for standard CPR following a modified Fontan procedure.

Evidence from 4 LOE 5 studies[665–668] of patients with BDG circulation who were not in cardiac arrest or shock supports increasing CO_2 tension and hypoventilation to improve cerebral, superior vena caval, and pulmonary blood flow in order to increase systemic oxygen delivery. In 2 LOE 5 stud ies[669,670] of patients with BDG circulation who were not in cardiac arrest or a prearrest state, excessive ventilation reduced cerebral oxygenation. In 2 LOE 5 studies[671,672] of patients following a Fontan procedure who were not in cardiac arrest or a prearrest state, negative-pressure ventilation improved stroke volume and cardiac output compared with intermittent positive-pressure ventilation.

One LOE 5 case series[673] of patients following a Fontan procedure who were not in cardiac arrest or a prearrest state showed that high-frequency jet ventilation improved pulmonary vascular resistance and cardiac index. However, another LOE 5 case series[674] found that high-frequency oscillation ventilation did not increase cardiac index or decrease pulmonary vascular resistance.

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Changes in pulmonary blood flow typically reflect changes in cardiac output, but in infants and children with right-to-left shunts, an increase in right-to-left shunting that bypasses the lungs, as occurs in some infants and children with congenital heart disease or pulmonary hypertension, decreases the proportion of blood flowing through the pulmonary circulation, and as a result, the P_{ETCO_2} falls.[675] Conversely, increasing pulmonary blood flow, as happens following shunt insertion in infants with cyanotic heart disease, increases the P_{ETCO_2} and reduces the difference between the $PaCO_2$ and end-tidal CO_2.[84,85] Likewise, if there are intrapulmonary shunts that bypass the alveoli, there will be a greater difference between the $PaCO_2$ and P_{ETCO_2}.[83]

Treatment Recommendations—In patients with Fontan or hemi-Fontan/BDG physiology who are in a prearrest state, hypercarbia achieved by hypoventilation may be beneficial to increase oxygenation and cardiac output, while negative-pressure ventilation, if available, may be beneficial by increasing cardiac output. During cardiopulmonary arrest it is reasonable to consider ECPR for patients with Fontan physiology. There is insufficient evidence to support or refute the use of ECPR in patients with hemi-Fontan/BDG physiology.

Knowledge Gaps—What is the optimal method for cannulation for ECPR in patients with hemi-Fontan/BDG or Fontan physiology? What is the optimal CPR strategy (eg, with or without manual external abdominal compression; with or without active chest decompression; with or without an impedance threshold device) for patients with hemi-Fontan/BDG or Fontan physiology? Is there an ideal compression-ventilation ratio during CPR for infants following hemi-Fontan/BDG or Fontan procedures? Are compression "boots" or a MAST (military antishock trouser) suit beneficial for patients in prearrest states or cardiac arrest following hemi-Fontan/BDG or Fontan procedures?

Pulmonary Hypertension[Peds-056A]

Consensus on Science—Two LOE 5 observational pediatric studies[676,677] showed that children with pulmonary hypertension are at increased risk for cardiac arrest. There are no studies that demonstrate the superiority of any specific therapy for resuscitation from cardiac arrest in infants and children with a pulmonary hypertensive crisis.

In 1 LOE 5 retrospective study in adults[678] standard CPR techniques were often unsuccessful in victims with pulmonary hypertension and cardiac arrest. Those who were successfully resuscitated had a reversible cause and received a bolus of IV iloprost or inhaled nitric oxide (NO) during the resuscitation.

One LOE 5 study of adults after cardiac transplant[679] and 2 LOE 5 studies in children with congenital heart disease[680,681] observed that inhaled NO and aerosolized prostacyclin or analogues appear to be equally effective in reducing pulmonary vascular resistance. In 1 LOE 5 study in children with pulmonary hypertension after cardiac surgery[682] inhaled NO and alkalosis appeared to be equally effective in reducing pulmonary vascular resistance. There is no evidence of benefit or harm of excessive ventilation for infants and children in cardiac arrest with pulmonary hypertension.

Four LOE 5 studies in pulmonary hypertensive adults and children with crises or cardiac arrest[683–686] showed that mechanical right ventricular support improved survival.

Treatment Recommendations—Rescuers should provide conventional pediatric advanced life support, including oxygenation and ventilation for cardiac arrest associated with pulmonary hypertension. It may be beneficial to attempt to correct hypercarbia. If the

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administration of medications (IV or inhaled) to decrease pulmonary artery pressure has been interrupted, it may be advisable to reinstitute it.

Inhaled NO or aerosolized prostacyclin or analogue to reduce pulmonary vascular resistance should be considered. If unavailable, an IV bolus of prostacyclin may be considered.

Knowledge Gaps—Is epinephrine harmful for resuscitation of pediatric patients with pulmonary hypertension who are in pre arrest states or cardiac arrest? Is excessive ventilation of infants and children in prearrest states or cardiac arrest in the setting of pulmonary hypertension helpful or harmful? Does vasopressin improve outcome for cardiac arrest in the setting of pulmonary hypertensive crisis? Is a pure β-agonist, such as isoproterenol, effective or harmful during prearrest states or cardiac arrest associated with pulmonary hypertension? If used early in resuscitation, does the use of ECLS improve the outcome of the infant or child with pulmonary hypertension?

Prognosis and Decision To Terminate CPR[peds060]

Consensus on Science

In 1 LOE 3[687] and 1 LOE 4[688] study, survival from in-hospital pediatric cardiac arrest in the 1980s was approximately 9%. One LOE 1[538] and 1 LOE 3 pediatric study[689] showed that survival from in-hospital cardiac arrest in the early 2000s was 16% to 18%. Three prognostic LOE 1 prospective observational pediatric studies from 2006[537,690,691] reported that survival from in-hospital cardiac arrest in 2006 was 26% to 27%. One LOE 1 prospective study[300] showed that survival from all pediatric out-of-hospital cardiac arrest was 6% compared with 5% for adults. Survival in infants was 3%, and in children and adolescents survival was 9%. This study demonstrated that earlier poor survival rates were heavily influenced by poor infant survival (many of whom probably had sudden infant death syndrome and had probably been dead for some time).

Thirteen (LOE 1[300,301,537,538,690,692,693]; LOE 3[577,687,694]; LOE 4[688,695,696]) studies showed an association between several factors and survival from cardiac arrest. These factors include duration of CPR, number of doses of epinephrine, age, witnessed versus unwitnessed cardiac arrest, obesity,[697] and the first and subsequent cardiac rhythm. Thirteen studies (LOE 1[300,645]; LOE 2[698]; LOE 3[643,650,694,699–703]; LOE 4[704,705]) showed an association between mortality and causes of arrest such as submersion and trauma for out-of-hospital cardiac arrest. None of the associations reported in these studies allow prediction of outcome.

Treatment Recommendations—There is insufficient evidence to allow a reliable prediction of success or failure to achieve ROSC or survival from cardiac arrest in infants and children.

Knowledge Gaps—Are there reliable prognostic factors to guide decision making to terminate CPR in infants and children? Are there reliable clinical factors to predict neurologic outcome following resuscitation from cardiac arrest in infants and children?

Acknowledgments

We thank the following individuals (the Pediatric Basic and Advanced Life Support Chapter Collaborators) for their collaborations on the worksheets contained in this section: Ian Adatia; Richard P. Aickin; John Berger; Jeffrey M. Berman; Desmond Bohn; Kate L. Brown; Mark G. Coulthard; Douglas S. Diekema; Aaron Donoghue; Jonathan Duff; Jonathan R. Egan; Christoph B. Eich; Diana G. Fendya; Ericka L. Fink; Loh Tsee Foong; Eugene B. Freid; Susan Fuchs; Anne-Marie Guerguerian; Bradford D. Harris; George M. Hoffman; James S. Hutchison; Sharon B. Kinney; Sasa Kurosawa; Jesús Lopez-Herce; Sharon E. Mace; Ian Maconochie; Duncan Macrae; Mioara D.

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Manole; Bradley S. Marino; Felipe Martinez; Reylon A. Meeks; Alfredo Misraji; Marilyn Morris; Akira Nishisaki; Masahiko Nitta; Gabrielle Nuthall; Sergio Pesutic Perez; Lester T. Proctor; Faiqa A. Qureshi; Sergio Rendich; Ricardo A. Samson; Kennith Sartorelli; Stephen M. Schexnayder; William Scott; Vijay Srinivasan; Robert M. Sutton; Mark Terry; Shane Tibby; Alexis Topjian; Elise W. van der Jagt; and David Wessel.

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Disclosures

CoSTR Part 10: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers's Bureau/ Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Monica E. Kleinman	Children's Hospital Anesthesia Foundation: Non-profit organization—Senior Associate in Critical Care Medicine	None	None	None	None	None	None
Allan R. de Caen	Self-employed, Clinical Associate Professor Pediatric Critical Care Medicine, Stollery Children's Hospital/ University of Alberta	None	None	None	None	None	*Medical Expert for the Canadian Medical Protective Association
Leon Chameides	Emeritus Director, Pediatric Cardiology, Connecticut Children's Medical Center; Clinical Professor, University of Connecticut	None	None	None	None	None	None
Dianne L. Atkins	University of Iowa: Medical School—Professor †Serving as a Worksheet editor for 2010 Guidelines Process. Compensation is paid partially to my institution (66%) and partially to me (34%). The salary from my institution is not altered by this	None	None	None	None	None	*Serving as a defense expert witness in a case of ventricular fibrillation in a 2 year old child. Compensation is paid directly to me
Robert A. Berg	U of Pennsylvania—Professor	None	None	None	None	None	None
Marc D. Berg	University of Arizona—Assoc. Prof. Clinical Pediatrics; Attending Physician' Healthcare (UPH): Also serve on the UPH Board of Directors—Intensivist, Pediatric Critical Care Medicine	None	None	None	None	None	None
Farhan Bhanji	Montreal Children's Hospital, McGill University—Assistant Professor of Pediatrics	None	None	None	None	None	None
Dominique Biarent	Hôpital Universitaire des Enfants reine Fabiola: PICU Director	None	None	None	None	None	*Medical expert consultant in one trial for an insurance co. (Fortis) Medical expert for legal proceedings †grant of 25000 euro from ‘Fondation Roi Baudoin’tothe non profit organization ‘sauvez mon enfant’ for a psychological research in the PICU (I am administrator of the non profit organization and promotor of

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Writing Group Member	Employment	Research Grant	Other Research Support	Speakers's Bureau/ Honoraria	Ownership Interest	Consultant/Advisory Board	Other
							research). The grant is not given to me but to the NPO Grant of 67500 euro from the Belgian 'Loterie Nationale'to build a teaching lab to teach paediatric resuscitation to health care provider Grant given to the non profit organization 'sauvez mon enfant' for psychological research in the PICU (I am administrator of the non profit organization and promotor of the research) the grant is not given to me but to the NPO Grant from Baxter Foundation to pay a psychologist in my PICU (44.540 $) the grant is paid to the NPO
Robert Bingham	National Health Service of England—Consultant paediatric anaesthetist	None	None	None	None	None	*Occasional expert witness reports on pediatric resuscitation related topics
Ashraf Coovadia	Rahima Moosa Mother and Child Hospital: Paediatric Consultant (Attending) in Department of Paediatrics and Child Health—Adjunct Professor in Paediatrics	None	None	None	None	None	None
Mary Fran Hazinski	Vanderbilt University School of Nursing—Prof; AHA ECC Product Dev.—Senior Science Editor. I receive significant compensation† from the AHA as consultant/SSE to provide protected time to serve as the co-editor of the 2010 ILCOR CoSTR and the 2010 AHA Guidelines	None	None	None	None	None	None
Robert W. Hickey	for CPR and ECC University of Pittsburgh—Associate Professor	†Salary support from NIH for examining cyclopentenone prosta-glandin effects in ischemic brain injury	None	None	None	None	*1–2 X/year medical malpractice expert

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Writing Group Member	Employment	Research Grant	Other Research Support	Speakers's Bureau/ Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Vinay M. Nadkarni	University of Pennsylvania School of Medicine, Children's Hospital of Philadelphia: Non-profit, Academic, University Hospital—Attending Physician, Anesthesia, Critical Care and Pediatrics	†NIH RO1: Therapeutic Hypothermia after Cardiac Arrest, Co-Investigator. †Center of Excellence Grant, Laerdal Foundation for Acute Care Medicine, PI: Understanding the mechanics and quality of CPR *NHTSA: Mechanics of Chest Compression in children, Co-Investigator	None	None	None	None	None
Amelia Reis	Hospital das Clinico Universidade de Sao Paulo, Pediatric Emergency Physician	None	None	None	None	None	None
Antonio Rodriguez-Nunez	Hospital Clinico Universitario de Santiago de Compostela—Pediatric Emergency and Critical Care Division; University of Santiago de Compostela—Associate Professor of Pediatrics	None	None	None	None	None	None
James Tibballs	Royal Children's Hospital, Melbourne Healthcare, Physician ICU	None	None	None	None	None	None
Arno L. Zaritsky	Children's Hospital of The King' Daughters—Sr. VP for Clinical Services	None	None	None	None	*Data Safety Monitoring Board for NIH-sponsored trial of therapeutic hypothermia after pediatric cardiac arrest	None
David Zideman	Imperial College NHS Trust: United Kingdom Healthcare provider—Consultant Anaesthetist; London Organizing Committee of the Olympic Games—Lead Clinician for EMS	None	None	None	None	None	*Expert testimony on Cardiac Arrest under General Anaesthesis to Her Majesty' Coroner for Surrey (Expert witness fee for case review and court appearance) less than 1500 US dollars

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

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* Modest.

† Significant.

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Disclosures

CoSTR Part 10: Worksheet Collaborator Disclosures

Worksheet Collaborator	Employment	Research Grant	Other Research Support	Speakers's Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Ian Adatia	University of Alberta and Alberta Health Services; Professor Pediatrics, Director Pediatric Cardiac Critical Care Program and Pulmonary Hypertension Clinic	None	None	None	None	None	None
Richard P. Aickin	Auckland District Health Board Government Funded Healthcare Provider (primary care through to tertiary hospital services) for Auckland population and for national tertiary services. Director of Child Health	None	None	None	None	*New Zealand Health and Disability Commission: occasional expert reports provided with respect to alleged breaches of healthcare standards. 1–2 reports per year. Small personal payment received	*Expert Witness: Occasional expert testimonyfor Coroner's Court and criminal (Child protection) cases Approx 1 × year. No personal payment—small payment to Auckland District Health Board for my time
John Berger	Children's National Medical Center Nonprofit Children's hospital Medical Director, Cardiac Intensive Care and Pulmonary Hypertension	†5 U 10 HD 049981—DL Wessel (PI) 12/1/09/–11/30/14 Sponsor: NIH/ NICHD/NCMRR Pediatric Critical Care Research Network The major aims of the network are to reduce morbidity and mortality in pediatric critical illness and injury, and to provide a framework for the development of the scientific basis of pediatric critical	None	None	None	None	None

Pediatrics. Author manuscript; available in PMC 2013 September 26.

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Worksheet Collaborator	Employment	Research Grant	Other Research Support	Speakers's Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
		care practice. I am responsible for conduct of network approved studies at CNMC. As a member of the network steering committee, I am responsible for contributing to design of studies, analyzing results and disseminating research findings. Grant money comes to institution. Role: Co-Investigator *Therapeutic Hypothermia after Pediatric Cardiac Arrest (THAPCA) Trials. PI:JT Berger 2009 Sponsor: of Michigan I am the site PI for the conduct of a randomized trial of therapeutic hypothermia in children who have had a cardiac arrest funded by NHLBI. Money comes to the institution. Role: Consortium Site PI *Tracking Outcomes and Practice in Pediatric Pulmonary Hypertension. PI: JT Berger. 2008 Sponsor: Association in Pediatric Pulmonary Hypertension I am the site PI responsible for contributing				

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		subject data to a registry of pediatric pulmonary hypertension patients and their therapy Role: Site PI					
Jeffrey M. Berman	University of North Carolina:Faculty member UNC School of Medicine—Professor of Anesthesiology	None	None	None	None	None	None
Desmond Bohn	The Hospital for Sick Children, Toronto—Chief, Department of Critical Care Medicine	None	None	None	None	None	None
Kate L. Brown	Great Ormond Street Hospital for Children NHS Trust Hospital consultant in paediatric intensive care Consultant paediatric cardiac intensive care	None	None	None	None	None	None
Mark G. Coulthard	Queensland Health: State Health Employer Organisation—Paediatric Intensive Care Specialist	None	None	None	None	None	None
Douglas S. Diekema	Children's University Medical Group: Delivery of medical care in Children's Hospital of Seattle and the University of Washington—Professor of Pediatrics, Attending Physician, Emergency Department	None	None	None	None	None	None
Aaron Donoghue	University of Pennsylvania—Assistant Professor	None	None	None	None	None	None
Jonathan Duff	Alberta Health Services: Pediatric Intensivist	None	None	None	None	None	None
Jonathan R. Egan	The Children's hospital at Westmead, Sydney—Pediatric Intensivist	None	None	None	None	None	None
Christoph B. Eich	University Medical Centre of Göttingen, Germany: Attending Anesthesiologist, Intensivist and Emergency Physician	None	None	None	None	None	None
Diana G. Fendya	Children's National Medical Center, EMSC National Resource Center; Trauma/Acute Care Nursing Specialist	None	None	None	None	None	None
Ericka L. Fink	Children's Hospital of Pittsburgh of UPMC—Assistant Professor	[7]P.I., K23 from NINDS Duration of Hypothermia for Neuroprotection	None	None	None	None	None

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		after Pediatric Cardiac Arrest Institution P.I., Laerdal Foundation grant $21, 365 Same topic Institution *Children's Hospital of Pittsburgh of UPMC Clinical and Translational Science Institute $6500 Same topic Institution					
Toh Tsee Foong	KK Women's and Children's Hospital	None	None	None	None	None	None
Eugene B. Freid	Nemours Children's Clinics Health Care Organization Staff Anesthesiologist and Intensivist University of Florida Jacksonville Health Care Organization Pediatric Intensivist	None	None	*University of North Carolina —Speaker at Anesthesiology Refresher Course. 1000–1500/ year honorarium sent to institution	None	None	None
Susan Fuchs	Children's Memorial Hospital-Assoc Director, Div Pediatric Emergency Medicine	None	None	None	None	None	*Currently on the American Academy of Pediatrics Advanced Pediatric Life Support Steering Committee and Currently Co-chairperson of the AAP Pediatric Education for Prehospital Professional (PEPP) steering committee
Anne-Marie Guerguerian	The Hospital for Sick Children; Staff Physician	None	None	None	None	None	None
Bradford D. Harris	UNC at Chapel Hill; Assist Prof	†5 P01 AT002620–02 (Peden) 09/30/04–	None	*Assoc Clinical Research Professor on peds pharm	None	None	None

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Worksheet Collaborator	Employment	Research Grant	Other Research Support	Speakers's Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
		06/30/09 5% NIH/ NCCAM $1, 660, 813 Annual Direct Translational Research Center for CAM Therapy of Asthma The objective of this research is to identify antioxidant complementary and alternative medicine therapies for application in asthma. 5 RO1 ES012706–02 (Peden) 09/01/04–07/31/09 5% NIH/ NIEHS $ 209, 314 O3 and LPS-Induced Airway Inflammation in Humans in vivo The objective is to test three hypotheses to define the ways that O3 and LPS interact to exacerbate airway disease. 5 R01 HL080337–02 (Peden) 05/06/05–04/30/09 5% NIH NHLBI/NIAID $350, 000 Airway Biology of Acute Asthma: Translational Studies The major goal is to determine if asthma exacerbation and allergen challenge models allow for examination of innate/acquired immune interactions. R82952201 Cooperative Agreement					

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		(Bromberg) 11/01/01–10/31/06 5% U.S. Environmental Protection Agency $1, 583, 867 Health Effects of Exposure to Air Pollutants in Humans The major goal of this cooperative agreement is to examine the health effects of inhalation of environmental ambient air pollutants on human subjects					
George M. Hoffman	Medical College of Wisconsin medica school Professor, Anesthesiology and Pediatrics [View] Children's Hospital of Wisconsin hospital Medical Director, Pediatric Anesthesiology	None	None	*Somanetics, Inc biomedical device manufacturer 1653 East Maple Road Troy, MI 48083-4208 i have informally served in consultant/advisory capacity and have received honoraria for speaking	None	*Edwards Life Sciences, Inc biomedical device manufacturer One Edwards Way Irvine, CA 92614 i have served informally in consultant/advisory capacity *Masimo, Inc biomedical device manufacturer 2852 Kelvin Ave. Irvine, CA, 92614 i have served informally in consultant/ advisory capacity	None
James S. Hutchison	SickKIds Hospital Director Neurocritical Care	None	None	None	None	None	None
Sharon B. Kinney	University of Melbourne and Royal Children's Hospital Melbourne—Lecturer and MET Coordinator	None	None	None	None	None	None
Sasa Kurosawa	Shizuoka Children's Hospital Depertoment of Pediatric Emergency & General Pediatrics Doctor National Center for Child Health & Development Department of Health Policy, Research Institution researcher	None	None	None	None	None	None
Jesús López-Herce	Hospital General Universitario Gregorio Marañón—Pediatric Assistant	None	None	None	None	None	None

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Worksheet Collaborator	Employment	Research Grant	Other Research Support	Speakers's Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Sharon E. Mace	Clerveland Clinic—Physician employed fulltime by the hospital; Attending staff physician	None	None	*Baxter Healthcare Pharmaceutical Speaker Bureau	None	*Baxter Healthcare Pharmaceutical Consultant, Advisory Board	None
Ian Maconochie	Imperial Academic Health Sciences Centre, London: I run the pediatric emergency medicine department at St Mary's Hospital in Paddington, London—Lead Consultant in Pediatric Emergency medicine	None	*Postal for survey of UK departments about use of pain relief from Therakind, a company looking to obtain license for use of commonly used drugs from the medical regulatory authority in UK. Estimated payment was about 150 pounds sterling	None	None	*I am a deputy editor for *The Emergency Medicine Journal*, a commissioning editor for the *Archives of Diseases of Childhood* and sit on the editorial advisory panel for the *British Medical Journal*. I am editorial board member for *Current Pediatric Reviews* and *Pediatric Emergency Medical Journal*. The latter 2 I do not receive payment. I act as a consultant advisory to TSG associates in relation to major disaster management systems. I have advised Therakind on the licensing of drugs in the pediatric population., ie approaching the medical regulatory authority to obtain a license on the use of a commonly used drug in the treatment of fitting children in UK	*I have acted as an expert witness in cases relating to the management of children who may have had non accidental injury.
Duncan Macrae	The Royal Brompton and Harefield NHS Foundation Trust—Director of Children's Services	None	None	None	None	None	None
Ioana D. Manole	Univ of Pittsburgh: Ped Emerg. Medicine attending physician; assist Prof Ped	NIH K08HD58798-funds go to Univ Children's Hosp of Pitts RAC grant-funds to Univer.	None	None	None	None	None
Bradley S. Marino	Cincinnati Children's Hospital Medical Center Associate Professor of Pediatrics	None	None	None	None	None	None
Felipe Martinez	Universidad de Valparaíso—Professor	None	None	None	None	None	None
Reylon A. Meeks	Blank Children's Hospital, Pleasant Hill Fire Dept., N Clinical Specialist	None	None	None	None	None	None
Alfredo Misraji	Unidad Coronaria Movil	None	None	None	None	None	None
Marilyn Morris	Columbia Univ; assist Prof Ped	None	None	None	None	None	*Expert witness $900 for 3

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							hour case for defense of child that received ECPR
Akira Nishisaki	Children's Hosp of Philadelphia, non profit tertiary Children's hospital; attending MD CCMedicine	None	None	None	None	None	None
Masahiko Nitta	Osaka Medical College—Assistant Professor	None	None	None	None	None	None
Gabrielle Nuthall	Auckland District Health Board: Pediatric Intensive Care Specialist	None	None	None	None	None	None
Sergio Pesutic Pérez	Centro de Formación en Apoyo Vital Director	None	None	None	None	None	None
Lester T. Proctor	University of Wisconsin-Madison College of Medicine and Public Health —Professor	None	None	None	None	None	None
Faiqa A. Qureshi	Children's Specialty Group—Physician	None	None	None	None	None	None
Sergio Rendich	Hospital Naval Almirante Nef—Pediatrician; Hospital Gustavo Fricke; Pediatrician—Intensive Care Unit; Universidad de Valparaíso Professor, Pediatrics Clínica Las Condes Critical Patient Unit Centro de Formación en Apoyo Vital; Instructor, NRP	None	None	None	None	None	None
Ricardo A. Samson	The University of Arizona: Faculty member within the Department of Pediatrics Chief of the Cardiology Section Provide clinical care, teaching and research related to the field of Pediatric Cardiology—Professor of Pediatrics	None	None	None	None	None	None
Kennith Sartorelli	University of Vermont Associate Professor of Surgery	None	None	None	None	None	None
Stephen M. Schexnayder	University of Arkansas for Medical Sciences–College of Medicine: Physician - Clinician Educator–Professor and Division Chief: AHA Consultant	*Pharmacokinetics of pantoperazole in pediatrics patients (Pediatric Pharmacology Research Unit) Pharmacokinetics of esomeprazole in pediatric patients (Astra Zeneca)	None	*Contemporary Forums (Nursing conference) Pediatric Clinics of North America (guest editor)	None	None	*Expert witness in various medicolegal cases involving pediatric critical care and emergency medicine

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William Scott	UT Southwestern Medical Center—Professor	None	None	None	None	None	None
Vijay Srinivasan	Children's Hospital of Philadelphia—Attending Physician, Pediatric Intensive Care Unit	*A Reproducible Method for Blood Glucose Control in Critically Ill Children (RC1 sub contract with Inter Mountain Medical Center, PI: Alan Morris), site PI: Vijay Srinivasan—submitted for NIH Challenge Grants July 2009, approval pending	*PI: A Novel Application of Impedance Threshold Device technologies to optimize Fluid Removal during Hemodialysis in Children (unfunded research at CHOP—IRB Research Protocol No: 2007–12-5712)—have received impedance threshold devices for this study from Advanced Circulatory Systems, Inc, EdenPrairieMN	None	None	None	None
Robert M. Sutton	The Children's Hospital of Philadelphia Critical Care Attending	*Unrestricted research grant support from the Laerdal Foundation for Acute Care Medicine	None	None	None	None	None
Mark Terry	Johnson County Med-Act: County government ambulance service—Deputy Chief Operations	None	None	None	None	None	None
Shane Tibby	Guy's and St Thomas' NHS Foundation Trust, London National Health Service Hospital trust in United Kingdom Consultant in Pediatric Intensive Care	None	None	None	None	None	None
Alexis Topjian	The Children's Hospital of Philadelphia—attending physician	*site PI for the Therapeutic hypothermia after cardiac arrest study. NIH funded study. Money goes to the institution	None	None	None	None	None
Elise W. van der Jagt	University of Rochester: Academic Institution including Medical School/Center—Professor of Pediatrics and Critical Care	†Project Title: Therapeutic Hypothermia After Pediatric Cardiac Arrest (THAPCA) Trials PI: Frank W. Moler, M.D. (University of Michigan)	None	None	None	None	None

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David Wessel	Children's National Medical Center Senior Vice President	Proposed project period: 7/1/2009–6/30/2014 We are part of this multi-institutional grant but after the grant was funded, the initial institutions that would be involved were the higher volume/ larger Children's hospitals. At this time we are not receiving any funding from this grant. *PI andCo-Investigator/Site None	None	None	None	†IKARIA Holdings Inc Pharmaceutical Consultant	None

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

* Modest.

† Significant.

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Appendix

CoSTR Part 10: Worksheet Appendix

Task Force	WS ID	PICO Title	Short Title	Authors	URL
Peds	Peds-001A	In infants (<1 year, not including newly born) in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of AEDs (I) compared with standard management (which does not include use of AEDs) (C), improve outcomes (eg. termination of rhythm, ROSC, survival) (O)?	AEDs in children less than 1 yr	Reylon A. Meeks	http://circ.ahajournals.org/site/C2010/Peds-001A.pdf
Peds	Peds-001B	In infants (<1 year, not including newly born) in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of AEDs (I) compared with standard management (which does not include use of AEDs) (C), improve outcomes (eg. termination of rhythm, ROSC, survival) (O)?	AEDs in children less than 1 yr	Antonio Rodriguez-Nunez	http://circ.ahajournals.org/site/C2010/Peds-001B.pdf
Peds	Peds-002A	For infants and children in cardiac arrest, does the use of a pulse check (I) vs. assessment for signs of life (C) improve the accuracy of diagnosis of pediatric CPA (O)?	Pulse check accuracy	Aaron Donoghue, James Tibballs	http://circ.ahajournals.org/site/C2010/Peds-002A.pdf
Peds	Peds-003	During cardiac arrest in infants or children (P), does the presence of family members during the resuscitation (I) compared to their absence (C) improve patient or family outcome measures (O)?	Family presence	Douglas S. Diekema	http://circ.ahajournals.org/site/C2010/Peds-003.pdf
Peds	Peds-004	In infants and children with respiratory failure who undergo endotracheal intubation (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of devices (eg. CO_2 detection device, CO_2 analyzer or esophageal detector device) (I) compared with usual management (C), improve the accuracy of diagnosis of airway placement (O)?	Verification of airway placement	Diana G. Fendya, Monica Kleinman	http://circ.ahajournals.org/site/C2010/Peds-004.pdf
Peds	Peds-005A	In pediatric patients with cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of end-tidal CO_2 (I), compared with clinical assessment (C), improve accuracy of diagnosis of a perfusing rhythm (O)?	End-tidal CO_2 to diagnose perfusing rhythm	Arno Zaritsky	http://circ.ahajournals.org/site/C2010/Peds-005A.pdf
Peds	Peds-005B	In pediatric patients with cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of end-tidal CO_2 (I), compared with clinical assessment (C), improve accuracy of diagnosis of a perfusing rhythm (O)?	End-tidal CO_2 to diagnose perfusing rhythm	Anne-Marie Guerguerian	http://circ.ahajournals.org/site/C2010/Peds-005B.pdf
Peds	Peds-006B	In pediatric patients in clinical cardiac arrest (prehospital [OHCA] or in hospital [IHCA]) (P),	Methods to diagnose perfusing rhythm	Christoph B. Eich, Faiqa A. Qureshi	http://circ.ahajournals.org/site/C2010/Peds-006B.pdf

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		does the use of a focused echocardiogram (I) compared with standard assessment, assist in the diagnosis of reversible causes of cardiac arrest?			
Peds	Peds-007	In children requiring emergent intubation (prehospital, in-hospital) (P), does the use of cuffed ETTs (I) compared with uncuffed ETTs (C) improve therapeutic endpoints (eg, oxygenation and ventilation) or reduce morbidity or risk of complications (eg, need for tube change, airway injury, aspiration) (O)?	Cuffed vs uncuffed ETTs	Ashraf Coovadia	http://circ.ahajournals.org/site/C2010/Peds-007.pdf
Peds	Peds-008	In children requiring assisted ventilation (prehospital, in-hospital) (P), does the use of bag-valve-mask (I) compared with endotracheal intubation (C) improve therapeutic endpoints (oxygenation and ventilation), reduce morbidity or risk of complications (eg, aspiration), or improve survival (O)?	BVM vs intubation	Dominique Biarent	http://circ.ahajournals.org/site/C2010/Peds-008.pdf
Peds	Peds-009	In pediatric patients in cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of supraglottic airway devices (I) compared with bag-valve-mask alone (C), improve therapeutic endpoints (eg, ventilation and oxygenation), improve quality of resuscitation (eg, reduce hands-off time, allow for continuous compressions), reduce morbidity or risk of complications (eg, aspiration) or improve survival (O)?	Supraglottic airway devices	Robert Bingham	http://circ.ahajournals.org/site/C2010/Peds-009.pdf
Peds	Peds-010A	For infants and children who have ROSC after cardiac arrest (P), does the use of induced hypothermia (I) compared with normothermia (C) improve outcome (survival to discharge, survival with good neurologic outcome) (O)?	Induced hypothermia after ROSC	Robert Hickey	http://circ.ahajournals.org/site/C2010/Peds-010A.pdf
Peds	Peds-010B	For infants and children who have ROSC after cardiac arrest (P), does the use of induced hypothermia (I) compared with normothermia (C) improve outcome (survival to discharge, survival with good neurologic outcome) (O)?	Induced hypothermia after ROSC	James S. Hutchison	http://circ.ahajournals.org/site/C2010/Peds-010B.pdf
Peds	Peds-011B	In infants and children with cardiac arrest from a non-asphyxial or asphyxial cause (excluding newborns) (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of another specific C:V ratio by laypersons and HCPs (I) compared with standard care (15:2) (C), improve outcome (eg, ROSC, survival) (O)?	Compression ventilation ratio	Robert Bingham, Robert Hickey	http://circ.ahajournals.org/site/C2010/Peds-011B.pdf
Peds	Peds-012A	In infants and children (not including newborns) with cardiac arrest (out-of-hospital and in-hospital) (P), does the use of compression-only CPR (I) as opposed to standard CPR (ventilations and compressions) (C), improve outcome (O) (eg, ROSC, survival)?	Compression only CPR	Robert A. Berg, Dominique Biarent	http://circ.ahajournals.org/site/C2010/Peds-012A.pdf

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Peds	Peds-013A	In pediatric patients with cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) and a secure airway (P), does the use of a specific minute ventilation (combination of respiratory rate and tidal volume) depending on the etiology of the arrest (I) as opposed to standard care (8–10 asynchronous breaths per minute) (C), improve outcome (O) (eg. ROSC, survival)?	Etiology specific minute ventilation	Monica Kleinman	http://circ.ahajournals.org/site/C2010/Peds-013A.pdf
Peds	Peds-013B	In pediatric patients with cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) and a secure airway (P), does the use of a specific minute ventilation (combination of respiratory rate and tidal volume) depending on the etiology of the arrest (I) as opposed to standard care (8–10 asynchronous breaths per minute) (C), improve outcome (O) (eg. ROSC, survival)?	Etiology specific minute ventilation	Naoki Shimizu	http://circ.ahajournals.org/site/C2010/Peds-013A.pdf
Peds	Peds-014	In pediatric patients in cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P) does the use of rapid deployment ECMO or emergency cardiopul-monary bypass (I), compared with standard treatment (C), improve outcome (ROSC, survival to hospital discharge, survival with favorable neurologic outcomes) (O)?”	ECMO	Marilyn Morris	http://circ.ahajournals.org/site/C2010/Peds-014.pdf
Peds	Peds-014B	In pediatric patients in cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P) does the use of rapid deployment ECMO or emergency cardiopul-monary bypass (I), compared with standard treatment (C), improve outcome (ROSC, survival to hospital discharge, survival with favorable neurologic outcomes) (O)?	ECMO	Kate L. Brown	http://circ.ahajournals.org/site/C2010/Peds-014B.pdf
Peds	Peds-015	In pediatric patients in cardiac arrest, associated with or without asphyxia (prehospital [OHCA] or in-hospital [IHCA]) (P) does ventilation with a specific oxygen concentration (room air or a titrated concentration between 0.21 and 1.0) (I), compared with standard treatment (100% oxygen) (C), improve outcome (ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?	Titrated oxygen vs 100% oxygen	Robert Hickey	http://circ.ahajournals.org/site/C2010/Peds-015.pdf
Peds	Peds-016	In infants and children with ROSC after cardiac arrest (prehospital or in-hospital) (P), does the use of a specific strategy to manage blood glucose (eg. target range) (I) as opposed to standard care (C), improve outcome (O) (eg. survival)?	Glucose control following resuscitation	Duncan Macrae, Vijay Srinivasan	http://circ.ahajournals.org/site/C2010/Peds-016.pdf
Peds	Peds-017B	In pediatric patients with cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of any specific alternative method for calculating drug dosages (I) compared with standard weight-based dosing (C), improve	Methods for calculating drug dosages	Ian Maconochie, Vijay Srinivasan	http://circ.ahajournals.org/site/C2010/Peds-017B.pdf

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		outcome (eg, achieving expected drug effect, ROSC, survival, avoidance of toxicity) (O)?			
Peds	Peds-018	In adult and pediatric patients with cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA) (P), does the use of any specific alternative dosing regimen for epinephrine (I) compared with standard recommendations (C), improve outcome (eg. ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?	Epinephrine dose	Amelia Reis	http://circ.ahajournals.org/site/C2010/Peds-018.pdf
Peds	Peds-019	In pediatric patients with cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA]) due to VF/pulseless VT (P), does the use of amiodarone (I) compared with lidocaine (C), improve outcome (eg, ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?	Amiodarone vs lidocaine for VF/VT	Dianne L. Atkins	http://circ.ahajournals.org/site/C2010/Peds-019.pdf
Peds	Peds-020A	In adult and pediatric patients with cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of vasopressin or vasopressin + epinephrine (I) compared with standard treatment recommendations (C), improve outcome (eg, ROSC, survival to hospital discharge, or survival with favorable neurologic outcome) (O)?	Vasopressin	Elise W. van der Jagt	http://circ.ahajournals.org/site/C2010/Peds-020A.pdf
Peds	Peds-020B	In adult and pediatric patients with cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of vasopressin or vasopressin + epinephrine (I) compared with standard treatment recommendations (C), improve outcome (eg, ROSC, survival to hospital discharge, or survival with favorable neurologic outcome) (O)?	Vasopressin	Dominique Biarent	http://circ.ahajournals.org/site/C2010/Peds-020B.pdf
Peds	Peds-021A	In pediatric patients with cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of calcium (I) compared with no calcium (C), improve outcome (O) (eg. ROSC, survival to hospital discharge, survival with favorable neurologic outcome)?	Calcium	Allan de Caen	http://circ.ahajournals.org/site/C2010/Peds-021A.pdf
Peds	Peds-021B	In pediatric patients with cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of calcium (I) compared with no calcium (C), improve outcome (O) (eg. ROSC, survival to hospital discharge, survival with favorable neurologic outcome)?	Calcium	Felipe Martinez, Sergio Pesutic, Sergio Rendich	http://circ.ahajournals.org/site/C2010/Peds-021B.pdf
Peds	Peds-022A	In pediatric patients with cardiac arrest due to primary or secondary VF or pulseless VT (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of more than one shock for the initial or subsequent defibrillation attempt(s) (I),	Single or stacked shocks	Marc Berg	http://circ.ahajournals.org/site/C2010/Peds-022A.pdf

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		compared with standard management (C), improve outcome (eg. termination of rhythm, ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?			
Peds	Peds-023A	In pediatric patients with cardiac arrest due to primary or secondary VF or pulseless VT (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of a specific energy dose or regimen of energy doses for the initial or subsequent defibrillation attempt(s) (I), compared with standard management (C), improve outcome (eg. termination of rhythm, ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?	Energy doses	Jonathan R. Egan	http://circ.ahajournals.org/site/C2010/Peds-023A.pdf
Peds	Peds-023B	In pediatric patients with cardiac arrest due to primary or secondary VF or pulseless VT (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of a specific energy dose or regimen of energy doses for the initial or subsequent defibrillation attempt(s) (I), compared with standard management (C), improve outcome (eg. termination of rhythm, ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?	Energy doses	Dianne L. Atkins	http://circ.ahajournals.org/site/C2010/Peds-023B.pdf
Peds	Peds-024A	In pediatric patients with ROSC after cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA]) who have signs of cardiovascular dysfunction (P), does the use of any specific cardioactive drugs (I) as opposed to standard care (or different cardioactive drugs) (C), improve physiologic endpoints (oxygen delivery, hemodynamics) or patient outcome (eg, survival to discharge or survival with favorable neurologic outcome) (O)?	Cardioactive drugs post resuscitation	Allan de Caen	http://circ.ahajournals.org/site/C2010/Peds-024A.pdf
Peds	Peds-024B	In pediatric patients with ROSC after cardiac arrest (pre-hospital [OHCA] or in-hospital [IHCA]) who have signs of cardiovascular dysfunction (P), does the use of any specific cardioactive drugs (I) as opposed to standard care (or different cardioactive drugs) (C), improve physiologic endpoints (oxygen delivery, hemodynamics) or patient outcome (eg, survival to discharge or survival with favorable neurologic outcome) (O)?	Cardioactive drugs post resuscitation	Mark G. Coulthard	http://circ.ahajournals.org/site/C2010/Peds-024B.pdf
Peds	Peds-025A	In pediatric patients with in-hospital cardiac or respiratory arrest (P), does use of EWSS/ response teams/MET systems (I) compared with no such responses (C), improve outcome (eg, reduce rate of cardiac and respiratory arrests and in-hospital mortality) (O)?	METs	Elise W. van der Jagt	http://circ.ahajournals.org/site/C2010/Peds-025A.pdf

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Peds	Peds-025B	In pediatric patients with in-hospital cardiac or respiratory arrest (P), does use of EWSS/ response teams/MET systems (I) compared with no such responses (C), improve outcome (eg, reduce rate of cardiac and respiratory arrests and in-hospital mortality) (O)?	METs	James Tibballs	http://circ.ahajournals.org/site/C2010/Peds-025B.pdf
Peds	Peds-026A	For intubated newborns within the first month of life (beyond the delivery room) who are receiving chest compressions (P), does the use of continuous chest compressions (without pause for ventilation) (I) vs. chest compressions with interruptions for ventilation (C) improve outcome (time to sustained heart rate >100, survival to ICU admission, survival to discharge, survival with favorable neurologic status) (O)?	Continuous chest compressions for intubated newborns outside of DR	Monica Kleinman	http://circ.ahajournals.org/site/C2010/Peds-026A.pdf
Peds	Peds-027A	For newborns within the first month of life (beyond the delivery room) who are not intubated and who are receiving CPR (P), does the use of a 3:1 compression to ventilation ratio (I), compared with a 15:2 compression to ventilation ratio (C) improve outcome (time to sustained heart rate >100, survival to ICU admission, survival to discharge, discharge with favorable neurologic status) (O)?	3:1 vs 15:2 ratio for neonates outside of DR	Leon Chameides	http://circ.ahajournals.org/site/C2010/Peds-027A.pdf
Peds	Peds-028	In pediatric patients with cardiac arrest (out-of-hospital and in-hospital) (including prolonged arrest states) (P), does the use of $NaHCO_3$ (I) compared with no $NaHCO_3$ (C), improve outcome (O) (eg. ROSC, survival)?	Sodium bicarbonate	Stephen M. Schexnayder	http://circ.ahajournals.org/site/C2010/Peds-028.pdf
Peds	Peds-029	In infants and children in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of any specific paddle/pad size/ orientation and position (I) compared with standard resuscitation or other specific paddle/ pad size/orientation and position) (C), improve outcomes (eg. Successful defibrillation, ROSC, survival) (O)?	Paddle size and placement for defibrillation	Dianne L. Atkins	http://circ.ahajournals.org/site/C2010/Peds-029.pdf
Peds	Peds-030	In infants and children with unstable ventricular tachycardia (pre-hospital and in-hospital) (P), does the use of any drug/combination of drugs/ intervention (eg. cardioversion) (I) compared with no drugs/intervention (C) improve outcome (eg, termination of rhythm, survival) (O)?	Unstable VT	Jeffrey M. Berman, Bradford D. Harris	http://circ.ahajournals.org/site/C2010/Peds-030.pdf
Peds	Peds-031	In infants and children with supraventricular tachycardia with a pulse (P), does the use of any drug or combination of drugs (I), compared with aden-osine (C), result in improved outcomes (termination of rhythm, survival)?	Drugs for SVT	Ricardo A. Samson	http://circ.ahajournals.org/site/C2010/Peds-031.pdf

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Peds	Peds-032	In infants and children with hemorrhagic shock following trauma (P), does the use of graded volume resuscitation (I) as opposed to standard care (C), improve outcome (hemodynamics, survival) (O)?	Graded volume resuscitation for traumatic shock	Jesus Lopez-Herce	http://circ.ahajournals.org/site/C2010/Peds-032.pdf
Peds	Peds-033	In pediatric patients in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of one hand chest compressions (I) compared with two hand chest compressions (C) improve outcomes (eg. ROSC, rescuer performance) (O)?	One hand vs two hand compressions	Sharon B. Kinney	http://circ.ahajournals.org/site/C2010/Peds-033.pdf
Peds	Peds-034	In infants with cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of two-thumb chest compression without circumferential squeeze (I) compared to two-thumb chest compression with circumferential squeeze (C) improve outcome (eg. ROSC, rescuer performance (O)?	Circumferential squeeze for infant CPR	James Tibballs	http://circ.ahajournals.org/site/C2010/Peds-034.pdf
Peds	Peds-035	In infants and children with cardiac arrest (P), does establishing intraosseous access (I) compared to establishing conventional (non-intraosseous) venous access (C) improve patient outcome (eg. ROSC, survival to hospital discharge (O)?	IO vs IV	Jonathan Duff	http://circ.ahajournals.org/site/C2010/Peds-035.pdf
Peds	Peds-036	In infants and children with cardiac arrest (P), does the use of tracheal drug delivery (I) compared to intravenous drug delivery (C) worsen patient outcome (eg. ROSC, survival to hospital discharge (O)?	ET vs IV drugs	Mioara D. Manole	http://circ.ahajournals.org/site/C2010/Peds-036.pdf
Peds	Peds-038B	In infants and children in shock, does early intubation and assisted ventilation compared to the use of these interventions only for associated respiratory failure lead to improved patient outcome (hemodynamics, survival?)	Intubation for shock (timing)	Amelia Reis	http://circ.ahajournals.org/site/C2010/Peds-038B.pdf
Peds	Peds-039A	In infants and children with respiratory failure who require emergent endotracheal intubation (P), does the use of cricoid pressure or laryngeal manipulation (I), when compared with standard practice (C), improve or worsen outcome (eg. success of intubation, aspiration risk, side effects, etc) (O)?	Cricoid pressure and laryngeal manipulation	Lester T. Proctor	http://circ.ahajournals.org/site/C2010/Peds-039A.pdf
Peds	Peds-039B	In infants and children with respiratory failure who require emergent endotracheal intubation (P), does the use of cricoid pressure or laryngeal manipulation (I), when compared with standard practice (C), improve or worsen outcome (eg. success of intubation, aspiration risk, side effects, etc) (O)?	Cricoid pressure and laryngeal manipulation	Ian Maconochie	http://circ.ahajournals.org/site/C2010/Peds-039B.pdf
Peds	Peds-040A	In infants and children in cardiac arrest (out-of-hospital and in-hospital) (P), does any specific	Compression depth	Robert M. Sutton	http://circ.ahajournals.org/site/C2010/Peds-040A.pdf

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		compression depth (I) as opposed to standard care (ie. depth specified in treatment algorithm) (C), improve outcome (O) (eg. Blood pressure, ROSC, survival)?			
Peds	Peds-040B	In infants and children in cardiac arrest (out-of-hospital and in-hospital) (P), does any specific compression depth (I) as opposed to standard care (ie. depth specified in treatment algorithm) (C), improve outcome (O) (eg. Blood pressure, ROSC, survival)?	Compression depth	David Zideman	http://circ.ahajournals.org/site/C2010/Peds-040B.pdf
Peds	Peds-041A	In children and infants with cardiac arrest due to major (blunt or penetrating) injury (out-of-hospital and in-hospital) (P), does the use of any specific modifications to standard resuscitation (I) compared with standard resuscitation (C), improve outcome (O) (eg. ROSC, survival)? eg. open vs closed chest CPR, other examples.	Traumatic arrest	Kennith Sartorelli	http://circ.ahajournals.org/site/C2010/Peds-041A.pdf
Peds	Peds-041B	In children and infants with cardiac arrest due to major (blunt or penetrating) injury (out-of-hospital and in-hospital) (P), does the use of any specific modifications to standard resuscitation (I) compared with standard resuscitation (C), improve outcome (O) (eg. ROSC, survival)? eg. open vs closed chest CPR, other examples.	Traumatic arrest	Jesus Lopez-Herce	http://circ.ahajournals.org/site/C2010/Peds-041B.pdf
Peds	Peds-043A	In infants and children in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of self-adhesive defibrillation pads (I) compared with paddles (C), improve outcomes (eg. successful defibrillation, ROSC, survival) (O)?	Hands off defibrillation vs paddles	Mark Terry	http://circ.ahajournals.org/site/C2010/Peds-043A.pdf
Peds	Peds-043B	In infants and children in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of self-adhesive defibrillation pads (I) compared with paddles (C), improve outcomes (eg. successful defibrillation, ROSC, survival) (O)?	Hands off defibrillation vs paddles	Farhan Bhanji	http://circ.ahajournals.org/site/C2010/Peds-043B.pdf
Peds	Peds-044A	In infants and children with any type of shock (P), does the use of any specific resuscitation fluid or combination of fluids [eg: isotonic crystalloid, colloid, hypertonic saline, blood products] (I) when compared with standard care (C) improve patient outcome (hemodynamics, survival) (O)?	Resuscitation fluids	Sharon E. Mace	http://circ.ahajournals.org/site/C2010/Peds-044A.pdf
Peds	Peds-044B	In infants and children with any type of shock (P), does the use of any specific resuscitation fluid or combination of fluids [eg: isotonic crystalloid, colloid, hypertonic saline, blood products] (I) when compared with standard care (C) improve patient outcome (hemodynamics, survival) (O)?	Resuscitation fluids	Richard P. Aickin	http://circ.ahajournals.org/site/C2010/Peds-044B.pdf

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Peds	Peds-045A	In infants and children with distributive shock with and without myocardial dysfunction (P), does the use of any specific inotropic agent (I) when compared to standard care (C), improve patient outcome (hemodynamics, survival) (O)?	Distributive shock and inotropes	Ericka L. Fink, Alfredo Misraji	http://circ.ahajournals.org/site/C2010/Peds-045A.pdf
Peds	Peds-045B	In infants and children with distributive shock with and without myocardial dysfunction (P), does the use of any specific inotropic agent (I) when compared to standard care (C), improve patient outcome (hemodynamics, survival) (O)?	Distributive shock and inotropes	Loh Tsee Foong	http://circ.ahajournals.org/site/C2010/Peds-045B.pdf
Peds	Peds-046A	In infants and children with cardiogenic shock (P), does the use of any specific inotropic agent (I) when compared with standard care (C), improve patient outcome (hemodynamics, survival) (O)?	Cardiogenic shock and inotropes	Akira Nishisaki	http://circ.ahajournals.org/site/C2010/Peds-046A.pdf
Peds	Peds-047A	In infants and children with hypotensive septic shock (P), does the use of etomidate as an induction agent to facilitate intubation (I) compared with a standard technique without etomidate (C) improve patient outcome (hemodynamics, survival) (O)?	Etomidate and septic shock	Stephen M. Schexnayder	http://circ.ahajournals.org/site/C2010/Peds-047A.pdf
Peds	Peds-047B	In infants and children with hypotensive septic shock (P), does the use of etomidate as an induction agent to facilitate intubation (I) compared with a standard technique without etomidate (C) improve patient outcome (hemodynamics, survival) (O)?	Etomidate and septic shock	Jonathan Duff	http://circ.ahajournals.org/site/C2010/Peds-047B.pdf
Peds	Peds-048A	In infants and children who are undergoing resuscitation from cardiac arrest (P), does consideration of a channelopathy as the etiology of the arrest (I), as compared with standard management (C), improve outcome (ROSC, survival to discharge, survival with favorable neurologic outcome) (O)?	Channelopathies	Robert Hickey	http://circ.ahajournals.org/site/C2010/Peds-048A.pdf
Peds	Peds-048B	In infants and children who are undergoing resuscitation from cardiac arrest (P), does consideration of a channelopathy as the etiology of the arrest (I), as compared with standard management (C), improve outcome (ROSC, survival to discharge, survival with favorable neurologic outcome) (O)?	Channelopathies	William Scott	http://circ.ahajournals.org/site/C2010/Peds-048B.pdf
Peds	Peds-049A	In infants and children with hypotensive septic shock (P), does the use of corticosteroids in addition to standard care (I) when compare with standard care without the use of corticosteroids (C), improve patient outcome (eg. Hemodynamics or survival) (O)?	Corticosteroids and septic shock	Arno Zaritsky	http://circ.ahajournals.org/site/C2010/Peds-049A.pdf
Peds	Peds-049B	In infants and children with hypotensive septic shock (P), does the use of corticosteroids in	Corticosteroids and septic shock	Mark G. Coulthard	http://circ.ahajournals.org/site/C2010/Peds-049B.pdf

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		addition to standard care (I) when compare with standard care without the use of corticosteroids (C), improve patient outcome (eg. Hemodynamics or survival) (O)?			
Peds	Peds-050A	In infants and children with acute illness or injury (P), do specific diagnostic tests (laboratory data [mixed venous oxygen saturation, pH, lactate], (I) as opposed to clinical data (vital signs, capillary refill, mental status, end-organ function [urine output]) (C), increase the accuracy of diagnosis of shock (O)?	Diagnostic tests for shock	Alexis Topjian	http://circ.ahajournals.org/site/C2010/Peds-050A.pdf
Peds	Peds-050B	In infants and children with acute illness or injury (P), do specific diagnostic tests (laboratory data [mixed venous oxygen saturation, pH, lactate], (I) as opposed to clinical data (vital signs, capillary refill, mental status, end-organ function [urine output]) (C), increase the accuracy of diagnosis of shock (O)?	Diagnostic tests for shock	Sharon B. Kinney	http://circ.ahajournals.org/site/C2010/Peds-050B.pdf
Peds	Peds-052A	In infants and children with cardiac arrest or symptomatic bradycardia that is unresponsive to oxygenation and/or ventilation (P), does the use of atropine (I), as compared with epinephrine or no atropine (C), improve patient outcome (return to age-appropriate heart rate, subsequent pulseless arrest, ROSC, survival) (O)?	Atropine vs epinephrine for bradycardia	Susan Fuchs, Sasa Kurosawa, Masahiko Nitta	http://circ.ahajournals.org/site/C2010/Peds-052A.pdf
Peds	Peds-055B	For infants and children with Fontan or hemi-Fontan circulation who require resuscitation from cardiac arrest or pre-arrest states (prehospital [OHCA] or in-hospital [IHCA]) (P), does any specific modification to standard practice (I) compared with standard resuscitation practice (C) improve outcome (eg. ROSC, survival to discharge, survival with good neurologic outcome (O)?	Resuscitation for hemi-Fontan/ Fontan circulation	Desmond Bohn, Bradley S. Marino	http://circ.ahajournals.org/site/C2010/Peds-055B.pdf
Peds	Peds-056A	For infants and children in cardiac arrest with pulmonary hypertension (prehospital [OHCA] or in-hospital [IHCA]) (P), do any specific modifications to resuscitation techniques (I) compared with standard resuscitation techniques (C), improve outcome (ROSC, survival to discharge, favorable neurologic survival) (O)?	Resuscitation of the patient with pulmonary hypertension	Ian Adatia, John Berger, David Wessel	http://circ.ahajournals.org/site/C2010/Peds-056A.pdf
Peds	Peds-057A	For infants and children who require endotracheal intubation (prehospital or in hospital) (P) does the use of a specific formula to guide cuffed endotracheal tube size (I), as opposed to the use of the existing formula of 3 + age/4 (C), achieve better outcomes (eg. successful tube placement) (O)?	Formula for cuffed ET tube size	Robert Bingham	http://circ.ahajournals.org/site/C2010/Peds-057A.pdf
Peds	Peds-057B	For infants and children who require endotracheal intubation (prehospital or in	Formulas for predicting ET tube size	Eugene B. Freid	http://circ.ahajournals.org/site/C2010/Peds-057B.pdf

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		hospital) (P) does the use of a specific formula to guide cuffed endotracheal tube size (I), as opposed to the use of the existing formula of 3 + age/4 (C), achieve better outcomes (eg. successful tube placement) (O)?			
Peds	Peds-059	For infants and children with single ventricle, s/p stage I repair who require resuscitation from cardiac arrest or pre-arrest states (prehospital [OHCA] or in-hospital [IHCA]) (P), does any specific modification to standard practice (I) compared with standard resuscitation practice (C) improve outcome (eg. ROSC, survival to discharge, survival with good neurologic outcome) (O)?	Resuscitation of the patient with single ventricle	George M. Hoffman, Shane Tibby	http://circ.ahajournals.org/site/C2010/Peds-059.pdf
Peds	Peds-060	For pediatric patients (in any setting (P), is there a clinical decision rule (I) that enables reliable prediction of ROSC (or futile resuscitation efforts)? (PROGNOSIS)	Clinical decision rules to predict ROSC	Gabrielle Nuthall	http://circ.ahajournals.org/site/C2010/Peds-060.pdf

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