

Part 6: Pediatric Basic and Advanced Life Support

The ILCOR Pediatric Task Force included expert reviewers from Africa, Asia, Australia, Asia, Europe, North America, and South America. These experts reviewed 45 topics related to pediatric resuscitation. Topics were selected from previous recommendations (the *ECC Guidelines 2000*^{1,2}), emerging science, and newly identified issues. Some well-established topics without controversies or new evidence (eg, adenosine for the treatment of supraventricular tachycardia [SVT]) are not included in this document.

Evidence-based worksheets on some topics were prepared and discussed but are not included here because there was insufficient evidence (eg, fibrinolytics in cardiac arrest,^{W13} securing the endotracheal tube in children,^{W1} use of impedance threshold device in children,^{W2} sodium bicarbonate for prolonged resuscitation attempts^{W34}) or because no new evidence was found (eg, evaluation of capillary refill,^{W10} ventilation before naloxone,^{W18} delayed volume resuscitation in trauma,^{W17} use of hypertonic saline in shock^{W16}).

The following is a summary of the most important changes in recommendations for pediatric resuscitation since the last ILCOR review in 2000.^{1,2} The scientific evidence supporting these recommendations is summarized in this document:

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

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

Identified knowledge gaps in pediatric resuscitation include

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

Initial Steps of CPR

The *ECC Guidelines 2000*¹ recommended that lone rescuers of *adult* victims of cardiac arrest phone the emergency medical services (EMS) system and get an AED (“call first”) before starting CPR. The lone rescuer of an unresponsive *infant or child* victim was instructed to provide a brief period

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of CPR before leaving the victim to phone for professional help and an AED (“call fast”). These sequence differences were based on the supposition that cardiac arrest in adults is due primarily to ventricular fibrillation (VF) and that a hypoxic-ischemic mechanism is more common in children. But this simplistic approach may be inaccurate and may not provide the ideal rescue sequence for many victims of cardiac arrest. Hypoxic-ischemic arrest may occur in adults, and VF may be the cause of cardiac arrest in up to 7% to 15% of infants and children. Resuscitation results might be improved if the sequence of lay rescuer CPR actions (ie, the priority of phoning for professional help, getting an AED, and providing CPR) is based on the etiology of cardiac arrest rather than age.

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

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

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

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

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

Activating Emergency Medical Services and Getting the AED^{W4}

Consensus on Science

Most cardiac arrests in children are caused by asphyxia (LOE 4).^{3–6} Observational studies of non-VF arrests in children show an association between bystander CPR and intact

neurologic outcome (LOE 4).^{6–8} Animal studies show that in asphyxial arrest, chest compressions plus ventilation CPR is superior to either chest compression-only CPR or ventilation-only CPR (LOE 6).⁹

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

Treatment Recommendation

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

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

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

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

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

Pulse Check^{W5A,W5B}

Consensus on Science

Ten studies (LOE 2^{20,21}; LOE 4^{22–26}; LOE 5²⁷; LOE 6^{28,29}) show that lay rescuers^{23,25,30} and healthcare providers^{20,21,24,26–29} are often unable to accurately determine the presence of a pulse within 10 seconds. Two studies in infants (LOE 5)^{31,32} reported that rescuers rapidly detected cardiac activity by direct chest auscultation but were biased because they knew that the infants were healthy.

Treatment Recommendation

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

Ventilations in Infants^{W7A,W7B}

Consensus on Science

One LOE 5³³ study and 10 LOE 7^{34–43} reports assessed a mouth-to-nose ventilation technique for infants. The LOE 5

study³³ is an anecdotal report of 3 infants ventilated with mouth-to-nose technique. The LOE 7 reports describe post-mortem anatomy,³⁴ physiology of nasal breathing,^{35–37} related breathing issues,^{38,39} and measurements of infants' faces compared with the measurement of adult mouths.^{40–43} There is great variation in these measurements, probably because of imprecise or inconsistent definitions.

Treatment Recommendation

There is no data to justify a change from the recommendation that the rescuer attempt mouth-to-mouth-and-nose ventilation for infants. Rescuers who have difficulty achieving a tight seal over the mouth and nose of an infant, however, may attempt either mouth-to-mouth or mouth-to-nose ventilation (LOE 5).³³

Circumferential Versus 2-Finger Chest Compressions^{W9A,W9B}

Consensus on Science

Two manikin (LOE 6)^{44,45} and 2 animal (LOE 6)^{46,47} studies showed that the 2 thumb–encircling hands technique of chest compressions with circumferential thoracic squeeze produces higher coronary perfusion pressures and more consistently correct depth and force of compression than the 2-finger technique.

Case reports (LOE 5)^{48,49} of hemodynamic monitoring in infants receiving chest compressions showed higher systolic and diastolic arterial pressures in the 2-thumb–encircling hands technique compared with the 2-finger technique.

Treatment Recommendation

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

One- Versus 2-Hand Chest Compression Technique^{W276}

Consensus on Science

There are no outcome studies that compare 1- versus 2-hand compressions of the chest in children. One (LOE 6)⁵⁰ study reported higher pressures generated in child manikins using the 2-hand technique to compress over the lower part of the sternum to a depth of approximately one third the anterior-posterior diameter of the chest. Rescuers reported that this technique was easy to perform.

Treatment Recommendation

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

Compression-Ventilation Ratio^{W3A,W3B,W3C}

Consensus on Science

There is insufficient data to identify an optimal compression-ventilation ratio for CPR in children. Manikin studies (LOE

6)^{51–54} have examined the feasibility of compression-ventilation ratios of 15:2 and 5:1. Lone rescuers cannot deliver the desired number of chest compressions per minute at a ratio of 5:1. A mathematical model (LOE 7)⁵⁵ supports compression-ventilation ratios higher than 5:1 for infants and children.

Two animal (LOE 6)^{56,57} studies show that coronary perfusion pressure, a major determinant of success in resuscitation, declines with interruptions in chest compressions. In addition, once compressions are interrupted, several chest compressions are needed to restore coronary perfusion pressure. Frequent interruptions of chest compressions (eg, with a 5:1 compression-ventilation ratio) prolongs the duration of low coronary perfusion pressure. Long interruptions in chest compressions have been documented in manikin studies (LOE 6)^{58,59} and both in- and out-of-hospital adult CPR studies (LOE 7).^{60,61} These interruptions reduce the likelihood of a return of spontaneous circulation (LOE 7).^{62–64}

Five animal (LOE 6)^{9,56,57,65,66} studies and one review (LOE 7)⁶⁷ suggest that ventilations are relatively less important in victims with VF or pulseless ventricular tachycardia (VT) cardiac arrest than in victims with asphyxia-induced arrest. But even in asphyxial arrest, few 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 Recommendation

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

Some CPR Versus No CPR^{W8}

Consensus on Science

Numerous reports (LOE 5)^{4,5,8,68–70} document survival of children after cardiac arrest when bystander CPR was provided. Bystander CPR in these reports included rescue breathing alone, chest compressions alone, or a combination of compressions and ventilations.

One prospective and 3 retrospective studies of adult VF (LOE 7)^{71–74} and numerous animal studies of VF cardiac arrest (LOE 6)^{56,57,66,75–79} document comparable long-term survival after chest compressions alone or chest compressions plus ventilations, and both techniques result in better outcomes compared with no CPR. In animals with asphyxial arrest (LOE 6),⁹ the more common mechanism of cardiac arrest in infants and children, best results are achieved with a combination of chest compressions and ventilations. But resuscitation with either ventilations only or chest compressions only is better than no CPR.

Treatment Recommendation

Bystander CPR is important for survival from cardiac arrest. Trained rescuers should be encouraged to provide both

ventilations and chest compressions. If rescuers are reluctant to provide rescue breaths, however, they should be encouraged to perform chest compressions alone without interruption.

Disturbances in Cardiac Rhythm

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

There is insufficient evidence to identify an optimal shock waveform, energy dose, and shock strategy (eg, fixed versus escalating shocks, 1 versus 3 stacked shocks) for defibrillation. The new recommendation for the sequence of defibrillation in children is based on extrapolated data from adult and animal studies with biphasic devices, data documenting the high rates of success for first shock conversion of VF with biphasic waveforms, and knowledge that interruption of chest compressions reduces coronary perfusion pressure. Thus, a 1-shock strategy may be preferable to the 3-shock sequence recommended in the *ECC Guidelines 2000*.² For further details, see Part 3: "Defibrillation."

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

Management of Supraventricular Tachycardias

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

Vagal Maneuvers for SVT^{W36}

Consensus on Science

One prospective (LOE 3)⁸⁰ and 9 observational studies (LOE 4⁸¹; LOE 5^{82,83}; LOE 7^{84–89}) show that vagal maneuvers are somewhat effective in terminating SVT in children. There are reports of complications from carotid sinus massage and application of ice to the face to stimulate the diving reflex (LOE 5),^{90,91} but virtually none from the Valsalva maneuver.

Treatment Recommendation

The Valsalva maneuver and ice application to the face may be used to treat hemodynamically stable SVT in infants and

children. When performed correctly, these maneuvers can be initiated quickly and safely and without altering subsequent therapies if they fail.

Amiodarone for Hemodynamically Stable SVT^{W38}

Consensus on Science

One prospective (LOE 3)⁹² and 10 observational (LOE 5)^{93–102} studies show that amiodarone is effective for treating SVT in children. A limitation of this evidence is that most of the studies in children describe treatment for postoperative junctional ectopic tachycardia.

Treatment Recommendation

Amiodarone may be considered in the treatment of hemodynamically stable SVT refractory to vagal maneuvers and adenosine. Rare but significant acute side effects include bradycardia, hypotension, and polymorphic VT (LOE 5).^{103–105}

Procainamide for Hemodynamically Stable SVT^{W37}

Consensus on Science

Experience with procainamide in children is limited. Twelve LOE 5^{106–117} and 4 LOE 6^{118–121} observational studies show that procainamide can terminate SVT that is resistant to other drugs. Most of these reports include mixed adult-pediatric populations. Hypotension following procainamide infusion results from its vasodilator action rather than a negative inotropic effect.(LOE 5^{122,123}; LOE 6¹²⁴).

Treatment Recommendation

Procainamide may be considered in the treatment of hemodynamically stable SVT refractory to vagal maneuvers and adenosine.

Management of Stable Wide-QRS Tachycardia

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

Amiodarone^{W39A,W39B,W40}

Consensus on Science

One case series (LOE 5)¹²⁵ suggests that wide-QRS tachycardia in children is more likely to be supraventricular than ventricular in origin. Two prospective studies (LOE 3)^{92,126} and 13 case series (LOE 5)^{93–102,127–129} show that amiodarone is effective for a wide variety of tachyarrhythmias in children. None of these reports specifically evaluates the role of amiodarone in the setting of a stable, unknown wide-complex tachycardia.

Treatment Recommendation

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

Procainamide for Stable VT^{W35}

Consensus on Science

Twenty (LOE 5)^{106,115,123,130–146} and 2 LOE 6^{118,124} observational studies primarily in adults but including some children

show that procainamide is effective in the treatment of stable VT.

Treatment Recommendation

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

Management of Unstable VT

Amiodarone^{W39A,W40}

Consensus on Science

In small pediatric case series (LOE 3¹⁰⁰; LOE 5^{93,95,97,99,147-149}) and extrapolation from animal (LOE 6)^{150,151} and adult (LOE 7)¹⁵²⁻¹⁶⁵ studies, amiodarone is safe and effective for hemodynamically unstable VT in children.

Treatment Recommendation

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

Pediatric Defibrillation

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

Manual and Automated External Defibrillation^{W41A,W41B}

Consensus on Science

The ideal energy dose for safe and effective defibrillation in children is unknown. Extrapolation from adult data (LOE 1^{166,167}; LOE 2¹⁶⁸⁻¹⁷⁰) and pediatric animal studies (LOE 6)¹⁷¹⁻¹⁷³ suggests that biphasic shocks are at least as effective as monophasic shocks and produce less postshock myocardial dysfunction. One LOE 5¹⁷⁴ and one LOE 6¹⁷¹ study show that an initial monophasic or biphasic shock dose of 2 J/kg generally terminates pediatric VF. Two pediatric case series (LOE 5)^{171,175,176} report that doses >4 J/kg (up to 9 J/kg) have effectively defibrillated children <12 years of age, with negligible adverse effects.

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

Treatment Recommendation

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

For automated defibrillation, we recommend an initial pediatric attenuated dose for children 1 to 8 years of age and up to about 25 kg (55 pounds) and 127 cm (50 inches) in

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

Management of Shock-Resistant VF/Pulseless VT

Amiodarone^{W20,W21A,W21B}

Consensus on Science

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

Treatment Recommendation

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

Airway and Ventilation

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

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

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

Bag-Valve-Mask Ventilation^{W6}

Consensus on Science

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

One study in pediatric cardiac arrest (LOE 4)¹⁸³ and 4 studies in children with trauma (LOE 3^{184,185}; LOE 4^{186,187})

found no advantage of tracheal intubation over BVM ventilation.

Treatment Recommendation

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

Advanced Airways

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

Cuffed Versus Uncuffed Tracheal Tubes^{W11A,W11B}

Consensus on Science

One randomized controlled trial (LOE 2),¹⁸⁸ 3 prospective cohort studies (LOE 3),^{189–191} and 1 cohort study (LOE 4)¹⁹² document no greater risk of complications for children <8 years of age when using cuffed tracheal tubes compared with uncuffed tubes in the operating room and intensive care unit.

Evidence from 1 randomized controlled trial (LOE 2)¹⁸⁸ and 1 small, prospective controlled study (LOE 3)¹⁹³ showed some advantage in cuffed over uncuffed tracheal tubes in children in the pediatric anesthesia and intensive care settings, respectively.

Treatment Recommendation

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

Laryngeal Mask Airway^{W26A,W26B}

Consensus on Science

There are no studies examining the use of the LMA in children during cardiac arrest. Evidence extrapolated from pediatric anesthesia shows a higher rate of complications with LMAs in smaller children compared with LMA experience in adults. The complication rate decreases with increasing operator experience (LOE 7).^{194,195} Case reports document that the LMA can be helpful for management of the difficult airway.

Treatment Recommendation

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

Confirmation of Tube Placement

Exhaled CO₂^{W25}

Consensus on Science

Misplaced, displaced, or obstructed tracheal tubes are associated with a high risk of death. No single method of tracheal tube confirmation is always accurate and reliable. One study (LOE 3)¹⁹⁶ showed that clinical assessment of tracheal tube position (observation of chest wall rise, mist in the tube, and auscultation of the chest) can be unreliable for distinguishing esophageal from tracheal intubation.

In 3 studies (LOE 5),^{197–199} when a perfusing cardiac rhythm was present in infants >2 kg and children, detection of exhaled CO₂ using a colorimetric detector or capnometer had a high sensitivity and specificity for tracheal tube placement. In one study (LOE 5)¹⁹⁸ during cardiac arrest, the sensitivity of exhaled CO₂ detection for tracheal tube placement was 85% and specificity 100%. Both with a perfusing rhythm and during cardiac arrest, the presence of exhaled CO₂ reliably indicates tracheal tube placement, but the absence of exhaled CO₂ during cardiac arrest does not prove tracheal tube misplacement.

Treatment Recommendation

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

Esophageal Detector Device^{W23}

Consensus on Science Statements

A study in the operating room (LOE 2)²⁰⁰ showed that the esophageal detector device (EDD) was highly sensitive and specific for correct tracheal tube placement in children weighing >20 kg with a perfusing cardiac rhythm. There have been no studies of the EDD in children during cardiac arrest. A pediatric animal study (LOE 6)²⁰¹ showed only fair results with the EDD, but accuracy improved with use of a larger syringe device. The same animal study showed no difference when the tracheal tube cuff was either inflated or deflated.

Treatment Recommendation

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

Confirmation of Tracheal Tube Placement During Transport^{W24}

Consensus on Science

Studies (LOE 1²⁰²; LOE 7²⁰³) have documented the high rate of inadvertent displacement of tracheal tubes during prehospital transport. There are no studies to evaluate the frequency of these events during intra- or interhospital transport.

Two studies (LOE 5)^{204,205} show that in the presence of a perfusing rhythm, exhaled CO₂ detection or measurement can confirm tracheal tube position accurately during transport. In

2 animal studies (LOE 6),^{206,207} loss of exhaled CO₂ detection indicated tracheal tube displacement more rapidly than pulse oximetry. On the basis of one case series (LOE 5),²⁰⁴ continuous use of colorimetric exhaled CO₂ detectors may not be reliable for long (>30 minutes) transport duration.

Treatment Recommendation

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

Oxygen

Oxygen During Resuscitation^{W14A,W14B}

Consensus on Science

Meta-analyses of 4 human studies (LOE 1)^{208,209} showed a reduction in mortality rates and no evidence of harm in newborns resuscitated with air compared with 100% oxygen (see Part 7: “Neonatal Resuscitation”). The 2 largest studies,^{210,211} however, were not blinded, so results should be interpreted with caution. Two animal studies (LOE 6)^{212,213} suggest that ventilation with room air may be superior to 100% oxygen during resuscitation from cardiac arrest, whereas one animal study (LOE 6)²¹⁴ showed no difference.

Treatment Recommendation

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

Vascular Access and Drugs for Cardiac Arrest

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

Routes of Drug Delivery

Intraosseous Access^{W29}

Consensus on Science

Two prospective randomized trials in adults and children (LOE 3)^{215,216} and 6 other studies (LOE 4²¹⁷; LOE 5^{218–220}; LOE 7^{221,222}) document that IO access is safe and effective for fluid resuscitation, drug delivery, and blood sampling for laboratory evaluation.

Treatment Recommendation

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

Drugs Given via Tracheal Tube^{W32}

Consensus on Science

One study in children (LOE 2),²²³ 5 studies in adults (LOE 2^{224–226}; LOE 3^{227,228}), and multiple animal studies (LOE 6)^{229–231} indicate that atropine, epinephrine, naloxone, lidocaine, and vasopressin are absorbed via the trachea. Administration of resuscitation drugs into the trachea results in lower blood concentrations than the same dose given intravascularly. Furthermore, animal studies (LOE 6)^{232–235} suggest that the lower epinephrine concentrations achieved when the drug is delivered by tracheal route may produce transient β -adrenergic effects. These effects can be detrimental, causing hypotension, lower coronary artery perfusion pressure and flow, and reduced potential for return of spontaneous circulation.

Treatment Recommendation

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

- Epinephrine 0.1 mg/kg (multiple LOE 6 studies)
- Lidocaine 2 to 3 mg/kg (LOE 3)²²⁸ and multiple LOE 6 studies
- Atropine 0.03mg/kg (LOE 2)²²⁴

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

Drugs in Cardiac Arrest

Dose of Epinephrine for Cardiac Arrest^{W31A,W31B}

Consensus on Science

In 4 pediatric studies (LOE 2^{236,237}; LOE 4^{238,239}) there was no improvement in survival rates and a trend toward worse neurologic outcome after administration of high-dose epinephrine for cardiac arrest. A prospective, randomized, controlled trial (LOE 2)²³⁶ comparing high-dose with standard-dose epinephrine for the second and subsequent (“rescue”) doses in pediatric in-hospital cardiac arrest showed reduced 24-hour survival rates in the high-dose epinephrine group. In subgroup analysis, survival rates in asphyxia and sepsis were significantly worse with high-dose rescue epinephrine.

Treatment Recommendation

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

Vasopressin in Cardiac Arrest^{W19A,W19B}

Consensus on Science

Based on a small series of children (LOE 5),²⁴⁰ vasopressin given after epinephrine may be associated with return of

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

Treatment Recommendation

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

Magnesium in Cardiac Arrest^{W15}

Consensus on Science

The relationship between serum magnesium concentrations and outcome of CPR was analyzed in 2 studies in adults (LOE 3²⁴⁸; LOE 4²⁴⁹) and one animal study (LOE 6).²⁵⁰ The first 2 studies indicated that a normal serum concentration of magnesium was associated with a higher rate of successful resuscitation, but it is unclear whether the association is causative. Six adult clinical studies (LOE 1²⁵¹; LOE 2^{252–255}; LOE 3²⁵⁶) and one study in an adult animal model (LOE 6)²⁵⁷ indicated no significant difference in any survival end point in patients who received magnesium before, during, or after CPR.

Treatment Recommendation

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

Postresuscitation Care

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

Ventilation

Hyperventilation^{W27}

Consensus on Science

One study in cardiac arrest patients (LOE 3)²⁵⁸ and extrapolation from 12 other studies (LOE 6²⁵⁹; LOE 2²⁶⁰; LOE 3^{261–267}; LOE 4²⁶⁸; LOE 5^{269,270}) suggest that hyperventilation may cause decreased venous return to the heart and cerebral ischemia and may be harmful in the comatose patient after cardiac arrest.

Treatment Recommendation

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

Temperature Control

Therapeutic Hypothermia^{W22B,W22C}

Consensus on Science

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

- Two prospective randomized studies of adults with VF arrest (LOE 1²⁷²; LOE 2²⁷³)
- One study of newborns with birth asphyxia (LOE 2)²⁷⁴
- Numerous animal studies (LOE 6) of both asphyxial and VF arrest
- Acceptable safety profiles in adults (LOE 7)^{272,273} and neonates (LOE 7)^{275–278} treated with hypothermia (32°C to 34°C) for up to 72 hours

Treatment Recommendation

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

Treatment of Hyperthermia^{W22A,W22D}

Consensus on Science

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

Treatment Recommendation

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

Hemodynamic Support

Vasoactive Drugs^{W33A,W33B,W33C,W33D}

Consensus on Science

Two studies in children (LOE 5),^{286,287} multiple studies in adults (LOE 7),^{288–290} and animal studies (LOE 6)^{291–293} indicate that myocardial dysfunction is common after resuscitation from cardiac arrest. Multiple animal studies (LOE 6)^{294–296} document consistent improvement in hemodynamics when selected vasoactive drugs are given in the post-cardiac arrest period. Evidence extrapolated from multiple adult and pediatric studies (LOE 7)^{297–302} of cardiovascular surgical patients with low cardiac output documents consistent improvement in hemodynamics when vasoactive drugs are titrated in the period after cardiopulmonary bypass.

Treatment Recommendation

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

Blood Glucose Control

Treatment of Hypoglycemia and Hyperglycemia^{W30A,W30B,W30C}

Consensus on Science

Adults with out-of-hospital cardiac arrest and elevated blood glucose on admission have poor neurologic and survival outcomes (LOE 7).^{303–308} In critically ill children, hypoglycemia (LOE 5)³⁰⁹ and hyperglycemia (LOE 5)³¹⁰ are associated with poor outcome. It is unknown if the association of hyperglycemia with poor outcome after cardiac arrest is causative or an epiphenomenon related to the stress response.

In critically ill adult surgical patients, (LOE 7)³¹¹ strict glucose control improves outcome, but there is currently insufficient data in children showing that the benefit of tight glucose control outweighs the risk of inadvertent hypoglycemia.

Several animal studies (LOE 6)^{312–316} and an adult clinical study (LOE 4)³¹⁷ show poor outcome when glucose is given immediately before or during cardiac arrest. It is unknown if there is harm in giving glucose-containing maintenance fluids to children after cardiac arrest.

Hypoglycemia is an important consideration in pediatric resuscitation because

- Critically ill children are hypermetabolic compared with baseline and have increased glucose requirement (6 to 8 mg/kg per minute) to prevent catabolism.
- The combined effects of hypoglycemia and hypoxia/ischemia on the immature brain (neonatal animals) appears more deleterious than the effect of either insult alone.³¹⁸
- Four retrospective studies of human neonatal asphyxia show an association between hypoglycemia and subsequent brain injury (LOE 4)^{319,320}; (LOE 5)^{321,322}.

Treatment Recommendation

Healthcare providers should check glucose concentration during cardiac arrest and monitor it closely afterward with the goal of maintaining normoglycemia. Glucose-containing fluids are not indicated during CPR unless hypoglycemia is present (LOE 7).³²³

Prognosis

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

Predictors of Outcome in Children^{W12B,W28}

Consensus on Science

Multiple studies in adults have linked characteristics of the patient or of the cardiac arrest with prognosis following

in-hospital or out-of-hospital cardiac arrest. Experience in children is more limited. Six pediatric studies (LOE 5)^{3,324–328} show that prolonged resuscitation is associated with a poor outcome. Although the likelihood of a good outcome is greater with short duration of CPR, 2 pediatric studies (LOE 3)^{328,329} reported good outcomes in some patients following 30 to 60 minutes of CPR in the in-patient setting when the arrests were witnessed and prompt and presumably excellent CPR was provided. Children with cardiac arrest associated with environmental hypothermia or immersion in icy water can have excellent outcomes despite >30 minutes of cardiac arrest (LOE 5).^{7,330}

One large pediatric study (LOE 4)³³¹ and several smaller studies (LOE 5)^{332–336} show that good outcome can be achieved when extracorporeal CPR is started after 30 to 90 minutes of refractory standard CPR for in-hospital cardiac arrests. The good outcomes were reported primarily in patients with isolated heart disease. This data shows that 15 or 30 minutes of CPR does not define the limits of cardiac and cerebral viability.

Witnessed events, bystander CPR, and a short interval from collapse to arrival of EMS system personnel are important prognostic factors associated with improved outcome in adult resuscitation, and it seems reasonable to extrapolate these factors to children. At least one pediatric study (LOE 5)³²⁸ showed that the interval from collapse to initiation of CPR is a significant prognostic factor.

Children with prehospital cardiac arrest caused by blunt trauma³³⁷ and in-hospital cardiac arrest caused by septic shock³²⁹ rarely survive.

Treatment Recommendation

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

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