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Part 11: Pediatric Basic Life Support

For best survival and quality of life, pediatric basic life support (BLS) should be part of a community effort that includes prevention, basic CPR, prompt access to the emergency medical services (EMS) system, and prompt pediatric advanced life support (PALS). These 4 links form the American Heart Association (AHA) pediatric Chain of Survival (Figure 1). The first 3 links constitute pediatric BLS.

Rapid and effective bystander CPR is associated with successful return of spontaneous circulation and neurologically intact survival in children.^{1,2} The greatest impact occurs in respiratory arrest,³ in which neurologically intact survival rates of >70% are possible,^{4–6} and in ventricular fibrillation (VF), in which survival rates of 30% have been documented.⁷ But only 2% to 10% of all children who develop out-of-hospital cardiac arrest survive, and most are neurologically devastated.^{7–13} Part of the disparity is that bystander CPR is provided for less than half of the victims of out-of-hospital arrest.^{8,11,14} Some studies show that survival and neurologic outcome can be improved with prompt CPR.^{6,15–17}

Prevention of Cardiopulmonary Arrest

The major causes of death in infants and children are respiratory failure, sudden infant death syndrome (SIDS), sepsis, neurologic diseases, and injuries.¹⁸

Injuries

Injuries, the leading cause of death in children and young adults, cause more childhood deaths than all other causes combined.¹⁸ Many injuries are preventable. The most common fatal childhood injuries amenable to prevention are motor vehicle passenger injuries, pedestrian injuries, bicycle injuries, drowning, burns, and firearm injuries.¹⁹

Motor Vehicle Injuries

Motor vehicle–related injuries account for nearly half of all pediatric deaths in the United States.¹⁸ Contributing factors include failure to use proper passenger restraints, inexperienced adolescent drivers, and alcohol.

Appropriate restraints include properly installed, rear-facing infant seats for infants <20 pounds (<9 kg) and <1 year of age, child restraints for children 1 to 4 years of age, and booster seats with seat belts for children 4 to 7 years of age.²⁰ The lifesaving benefit of air bags for older children and adults far outweighs their risk. Most pediatric air bag–related fatalities occur when children <12 years of age are in the vehicle's front seat or are improperly restrained for their age. For additional information consult the website of the National Highway Traffic Safety Administration (NHTSA): <http://www.nhtsa.gov>



Figure 1. Pediatric Chain of Survival.

[nhtsa.gov](http://www.nhtsa.gov). Look for the Comprehensive Child Passenger Safety Information.

Adolescent drivers are responsible for a disproportionate number of motor vehicle–related injuries; the risk is highest in the first 2 years of driving. Driving with teen passengers and driving at night dramatically increase the risk. Additional risks include not wearing a seat belt, drinking and driving, speeding, and aggressive driving.²¹

Pedestrian Injuries

Pedestrian injuries account for a third of motor vehicle–related injuries. Adequate supervision of children in the street is important because injuries typically occur when a child darts out mid-block, dashes across intersections, or gets off a bus.²²

Bicycle Injuries

Bicycle crashes are responsible for approximately 200 000 injuries and nearly 150 deaths per year in children and adolescents.²³ Head injuries are a major cause of bicycle–related morbidity and mortality. It is estimated that bicycle helmets can reduce the severity of head injuries by >80%.²⁴

Burns

Approximately 80% of fire-related and burn-related deaths result from house fires and smoke inhalation.^{25,26} Smoke detectors are the most effective way to prevent deaths and injuries; 70% of deaths occur in homes without functioning smoke alarms.²⁷

Firearm Injuries

The United States has the highest firearm-related injury rate of any industrialized nation—more than twice that of any other country.²⁸ The highest number of deaths is in adolescents and young adults, but firearm injuries are more likely to be fatal in young children.²⁹ The presence of a gun in the home is associated with an increased likelihood of adolescent^{30,31} and adult suicides or homicides.³² Although overall firearm-related deaths declined from 1995 to 2002, firearm homicide remains the leading cause of death among African-American adolescents and young adults.¹⁸

Sudden Infant Death Syndrome

SIDS is “the sudden death of an infant under 1 year of age, which remains unexplained after a thorough case investigation, including performance of a complete autopsy, examination of the death scene, and review of the clinical history.”³³ The peak incidence of SIDs occurs in infants 2 to 4 months of

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age.³⁴ The etiology of SIDS remains unknown, but risk factors include prone sleeping position, sleeping on a soft surface,^{35–37} and second-hand smoke.^{38,39} The incidence of SIDS has declined 40%⁴⁰ since the “Back to Sleep” public education campaign was introduced in the United States in 1992. This campaign aims to educate parents about placing an infant on the back rather than the abdomen or side to sleep.

Drowning

Drowning is the second major cause of death from unintentional injury in children <5 years of age and the third major cause of death in adolescents. Most young children drown after falling into swimming pools while unsupervised; adolescents more commonly drown in lakes and rivers while swimming or boating. Drowning can be prevented by installing isolation fencing around swimming pools (gates should be self-closing and self-latching)⁴¹ and wearing personal flotation devices (life jackets) while in, around, or on water.

The BLS Sequence for Infants and Children

For the purposes of these guidelines, an “infant” is less than approximately 1 year of age. This section does not deal with newborn infants (see Part 13: “Neonatal Resuscitation Guidelines”). For lay rescuers the “child” BLS guidelines should be applied when performing CPR for a child from about 1 year of age to about 8 years of age. For a healthcare provider, the pediatric (“child”) guidelines apply from about 1 year to about the start of puberty. For an explanation of the differences in etiology of arrest and elaboration of the differences in the recommended sequence for lay rescuer and healthcare provider CPR for infants, children, and adults, see Part 3: “Overview of CPR.”

These guidelines delineate a series of skills as a *sequence* of distinct steps, but they are often performed simultaneously (eg, starting CPR and activating the EMS system), especially when more than one rescuer is present. This sequence is depicted in the Pediatric Healthcare Provider BLS Algorithm (Figure 2). The numbers listed with the headings below refer to the corresponding box in that algorithm.

Safety of Rescuer and Victim

Always make sure that the area is safe for you and the victim. Move a victim only to ensure the victim’s safety. Although exposure to a victim while providing CPR carries a theoretical risk of infectious disease transmission, the risk is very low.⁴²

Check for Response (Box 1)

- Gently tap the victim and ask loudly, “Are you okay?” Call the child’s name if you know it.
- Look for movement. If the child is *responsive*, he or she will answer or move. Quickly check to see if the child has any injuries or needs medical assistance. If necessary, leave the child to phone EMS, but return quickly and recheck the child’s condition frequently. Children with respiratory distress often assume a position that maintains airway patency and optimizes ventilation. Allow the child with

respiratory distress to remain in a position that is most comfortable.

- If the child is *unresponsive* and is not moving, shout for help and start CPR. If you are alone, continue CPR for 5 cycles (about 2 minutes). One cycle of CPR for the lone rescuer is 30 compressions and 2 breaths (see below). Then activate the EMS system and get an automated external defibrillator (AED) (see below). If you are alone and there is no evidence of trauma, you may carry a small child with you to the telephone. The EMS dispatcher can guide you through the steps of CPR. If a second rescuer is present, that rescuer should immediately activate the EMS system and get an AED (if the child is 1 year of age or older) while you continue CPR. If you suspect trauma, the second rescuer may assist by stabilizing the child’s cervical spine (see below). If the child must be moved for safety reasons, support the head and body to minimize turning, bending, or twisting of the head and neck.

Activate the EMS System and Get the AED (Box 2)

If the arrest is witnessed and sudden^{2,7,43} (eg, an athlete who collapses on the playing field), a lone healthcare provider should activate the EMS system (by telephoning 911 in most locales) and get an AED (if the child is 1 year of age or older) before starting CPR. It would be ideal for the lone lay rescuer who witnesses the sudden collapse of a child to also activate the EMS system and get an AED and return to the child to begin CPR and use the AED. But for simplicity of lay rescuer education it is acceptable for the lone lay rescuer to provide about 5 cycles (about 2 minutes) of CPR for any infant or child victim before leaving to phone 911 and get an AED (if appropriate). This sequence may be tailored for some learners (eg, the mother of a child at high risk for a sudden arrhythmia). If two rescuers are present, one rescuer should begin CPR while the other rescuer activates the EMS system and gets the AED.

Position the Victim

If the victim is unresponsive, make sure that the victim is in a supine (face up) position on a flat, hard surface, such as a sturdy table, the floor, or the ground. If you must turn the victim, minimize turning or twisting of the head and neck.

Open the Airway and Check Breathing (Box 3)

In an unresponsive infant or child, the tongue may obstruct the airway, so the rescuer should open the airway.^{44–47}

Open the Airway: Lay Rescuer

If you are a lay rescuer, open the airway using a head tilt–chin lift maneuver for both injured and noninjured victims (Class IIa). The jaw thrust is no longer recommended for lay rescuers because it is difficult to learn and perform, is often not an effective way to open the airway, and may cause spinal movement (Class IIb).

Open the Airway: Healthcare Provider

A healthcare provider should use the head tilt–chin lift maneuver to open the airway of a victim without evidence of head or neck trauma.

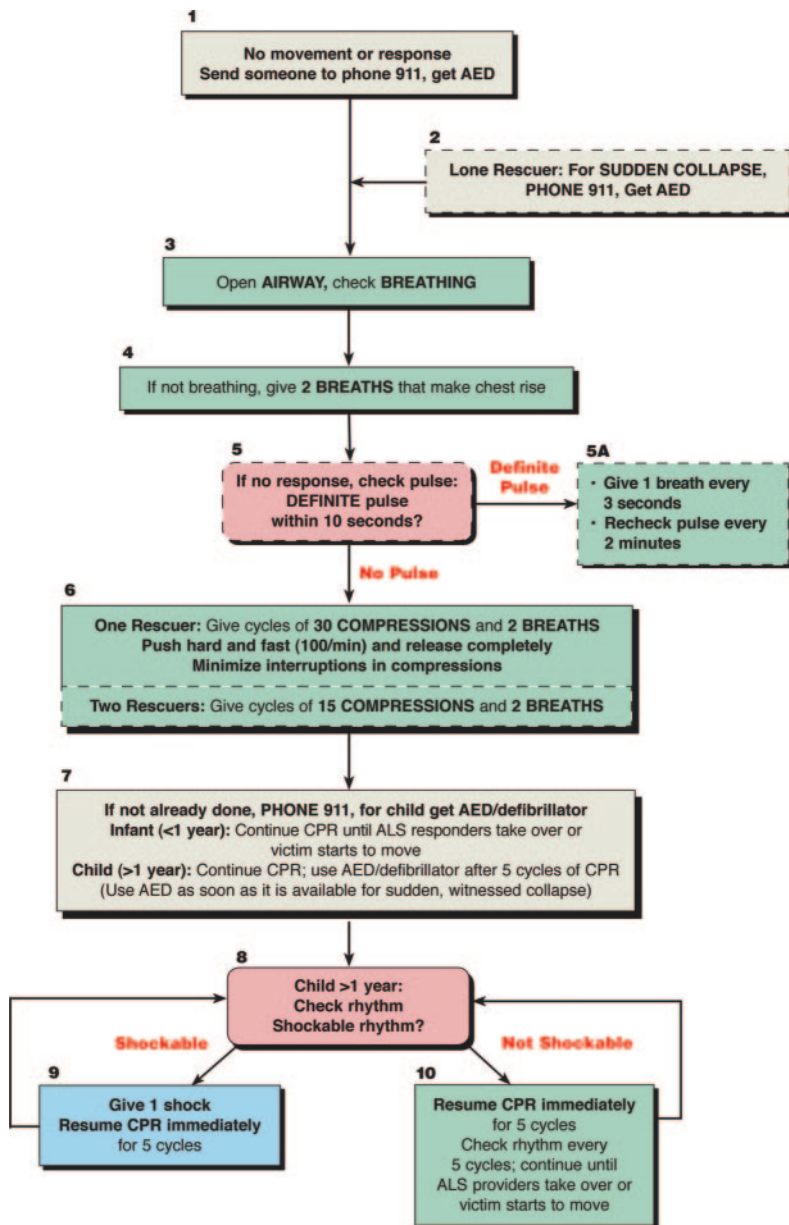


Figure 2. Pediatric Healthcare Provider BLS Algorithm. Note that the boxes bordered by dotted lines are performed by healthcare providers and not by lay rescuers.

Approximately 2% of all victims with blunt trauma requiring spinal imaging in an emergency department have a spinal injury. This risk is tripled if the victim has craniofacial injury,⁴⁸ a Glasgow Coma Scale score of <8,⁴⁹ or both.^{48,50} If you are a healthcare provider and suspect that the victim may have a cervical spine injury, open the airway using a jaw thrust without head tilt (Class IIb).^{46,51,52} Because maintaining a patent airway and providing adequate ventilation is a priority in CPR (Class I), use a head tilt–chin lift maneuver if the jaw thrust does not open the airway.

Check Breathing (Box 3)

While maintaining an open airway, take no more than 10 seconds to check whether the victim is breathing: *Look* for rhythmic chest and abdominal movement, *listen* for exhaled breath sounds at the nose and mouth, and *feel* for exhaled air on your cheek. Periodic gasping, also called *agonal gasps*, is not breathing.^{53,54}

- If the child is *breathing* and there is no evidence of trauma: turn the child onto the side (recovery position, Figure 3). This helps maintain a patent airway and decreases risk of aspiration.

Give Rescue Breaths (Box 4)

If the child is *not breathing or has only occasional gasps*:

- For the lay rescuer: maintain an open airway and give 2 breaths.
- For the healthcare provider: maintain an open airway and give 2 breaths. Make sure that the breaths are effective (ie, the chest rises). If the chest does not rise, reposition the head, make a better seal, and try again.⁵⁵ It may be necessary to move the child’s head through a range of positions to obtain optimal airway patency and effective rescue breathing.



Figure 3. Recovery position.

In an infant, use a mouth-to-mouth-and-nose technique (LOE 7; Class IIb); in a child, use a mouth-to-mouth technique.⁵⁵

Comments on Technique

In an infant, if you have difficulty making an effective seal over the mouth and nose, try either mouth-to-mouth or mouth-to-nose ventilation (LOE 5; Class IIb).^{56–58} If you use the mouth-to-mouth technique, pinch the nose closed. If you use the mouth-to-nose technique, close the mouth. In either case make sure the chest rises when you give a breath.

Barrier Devices

Despite its safety,⁴² some healthcare providers^{59–61} and lay rescuers^{8,62,63} may hesitate to give mouth-to-mouth rescue breathing and prefer to use a barrier device. Barrier devices have not reduced the risk of transmission of infection,⁴² and some may increase resistance to air flow.^{64,65} If you use a barrier device, do not delay rescue breathing.

Bag-Mask Ventilation (Healthcare Providers)

Bag-mask ventilation can be as effective as endotracheal intubation and safer when providing ventilation for short periods.^{66–69} But bag-mask ventilation requires training and periodic retraining in the following skills: selecting the correct mask size, opening the airway, making a tight seal between the mask and face, delivering effective ventilation, and assessing the effectiveness of that ventilation. In the out-of-hospital setting, preferentially ventilate and oxygenate infants and children with a bag and mask rather than attempt intubation if transport time is short (Class IIa; LOE 1⁶⁶; 3⁶⁷; 4^{68,69}).

Ventilation Bags

Use a self-inflating bag with a volume of at least 450 to 500 mL⁷⁰; smaller bags may not deliver an effective tidal volume or the longer inspiratory times required by full-term neonates and infants.⁷¹

A self-inflating bag delivers only room air unless supplementary oxygen is attached, but even with an oxygen inflow of 10 L/min, the concentration of delivered oxygen varies from 30% to 80% and depends on the tidal volume and peak inspiratory flow rate.⁷² To deliver a high oxygen concentration (60% to 95%), attach an oxygen reservoir to the self-inflating bag. You must maintain an oxygen flow of 10 to

15 L/min into a reservoir attached to a pediatric bag⁷² and a flow of at least 15 L/min into an adult bag.

Precautions

Avoid hyperventilation; use only the force and tidal volume necessary to make the chest rise. Give each breath over 1 second.

- In a victim of cardiac arrest with no advanced airway in place, pause after 30 compressions (1 rescuer) or 15 compressions (2 rescuers) to give 2 ventilations when using either mouth-to-mouth or bag-mask technique.
- During CPR for a victim with an advanced airway (eg, endotracheal tube, esophageal-tracheal combitube [Combitube], or laryngeal mask airway [LMA]) in place, rescuers should no longer deliver “cycles” of CPR. The compressing rescuer should compress the chest at a rate of 100 times per minute without pauses for ventilations, and the rescuer providing the ventilation should deliver 8 to 10 breaths per minute. Two or more rescuers should change the compressor role approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions.
- If the victim has a perfusing rhythm (ie, pulses are present) but no breathing, give 12 to 20 breaths per minute (1 breath every 3 to 5 seconds).

Healthcare providers often deliver excessive ventilation during CPR,^{73–75} particularly when an advanced airway is in place. Excessive ventilation is detrimental because it

- Impedes venous return and therefore decreases cardiac output, cerebral blood flow, and coronary perfusion by increasing intrathoracic pressure⁷⁴
- Causes air trapping and barotrauma in patients with small-airway obstruction
- Increases the risk of regurgitation and aspiration

Rescuers should provide the recommended number of rescue breaths per minute.

You may need high pressures to ventilate patients with airway obstruction or poor lung compliance. A pressure-relief valve can prevent delivery of sufficient tidal volume.⁷² Make sure that the manual bag allows you to use high pressures if necessary to achieve visible chest expansion.⁷⁶

Two-Person Bag-Mask Ventilation

A 2-person technique may be necessary to provide effective bag-mask ventilation when there is significant airway obstruction, poor lung compliance,⁷⁶ or difficulty in creating a tight seal between the mask and the face. One rescuer uses both hands to open the airway and maintain a tight mask-to-face seal while the other compresses the ventilation bag. Both rescuers should observe the chest to ensure chest rise.

Gastric Inflation and Cricoid Pressure

Gastric inflation may interfere with effective ventilation⁷⁷ and cause regurgitation. To minimize gastric inflation:

- Avoid excessive peak inspiratory pressures (eg, ventilate slowly).⁶⁶

- Apply cricoid pressure. Do this only in an unresponsive victim and if there is a second rescuer.^{78–80} Avoid excessive pressure so as not to obstruct the trachea.⁸¹

Oxygen

Despite animal and theoretic data suggesting possible adverse effects of 100% oxygen,^{82–85} there are no studies comparing various concentrations of oxygen during resuscitation beyond the newborn period. Until additional information becomes available, healthcare providers should use 100% oxygen during resuscitation (Class Indeterminate). Once the patient is stable, wean supplementary oxygen but ensure adequate oxygen delivery by appropriate monitoring. Whenever possible, humidify oxygen to prevent mucosal drying and thickening of pulmonary secretions.

Masks

Masks provide an oxygen concentration of 30% to 50% to a victim with spontaneous breathing. For a higher concentration of oxygen, use a tight-fitting nonrebreathing mask with an oxygen inflow rate of approximately 15 L/min that maintains inflation of the reservoir bag.

Nasal Cannulas

Infant and pediatric size nasal cannulas are suitable for children with spontaneous breathing. The concentration of delivered oxygen depends on the child's size, respiratory rate, and respiratory effort.⁸⁶ For example, a flow rate of only 2 L/min can provide young infants with an inspired oxygen concentration >50%.

Pulse Check (for Healthcare Providers) (Box 5)

If you are a healthcare provider, you should try to palpate a pulse (brachial in an infant and carotid or femoral in a child). Take no more than 10 seconds. Studies show that healthcare providers^{87–93} as well as lay rescuers^{94–96} are unable to reliably detect a pulse and at times will think a pulse is present when there is no pulse. For this reason, if you do not definitely feel a pulse (eg, there is no pulse or you are not sure you feel a pulse) within 10 seconds, proceed with chest compressions.

If despite oxygenation and ventilation the pulse is <60 beats per minute (bpm) and there are signs of poor perfusion (ie, pallor, cyanosis), begin chest compressions. Profound bradycardia in the presence of poor perfusion is an indication for chest compressions because an inadequate heart rate with poor perfusion indicates that cardiac arrest is imminent. Cardiac output in infancy and childhood largely depends on heart rate. No scientific data has identified an absolute heart rate at which chest compressions should be initiated; the recommendation to provide cardiac compression for a heart rate <60 bpm with signs of poor perfusion is based on ease of teaching and skills retention. For additional information see “Bradycardia” in Part 12: “Pediatric Advanced Life Support.”

If the pulse is ≥ 60 bpm but the infant or child is not breathing, provide rescue breathing without chest compressions (see below).

Lay rescuers are not taught to check for a pulse. The lay rescuer should immediately begin chest compressions after delivering 2 rescue breaths.

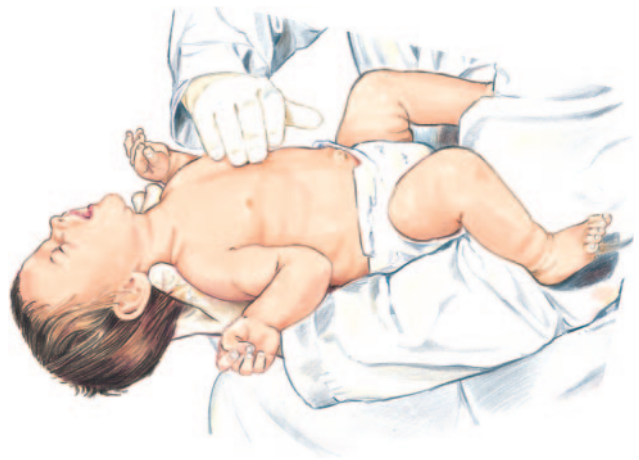


Figure 4. Two-finger chest compression technique in infant (1 rescuer).

Rescue Breathing Without Chest Compressions (for Healthcare Providers Only) (Box 5A)

If the pulse is ≥ 60 bpm but there is no spontaneous breathing or inadequate breathing, give rescue breaths at a rate of about 12 to 20 breaths per minute (1 breath every 3 to 5 seconds) until spontaneous breathing resumes (Box 5A). Give each breath over 1 second. Each breath should cause visible chest rise.

During delivery of rescue breaths, reassess the pulse about every 2 minutes (Class IIa), but spend no more than 10 seconds doing so.

Chest Compressions (Box 6)

To give chest compressions, compress the lower half of the sternum but do not compress over the xiphoid. After each compression allow the chest to recoil fully (Class IIb) because complete chest reexpansion improves blood flow into the heart.⁹⁷ A manikin study⁹⁷ showed that one way to ensure complete recoil is to lift your hand slightly off the chest at the end of each compression, but this has not been studied in humans (Class Indeterminate). The following are characteristics of good compressions:

- “Push hard”: push with sufficient force to depress the chest approximately one third to one half the anterior-posterior diameter of the chest.
- “Push fast”: push at a rate of approximately 100 compressions per minute.
- Release completely to allow the chest to fully recoil.
- Minimize interruptions in chest compressions.

In an *infant victim*, lay rescuers and lone rescuers should compress the sternum with 2 fingers (Figure 4) placed just below the intermammary line (Class IIb; LOE 5, 6).^{98–102}

The 2 thumb–encircling hands technique (Figure 5) is recommended for healthcare providers when 2 rescuers are present. Encircle the infant's chest with both hands; spread your fingers around the thorax, and place your thumbs together over the lower half of the sternum.^{98–102} Forcefully compress the sternum with your thumbs as you squeeze the thorax with your fingers for counterpressure (Class IIa; LOE



Figure 5. Two thumb-encircling hands chest compression in infant (2 rescuers).

^{5103,104}; ^{6105,106}). If you are alone or you cannot physically encircle the victim's chest, compress the chest with 2 fingers (as above). The 2 thumb-encircling hands technique is preferred because it produces higher coronary artery perfusion pressure, more consistently results in appropriate depth or force of compression,^{105–108} and may generate higher systolic and diastolic pressures.^{103,104,109,110}

In a *child*, lay rescuers and healthcare providers should compress the lower half of the sternum with the heel of 1 hand or with 2 hands (as used for adult victims) but should not press on the xiphoid or the ribs. There is no outcome data that shows a 1-hand or 2-hand method to be superior; higher compression pressures can be obtained on a child manikin with 2 hands.¹¹¹ Because children and rescuers come in all sizes, rescuers may use either 1 or 2 hands to compress the child's chest. It is most important that the chest be compressed about one third to one half the anterior-posterior depth of the chest.

Coordinate Chest Compressions and Breathing (Box 6)

The ideal compression-ventilation ratio is unknown, but studies have emphasized the following:

- In 2000¹¹² a compression-ventilation ratio of 5:1 and a compression rate of 100 per minute were recommended. But at that ratio and compression rate, fewer than 50 compressions per minute were performed in an adult manikin, and fewer than 60 compressions per minute were performed in a pediatric manikin even under ideal circumstances.^{113–115}
- It takes a number of chest compressions to raise coronary perfusion pressure, which drops with each pause (eg, to provide rescue breathing, check for a pulse, attach an AED).^{116,117}
- Long and frequent interruptions in chest compressions have been documented during CPR by lay rescuers^{118,119} and by healthcare providers^{75,120} in the out-of-hospital and in-hospital settings. Interruptions in chest compressions are associated with decreased rate of return of spontaneous circulation.^{121–123}
- Ventilations are relatively less important during the first minutes of CPR for victims of a sudden arrhythmia-induced cardiac arrest (VF or pulseless ventricular

tachycardia [VT]) than they are after asphyxia-induced arrest,^{116,117,124–127} but even in asphyxial arrest, a minute ventilation that is lower than normal is likely to maintain an adequate ventilation-perfusion ratio because cardiac output and, therefore, pulmonary blood flow produced by chest compressions is quite low.

- For lay rescuers, a single compression-ventilation ratio (30:2) for all age groups may increase the number of bystanders who perform CPR because it is easier to remember.

If you are the only rescuer, perform cycles of 30 chest compressions (Class Indeterminate) followed by 2 effective ventilations with as short a pause in chest compressions as possible (Class IIb). Make sure to open the airway before giving ventilations.

For 2-rescuer CPR (eg, by healthcare providers or others, such as lifeguards, who are trained in this technique), one provider should perform chest compressions while the other maintains the airway and performs ventilations at a ratio of 15:2 with as short a pause in compressions as possible. Do not ventilate and compress the chest simultaneously with either mouth-to-mouth or bag-mask ventilation. The 15:2 ratio for 2 rescuers is applicable in children up to the start of puberty.

Rescuer fatigue can lead to inadequate compression rate and depth and may cause the rescuer to fail to allow complete chest wall recoil between compressions.¹²⁸ The quality of chest compressions deteriorates within minutes even when the rescuer denies feeling fatigued.^{129,130} Once an advanced airway is in place for infant, child, or adult victims, 2 rescuers no longer deliver cycles of compressions interrupted with pauses for ventilation. Instead, the compressing rescuer should deliver 100 compressions per minute continuously without pauses for ventilation. The rescuer delivering the ventilations should give 8 to 10 breaths per minute and should be careful to avoid delivering an excessive number of ventilations. Two or more rescuers should rotate the compressor role approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions. The switch should be accomplished as quickly as possible (ideally in less than 5 seconds) to minimize interruptions in chest compressions.

Compression-Only CPR

Ventilation may not be essential in the first minutes of VF cardiac arrest,^{116,124,127,131} during which periodic gasps and passive chest recoil may provide some ventilation if the airway is open.¹²⁴ This, however, is not true for most cardiac arrests in infants and children, which are more likely to be asphyxial cardiac arrest. These victims require both prompt ventilations and chest compressions for optimal resuscitation. If a rescuer is unwilling or unable to provide ventilations, chest compressions alone are better than no resuscitation at all (LOE 5 through 7; Class IIb).^{125,126}

Activate the EMS System and Get the AED (Box 7)

In the majority of infants and children with cardiac arrest, the arrest is asphyxial.^{8,11,17,132,133} Lone rescuers (with the exception of healthcare providers who witness sudden collapse) should perform CPR for 5 cycles (about 2 minutes) before

activating EMS, then start CPR again with as few interruptions of chest compressions as possible. If there are more rescuers present, one rescuer should begin the steps of CPR as soon as the infant or child is found to be unresponsive and a second rescuer should activate the EMS system and get an AED. Minimize interruption of chest compressions.

Defibrillation (Box 8)

VF can be the cause of sudden collapse, or it may develop during resuscitation attempts.^{7,134} Children with sudden witnessed collapse (eg, a child collapsing during an athletic event) are likely to have VF or pulseless VT and need immediate CPR and rapid defibrillation. VF and pulseless VT are referred to as “shockable rhythms” because they respond to electric shocks (defibrillation).

Many AEDs have high specificity in recognizing pediatric shockable rhythms, and some are equipped to decrease the delivered energy to make it suitable for children 1 to 8 years of age.^{134,135} Since the publication of the *ECC Guidelines 2000*,¹¹² data has shown that AEDs can be safely and effectively used in children 1 to 8 years of age.^{136–138} However, there is insufficient data to make a recommendation for or against using an AED in infants <1 year of age (Class Indeterminate).^{136–138}

In systems and institutions that care for children and have an AED program, it is recommended that the AED have both a high specificity in recognizing pediatric shockable rhythms and a pediatric dose-attenuating system to reduce the dose delivered by the device. In an emergency if an AED with a pediatric attenuating system is not available, use a standard AED. Turn the AED on, follow the AED prompts, and resume chest compressions immediately after the shock. Minimize interruptions in chest compressions.

CPR Techniques and Adjuncts

There is insufficient data in infants and children to recommend for or against the use of mechanical devices to compress the sternum, active compression-decompression CPR, interposed abdominal compression CPR (IAC-CPR), or the impedance threshold device (Class Indeterminate). See Part 6: “CPR Techniques and Devices” for adjuncts in adults.

Foreign-Body Airway Obstruction (Choking)

Epidemiology and Recognition

More than 90% of deaths from foreign-body aspiration occur in children <5 years of age; 65% of the victims are infants. Liquids are the most common cause of choking in infants,¹³⁹ whereas balloons, small objects, and foods (eg, hot dogs, round candies, nuts, and grapes) are the most common causes of foreign-body airway obstruction (FBAO) in children.^{140–142} Signs of FBAO include a *sudden* onset of respiratory distress with coughing, gagging, stridor (a high-pitched, noisy sound), or wheezing. The characteristics that distinguish FBAO from other causes (eg, croup) are sudden onset in a proper setting and the absence of antecedent fever or respiratory symptoms.

Relief of FBAO

FBAO may cause mild or severe airway obstruction. When the airway obstruction is mild, the child can cough and make some sounds. When the airway obstruction is severe, the victim cannot cough or make any sound.

- If FBAO is mild, do not interfere. Allow the victim to clear the airway by coughing while you observe for signs of severe FBAO.
- If the FBAO is severe (ie, the victim is unable to make a sound):
 - For a child, perform subdiaphragmatic abdominal thrusts (Heimlich maneuver)^{143,144} until the object is expelled or the victim becomes unresponsive. For an infant, deliver 5 back blows (slaps) followed by 5 chest thrusts^{145–149} repeatedly until the object is expelled or the victim becomes unresponsive. Abdominal thrusts are not recommended for infants because they may damage the relatively large and unprotected liver.^{150–152}
 - If the victim becomes unresponsive, lay rescuers and healthcare providers should perform CPR but should look into the mouth before giving breaths. If you see a foreign body, remove it. Healthcare providers should not perform blind finger sweeps because they may push obstructing objects further into the pharynx and may damage the oropharynx.^{153,154} Healthcare providers should attempt to remove an object only if they can see it in the pharynx. Then rescuers should attempt ventilation and follow with chest compressions.

Special Resuscitation Situations

Children With Special Healthcare Needs

Children with special healthcare needs^{155–157} may require emergency care for complications of chronic conditions (eg, obstruction of a tracheostomy), failure of support technology (eg, ventilator failure), progression of underlying disease, or events unrelated to those special needs.¹⁵⁸ Care is often complicated by a lack of medical information, plan of medical care, list of current medications, and Do Not Attempt Resuscitation (DNAR) orders. Parents and child-care providers are encouraged to keep copies of medical information at home, with the child, and at the child’s school or child-care facility. School nurses should have copies and should maintain a readily available list of children with DNAR orders.^{158,159} An Emergency Information Form (EIF) was developed by the American Academy of Pediatrics and the American College of Emergency Physicians¹⁵⁷ and is available on the Worldwide Web at <http://www.pediatrics.org/cgi/content/full/104/4/e53>.

If a decision to limit or withhold resuscitative efforts is made, the physician must write an order clearly detailing the limits of any attempted resuscitation. A separate order must be written for the out-of-hospital setting. Regulations regarding out-of-hospital “do not attempt resuscitation” (DNAR or so-called “no-CPR”) directives vary from state to state. For further information about ethical issues of resuscitation, see Part 2: “Ethical Issues.”

When a child with a chronic or potentially life-threatening condition is discharged from the hospital, parents, school nurses, and home healthcare providers should be informed about the reason for hospitalization, hospital course, and how

to recognize signs of deterioration. They should receive specific instructions about CPR and whom to contact.¹⁵⁹

Ventilation With a Tracheostomy or Stoma

Everyone involved with the care of a child with a tracheostomy (parents, school nurses, and home healthcare providers) should know how to assess patency of the airway, clear the airway, and perform CPR using the artificial airway.

Use the tracheostomy tube for ventilation and verify adequacy of airway and ventilation by watching for chest expansion. If the tracheostomy tube does not allow effective ventilation even after suctioning, replace it. Alternative ventilation methods include mouth-to-stoma ventilation and bag-mask ventilation through the nose and mouth while you or someone else occludes the tracheal stoma.

Trauma

The principles of BLS resuscitation for the injured child are the same as those for the ill child, but some aspects require emphasis; improper resuscitation is a major cause of preventable pediatric trauma death.¹⁶⁰ Errors include failure to properly open and maintain the airway and failure to recognize and treat internal bleeding.

The following are important aspects of resuscitation of pediatric victims of trauma:

- Anticipate airway obstruction by dental fragments, blood, or other debris. Use a suction device if necessary.
- Stop all external bleeding with pressure.
- When the mechanism of injury is compatible with spinal injury, minimize motion of the cervical spine and avoid traction or movement of the head and neck. Open and maintain the airway with a jaw thrust and try not to tilt the head. If a jaw thrust does not open the airway, use a head tilt–chin lift. If there are 2 rescuers, the first opens the airway while the second restricts cervical spine motion. To limit spine motion, secure at least the thighs, pelvis, and shoulders to the immobilization board. Because of the disproportionately large size of the head in infants and young children, optimal positioning may require recessing the occiput¹⁶¹ or elevating the torso to avoid undesirable backboard-induced cervical flexion.^{161,162}
- If possible, transport children with multisystem trauma to a trauma center with pediatric expertise.

Drowning

Outcome after drowning depends on the duration of submersion, the water temperature, and how promptly CPR is started.^{1,16,163} An excellent outcome can occur after prolonged submersion in icy waters.^{164,165} Start resuscitation by safely removing the victim from the water as rapidly as possible. If you have special training, start rescue breathing while the victim is still in the water¹⁶⁶ if doing so will not delay removing the victim from the water. Do not attempt chest compressions in the water, however.

There is no evidence that water acts as an obstructive foreign body; don't waste time trying to remove water from the victim. Start CPR by opening the airway and giving 2 effective breaths followed by chest compressions; if you are alone, continue with 5 cycles (about 2 minutes) of compressions

and ventilations before activating EMS and (for children 1 year of age and older) getting an AED. If 2 rescuers are present, send the second rescuer to activate the EMS system immediately and get an AED (if appropriate), while you continue CPR.

Summary: The Quality of BLS

Immediate CPR can improve survival from cardiorespiratory arrest in children, but not enough children receive high-quality CPR. We must increase the number of laypersons who learn, remember, and perform CPR and must improve the quality of CPR provided by lay rescuers and healthcare providers alike.

Systems that deliver professional CPR should implement processes of continuous quality improvement that include monitoring the quality of CPR delivered at the scene of cardiac arrest, other process-of-care measures (eg, initial rhythm, bystander CPR, and response intervals), and patient outcome up to hospital discharge (see Part 3: “Overview of CPR”). This evidence should be used to optimize the quality of CPR delivered (Class Indeterminate).

References

1. Kyriacou DN, Arcinue EL, Peek C, Kraus JF. Effect of immediate resuscitation on children with submersion injury. *Pediatrics*. 1994;94(pt 1):137–142.
2. Hickey RW, Cohen DM, Strausbaugh S, Dietrich AM. Pediatric patients requiring CPR in the prehospital setting. *Ann Emerg Med*. 1995;25:495–501.
3. Kuisma M, Alaspa A. Out-of-hospital cardiac arrests of non-cardiac origin: epidemiology and outcome. *Eur Heart J*. 1997;18:1122–1128.
4. Friesen RM, Duncan P, Tweed WA, Bristow G. Appraisal of pediatric cardiopulmonary resuscitation. *Can Med Assoc J*. 1982;126:1055–1058.
5. Zaritsky A, Nadkarni V, Getson P, Kuehl K. CPR in children. *Ann Emerg Med*. 1987;16:1107–1111.
6. Lopez-Herce J, Garcia C, Rodriguez-Nunez A, Dominguez P, Carrillo A, Calvo C, Delgado MA. Long-term outcome of paediatric cardiorespiratory arrest in Spain. *Resuscitation*. 2005;64:79–85.
7. Mogayzel C, Quan L, Graves JR, Tiedeman D, Fahrenbruch C, Herndon P. Out-of-hospital ventricular fibrillation in children and adolescents: causes and outcomes. *Ann Emerg Med*. 1995;25:484–491.
8. Sirbaugh PE, Pepe PE, Shook JE, Kimball KT, Goldman MJ, Ward MA, Mann DM. A prospective, population-based study of the demographics, epidemiology, management, and outcome of out-of-hospital pediatric cardiopulmonary arrest [published correction appears in *Ann Emerg Med*. 1999;33:358]. *Ann Emerg Med*. 1999;33:174–184.
9. Schindler MB, Bohn D, Cox PN, McCrindle BW, Jarvis A, Edmonds J, Barker G. Outcome of out-of-hospital cardiac or respiratory arrest in children. *N Engl J Med*. 1996;335:1473–1479.
10. O'Rourke PP. Outcome of children who are apneic and pulseless in the emergency room. *Crit Care Med*. 1986;14:466–468.
11. Young KD, Seidel JS. Pediatric cardiopulmonary resuscitation: a collective review. *Ann Emerg Med*. 1999;33:195–205.
12. Dieckmann R, Vardis R. High-dose epinephrine in pediatric out-of-hospital cardiopulmonary arrest. *Pediatrics*. 1995;95:901–913.
13. Herlitz J, Engdahl J, Svensson L, Young M, Angquist KA, Holmberg S. Characteristics and outcome among children suffering from out of hospital cardiac arrest in Sweden. *Resuscitation*. 2005;64:37–40.
14. Pell JP, Sirel JM, Marsden AK, Ford I, Walker NL, Cobbe SM. Presentation, management, and outcome of out of hospital cardiopulmonary arrest: comparison by underlying aetiology. *Heart (British Cardiac Society)*. 2003;89:839–842.
15. Lopez-Herce J, Garcia C, Dominguez P, Carrillo A, Rodriguez-Nunez A, Calvo C, Delgado MA. Characteristics and outcome of cardiorespiratory arrest in children. *Resuscitation*. 2004;63:311–320.
16. Suominen P, Baillie C, Korpela R, Rautanen S, Ranta S, Olkkola KT. Impact of age, submersion time and water temperature on outcome in near-drowning. *Resuscitation*. 2002;52:247–254.

17. Kuisma M, Suominen P, Korpela R. Paediatric out-of-hospital cardiac arrests: epidemiology and outcome. *Resuscitation*. 1995;30:141–150.
18. Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System (WISQARS) (Online). National Center for Injury Prevention and Control, Centers for Disease Control and Prevention (producer). Available from: URL: www.cdc.gov/ncipc/wisqars (February 3, 2005). 2005.
19. Pressley JC, Barlow B. Preventing injury and injury-related disability in children and adolescents. *Semin Pediatr Surg*. 2004;13:133–140.
20. Durbin DR, Elliott MR, Winston FK. Belt-positioning booster seats and reduction in risk of injury among children in vehicle crashes. *Jama*. 2003;289:2835–2840.
21. Foss RD, Feaganes JR, Rodgman EA. Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. *Jama*. 2001;286:1588–1592.
22. Schieber RA, Vegega ME. Reducing childhood pedestrian injuries. *Inj Prev*. 2002;8 Suppl 1:i1–10.
23. National SAFE KIDS Campaign (NSKC) Bicycle Injury Fact Sheet. Washington, DC: NSKC; 2004.
24. Thompson DC, Thompson RS, Rivara FP, Wolf ME. A case-control study of the effectiveness of bicycle safety helmets in preventing facial injury. *Am J Public Health*. 1990;80:1471–1474.
25. Karter M. Fire Loss in the United States During 2003. Quincy, Mass: National Fire Protection Agency Association; 2004.
26. National SAFE KIDS Campaign (NSKC) Injury Facts: Fire Injury (Residential). Washington, DC: NSKC; 2004.
27. Ahrens M. *U.S. Experience with Smoke Alarms and Other Fire Detection/Alarm Equipment*. Quincy, MA: National Fire Protection Agency Association; 2004.
28. Hemenway D. *Private Guns, Public Health 2004*. Ann Arbor, MI: The University of Michigan Press; 2004.
29. Beaman V, Annet JL, Mercy JA, Kresnow Mj, Pollock DA. Lethality of firearm-related injuries in the United States population. *Ann Emerg Med*. 2000;35:258–266.
30. Brent DA, Perper JA, Allman CJ, Moritz GM, Wartella ME, Zelenak JP. The presence and accessibility of firearms in the homes of adolescent suicides: a case-control study. *JAMA*. 1991;266:2989–2995.
31. Svenson JE, Spurlock C, Nypaver M. Pediatric firearm-related fatalities: not just an urban problem. *Arch Pediatr Adolesc Med*. 1996;150:583–587.
32. Dahlberg LL, Ikeda RM, Kresnow MJ. Guns in the home and risk of a violent death in the home: findings from a national study. *Am J Epidemiol*. 2004;160:929–936.
33. Willinger M, James LS, Catz C. Defining the sudden infant death syndrome (SIDS): deliberations of an expert panel convened by the National Institute of Child Health and Human Development. *Pediatr Pathol*. 1991;11:677–684.
34. Changing concepts of sudden infant death syndrome: implications for infant sleeping environment and sleep position. American Academy of Pediatrics. Task Force on Infant Sleep Position and Sudden Infant Death Syndrome. *Pediatrics*. 2000;105:650–656.
35. Positioning and sudden infant death syndrome (SIDS): update. American Academy of Pediatrics Task Force on Infant Positioning and SIDS. *Pediatrics*. 1996;98:1216–1218.
36. American Academy of Pediatrics AAP Task Force on Infant Positioning and SIDS: Positioning and SIDS. *Pediatrics*. 1992;89:1120–1126.
37. Willinger M, Hoffman HJ, Hartford RB. Infant sleep position and risk for sudden infant death syndrome: report of meeting held January 13 and 14, 1994, National Institutes of Health, Bethesda, MD. *Pediatrics*. 1994;93:814–819.
38. Tong EK, England L, Glantz SA. Changing conclusions on secondhand smoke in a sudden infant death syndrome review funded by the tobacco industry. *Pediatrics*. 2005;115:e356–e366.
39. Anderson ME, Johnson DC, Batal HA. Sudden Infant Death Syndrome and prenatal maternal smoking: rising attributed risk in the Back to Sleep era. *BMC Med*. 2005;3:4.
40. Hoyert DL, Kochanek KD, Murphy SL. Deaths: final data for 1997. *Natl Vital Stat Rep*. 1999;47:1–104.
41. Prevention of drowning in infants, children, and adolescents. *Pediatrics*. 2003;112:437–439.
42. Mejicano GC, Maki DG. Infections acquired during cardiopulmonary resuscitation: estimating the risk and defining strategies for prevention. *Ann Intern Med*. 1998;129:813–828.
43. Appleton GO, Cummins RO, Larson MP, Graves JR. CPR and the single rescuer: at what age should you “call first” rather than “call fast”? *Ann Emerg Med*. 1995;25:492–494.
44. Ruben HM, Elam JO, Ruben AM, Greene DG. Investigation of upper airway problems in resuscitation, 1: studies of pharyngeal x-rays and performance by laymen. *Anesthesiology*. 1961;22:271–279.
45. Safar P, Aguto-Escarraga L. Compliance in apneic anesthetized adults. *Anesthesiology*. 1959;20:283–289.
46. Elam JO, Greene DG, Schneider MA, Ruben HM, Gordon AS, Husted RF, Benson DW, Clements JA, Ruben A. Head-tilt method of oral resuscitation. *JAMA*. 1960;172:812–815.
47. Guildner CW. Resuscitation: opening the airway. A comparative study of techniques for opening an airway obstructed by the tongue. *JACEP*. 1976;5:588–590.
48. Hackl W, Hausberger K, Sailer R, Ulmer H, Gassner R. Prevalence of cervical spine injuries in patients with facial trauma. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2001;92:370–376.
49. Demetriades D, Charalambides K, Chahwan S, Hanpeter D, Alo K, Velmahos G, Murray J, Asensio J. Nonskeletal cervical spine injuries: epidemiology and diagnostic pitfalls. *J Trauma*. 2000;48:724–727.
50. Holly LT, Kelly DF, Counelis GJ, Blinman T, McArthur DL, Cryer HG. Cervical spine trauma associated with moderate and severe head injury: incidence, risk factors, and injury characteristics. *J Neurosurg Spine*. 2002;96:285–291.
51. Roth B, Magnusson J, Johansson I, Holmberg S, Westrin P. Jaw lift: a simple and effective method to open the airway in children. *Resuscitation*. 1998;39:171–174.
52. Bruppacher H, Reber A, Keller JP, Geiduschek J, Erb TO, Frei FJ. The effects of common airway maneuvers on airway pressure and flow in children undergoing adenoidectomies. *Anesth Analg*. 2003;97:29–34, table of contents.
53. Clark JJ, Larsen MP, Culley LL, Graves JR, Eisenberg MS. Incidence of agonal respirations in sudden cardiac arrest. *Ann Emerg Med*. 1992;21:1464–1467.
54. Poets CF, Meny RG, Chobanian MR, Bonofiglio RE. Gasping and other cardiorespiratory patterns during sudden infant deaths. *Pediatr Res*. 1999;45:350–354.
55. Zideman DA. Paediatric and neonatal life support. *Br J Anaesth*. 1997;79:178–187.
56. Tonkin SL, Davis SL, Gunn TR. Nasal route for infant resuscitation by mothers. *Lancet*. 1995;345:1353–1354.
57. Segedin E, Torrie J, Anderson B. Nasal airway versus oral route for infant resuscitation. *Lancet*. 1995;346:382.
58. Tonkin SL, Gunn AJ. Failure of mouth-to-mouth resuscitation in cases of sudden infant death. *Resuscitation*. 2001;48:181–184.
59. Ornato JP, Hallagan LF, McMahan SB, Peoples EH, Rostafinski AG. Attitudes of BCLS instructors about mouth-to-mouth resuscitation during the AIDS epidemic. *Ann Emerg Med*. 1990;19:151–156.
60. Brenner BE, Van DC, Cheng D, Lazar EJ. Determinants of reluctance to perform CPR among residents and applicants: the impact of experience on helping behavior. *Resuscitation*. 1997;35:203–211.
61. Hew P, Brenner B, Kaufman J. Reluctance of paramedics and emergency medical technicians to perform mouth-to-mouth resuscitation. *J Emerg Med*. 1997;15:279–284.
62. Locke CJ, Berg RA, Sanders AB, Davis MF, Milander MM, Kern KB, Ewy GA. Bystander cardiopulmonary resuscitation. Concerns about mouth-to-mouth contact. *Arch Intern Med*. 1995;155:938–943.
63. Shibata K, Taniguchi T, Yoshida M, Yamamoto K. Obstacles to bystander cardiopulmonary resuscitation in Japan. *Resuscitation*. 2000;44:187–193.
64. Terndrup TE, Warner DA. Infant ventilation and oxygenation by basic life support providers: comparison of methods. *Prehospital Disaster Med*. 1992;7:35–40.
65. Hess D, Ness C, Oppel A, Rhoads K. Evaluation of mouth-to-mask ventilation devices. *Respir Care*. 1989;34:191–195.
66. Gausche M, Lewis RJ, Stratton SJ, Haynes BE, Gunter CS, Goodrich SM, Poore PD, McCollough MD, Henderson DP, Pratt FD, Seidel JS. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. *JAMA*. 2000;283:783–790.
67. Cooper A, DiScala C, Foltin G, Tunik M, Markenson D, Welborn C. Prehospital endotracheal intubation for severe head injury in children: a reappraisal. *Semin Pediatr Surg*. 2001;10:3–6.
68. Stockinger ZT, McSwain NE, Jr. Prehospital endotracheal intubation for trauma does not improve survival over bag-valve-mask ventilation. *J Trauma*. 2004;56:531–536.
69. Pletti R, Glustein JZ, Bhende MS. Prehospital care and outcome of pediatric out-of-hospital cardiac arrest. *Prehosp Emerg Care*. 2002;6:283–290.

70. Terndrup TE, Kanter RK, Cherry RA. A comparison of infant ventilation methods performed by prehospital personnel. *Ann Emerg Med.* 1989;18:607–611.
71. Field D, Milner AD, Hopkin IE. Efficiency of manual resuscitators at birth. *Arch Dis Child.* 1986;61:300–302.
72. Finer NN, Barrington KJ, Al-Fadley F, Peters KL. Limitations of self-inflating resuscitators. *Pediatrics.* 1986;77:417–420.
73. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. *Arch Intern Med.* 1992;152:145–149.
74. Aufderheide TP, Sigurdsson G, Pirralo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. *Circulation.* 2004;109:1960–1965.
75. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA.* 2005;293:305–310.
76. Hirschman AM, Kravath RE. Venting vs ventilating. A danger of manual resuscitation bags. *Chest.* 1982;82:369–370.
77. Berg MD, Idris AH, Berg RA. Severe ventilatory compromise due to gastric distention during pediatric cardiopulmonary resuscitation. *Resuscitation.* 1998;36:71–73.
78. Moynihan RJ, Brock-Utne JG, Archer JH, Feld LH, Kreitzman TR. The effect of cricoid pressure on preventing gastric insufflation in infants and children. *Anesthesiology.* 1993;78:652–656.
79. Salem MR, Wong AY, Mani M, Sellick BA. Efficacy of cricoid pressure in preventing gastric inflation during bag- mask ventilation in pediatric patients. *Anesthesiology.* 1974;40:96–98.
80. Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anaesthesia. *Lancet.* 1961;2:404–406.
81. Hartsilver EL, Vanner RG. Airway obstruction with cricoid pressure. *Anaesthesia.* 2000;55:208–211.
82. Lipinski CA, Hicks SD, Callaway CW. Normoxic ventilation during resuscitation and outcome from asphyxial cardiac arrest in rats. *Resuscitation.* 1999;42:221–229.
83. Liu Y, Rosenthal RE, Haywood Y, Miljkovic-Lolic M, Vanderhoek JY, Fiskum G. Normoxic ventilation after cardiac arrest reduces oxidation of brain lipids and improves neurological outcome. *Stroke.* 1998;29:1679–1686.
84. Lefkowitz W. Oxygen and resuscitation: beyond the myth. *Pediatrics.* 2002;109:517–519.
85. Zwemer CF, Whitesall SE, D'Alecy LG. Cardiopulmonary-cerebral resuscitation with 100% oxygen exacerbates neurological dysfunction following nine minutes of normothermic cardiac arrest in dogs. *Resuscitation.* 1994;27:159–170.
86. Finer NN, Bates R, Tomat P. Low flow oxygen delivery via nasal cannula to neonates. *Pediatr Pulmonol.* 1996;21:48–51.
87. Inagawa G, Morimura N, Miwa T, Okuda K, Hirata M, Hiroki K. A comparison of five techniques for detecting cardiac activity in infants. *Paediatr Anaesth.* 2003;13:141–146.
88. Eberle B, Dick WF, Schneider T, Wissner G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. *Resuscitation.* 1996;33:107–116.
89. Graham CA, Lewis NF. Evaluation of a new method for the carotid pulse check in cardiopulmonary resuscitation. *Resuscitation.* 2002;53:37–40.
90. Ochoa FJ, Ramalle-Gomara E, Carpintero JM, Garcia A, Saralegui I. Competence of health professionals to check the carotid pulse. *Resuscitation.* 1998;37:173–175.
91. Mather C, O'Kelly S. The palpation of pulses. *Anaesthesia.* 1996;51:189–191.
92. Lapostolle F, Le Toumelin P, Agostinucci JM, Catineau J, Adnet F. Basic cardiac life support providers checking the carotid pulse: performance, degree of conviction, and influencing factors. *Acad Emerg Med.* 2004;11:878–880.
93. Moule P. Checking the carotid pulse: diagnostic accuracy in students of the healthcare professions. *Resuscitation.* 2000;44:195–201.
94. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. *Resuscitation.* 1997;35:23–26.
95. Cavallaro DL, Melker RJ. Comparison of two techniques for detecting cardiac activity in infants. *Crit Care Med.* 1983;11:189–190.
96. Lee CJ, Bullock LJ. Determining the pulse for infant CPR: time for a change? *Mil Med.* 1991;156:190–193.
97. Aufderheide TP, Pirralo RG, Yannopoulos D, Klein JP, von Briesen C, Sparks CW, Deja KA, Conrad CJ, Kitscha DJ, Provo TA, Lurie KG. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. *Resuscitation.* 2005;64:353–362.
98. Clements F, McGowan J. Finger position for chest compressions in cardiac arrest in infants. *Resuscitation.* 2000;44:43–46.
99. Finholt DA, Ketrick RG, Wagner HR, Swedlow DB. The heart is under the lower third of the sternum: implications for external cardiac massage. *Am J Dis Child.* 1986;140:646–649.
100. Phillips GW, Zideman DA. Relation of infant heart to sternum: its significance in cardiopulmonary resuscitation. *Lancet.* 1986;1:1024–1025.
101. Orlowski JP. Optimum position for external cardiac compression in infants and young children. *Ann Emerg Med.* 1986;15:667–673.
102. Shah NM, Gaur HK. Position of heart in relation to sternum and nipple line at various ages. *Indian Pediatr.* 1992;29:49–53.
103. David R. Closed chest cardiac massage in the newborn infant. *Pediatrics.* 1988;81:552–554.
104. Todres ID, Rogers MC. Methods of external cardiac massage in the newborn infant. *J Pediatr.* 1975;86:781–782.
105. Menegazzi JJ, Auble TE, Nicklas KA, Hosack GM, Rack L, Goode JS. Two-thumb versus two-finger chest compression during CRP in a swine infant model of cardiac arrest. *Ann Emerg Med.* 1993;22:240–243.
106. Houry PK, Frank LR, Menegazzi JJ, Taylor R. A randomized, controlled trial of two-thumb vs two-finger chest compression in a swine infant model of cardiac arrest. *Prehosp Emerg Care.* 1997;1:65–67.
107. Dorfman ML, Menegazzi JJ, Wadas RJ, Auble TE. Two-thumb vs two-finger chest compression in an infant model of prolonged cardiopulmonary resuscitation. *Acad Emerg Med.* 2000;7:1077–1082.
108. Whitelaw CC, Slywka B, Goldsmith LJ. Comparison of a two-finger versus two-thumb method for chest compressions by healthcare providers in an infant mechanical model. *Resuscitation.* 2000;43:213–216.
109. Thaler MM, Stobie GH. An improved technique of external cardiac compression in infants and young children. *N Engl J Med.* 1963;269:606–610.
110. Ishimine P, Menegazzi J, Weinstein D. Evaluation of two-thumb chest compression with thoracic squeeze in a swine model of infant cardiac arrest. *Acad Emerg Med.* 1998;5:397.
111. Stevenson AG, McGowan J, Evans AL, Graham CA. CPR for children: one hand or two? *Resuscitation.* 2005;64:205–208.
112. American Heart Association in collaboration with International Liaison Committee on Resuscitation. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care: International Consensus on Science, Part 9: Pediatric Basic Life Support. *Circulation.* 2000;102(suppl 1):I-253–I-290.
113. Dorph E, Wik L, Steen PA. Effectiveness of ventilation-compression ratios 1:5 and 2:15 in simulated single rescuer paediatric resuscitation. *Resuscitation.* 2002;54:259–264.
114. Greingor JL. Quality of cardiac massage with ratio compression-ventilation 5/1 and 15/2. *Resuscitation.* 2002;55:263–267.
115. Srikantan S, Berg RA, Cox T, Tice L, Nadkarni VM. Effect of 1-rescuer compression: ventilation ratios on CPR in infant, pediatric and adult manikins. *Crit Care Med.* In Press.
116. Berg RA, Sanders AB, Kern KB, Hilwig RW, Heidenreich JW, Porter ME, Ewy GA. Adverse hemodynamic effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest. *Circulation.* 2001;104:2465–2470.
117. Kern KB, Hilwig RW, Berg RA, Ewy GA. Efficacy of chest compression-only BLS CPR in the presence of an occluded airway. *Resuscitation.* 1998;39:179–188.
118. Assar D, Chamberlain D, Colquhoun M, Donnelly P, Handley AJ, Leaves S, Kern KB. Randomised controlled trials of staged teaching for basic life support, 1: skill acquisition at bronze stage. *Resuscitation.* 2000;45:7–15.
119. Heidenreich JW, Higdon TA, Kern KB, Sanders AB, Berg RA, Niebler R, Hendrickson J, Ewy GA. Single-rescuer cardiopulmonary resuscitation: 'two quick breaths'—an oxymoron. *Resuscitation.* 2004;62:283–289.
120. Wik L, Kramer-Johansen J, Myklebust H, Sorebo H, Svensson L, Fellows B, Steen PA. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. *JAMA.* 2005;293:299–304.
121. Eftestol T, Sunde K, Steen PA. Effects of interrupting precordial compressions on the calculated probability of defibrillation success during out-of-hospital cardiac arrest. *Circulation.* 2002;105:2270–2273.
122. Yu T, Weil MH, Tang W, Sun S, Klouche K, Povoas H, Bisera J. Adverse outcomes of interrupted precordial compression during automated defibrillation. *Circulation.* 2002;106:368–372.
123. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, Hoffman P, Tynus K, Vanden Hoek TL, Becker LB. Chest compression

- rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. *Circulation*. 2005;111:428–434.
124. Becker LB, Berg RA, Pepe PE, Idris AH, Aufderheide TP, Barnes TA, Stratton SJ, Chandra NC. A reappraisal of mouth-to-mouth ventilation during bystander-initiated cardiopulmonary resuscitation. A statement for healthcare professionals from the Ventilation Working Group of the Basic Life Support and Pediatric Life Support Subcommittees, American Heart Association. *Resuscitation*. 1997;35:189–201.
 125. Berg RA, Hilwig RW, Kern KB, Babar I, Ewy GA. Simulated mouth-to-mouth ventilation and chest compressions (bystander cardiopulmonary resuscitation) improves outcome in a swine model of prehospital pediatric asphyxial cardiac arrest. *Crit Care Med*. 1999;27:1893–1899.
 126. Berg RA, Hilwig RW, Kern KB, Ewy GA. “Bystander” chest compressions and assisted ventilation independently improve outcome from piglet asphyxial pulseless “cardiac arrest”. *Circulation*. 2000;101:1743–1748.
 127. Kern KB, Hilwig RW, Berg RA, Sanders AB, Ewy GA. Importance of continuous chest compressions during cardiopulmonary resuscitation: improved outcome during a simulated single lay-rescuer scenario. *Circulation*. 2002;105:645–649.
 128. Ashton A, McCluskey A, Gwinnutt CL, Keenan AM. Effect of rescuer fatigue on performance of continuous external chest compressions over 3 min. *Resuscitation*. 2002;55:151–155.
 129. Ochoa FJ, Ramalle-Gomara E, Lisa V, Saralegui I. The effect of rescuer fatigue on the quality of chest compressions. *Resuscitation*. 1998;37:149–152.
 130. Hightower D, Thomas SH, Stone CK, Dunn K, March JA. Decay in quality of closed-chest compressions over time. *Ann Emerg Med*. 1995;26:300–303.
 131. Sanders AB, Kern KB, Berg RA, Hilwig RW, Heidenrich J, Ewy GA. Survival and neurologic outcome after cardiopulmonary resuscitation with four different chest compression-ventilation ratios. *Ann Emerg Med*. 2002;40:553–562.
 132. Young KD, Gausche-Hill M, McClung CD, Lewis RJ. A prospective, population-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. *Pediatrics*. 2004;114:157–164.
 133. Reis AG, Nadkarni V, Perondi MB, Grisi S, Berg RA. A prospective investigation into the epidemiology of in-hospital pediatric cardiopulmonary resuscitation using the international Utstein reporting style. *Pediatrics*. 2002;109:200–209.
 134. Atkins DL, Jorgenson DB. Attenuated pediatric electrode pads for automated external defibrillator use in children. *Resuscitation*. 2005;66:31–37.
 135. Berg RA, Chapman FW, Berg MD, Hilwig RW, Banville I, Walker RG, Nova RC, Sherrill D, Kern KB. Attenuated adult biphasic shocks compared with weight-based monophasic shocks in a swine model of prolonged pediatric ventricular fibrillation. *Resuscitation*. 2004;61:189–197.
 136. Atkinson E, Mikysa B, Conway JA, Parker M, Christian K, Deshpande J, Knilians TK, Smith J, Walker C, Stickney RE, Hampton DR, Hazinski MF. Specificity and sensitivity of automated external defibrillator rhythm analysis in infants and children. *Ann Emerg Med*. 2003;42:185–196.
 137. Cecchin F, Jorgenson DB, Berul CI, Perry JC, Zimmerman AA, Duncan BW, Lupinetti FM, Snyder D, Lyster TD, Rosenthal GL, Cross B, Atkins DL. Is arrhythmia detection by automatic external defibrillator accurate for children? Sensitivity and specificity of an automatic external defibrillator algorithm in 696 pediatric arrhythmias. *Circulation*. 2001;103:2483–2488.
 138. Samson RA, Berg RA, Bingham R, Biarent D, Coovadia A, Hazinski MF, Hickey RW, Nadkarni V, Nichol G, Tibballs J, Reis AG, Tse S, Zideman D, Potts J, Uzark K, Atkins D. Use of automated external defibrillators for children: an update: an advisory statement from the pediatric advanced life support task force, International Liaison Committee on Resuscitation. *Circulation*. 2003;107:3250–3255.
 139. Vilke GM, Smith AM, Ray LU, Steen PJ, Murrin PA, Chan TC. Airway obstruction in children aged less than 5 years: the prehospital experience. *Prehosp Emerg Care*. 2004;8:196–199.
 140. Morley RE, Ludemann JP, Moxham JP, Kozak FK, Riding KH. Foreign body aspiration in infants and toddlers: recent trends in British Columbia. *J Otolaryngol*. 2004;33:37–41.
 141. Harris CS, Baker SP, Smith GA, Harris RM. Childhood asphyxiation by food. A national analysis and overview. *Jama*. 1984;251:2231–2235.
 142. Rimell FL, Thome AJ, Stool S, Reilly JS, Rider G, Stool D, Wilson CL. Characteristics of objects that cause choking in children. *JAMA*. 1995;274:1763–1766.
 143. Heimlich HJ. A life-saving maneuver to prevent food-choking. *Jama*. 1975;234:398–401.
 144. Day RL, Crelin ES, DuBois AB. Choking: the Heimlich abdominal thrust vs back blows: an approach to measurement of inertial and aerodynamic forces. *Pediatrics*. 1982;70:113–119.
 145. Langhelle A, Sunde K, Wik L, Steen PA. Airway pressure with chest compressions versus Heimlich manoeuvre in recently dead adults with complete airway obstruction. *Resuscitation*. 2000;44:105–108.
 146. Sternbach G, Kiskaddon RT, Henry Heimlich: a life-saving maneuver for food choking. *J Emerg Med*. 1985;3:143–148.
 147. Redding JS. The choking controversy: critique of evidence on the Heimlich maneuver. *Crit Care Med*. 1979;7:475–479.
 148. Gordon AS, Belton MK, Ridolpho PF. Emergency management of foreign body obstruction. In: Safar P, Elam JO, eds. *Advances in Cardiopulmonary Resuscitation*. New York: Springer-Verlag, Inc.; 1977:39–50.
 149. Guildner CW, Williams D, Subitch T. Airway obstructed by foreign material: the Heimlich maneuver. *JACEP*. 1976;5:675–677.
 150. Rosen P, Stoto M, Harley J. The use of the Heimlich maneuver in near-drowning: Institute of Medicine report. *J Emerg Med*. 1995;13:397–405.
 151. Majumdar A, Sedman PC. Gastric rupture secondary to successful Heimlich manoeuvre. *Postgrad Med J*. 1998;74:609–610.
 152. Fink JA, Klein RL. Complications of the Heimlich maneuver. *J Pediatr Surg*. 1989;24:486–487.
 153. Kabbani M, Goodwin SR. Traumatic epiglottitis following blind finger sweep to remove a pharyngeal foreign body. *Clin Pediatr (Phila)*. 1995;34:495–497.
 154. Hartrey R, Bingham RM. Pharyngeal trauma as a result of blind finger sweeps in the choking child. *J Accid Emerg Med*. 1995;12:52–54.
 155. McPherson M, Arango P, Fox H, Lauer C, McManus M, Newacheck PW, Perrin JM, Shonkoff JP, Strickland B. A new definition of children with special health care needs. *Pediatrics*. 1998;102:137–140.
 156. Newacheck PW, Strickland B, Shonkoff JP, Perrin JM, McPherson M, McManus M, Lauer C, Fox H, Arango P. An epidemiologic profile of children with special health care needs. *Pediatrics*. 1998;102:117–123.
 157. Emergency preparedness for children with special health care needs. Committee on Pediatric Emergency Medicine. American Academy of Pediatrics. *Pediatrics*. 1999;104:e53.
 158. Spaite DW, Conroy C, Tibbitts M, Karriker KJ, Seng M, Battaglia N, Criss EA, Valenzuela TD, Meislin HW. Use of emergency medical services by children with special health care needs. *Prehosp Emerg Care*. 2000;4:19–23.
 159. Schultz-Grant LD, Young-Cureton V, Kataoka-Yahiro M. Advance directives and do not resuscitate orders: nurses’ knowledge and the level of practice in school settings. *J Sch Nurs*. 1998;14:4–10, 12–13.
 160. Dykes EH, Spence LJ, Young JG, Bohn DJ, Filler RM, Wesson DE. Preventable pediatric trauma deaths in a metropolitan region. *J Pediatr Surg*. 1989;24:107–110.
 161. Herzenberg JE, Hensinger RN, Dedrick DK, Phillips WA. Emergency transport and positioning of young children who have an injury of the cervical spine. The standard backboard may be hazardous. *J Bone Joint Surg Am*. 1989;71:15–22.
 162. Nypaver M, Treloar D. Neutral cervical spine positioning in children. *Ann Emerg Med*. 1994;23:208–211.
 163. Graf WD, Cummings P, Quan L, Brutocao D. Predicting outcome in pediatric submersion victims. *Ann Emerg Med*. 1995;26:312–319.
 164. Modell JH, Idris AH, Pineda JA, Silverstein JH. Survival after prolonged submersion in freshwater in Florida. *Chest*. 2004;125:1948–1951.
 165. Mehta SR, Srinivasan KV, Bindra MS, Kumar MR, Lahiri AK. Near drowning in cold water. *J Assoc Physicians India*. 2000;48:674–676.
 166. Szpilman D, Soares M. In-water resuscitation—is it worthwhile? *Resuscitation*. 2004;63:25–31.