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2005 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) of Pediatric and Neonatal Patients: Pediatric Basic Life Support

American Heart Association

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SPECIAL ARTICLE

2005 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) of Pediatric and Neonatal Patients: Pediatric Basic Life Support

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The authors have indicated they have no financial relationships relevant to this article to disclose.

ABSTRACT

This publication presents the 2005 American Heart Association (AHA) guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiovascular care (ECC) of the pediatric patient and the 2005 American Academy of Pediatrics/AHA guidelines for CPR and ECC of the neonate. The guidelines are based on the evidence evaluation from the 2005 International Consensus Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations, hosted by the American Heart Association in Dallas, Texas, January 23–30, 2005.

The "2005 AHA Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" contain recommendations designed to improve survival from sudden cardiac arrest and acute life-threatening cardiopulmonary problems. The evidence evaluation process that was the basis for these guidelines was accomplished in collaboration with the International Liaison Committee on Resuscitation (ILCOR). The ILCOR process is described in more detail in the "International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations."

The recommendations in the "2005 AHA Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" confirm the safety and effectiveness of many approaches, acknowledge that other approaches may not be optimal, and recommend new treatments that have undergone evidence evaluation. *These new recommendations do not imply that care involving the use of earlier guidelines is unsafe*. In addition, it is important to note that these guidelines will not apply to all rescuers and all victims in all situations. The leader of a resuscitation attempt may need to adapt application of the guidelines to unique circumstances.

The following are the major pediatric advanced life support changes in the 2005 guidelines:

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The American Academy of Pediatrics Neonatal Resuscitation Program Steering Committee coauthored the neonatal portion of the Guidelines.
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Key Words
resuscitation, neonatal resuscitation, pediatric advanced life support (PALS)

Abbreviations
BLS—basic life support
CPR—cardiopulmonary resuscitation
EMS—emergency medical services
VF—ventricular fibrillation
SIDS—sudden infant death syndrome
AED—automated external defibrillator
LOE—level of evidence
bpm—beats per minute
VT—ventricular tachycardia
FBAO—foreign-body airway obstruction
DNAR—do not attempt resuscitation

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- There is further caution about the use of endotracheal tubes. Laryngeal mask airways are acceptable when used by experienced providers.
- Cuffed endotracheal tubes may be used in infants (except newborns) and children in in-hospital settings provided that cuff inflation pressure is kept $<$20 cm H_2O.
- Confirmation of tube placement requires clinical assessment and assessment of exhaled carbon dioxide (CO_2); esophageal detector devices may be considered for use in children weighing $>$20 kg who have a perfusing rhythm. Correct placement must be verified when the tube is inserted, during transport, and whenever the patient is moved.
- During CPR with an advanced airway in place, rescuers will no longer perform "cycles" of CPR. Instead, the rescuer performing chest compressions will perform them continuously at a rate of 100/minute without pauses for ventilation. The rescuer providing ventilation will deliver 8 to 10 breaths per minute (1 breath approximately every 6–8 seconds).
- Timing of 1 shock, CPR, and drug administration during pulseless arrest has changed and now is identical to that for advanced cardiac life support.
- Routine use of high-dose epinephrine is not recommended.
- Lidocaine is de-emphasized, but it can be used for treatment of ventricular fibrillation/pulseless ventricular tachycardia if amiodarone is not available.
- Induced hypothermia (32–34°C for 12–24 hours) may be considered if the child remains comatose after resuscitation.
- Indications for the use of inodilators are mentioned in the postresuscitation section.
- Termination of resuscitative efforts is discussed. It is noted that intact survival has been reported following prolonged resuscitation and absence of spontaneous circulation despite 2 doses of epinephrine.

The following are the major neonatal resuscitation changes in the 2005 guidelines:

- Supplementary oxygen is recommended whenever positive-pressure ventilation is indicated for resuscitation; free-flow oxygen should be administered to infants who are breathing but have central cyanosis. Although the standard approach to resuscitation is to use 100% oxygen, it is reasonable to begin resuscitation with an oxygen concentration of less than 100% or to start with no supplementary oxygen (ie, start with room air). If the clinician begins resuscitation with room air, it is recommended that supplementary oxygen be available to use if there is no appreciable improvement within 90 seconds after birth. In situations where supplementary oxygen is not readily available, positive-pressure ventilation should be administered with room air.
- Current recommendations no longer advise routine intrapartum oropharyngeal and nasopharyngeal suctioning for infants born to mothers with meconium staining of amniotic fluid. Endotracheal suctioning for infants who are not vigorous should be performed immediately after birth.
- A self-inflating bag, a flow-inflating bag, or a T-piece (a valved mechanical device designed to regulate pressure and limit flow) can be used to ventilate a newborn.
- An increase in heart rate is the primary sign of improved ventilation during resuscitation. Exhaled CO_2 detection is the recommended primary technique to confirm correct endotracheal tube placement when a prompt increase in heart rate does not occur after intubation.
- The recommended intravenous (IV) epinephrine dose is 0.01 to 0.03 mg/kg per dose. Higher IV doses are not recommended, and IV administration is the preferred route. Although access is being obtained, administration of a higher dose (up to 0.1 mg/kg) through the endotracheal tube may be considered.
- It is possible to identify conditions associated with high mortality and poor outcome in which withholding resuscitative efforts may be considered reasonable, particularly when there has been the opportunity for parental agreement. The following guidelines must be interpreted according to current regional outcomes:
  - When gestation, birth weight, or congenital anomalies are associated with almost certain early death and when unacceptably high morbidity is likely among the rare survivors, resuscitation is not indicated. Examples are provided in the guidelines.
  - In conditions associated with a high rate of survival and acceptable morbidity, resuscitation is nearly always indicated.
  - In conditions associated with uncertain prognosis in which survival is borderline, the morbidity rate is relatively high, and the anticipated burden to the child is high, parental desires concerning initiation of resuscitation should be supported.
- Infants without signs of life (no heartbeat and no respiratory effort) after 10 minutes of resuscitation show either a high mortality rate or severe neurodevelopmental disability. After 10 minutes of continuous and adequate resuscitative efforts, discontinuation of resuscitation may be justified if there are no signs of life.

FOR BEST SURVIVAL and quality of life, pediatric basic life support (BLS) should be part of a community effort that includes prevention, basic cardiopulmonary resuscitation (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 pediatric chain of survival (Fig 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 lb (<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 life-saving 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 Web site of the National Highway Traffic Safety Administration: http://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 midblock, dashes across intersections, or gets off a bus.[22]

Bicycle Injuries

Bicycle crashes are responsible for ~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 homi-

FIGURE 1
Pediatric chain of survival.

cides.[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]

SIDS

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 age.[34] The etiology of SIDS remains unknown, but risk factors include prone sleeping position, sleeping on a soft surface,[35–37] and secondhand 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 health care 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 health care 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 1 rescuer is present. This sequence is depicted in the pediatric health care provider BLS algorithm (Fig 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 health care 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 2 rescuers are present, 1 rescuer should begin CPR while the other rescuer activates the EMS system and gets the AED.

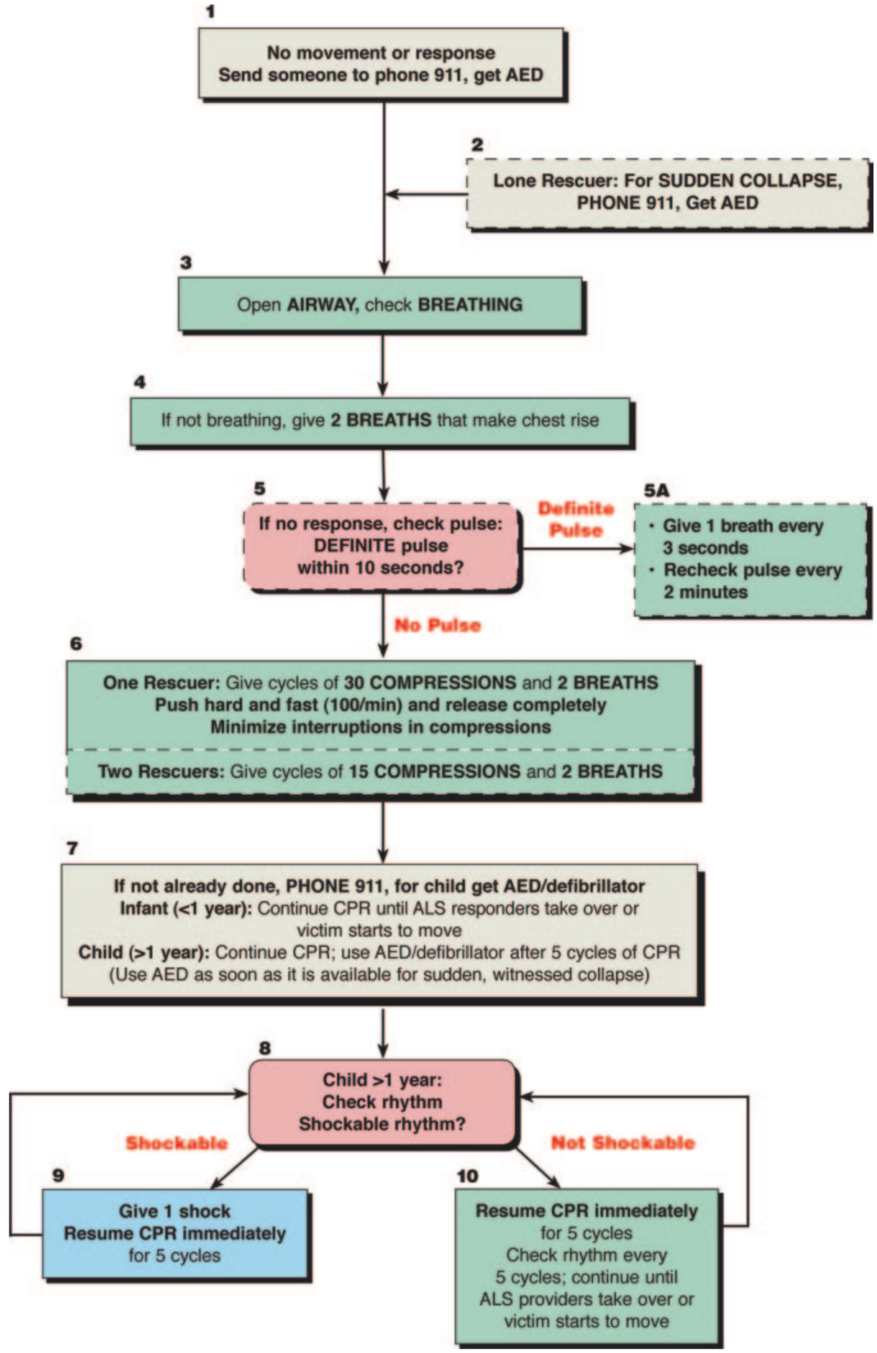

FIGURE 2
Pediatric health care provider BLS algorithm. Note that the boxes bordered by dotted lines are performed by health care providers and not by lay rescuers.

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: Health Care Provider

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

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 health care 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; Fig 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 health care 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.

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

FIGURE 3
Recovery position.

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 health care 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 (Health Care 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 1[66]; 3[67]; 4[68,69]).

Ventilation Bags

Use a self-inflating bag with a volume of at least 450 to 500 mL[70]; smaller bags may not deliver an effective tidal volume or the longer inspiratory times required by 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/minute, 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 (60–95%), attach an oxygen reservoir to the self-inflating bag. You must maintain an oxygen flow of 10 to 15 L/minute into a reservoir attached to a pediatric bag[72] and a flow of at least 15 L/minute 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) 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 3–5 seconds).

Health care 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 pressure[74]
- 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 ventilation[77] 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, health care 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 ~15 L/minute 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/minute can provide young infants with an inspired oxygen concentration >50%.

Pulse Check (for Health Care Providers) (Box 5)

If you are a health care 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 health care 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 have 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.

Rescue Breathing Without Chest Compressions (for Health Care 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 3–5 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.

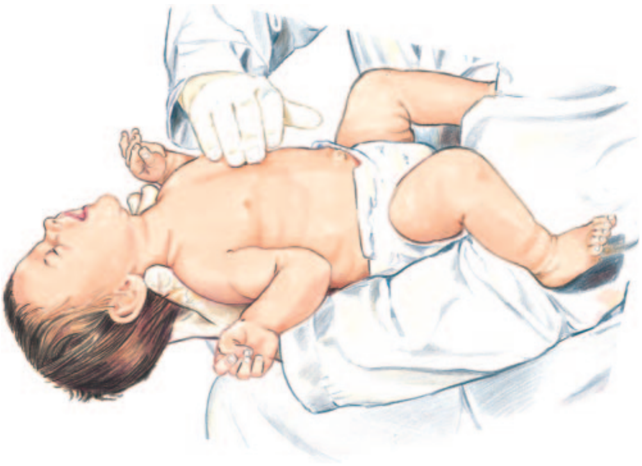

FIGURE 4
Two-finger chest compression technique in infant (1 rescuer).

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

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 re-expansion improves blood flow into the heart.[97] A manikin study[97] 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 ~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 (Fig 4) placed just below the intermammary line (Class IIb; LOE 5, 6).[98–102]

The 2 thumb-encircling hands technique (Fig 5) is recommended for health care 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 5[103,104]; 6[105,106]). 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 health care 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 are no outcome data that show 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 2000[112] 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 health care 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 health care providers or others, such as lifeguards, who are trained in this technique), 1 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 <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 health care 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 "Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care,"[112] data have shown that AEDs can be safely and effectively used in children 1 to 8 years of age.[136–138] However, there are 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 are 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 health care providers should perform CPR but should look into the mouth before giving breaths. If you see a foreign body, remove it. Health care providers should not perform blind finger sweeps because they may push obstructing objects further into the pharynx and may damage the oropharynx.[153,154] Health care 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 Health Care Needs

Children with special health care 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 Physicians[157] and is available on the Worldwide Web at 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 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 health care 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 health care 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 occiput[161] 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 water[166] 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 health care 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).

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