

# Circulation

JOURNAL OF THE AMERICAN HEART ASSOCIATION



## **Part 13: Pediatric Basic Life Support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care**

Marc D. Berg, Stephen M. Schexnayder, Leon Chameides, Mark Terry, Aaron Donoghue, Robert W. Hickey, Robert A. Berg, Robert M. Sutton and Mary Fran Hazinski

*Circulation* 2010;122;S862-S875

DOI: 10.1161/CIRCULATIONAHA.110.971085

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75214

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# Part 13: Pediatric Basic Life Support

## 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Marc D. Berg, Chair; Stephen M. Schexnayder; Leon Chameides; Mark Terry; Aaron Donoghue; Robert W. Hickey; Robert A. Berg; Robert M. Sutton; Mary Fran Hazinski

For best survival and quality of life, pediatric basic life support (BLS) should be part of a community effort that includes prevention, early cardiopulmonary resuscitation (CPR), prompt access to the emergency response system, and rapid pediatric advanced life support (PALS), followed by integrated post-cardiac arrest care. These 5 links form the American Heart Association (AHA) pediatric Chain of Survival (Figure 1), the first 3 links of which constitute pediatric BLS.

Rapid and effective bystander CPR can be associated with successful return of spontaneous circulation (ROSC) and neurologically intact survival in children following out-of-hospital cardiac arrest.<sup>1-3</sup> Bystander resuscitation may have the greatest impact for out-of-hospital respiratory arrest,<sup>4</sup> because survival rates >70% have been reported with good neurologic outcome.<sup>5,6</sup> Bystander resuscitation may also have substantial impact on survival from primary ventricular fibrillation (VF), because survival rates of 20% to 30% have been documented in children with sudden out-of-hospital witnessed VF.<sup>7</sup>

Overall about 6%<sup>8</sup> of children who suffer an out-of-hospital cardiac arrest and 8% of those who receive prehospital emergency response resuscitation survive, but many suffer serious permanent brain injury as a result of their arrest.<sup>7,9-14</sup> Out-of-hospital survival rates and neurological outcome can be improved with prompt bystander CPR,<sup>3,6,15-17</sup> but only about one third to one half of infants and children who suffer cardiac arrest receive bystander CPR.<sup>3,9,12,18</sup> Infants are less likely to survive out-of-hospital cardiac arrest (4%) than children (10%) or adolescents (13%), presumably because many infants included in the arrest figure are found dead after a substantial period of time, most from sudden infant death syndrome (SIDS).<sup>8</sup> As in adults, survival is greater in pediatric patients with an initial rhythm of VF or pulseless ventricular tachycardia (VT) than in those with asystole or pulseless electric activity.<sup>7,8</sup>

Results of in-hospital resuscitation are better with an overall survival of 27%.<sup>19-21</sup> The 2008 pediatric data from the National Registry of CardioPulmonary Resuscitation

(NRCPR) recorded an overall survival of 33% for pulseless arrests among the 758 cases of in-hospital pediatric arrests that occurred in the participating hospitals. Pediatric patients with VF/pulseless VT had a 34% survival to discharge, while patients with pulseless electric activity had a 38% survival. The worst outcome was in patients with asystole, only 24% of whom survived to hospital discharge. Infants and children with a pulse, but poor perfusion and bradycardia who required CPR, had the best survival (64%) to discharge. Children are more likely to survive in-hospital arrests than adults,<sup>19</sup> and infants have a higher survival rate than children.<sup>20</sup>

### Prevention of Cardiopulmonary Arrest

In infants, the leading causes of death are congenital malformations, complications of prematurity, and SIDS. In children over 1 year of age, injury is the leading cause of death. Survival from traumatic cardiac arrest is rare, emphasizing the importance of injury prevention in reducing deaths.<sup>22,23</sup> Motor vehicle crashes are the most common cause of fatal childhood injuries; targeted interventions, such as the use of child passenger safety seats, can reduce the risk of death. Resources for the prevention of motor vehicle-related injuries are detailed on the US National Highway Traffic Safety Administration's website at [www.nhtsa.gov](http://www.nhtsa.gov). The World Health Organization provides information on the prevention of violence and injuries at [www.who.int/violence\\_injury\\_prevention/en/](http://www.who.int/violence_injury_prevention/en/).

### ABC or CAB?

The recommended sequence of CPR has previously been known by the initials "ABC": Airway, Breathing/ventilation, and Chest compressions (or Circulation). The 2010 AHA Guidelines for CPR and ECC recommend a CAB sequence (chest compressions, airway, breathing/ventilations). This section will review some of the rationale for making the change for children as well as for adults.

During cardiac arrest high-quality CPR, particularly high-quality chest compressions are essential to generate

The American Heart Association requests that this document be cited as follows: Berg MD, Schexnayder SM, Chameides L, Terry M, Donoghue A, Hickey RW, Berg RA, Sutton RM, Hazinski MF. Part 13: pediatric basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122(suppl 3):S862-S875.

(*Circulation*. 2010;122[suppl 3]:S862-S875.)

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*Circulation* is available at <http://circ.ahajournals.org>

DOI: 10.1161/CIRCULATIONAHA.110.971085



Figure 1. Pediatric Chain of Survival.

blood flow to vital organs and to achieve ROSC. The arguments in favor of starting with chest compressions are as follows:

- The vast majority of victims who require CPR are adults with VF cardiac arrest in whom compressions are more important than ventilations.<sup>24</sup> They have a better outcome if chest compressions are started as early as possible with minimal interruptions. Beginning CPR with 30 compressions rather than 2 ventilations leads to a shorter delay to first compression in adult studies.<sup>25–27</sup>
- All rescuers should be able to start chest compressions almost immediately. In contrast, positioning the head and attaining a seal for mouth-to-mouth or a bag-mask apparatus for rescue breathing take time and delays the initiation of chest compressions.

Asphyxial cardiac arrest is more common than VF cardiac arrest in infants and children, and ventilations are extremely important in pediatric resuscitation. Animal studies<sup>28–30</sup> and a recent large pediatric study<sup>3</sup> show that resuscitation results for asphyxial arrest are better with a combination of ventilations and chest compressions. It is, however, unknown whether it makes a difference if the sequence begins with ventilations (ABC) or with chest compressions (CAB). Starting CPR with 30 compressions followed by 2 ventilations should theoretically delay ventilations by only about 18 seconds for the lone rescuer and by an even a shorter interval for 2 rescuers. The CAB sequence for infants and children is recommended in order to simplify training with the hope that more victims of sudden cardiac arrest will receive bystander CPR. It offers the advantage of consistency in teaching rescuers, whether their patients are infants, children, or adults.

For the purposes of these guidelines

- Infant BLS guidelines apply to infants < approximately 1 year of age.
- Child BLS guidelines apply to children approximately 1 year of age until puberty. For teaching purposes puberty is defined as breast development in females and the presence of axillary hair in males.
- Adult BLS guidelines (see Part 5) apply at and beyond puberty.

### BLS Sequence for Lay Rescuers

These guidelines delineate a series of skills as a *sequence* of distinct steps depicted in the Pediatric BLS Algorithm,

but they should be performed *simultaneously* (eg, starting CPR and activating the emergency response system) when there is more than 1 rescuer.

### Safety of Rescuer and Victim

Always make sure that the area is safe for you and the victim. Although provision of CPR carries a theoretical risk of transmitting infectious disease, the risk to the rescuer is very low.<sup>31</sup>

### Assess Need for CPR

To assess the need for CPR, the lay rescuer should assume that cardiac arrest is present if the victim is unresponsive and not breathing or only gasping.

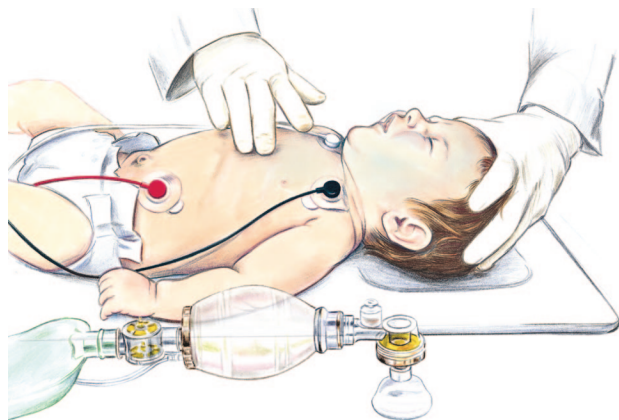
### Check for Response

Gently tap the victim and ask loudly, “Are you okay?” Call the child’s name if you know it. If the child is responsive, he or she will answer, move, or moan. Quickly check to see if the child has any injuries or needs medical assistance. If you are alone and the child is breathing, leave the child to phone the emergency response system, 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, shout for help.

### Check for Breathing

If you see regular breathing, the victim does not need CPR. If there is no evidence of trauma, turn the child onto the side (recovery position), which helps maintain a patent airway and decreases risk of aspiration.

If the victim is unresponsive and not breathing (or only gasping), begin CPR. Sometimes victims who require CPR will gasp, which may be misinterpreted as breathing. Treat the victim with gasps as though there is no breathing and begin CPR. Formal training as well as “just in time” training, such as that provided by an emergency response system dispatcher, should emphasize how to recognize the difference between gasping and normal breathing; rescuers should be instructed to provide CPR even when the unresponsive victim has occasional gasps (Class IIa, LOE C).



**Figure 2.** Two-finger chest compression technique in infant (1 rescuer).

### Start Chest Compressions

During cardiac arrest, high-quality chest compressions generate blood flow to vital organs and increase the likelihood of ROSC. If the infant or child is unresponsive and not breathing, give 30 chest compressions.

The following are characteristics of high-quality CPR:

- Chest compressions of appropriate rate and depth. “Push fast”: push at a rate of at least 100 compressions per minute. “Push hard”: push with sufficient force to depress at least one third the anterior-posterior (AP) diameter of the chest or approximately 1 ½ inches (4 cm) in infants and 2 inches (5 cm) in children (Class I, LOE C). Inadequate compression depth is common<sup>32–34</sup> even by health care providers.
- Allow complete chest recoil after each compression to allow the heart to refill with blood.
- Minimize interruptions of chest compressions.
- Avoid excessive ventilation.

For best results, deliver chest compressions on a firm surface.<sup>35,36</sup>

For an *infant*, lone rescuers (whether lay rescuers or healthcare providers) should compress the sternum with 2 fingers (Figure 2) placed just below the intermammary line (Class IIb, LOE C).<sup>37–41</sup> Do not compress over the xiphoid or ribs. Rescuers should compress at least one third the depth of the chest, or about 4 cm (1.5 inches).

For a *child*, lay rescuers and healthcare providers should compress the lower half of the sternum *at least* one third of the AP dimension of the chest or approximately 5 cm (2 inches) with the heel of 1 or 2 hands. Do not press on the xiphoid or the ribs. There are no data to determine if the 1- or 2-hand method produces better compressions and better outcome (Class IIb, LOE C). In a child manikin study, higher chest compression pressures were obtained<sup>42</sup> with less rescuer fatigue<sup>43</sup> with the 2-hand technique. Because children and rescuers come in all sizes, rescuers may use either 1 or 2 hands to compress the child’s chest. Whichever you use, make sure to achieve an adequate compression depth with complete release after each compression.

After each compression, allow the chest to recoil completely (Class IIb, LOE B) because complete chest re-

expansion improves the flow of blood returning to the heart and thereby blood flow to the body during CPR.<sup>44–46</sup> During pediatric CPR incomplete chest wall recoil is common, particularly when rescuers become fatigued.<sup>32,47,48</sup> Incomplete recoil during CPR is associated with higher intrathoracic pressures and significantly decreased venous return, coronary perfusion, blood flow, and cerebral perfusion.<sup>45,46</sup> Manikin studies suggest that techniques to lift the heel of the hand slightly, but completely, off the chest can improve chest recoil, but this technique has not been studied in humans.<sup>44,49</sup> Automated CPR feedback devices hold promise as monitors of CPR quality parameters, including chest recoil, by providing real-time, corrective feedback to the rescuer. However, there is currently insufficient evidence for or against their use in infants and children.

Rescuer fatigue can lead to inadequate compression rate, depth, and recoil.<sup>32,47,50</sup> The quality of chest compressions may deteriorate within minutes even when the rescuer denies feeling fatigued.<sup>51,52</sup> Rescuers should therefore rotate the compressor role approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions. Recent data suggest that when feedback devices are used and compressions are effective, some rescuers may be able to effectively continue past the 2-minute interval.<sup>47</sup> The switch should be accomplished as quickly as possible (ideally in less than 5 seconds) to minimize interruptions in chest compressions.

Resuscitation outcomes in infants and children are best if chest compressions are combined with ventilations (see below), but if a rescuer is not trained in providing ventilations, or is unable to do so, the lay rescuer should continue with chest compressions (“Hands-Only” or compression-only CPR) until help arrives.

### Open the Airway and Give Ventilations

For the lone rescuer a compression-to-ventilation ratio of 30:2 is recommended. After the initial set of 30 compressions, open the airway and give 2 breaths. In an unresponsive infant or child, the tongue may obstruct the airway and interfere with ventilations.<sup>53–55</sup> Open the airway using a head tilt–chin lift maneuver for both injured and noninjured victims (Class I, LOE B).

To give breaths to an infant, use a mouth-to-mouth-and-nose technique; to give breaths to a child, use a mouth-to-mouth technique.<sup>56</sup> Make sure the breaths are effective (ie, the chest rises). Each breath should take about 1 second. If the chest does not rise, reposition the head, make a better seal, and try again.<sup>56</sup> It may be necessary to move the child’s head through a range of positions to provide optimal airway patency and effective rescue breathing.

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 (Class IIb, LOE C).<sup>57–59</sup> 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. If you are the only rescuer, provide 2 effective ventilations using as

short a pause in chest compressions as possible after each set of 30 compressions (Class IIa, LOE C).

### Coordinate Chest Compressions and Breathing

After giving 2 breaths, immediately give 30 compressions. The lone rescuer should continue this cycle of 30 compressions and 2 breaths for approximately 2 minutes (about 5 cycles) before leaving the victim to activate the emergency response system and obtain an automated external defibrillator (AED) if one is nearby.

The ideal compression-to-ventilation ratio in infants and children is unknown. The following have been considered in recommending a compression-to-ventilation ratio of 30:2 for single rescuers:

- Evidence from manikin studies shows that lone rescuers cannot deliver the desired number of compressions per minute with the compression-to-ventilation ratio of 5:1 that was previously recommended (2000 and earlier).<sup>60–63</sup> For the lone rescuer, manikin studies show that a ratio of 30:2 yields more chest compressions than a 15:2 ratio with no, or minimal, increase in rescuer fatigue.<sup>64–68</sup>
- Volunteers recruited at an airport to perform single-rescuer layperson CPR on an adult manikin had less “no flow time” (ie, arrest time without chest compressions, when no blood flow is generated) with 30:2 compared with a 15:2 ratio.<sup>69</sup>
- An observational human study<sup>70</sup> comparing resuscitations by firefighters prior to and following the change from 15:2 to 30:2 compression-to-ventilation ratio reported more chest compressions per minute with a 30:2 ratio; ROSC was unchanged.
- Animal studies<sup>71–73</sup> show that coronary perfusion pressure, a major determinant of success in resuscitation, rapidly declines when chest compressions are interrupted; once compressions are resumed, several chest compressions are needed to restore coronary perfusion pressure. Thus, frequent interruptions of chest compressions prolong the duration of low coronary perfusion pressure and flow.
- Manikin studies,<sup>25,69,74</sup> as well as in- and out-of-hospital adult human studies,<sup>33,34,75</sup> have documented long interruptions in chest compressions. Adult studies<sup>76–78</sup> have also demonstrated that these interruptions reduce the likelihood of ROSC.

### Activate Emergency Response System

If there are 2 rescuers, one should start CPR immediately and the other should activate the emergency response system (in most locales by phoning 911) and obtain an AED, if one is available. Most infants and children with cardiac arrest have an asphyxial rather than a VF arrest<sup>3,9,12</sup>; therefore 2 minutes of CPR are recommended before the lone rescuer activates the emergency response system and gets an AED if one is nearby. The lone rescuer should then return to the victim as soon as possible and use the AED (if available) or resume CPR, starting with chest compressions. Continue with cycles of 30 compressions to 2 ventilations until emergency response rescuers arrive or the victim starts breathing spontaneously.

### BLS Sequence for Healthcare Providers and Others Trained in 2-Rescuer CPR

For the most part the sequence of BLS for healthcare providers is similar to that for laypeople with some variation as indicated below (see Figure 3). Healthcare providers are more likely to work in teams and less likely to be lone rescuers. Activities described as a series of individual sequences are often performed simultaneously (eg, chest compressions and preparing for rescue breathing) so there is less significance regarding which is performed first.

It is reasonable for healthcare providers to tailor the sequence of rescue actions to the most likely cause of arrest. For example, if the arrest is witnessed and sudden (eg, sudden collapse in an adolescent or a child identified at high risk for arrhythmia or during an athletic event), the healthcare provider may assume that the victim has suffered a sudden VF–cardiac arrest and as soon as the rescuer verifies that the child is unresponsive and not breathing (or only gasping) the rescuer should immediately phone the emergency response system, get the AED and then begin CPR and use the AED. (Class IIa LOE C).<sup>2,7,79</sup>

#### Assess the Need for CPR (BOX 1)

If the victim is unresponsive and is not breathing (or only gasping), send someone to activate the emergency response system.

#### Pulse Check (BOX 3)

If the infant or child is unresponsive and not breathing (gasps do not count as breathing), healthcare providers may take up to 10 seconds to attempt to feel for a pulse (brachial in an infant and carotid or femoral in a child). If, within 10 seconds, you don't feel a pulse or are not sure if you feel a pulse, begin chest compressions (Class IIa, LOE C). It can be difficult to feel a pulse, especially in the heat of an emergency, and studies show that healthcare providers,<sup>80</sup> as well as lay rescuers, are unable to reliably detect a pulse.<sup>81–95</sup>

#### Inadequate Breathing With Pulse

If there is a palpable pulse  $\geq 60$  per minute but there is 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 3A). Reassess the pulse about every 2 minutes (Class IIa, LOE B) but spend no more than 10 seconds doing so.

#### Bradycardia With Poor Perfusion

If the pulse is  $< 60$  per minute and there are signs of poor perfusion (ie, pallor, mottling, cyanosis) despite support of oxygenation and ventilation, begin chest compressions. Because cardiac output in infancy and childhood largely depends on heart rate, profound bradycardia with poor perfusion is an indication for chest compressions because cardiac arrest is imminent and beginning CPR prior to full cardiac arrest results in improved survival.<sup>96</sup> The absolute heart rate at which chest compressions should be initiated is unknown; the recommendation to provide chest compressions for a heart rate  $< 60$  per minute with signs of

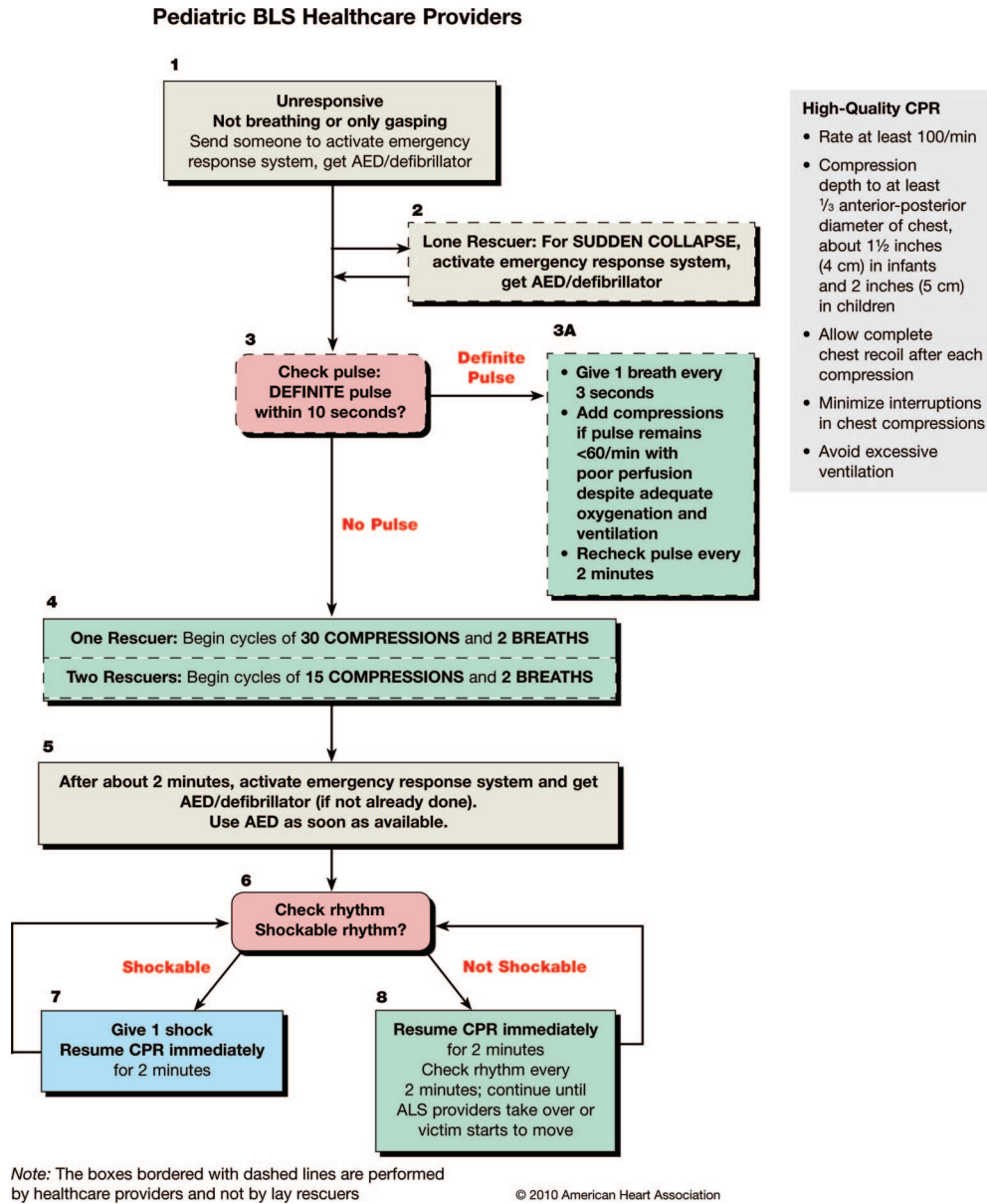


Figure 3. Pediatric BLS Algorithm.

poor perfusion is based on ease of teaching and retention of skills. For additional information see “Bradycardia” in Part 14: “Pediatric Advanced Life Support.”

**Chest Compressions (BOX 4)**

If the infant or child is unresponsive, not breathing, and has no pulse (or you are unsure whether there is a pulse), start chest compressions (see “Start Chest Compressions” in “BLS Sequence for Lay Rescuers”). The only difference in chest compressions for the healthcare provider is in chest compression for infants.

The lone healthcare provider should use the 2-finger chest compression technique for infants. The 2-thumb-encircling hands technique (Figure 4) is recommended when CPR is provided by 2 rescuers. Encircle the infant’s chest with both hands; spread your fingers around the

thorax, and place your thumbs together over the lower third of the sternum.<sup>37–41,97–103</sup> Forcefully compress the sternum with your thumbs. In the past, it has been recommended that the thorax be squeezed at the time of chest compression, but there is no data that show benefit from a circumferential squeeze. The 2-thumb-encircling hands technique is preferred over the 2-finger technique because it produces higher coronary artery perfusion pressure, results more consistently in appropriate depth or force of compression,<sup>99–102</sup> and may generate higher systolic and diastolic pressures.<sup>97,98,103,104</sup> If you cannot physically encircle the victim’s chest, compress the chest with 2 fingers (see “Chest Compressions” above).

**Ventilations (Box 4)**

After 30 compressions (15 compressions if 2 rescuers), open the airway with a head tilt–chin lift and give 2



**Figure 4.** Two thumb-encircling hands chest compression in infant (2 rescuers).

breaths. If there is evidence of trauma that suggests spinal injury, use a jaw thrust without head tilt to open the airway (Class IIb LOE C).<sup>55,105,106</sup> Because maintaining a patent airway and providing adequate ventilation is important in pediatric CPR, use a head tilt–chin lift maneuver if the jaw thrust does not open the airway.

### Coordinate Chest Compressions and Ventilations

A lone rescuer uses a compression-to-ventilation ratio of 30:2. For 2-rescuer infant and child CPR, one provider should perform chest compressions while the other keeps the airway open and performs ventilations at a ratio of 15:2. Deliver ventilations with minimal interruptions in chest compressions (Class IIa, LOE C). If an advanced airway is in place, cycles of compressions and ventilations are no longer delivered. Instead the compressing rescuer should deliver at least 100 compressions per minute continuously without pauses for ventilation. The ventilation rescuer delivers 8 to 10 breaths per minute (a breath every 6 to 8 seconds), being careful to avoid excessive ventilation in the stressful environment of a pediatric arrest.

### Defibrillation (Box 6)

VF can be the cause of sudden collapse<sup>7,107</sup> or may develop during resuscitation attempts.<sup>19,108</sup> 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 (or attenuate) the delivered energy to make them suitable for infants and children <8 years of age.<sup>109–111</sup> For infants a manual defibrillator is preferred when a shockable rhythm is identified by a trained healthcare provider (Class IIb, LOE C). The recommended first energy dose for defibrillation is 2 J/kg. If a second dose is required, it should be doubled to 4 J/kg. If a manual defibrillator is not available, an AED equipped with a pediatric attenuator is

preferred for infants. An AED with a pediatric attenuator is also preferred for children <8 year of age. If neither is available, an AED without a dose attenuator may be used (Class IIb, LOE C). AEDs that deliver relatively high energy doses have been successfully used in infants with minimal myocardial damage and good neurological outcomes.<sup>112,113</sup>

Rescuers should coordinate chest compressions and shock delivery to minimize the time between compressions and shock delivery and to resume CPR, beginning with compressions, immediately after shock delivery. The AED will prompt the rescuer to re-analyze the rhythm about every 2 minutes. Shock delivery should ideally occur as soon as possible after compressions.

### Defibrillation Sequence Using an AED

Turn the AED on.

- Follow the AED prompts.
- End CPR cycle (for analysis and shock) with compressions, if possible
- Resume chest compressions immediately after the shock. Minimize interruptions in chest compressions.

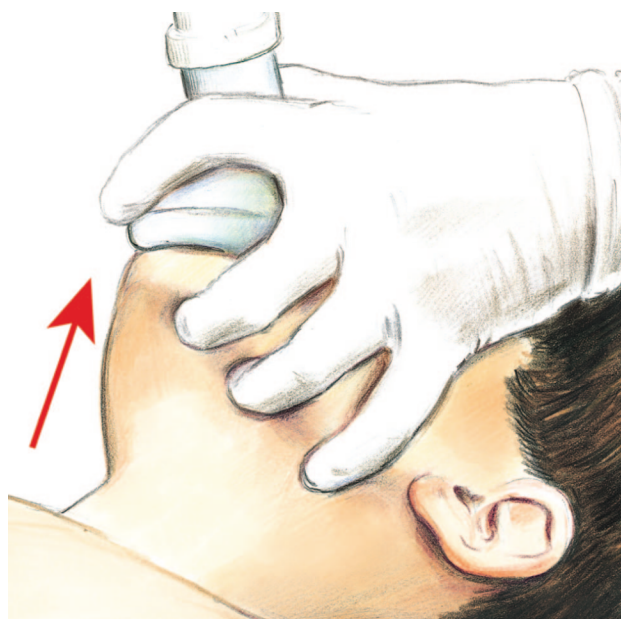
### Hands-Only (Compression-Only) CPR

Optimal CPR for infants and children includes both compressions and ventilations (Class I LOE B). Animal studies<sup>71–73,114,115</sup> demonstrated that chest compressions alone, without ventilations, are sufficient to resuscitate VF-induced cardiac arrest. In contrast, in asphyxial cardiac arrest, 3 animal studies<sup>28–30</sup> showed that ventilations, when added to chest compressions, improved outcome. One large pediatric study demonstrated that bystander CPR with chest compressions and mouth-to-mouth rescue breathing is more effective than compressions alone when the arrest was from a noncardiac etiology.<sup>3</sup> In fact, although the numbers are small, outcomes from chest compressions-only CPR were no better than if no bystander resuscitation was provided for asphyxial arrest. In contrast, bystander CPR with compressions-only was as effective as compressions plus mouth-to-mouth rescue breathing for the 29% of arrests of cardiac etiology.<sup>3</sup> Thus ventilations are more important during resuscitation from asphyxia-induced arrest, the most common etiology in infants and children, than during resuscitation from VF or pulseless VT. But even in asphyxial arrest, fewer ventilations are needed to maintain an adequate ventilation-perfusion ratio in the presence of reduced cardiac output and, consequently, low pulmonary blood flow, achieved by chest compressions. Optimal CPR in infants and children includes both compressions and ventilations, but compressions alone are preferable to no CPR (Class I LOE B).

### Breathing Adjuncts

#### Barrier Devices

Despite its safety,<sup>31</sup> some healthcare providers<sup>116–118</sup> and lay rescuers<sup>9,119,120</sup> may hesitate to give mouth-to-mouth rescue breathing without a barrier device. Barrier devices have not reduced the low risk of transmission of infec-



**Figure 5.** The EC clamp technique of bag-mask ventilations. Three fingers of one hand lift the jaw (they form the “E”) while the thumb and index finger hold the mask to the face (making a “C”).

tion,<sup>31</sup> and some may increase resistance to air flow.<sup>121,122</sup> If you use a barrier device, do not delay rescue breathing. If there is any delay in obtaining a barrier device or ventilation equipment, give mouth-to-mouth ventilation (if willing and able) or continue chest compressions alone.

#### **Bag-Mask Ventilation (Healthcare Providers)**

Bag-mask ventilation is an essential CPR technique for healthcare providers. 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.

Use a self-inflating bag with a volume of at least 450 to 500 mL<sup>123</sup> for infants and young children, as smaller bags may not deliver an effective tidal volume or the longer inspiratory times required by full-term neonates and infants.<sup>124</sup> In older children or adolescents, an adult self-inflating bag (1000 mL) may be needed to reliably achieve chest rise.

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 is affected by the tidal volume and peak inspiratory flow rate.<sup>125</sup> To deliver a high oxygen concentration (60% to 95%), attach an oxygen reservoir to the self-inflating bag. Maintain an oxygen flow of 10 to 15 L/min into a reservoir attached to a pediatric bag<sup>125</sup> and a flow of at least 15 L/min into an adult bag.

Effective bag-mask ventilation requires a tight seal between the mask and the victim’s face. Open the airway by lifting the jaw toward the mask making a tight seal and squeeze the bag until the chest rises (see Figure 5). Because effective bag-mask ventilation requires complex steps, bag-mask ventilation is not recommended for a lone rescuer during CPR. During CPR the lone rescuer should use mouth-

to-barrier device techniques for ventilation. Bag-mask ventilation can be provided effectively during 2-person CPR.

#### **Precautions**

Healthcare providers often deliver excessive ventilation during CPR,<sup>34,126,127</sup> particularly when an advanced airway is in place. Excessive ventilation is harmful because it

- Increases intrathoracic pressure and impedes venous return and therefore decreases cardiac output, cerebral blood flow, and coronary perfusion.<sup>127</sup>
- Causes air trapping and barotrauma in patients with small-airway obstruction.
- Increases the risk of regurgitation and aspiration in patients without an advanced airway.

Avoid excessive ventilation (Class III, LOE C); use only the force and tidal volume necessary to just make the chest rise. Give each breath slowly, over approximately 1 second, and watch for chest rise. If the chest does not rise, reopen the airway, verify that there is a tight seal between the mask and the face (or between the bag and the advanced airway), and reattempt ventilation.

Because effective bag-mask ventilation requires complex steps, bag-mask ventilation is not recommended for ventilation by a lone rescuer during CPR.

Patients with airway obstruction or poor lung compliance may require high inspiratory pressures to be properly ventilated (sufficient to produce chest rise). A pressure-relief valve may prevent the delivery of a sufficient tidal volume in these patients.<sup>125</sup> Make sure that the bag-mask device allows you to bypass the pressure-relief valve and use high pressures, if necessary, to achieve visible chest expansion.<sup>128</sup>

#### **Two-Person Bag-Mask Ventilation**

If skilled rescuers are available, a 2-person technique may provide more effective bag-mask-ventilation than a single-person technique.<sup>129</sup> A 2-person technique may be required to provide effective bag-mask ventilation when there is significant airway obstruction, poor lung compliance,<sup>128</sup> 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. Because the 2-person technique may be more effective, be careful to avoid delivering too high a tidal volume that may contribute to excessive ventilation.

#### **Gastric Inflation and Cricoid Pressure**

Gastric inflation may interfere with effective ventilation<sup>130</sup> and cause regurgitation. To minimize gastric inflation

- Avoid creation of excessive peak inspiratory pressures by delivering each breath over approximately 1 second.<sup>131</sup>
- Cricoid pressure may be considered, but only in an unresponsive victim if there is an additional healthcare provider.<sup>132–134</sup> Avoid excessive cricoid pressure so as not to obstruct the trachea.<sup>135</sup>



**Oxygen**

Animal and theoretical data suggest possible adverse effects of 100% oxygen,<sup>136–139</sup> but studies comparing various concentrations of oxygen during resuscitation have been performed only in the newborn period.<sup>137,139–145</sup> Until additional information becomes available, it is reasonable for healthcare providers to use 100% oxygen during resuscitation. Once circulation is restored, monitor systemic oxygen saturation. It may be reasonable, when appropriate equipment is available, to titrate oxygen administration to maintain the oxyhemoglobin saturation  $\geq 94\%$ . Provided appropriate equipment is available, once ROSC is achieved, adjust the  $F_{IO_2}$  to the minimum concentration needed to achieve transcutaneous or arterial oxygen saturation of at least 94% with the goal of avoiding hyperoxia while ensuring adequate oxygen delivery. Since an oxygen saturation of 100% may correspond to a  $P_{aO_2}$  anywhere between  $\sim 80$  and 500 mm Hg, in general it is appropriate to wean the  $F_{IO_2}$  for a saturation of 100%, provided the oxyhemoglobin saturation can be maintained  $\geq 94\%$  (Class IIb, LOE C). Whenever possible, humidify oxygen to prevent mucosal drying and thickening of pulmonary secretions.

**Oxygen Masks**

Simple oxygen masks can provide an oxygen concentration of 30% to 50% to a victim who is breathing spontaneously. To deliver a higher concentration of oxygen, use a tight-fitting nonbreathing mask with an oxygen inflow rate of approximately 15 L/min to maintain 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,<sup>146</sup> but the concentration of inspired oxygen is limited unless a high-flow device is used.

**Other CPR Techniques and Adjuncts**

There is insufficient data in infants and children to recommend for or against the use of the following: mechanical devices to compress the chest, active compression-decompression CPR, interposed abdominal compression CPR (IAC-CPR), the impedance threshold device, or pressure sensor accelerometer (feedback) devices. For further information, see Part 7: "CPR Devices" for adjuncts in adults.

**Foreign-Body Airway Obstruction (Choking)****Epidemiology and Recognition**

More than 90% of childhood 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,<sup>147</sup> 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.<sup>148–151</sup>

Signs of FBAO include a *sudden* onset of respiratory distress with coughing, gagging, stridor, or wheezing. Sudden onset of respiratory distress in the absence of fever or other respiratory symptoms (eg, antecedent cough, congestion) suggests FBAO rather than an infectious cause of respiratory distress, such as croup.

**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) you must act to relieve the obstruction.

For a child perform subdiaphragmatic abdominal thrusts (Heimlich maneuver)<sup>152,153</sup> until the object is expelled or the victim becomes unresponsive. For an infant, deliver repeated cycles of 5 back blows (slaps) followed by 5 chest compressions<sup>154–156</sup> until the object is expelled or the victim becomes unresponsive. Abdominal thrusts are not recommended for infants because they may damage the infant's relatively large and unprotected liver.

If the victim becomes unresponsive, start CPR with chest compressions (do not perform a pulse check). After 30 chest compressions, open the airway. If you see a foreign body, remove it but do not perform blind finger sweeps because they may push obstructing objects farther into the pharynx and may damage the oropharynx.<sup>157–159</sup> Attempt to give 2 breaths and continue with cycles of chest compressions and ventilations until the object is expelled. After 2 minutes, if no one has already done so, activate the emergency response system.

**Special Resuscitation Situations****Children With Special Healthcare Needs**

Children with special healthcare needs may require emergency care for complications of chronic conditions (eg, obstruction of a tracheostomy), failure of support technology (eg, ventilator malfunction), progression of underlying disease, or events unrelated to those special needs.<sup>160</sup> Care is often complicated by a lack of medical information, a comprehensive plan of medical care, a list of current medications, and lack of clarity in limitation of resuscitation orders such as "Do Not Attempt Resuscitation (DNAR)" or "Allow Natural Death (AND)." Parents and child-care providers of children with special healthcare needs 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/AND orders.<sup>160,161</sup> An Emergency Information Form (EIF) developed by the American Academy of Pediatrics and the

American College of Emergency Physicians<sup>162</sup> is available online ([www.aap.org/advocacy/EIFTemp09.pdf](http://www.aap.org/advocacy/EIFTemp09.pdf)).

#### **Advanced Directives**

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 AND directives vary from state to state.

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, a summary of the hospital course, and how to recognize signs of deterioration. They should receive specific instructions about CPR and whom to contact.<sup>161</sup>

#### **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, change the tracheostomy tube, 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. If you are still unable to achieve chest rise, remove the tracheostomy tube and attempt alternative ventilation methods, such as mouth-to-stoma ventilation or 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.

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 direct pressure.
- When the mechanism of injury is compatible with spinal injury, minimize motion of the cervical spine and movement of the head and neck.
- Professional rescuers should 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, because a patent airway is necessary. If there are 2 rescuers, 1 can manually restrict cervical spine motion while the other rescuer opens the airway.

- 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<sup>163</sup> or elevating the torso to avoid undesirable backboard-induced cervical flexion.<sup>163,164</sup>
- If possible, transport children with potential for serious trauma to a trauma center with pediatric expertise.

#### **Drowning**

Outcome after drowning is determined by the duration of submersion, the water temperature, and how promptly and effectively CPR is provided.<sup>1,16,165</sup> Neurologically intact survival has been reported after prolonged submersion in icy waters.<sup>166,167</sup> 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<sup>168</sup> if doing so will not delay removing the victim from the water. Do not attempt chest compressions in the water.

After removing the victim from the water start CPR if the victim is unresponsive and is not breathing. If you are alone, continue with 5 cycles (about 2 minutes) of compressions and ventilations before activating the emergency response system and getting an AED. If 2 rescuers are present, send the second rescuer to activate the emergency response system immediately and get the AED while you continue CPR.

### **The Quality of BLS**

Immediate CPR can improve survival from cardiac 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.

Healthcare systems that deliver CPR should implement processes of performance improvement. These include monitoring the time required for recognition and activation of the emergency response system, 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 4: “Overview of CPR”). This evidence should be used to optimize the quality of CPR delivered.

Disclosures

Guidelines Part 13: Pediatric BLS Writing Group Disclosures

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Mary Fran Hazinski	Vanderbilt University School of Nursing—Professor; AHA ECC Product Development—Senior Science Editor. †Significant compensation from the AHA to provide protected time to edit, review, write for the development of the 2010 AHA Guidelines for CPR and ECC and the 2010 International Liaison Committee on Resuscitation Consensus on CPR and ECC Science with Treatment Recommendation	None	None	None	None	None	None

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

\*Modest.

†Significant.

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KEY WORDS: automatic external defibrillator ■ cardiopulmonary resuscitation ■ pediatrics