This chapter discusses the 2010 American Heart Association (AHA) guidelines for cardiopulmonary resuscitation and focuses on the resuscitation of pediatric patients from cardiac arrest. http://www.heart.org

The causes of arrest and the priorities and techniques for cardiopulmonary resuscitation differ in children and adults. Fortunately, cardiac arrest is uncommon in pediatric patients. When it does occur, it is usually preceded by a respiratory arrest or shock. The terminal cardiac rhythm in children is typically bradycardia followed by pulseless electrical activity (i.e., there are no pulses but there is ECG activity) or asystole. Few patients (6-8%) survive cardiopulmonary arrest when it occurs outside a hospital. Those who survive are frequently left with severe neurologic injury. If the cardiac arrest occurs in hospital, about 27% of children survive.

Congenital malformations, complications of prematurity, and sudden infant death syndrome (SIDS) are the leading causes of infant deaths in developed countries. The leading cause of death in children over one year of age is injury (trauma).

When caring for pediatric patients, it is important to address the unique and varied needs of patients of different ages (newborns, infants, children, and adolescents). Age and patient size are also important considerations when performing chest compressions, ventilating the lungs, giving drugs, and determining the cause(s) of the arrest. For the purposes of this chapter, infants are patients under one year of age. Children are one year of age to puberty (breast development in girls and axillary hair in males).

Prior to 2010, the AHA recommended a sequence for resuscitation of ABC (airway, breathing/ventilations, circulation/chest compressions) in this order. The 2010 the guidelines were changed to recommend a sequence of CAB (chest compressions, airway, breathing/ventilations). To simplify the guidelines and training of people doing resuscitation, the AHA made the resuscitation algorithm for adults and children the same; chest compressions are begun before ventilation. The majority of adults undergoing cardiac arrest have ventricular fibrillation (VF) when they arrest. More adults survive if chest compressions are started early and continue with minimal interruptions. Thus, it is important that all rescuers are able to perform effective chest compressions. Rescue breathing is harder to perform effectively, takes time to initiate, and may delay initiation of chest compressions. For rescue breathing to be effective,
pulmonary blood flow must be present. Thus, cardiac massage (chest compressions) must be initiated quickly.

In adults ventricular fibrillation (VF) is the most common cause of cardiac arrest. In infants and children asphyxia is the most common cause. This makes early initiation of artificial ventilation (rescue breathing) more important in children. However, resuscitation should start with giving 30 chest compressions before giving two breaths; giving these 30 chest compressions should not delay starting rescue breathing by more than about 18 seconds. Healthcare providers often tailor the sequence of rescue actions (ABC versus CAB) to the most likely cause of arrest. If the cardiac arrest is witnessed and occurs suddenly, or the child is at high risk for developing a life-threatening arrhythmia, VF cardiac arrest may be more likely than asphyxia induced cardiac arrest. In this case, an automatic external defibrillator (AED) (if available) and additional help with the resuscitation are extremely important.
Figure 5-1: Basic Life Support Algorithm for Health Care Providers

**Pediatric BLS Healthcare Providers**

1. Unresponsive
   - Not breathing or only gasping
   - Send someone to activate emergency response system, get AED/defibrillator

2. Lone Rescuer: For SUDDEN COLLAPSE, activate emergency response system, get AED/defibrillator

3. Check pulse: DEFINITE pulse within 10 seconds?
   - High-Quality CPR
     - Rate at least 100/min
     - Compressions depth to at least 1/2 anterior-posterior diameter of chest, about 1 1/2 inches (4 cm) in infants and 2 inches (5 cm) in children
     - Allow complete chest recoil after each compression
     - Minimize interruptions in chest compressions
     - Avoid excessive ventilation
   - Give 1 breath every 3 seconds
   - Add compressions if pulse remains <60/min with poor perfusion despite adequate oxygenation and ventilation
   - Recheck pulse every 2 minutes

4. No Pulse
   - One Rescuer: Begin cycles of 30 COMPRESSIONS and 2 BREATHS
   - Two Rescuers: Begin cycles of 15 COMPRESSIONS and 2 BREATHS

5. After about 2 minutes, activate emergency response system and get AED/defibrillator (if not already done).
   - Use AED as soon as available.

6. Check rhythm
   - Shockable
     - Give 1 shock
     - Resume CPR immediately for 2 minutes
   - Not Shockable
     - Resume CPR immediately for 2 minutes
     - Check rhythm every 2 minutes; continue until ALS providers take over or victim starts to move

Note: The boxes bordered with dashed lines are performed by healthcare providers and not by lay rescuers

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The following is an organized approach to the resuscitation of patients from cardiac arrest.

**Assess the need for CPR** – If the victim is unresponsive and is not breathing (or only gasping), send someone to both get help and to obtain equipment needed to resuscitate the patient.

**Pulse check** – If the child is unresponsive and not breathing, feel for a pulse (brachial pulse in an infant and carotid or femoral pulse in a child). If no pulse is felt within 10 seconds or you are not sure if there is a pulse, begin chest compressions (See below).

**Inadequate breathing with a pulse** - If the pulse is palpable and the pulse rate is greater than 60 per minute, but breathing is inadequate, give 10-to-20 breaths per minute. Reassess the pulses for no more than 10 seconds every two minutes and continue breathing for the patient. The heart rate should increase and be normal for that patient’s age (See Appendix 1).

**Bradycardia with poor perfusion** - If the pulse rate is below 60 beats per minute and the patient has signs of poor perfusion (pallor, mottling, or cyanosis of the skin), begin chest compressions. Cardiac output in infants and children depends largely on the heart rate. When cardiopulmonary resuscitation (CRP) is started before a full cardiac arrest occurs, survival is improved.

**Chest compressions** - If the infant or child is unresponsive to voice and/or tactile stimulation, is not breathing, and has no palpable pulse, place the child on a hard surface (a table, a board, or the floor) and immediately start chest compressions; chest compressions done in a bed are ineffective. Deliver 30 chest compressions at a rate of 100 compressions per minute or more and use sufficient force to depress the sternum at least one-third of the anterior-posterior (AP) diameter of the chest [1.5 inches (4 cm) in infants; 2 inches (5 cm) in children]. Allow the chest to completely return to its normal resting position between compressions. Interruption of chest compressions must be minimized.

The method by which one does chest compression depends on both the patient’s age and her/his size. In infants, lone rescuers place the second and third fingers of one hand on the lower half of the sternum, just below an imaginary line drawn between the patient’s two nipples (Figure 5-2), and compress the sternum as described above. Do not compress over the xiphoid process or the ribs because this may injure the lungs, liver, spleen, and/or other intra-abdominal organs.
The image shows the two-finger method of doing cardiac compression in a baby. Note the fingers are in the midline just below an imaginary line drawn between the child’s two nipples; the back is supported on a hard surface. Artificial ventilation should be done as soon as possible.

If two rescuers are available to perform CPR, the two thumb-encircling hands technique (Figure 5-3) is used in young children because it provides more effective chest compression and causes less rescuer fatigue. The fingers of both hands are placed around the thorax, and the thumbs are positioned in the midline over the lower third of the sternum while compressing the sternum. Avoid compressing over the xiphoid process and/or ribs. The fingers surrounding the chest support it during compressions. The second resuscitator can ventilate the patient’s lungs if he/she is capable of doing this.
The figure shows cardiac compression using the two-thumb technique. The fingers of both hands are placed around the patient’s chest and the thumbs compress the heart between the sternum and the spine. The fingers and thumbs are placed just below an imaginary line drawn between the baby’s nipples and the sternum is compressed. Ventilation can be produced with a bag-and-mask.

Chest compressions can be done in children with either the heel of one hand (the back muscular part of the palm of the hand) while the other hand is situated on top of the first hand. The heel of one hand may also be used alone. In adolescents, chest compressions should be done using the two hands method, as in adults. To decrease resuscitator fatigue and to improve the quality of CPR, the person doing chest compressions should switch with the second rescuer every two minutes, if there are two rescuers. If only one rescuer is available to ventilate the patient’s lungs (because of lack of training or for other reasons), chest compressions should be started and continue until help arrives.

Ventilation of the lungs - After 30 chest compressions for a single rescuer and 15 compressions for two rescuers (one person to compress the chest and the other to ventilate the lungs), breaths are given. Before starting artificial ventilation, the airway is opened by tilting the head back (head
tilt) and lifting the chin (Figure 5-4). Then two breaths are given. If one suspects that the patient has a cervical spine injury, open the airway by performing a jaw thrust without doing a head tilt. If this does not provide an airway, an airway adjunct is used (See below). If the airway still is not patent, a head tilt must be done to open the airway. Doing so may increase spinal cord injury if present, but will usually allow the lungs of the victim to be ventilated in this desperate situation. Airway adjunct can also be used in some patients to avoid having to extend the head (see below).

**Figure 5-4: Head Tilt-Chin Lift Maneuver.**

This figure shows the method for chin lift. The fingers of the hand lifting the chin should be on the bone of the mandible, not in the soft parts of the chin. Placing the fingers in the soft parts of the chin can push the tongue back into the throat, causing worse airway obstruction.
Figure 5-5 shows method for chin lift and application of a facemask at the same time.

Figure 5-5: Chin Lift While Holding a Facemask.

The fingers of the hand holding the mandible pull the mandible upward to move the tongue out of the pharynx. Since the tongue is attached to the posterior mandible, this maneuver moves the tongue away from the pharyngeal wall. To avoid causing more airway obstruction, the resuscitator’s fingers should be placed on bone, not in the soft tissues of the chin.

If the stomach becomes inflated with air during artificial ventilation, this may prevent the diaphragm from moving freely during inspiration and interfere with effective pulmonary ventilation. Distention of the stomach also increases the risk of regurgitation and aspiration of gastric contents. Thus, an oral gastric tube should be placed during resuscitation to remove gas that enters the stomach. Avoid applying excessive peak inspiratory pressures because they often force gas into the stomach. Ventilate the patient’s lungs at a rate appropriate for the child’s age, and use only enough pressure to raise the chest a normal amount with each breath.

Coordinate chest compressions and ventilation – Ventilation of the lungs should only interrupt chest compressions a minimal amount. If ventilation is being done through a tracheal tube, chest compressions should continue while breaths are given at rates of up to 60 breaths per minute at 3 months of age, 40/minute at 1 year of age, and 30 breaths per minute at 12 years of age.
Excessive ventilation rates and/or pressures are to be avoided. Most rescuers are frightened when resuscitating a patient from cardiac arrest and tend to ventilate very rapidly and give deep breaths. Both can injure the lungs and interfere with pulmonary blood flow.

When only one rescuer is available to resuscitate the patient, he/she should give 30 chest compressions and two breaths for two minutes or for five cycles of 30 and 2. If there is no one else to do it, leave the victim and call for help and obtain an Automated External Defibrillator (AED). The time away from the arrested patient should be very short. A lone rescuer should begin resuscitation as soon as possible, starting with chest compressions and continue the chest compressions until the second resuscitator or other help arrives or until the victim starts to breath spontaneously. When there are two rescuers, one should start CPR and the other should quickly call for help and obtain an AED, if available.

Defibrillation - Ventricular fibrillation and pulseless ventricular tachycardia are shockable rhythms’, i.e., they often convert to a sinus rhythm or to one that perfuses organs when the heart is shocked by the electrical discharge from a defibrillator. A manual defibrillator (a device that monitors the heart rhythm and allow the user to manually set the energy to be delivered) is preferred for infants if a trained healthcare provider is available who can identify a shockable rhythm. The initial shock is 2 Joules/kg of body weight; 4 J/kg are used for subsequent shocks, if needed. If no one trained to use a manual defibrillator is available, an AED equipped with a pediatric attenuator can be used for patients who are less than nine years of age. An attenuator is a device that decreases the AED’s power, allowing the AED to be used for young pediatric patients. This attenuator prevents delivery of adult doses of electricity to a pediatric heart, which can damage it. A standard adult AED is used for children who are nine years of age and older. If an AED with a pediatric dose attenuator is not available, an adult AED should be used. Stacked shocks (multiple shocks given one after the other) should be avoided in young pediatric patients. Minimize the time between chest compressions and shock delivery by coordinating the chest compressions and shock delivery.

Obtaining vascular access, administering drugs, or placing an advanced airway (tracheal tube, laryngeal mask airway), while very useful and usually necessary, should not significantly interrupt chest compressions or delay shocking the heart when needed.

Breathing Adjuncts

If starting artificial breathing will be delayed by waiting to obtain a barrier to place between the patient’s and resuscitator’s mouths, or to obtain ventilation equipment (i.e., bag and mask), mouth-to-mouth breathing should be initiated without waiting for these items if the resuscitator is willing and able to breath for the patient. If the resuscitator is unwilling or unable to provide mouth-to-mouth ventilation, chest compression alone should be provided without interruption until help arrives.
Bag and mask ventilation is the preferred method for ventilating a patient’s lungs during cardiac arrest, but it takes training and practice to effectively ventilate a patient’s lungs with these devices and requires training and practice to effectively ventilate a patient’s lungs. Rescuers must be able to select the proper mask size for each patient, open the airway with a head tilt-chin lift, make a tight seal between the mask and the patient’s face, deliver an effective volume of gas with each breath, and assess the effectiveness of the ventilation. A self-inflating bag, such as those produced by AMBU™, is very useful because it will function without added oxygen. Avoid excessive ventilation rates and pressures.

If the ventilation being used fails to produce adequate chest rise, readjust the head tilt-chin-lift and make sure the mask seal is adequate. If the chest rise is still inadequate, use an airway adjunct, such as an oropharyngeal airway (OPA) or nasopharyngeal (NPA) airway. A properly sized and placed OPA or NPA aids in opening the airway by displacing the tongue or soft palate away from the pharynx. In some children inserting a NPA will remove a portion of infected adenoids, which can cause significant bleeding once blood is again circulating. A laryngeal mask airway (LMA), if available, can also be useful. However, it is often difficult to generate more than 20cmH2O airway pressure through this device. This amount of pressure may be inadequate in some patients to provide an adequate breath. The first priority (after chest compression) is to ventilate the patient’s lungs using a bag and mask when available. Spending time trying to insert a tracheal tube (unless it is impossible to obtain an effective airway otherwise) wastes time and makes it more difficult to effectively resuscitate a patient from cardiac arrest. Very few people die from lack of a tracheal tube. Almost everyone dies from a lack of oxygen. Deliver basic ventilation with a bag and mask (if possible) until the patient’s condition is stable. Then intubate the trachea if necessary.

If the caregiver is skilled in tracheal intubation and airway management and can place a tracheal tube into the trachea in less than 10 seconds, CPR may be paused briefly to insert the tube. Either cuffed or uncuffed tracheal tubes are used, but cuffed tracheal tubes are thought to decrease the risk of aspirating gastric contents or the need to change the tube because it is too small or too large.

**Newborn Resuscitation**

Since asphyxia is the primary cause of cardiac arrest in neonates, the prior recommendation of airway/breathing before starting chest compressions is still appropriate. If a patient is not breathing or is not adequately oxygenating (SaO2), enough positive pressure ventilation is used to normally expand the chest; a respiratory rate of about 30 breaths per minute is used. Avoid using excessive pressure because it can injure the newborn lung.

If the patient has no pulse or her/his heart is rate below 60 beats/minute, start chest compressions as described earlier. The recommended chest compression-to-lung ventilation ratio
when asphyxia is presumed to be the cause of arrest is three compressions of the chest for each breath. If the arrest is known to be of cardiac origin, higher ratios (15:2) may be used.

The AHA guidelines recommend attaching a pulse oximeter probe to the right upper extremity of babies and basing the need for giving supplemental oxygen on the patient’s oxygen saturation (SaO₂). For babies born at term (37-42 weeks gestation), these guidelines suggest starting resuscitation with room air rather than 100% oxygen. The amount of oxygen that is added to the inspired air should be based on the patient’s SaO₂. However, if the SaO₂ is below 85% and does not increase rapidly with effective resuscitation, enough oxygen is added to the inspired gases to raise the SaO₂ to 90% or higher. Hyperoxia (SaO₂ above normal for age) may be toxic to newborns, particularly if they are preterm (<37 weeks gestation age). High concentrations of oxygen can cause chronic lung disease or blindness (retinopathy of prematurity). Thus, it is best to keep the SaO₂ of term babies between 94%-97% and that of premature babies between 88% and 94%. Airway suctioning after birth is reserved for babies who have obvious airway obstruction (intercostal, supra-sternal, infra-sternal, and sternal retractions), hypoxemia, or require positive pressure ventilation. There is little evidence that routine suctioning of the airway is beneficial, and there are risks associated with airway suctioning (hypoxemia, apnea, arrhythmias, damage to the airway).

**Medications Used for Pediatric Resuscitation**

The doses of medications used for resuscitation are usually calculated using the child’s weight in kilograms, if known. A Broselow tape, a device used throughout the world to calculate drug doses to be given to pediatric patients during emergencies, is very useful for pediatric emergencies. The tape is laid beside the child and, based on her/his weight and height, predetermined drug doses are provided on the tape. In addition to drug doses, the tape also provides the appropriate size equipment (tracheal tubes, masks, etc.), and the joules needed to defibrillate the patient’s heart.

**Table 5-1** lists medications commonly used during resuscitation. Intravascular (IV) injection of drugs is the preferred method for drug administration, but if IV access is unavailable, lidocaine, epinephrine, atropine, and naloxone can be administered via a tracheal tube. However, drugs administered via the trachea may not be as effective as when the same drug given IV. An IV should be placed as soon as possible in an arrest.
Table 5-1: Medications for Pediatric Resuscitation

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dose</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenosine</td>
<td>0.1mg/kg (maximum 6 mg); Second dose: 0.2mg/kg (maximum 12 mg)</td>
<td>Monitor ECG. Give as a rapid IV/IO bolus with flush</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>5mg/kg IV/IO; may repeat twice up to 15mg/kg; Maximum single dose 300mg</td>
<td>Monitor ECG and Blood pressure; adjust administration rate to urgency (IV push during cardiac arrest, more slowly–over 20–60 min when the heart rhythm produces peripheral perfusion. Expert consultation strongly recommended prior to using this drug when a patient has a perfusing rhythm; Use caution when administering with other drugs that prolong the QT interval - (obtain expert consultation)</td>
</tr>
<tr>
<td>Atropine</td>
<td>0.02mg/kg IV/IO 0.04–0.06mg/kg/TT. Repeat once if needed. Minimum dose: 0.1mg. Maximum single dose: 0.5mg</td>
<td>Higher doses may be used with organophosphate poisoning</td>
</tr>
<tr>
<td>Calcium Chloride (10% solution)</td>
<td>20mg/kg IV/IO (0.2mL/kg) Maximum single dose 2 g</td>
<td>Administer slowly</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>0.01mg/kg (0.1 mL/kg of a 1:10,000 solution) IV/IO; 0.1mL/kg of a 1:1000 solution per TT*. Maximum dose 1 mg IV/IO; 2.5mg/TT</td>
<td>May repeat every 3–5 minutes</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.5–1g/kg IV/IO for hypoglycemia</td>
<td>Newborn: 5–10mL/kg D_{10}W Infants and Children: 2–4mL/kg D_{25}W Adolescents: 1–2mL/kg D_{50}W</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>Bolus: 1mg/kg IV/IO; 20–50mcg/kg/minute by infusion</td>
<td></td>
</tr>
<tr>
<td>Magnesium Sulfate</td>
<td>25–50mg/kg IV/IO over 10–20 minutes; give faster in torsades de pointes; Maximum dose 2g</td>
<td></td>
</tr>
<tr>
<td>Naloxone</td>
<td>Full Reversal: &lt;5 y or ≤20 kg: 0.1mg/kg IV/IO/ET*; ≥5y or &gt;20 kg: 2mg IV/IO/ET*</td>
<td>Use lower doses to reverse respiratory depression associated with therapeutic opioid use (1–5 mcg/kg – <em>titrate the dose to effect</em>)</td>
</tr>
</tbody>
</table>
Table 5-1 (Continued)

<table>
<thead>
<tr>
<th>Procainamide</th>
<th>15mg/kg IV/IO. Adult Dose: 20mg/min IV by infusion to a total maximum dose of 17 mg/kg</th>
<th>Monitor ECG and blood pressure; Give over 30–60 minutes. Use caution when administering with other drugs that prolong QT interval (obtain expert consultation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium bicarbonate</td>
<td>1mEq/kg per dose IV/IO slowly</td>
<td>After adequate spontaneous or mechanical ventilation is present</td>
</tr>
</tbody>
</table>

IV indicates intravenous; IO, intraosseous; and TT, via tracheal tube.

* Flush with 5 mL of normal saline and follow with 5 ventilations.

http://circ.ahajournals.org/content/122/18_suppl_3/S876.full.pdf+html

## Adenosine

Adenosine briefly blocks conduction through the atrioventricular (AV) node and is used to treat supraventricular tachycardia (SVT), including super SVT associated with Wolff-Parkinson-White Syndrome.

## Amiodarone

Amiodarone should not be used without expert consultation (i.e., cardiologist).

## Atropine

Atropine in an anticholinergic drug that increases the heart rate and is used to treat symptomatic bradycardia, organophosphate poisoning, and nerve gas exposure.

## Calcium

Calcium administration is not recommended for pediatric cardiopulmonary arrest unless there is documented hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia.

## Epinephrine

Epinephrine is indicated for anaphylaxis, asthma, symptomatic bradycardia, croup, pulseless cardiac arrest, hypotensive shock, and overdose of beta-adrenergic blockers or calcium channel blockers.
Chapter 5: PEDIATRIC RESUSCITATION

**Glucose**

Measure serum glucose levels during resuscitation if possible and treat hypoglycemia (<40 mg/dl in infants and <70 mg/dl in children.

**Lidocaine**

Lidocaine decreases automaticity (i.e., ability of the heart to respond without outside influences) and suppresses ventricular arrhythmias; it may be used in patients when ventricular fibrillation (VF) does not respond to electrical shocks and epinephrine. Avoid causing lidocaine toxicity by giving too much lidocaine (7 mg/kg or 500 mg total).

**Magnesium**

Magnesium is indicated for the treatment of documented hypomagnesemia or for torsades de pointes (polymorphic ventricular tachycardia). Magnesium is not used routinely during cardiac arrest.

**Procainamide**

Expert consultation is recommended.

**Sodium Bicarbonate**

Routine administration of sodium bicarbonate is not recommended in cardiac arrest because it produces large amounts of carbon dioxide (CO$_2$), 2,500 cc of CO$_2$/50 mEq of bicarbonate when fully reacted with hydrogen ions. The lungs cannot clear the CO$_2$ produced during an arrest, due to lack of pulmonary blood flow and ventilation. Bicarbonate is used to treat hyperkalemia and overdose of sodium channel blockers.

**Vasopressin**

There is insufficient evidence to make a recommendation for or against the routine use of vasopressin during cardiac arrest.
Summary

1. The AHA guidelines were changed in 2010 to emphasize chest compressions/circulation. Although asphyxia is the cause of most cardiac arrests in children, resuscitation begins with chest compression before the lungs are ventilated or the airway is manipulated. The exception to this rule is newborn resuscitation, where ventilation may be started before beginning chest compression.

2. It is possible to provide CPR with limited resources; the lungs can be ventilated with mouth-to-mouth breathing if no bag-mask equipment is available.

3. Chest compression should be “hard” and fast (100 times/minute) with the chest returning to its normal position following each compression of the chest.

4. Pauses to evaluate return of pulses, to give breaths if no tracheal tube is present, or to analyze the heart rhythm, and to shock the heart should be very brief (<10 seconds). Chest compression should be restarted immediately after a shock is delivered.

References

1. http://circ.ahajournals.org/content/122/18_suppl_3/S862 (source of figures)
3. http://circ.ahajournals.org/content/122/18_suppl_3/S876.full.pdf+html
4. http://pediatrics.aappublications.org/content/126/5/e1361.full