CHAPTER 26. CARDIOPULMONARY RESUSCITATION

HIGH-YIELD FACTS

- Primary cardiac arrest is rare in children. Early recognition and prompt treatment of respiratory distress and shock are essential to prevent the progression to cardiopulmonary arrest.
- High-quality cardiopulmonary resuscitation (CPR) must be integrated into advanced life-support measures in order to ensure a good outcome during resuscitation. The code leader must therefore continually monitor the quality of chest compressions during the entire resuscitation.
- When two or more health care providers are performing CPR in an infant or child the correct compression to ventilation ratio is 15:2 (15 compressions followed by 2 ventilations). In all other circumstances, the new universal 30:2 compression to ventilation ratio should be used.
- Minimizing interruptions of chest compressions provides for better myocardial perfusion during CPR. Two-minute cycles of CPR should be performed before stopping compressions to reassess the child.
- Automated external defibrillators can be safely and effectively used in children older than 1 year. If at all possible a pediatric attenuator device should be used if the automated external defibrillator is being used in a child younger than 8 years of age or less than 25 kg.
- Overzealous ventilations via an advanced airway can impede venous return to the heart and thus potentially decrease cardiac output during CPR.
- Ventricular fibrillation and pulseless ventricular tachycardia are now treated with single shocks followed immediately by 2-minute cycles of CPR in order to maintain myocardial perfusion after each defibrillation.
- The use of length-based tapes are encouraged during resuscitations in order to more accurately calculate proper doses of medications and select the appropriate size equipment.
- Intraosseous (IO) lines can be safely and effectively used in victims of any age. Anything that can be administered through an intravenous (IV) line can also be given via an IO line.
- Medication administration via vascular access (IV or IO) is highly preferred over endotracheal administration because of an unreliable absorption of medications via the endotracheal route.
- Always remember to consider the possibility of paroxysmal supraventricular tachycardia in any infant who presents with lethargy, fussiness, poor feeding, pallor, tachypnea, or shock.
- The key to treating a child with pulseless electrical activity (PEA) is to quickly search for and correct any reversible causes. The most common cause of PEA in children is hypovolemia so always consider a rapid fluid bolus in any child presenting in a PEA rhythm.

CARDIOPULMONARY RESUSCITATION: INTRODUCTION

The primary etiology of cardiopulmonary arrest in children differs from that in adult patients. Sudden cardiac arrest because of a primary cardiac dysrhythmia is rare in children. Unrecognized respiratory distress and shock are the most common etiologies of cardiopulmonary arrest in children. Once cardiopulmonary arrest has occurred in an out-of-hospital setting, the outcome generally remains poor with only 5% to 12% of children surviving to hospital discharge. The survival rate for children who experience cardiopulmonary arrest in an in-hospital setting has a slightly better survival rate to discharge of approximately 27%. Therefore, early recognition of a child in respiratory distress and/or compensated shock is essential to prevent the progression to cardiopulmonary arrest. The recognition and management of respiratory distress, respiratory failure, and shock are addressed in Chapters 23, 24, and 25.

THE IMPORTANCE OF INCORPORATING HIGH-QUALITY BASIC LIFE SUPPORT INTO ADVANCED LIFE-SUPPORT MEASURES

Once cardiopulmonary arrest occurs, the resuscitation team must integrate the most up-to-date guidelines in basic pediatric life support with their assessment and management skills in advanced pediatric life support. The updated 2005 American Heart Association’s (AHA) Pediatric Advanced Life Support (PALS) guidelines are based on an international consensus of the largest review of the resuscitation literature. One of the essential points in the 2005 AHA guidelines is an emphasis on high-quality CPR by lay rescuers and by health care providers. Because there are many barriers to lay rescuers being willing to perform bystander CPR, the 2005 guidelines have simplified the process in hopes that more victims of cardiac arrest will receive immediate bystander CPR. The five essential components of high-quality chest compressions are listed in Table 26-1. The “5 & 2” rule for high-quality CPR reminds the code leader to closely monitor the five components of high-quality chest compressions and to continue CPR in 2-minute intervals before stopping compressions to reassess the patient. The universal compression to ventilation ratio for one-rescuer CPR in any age victim is 30:2. When there are two health care providers performing CPR, the compression to ventilation ratio for infants and children is 15:2. The effectiveness of CPR is measured by palpable pulses during cardiac compressions. Overzealous ventilations during CPR may be harmful by decreasing venous return to the heart and limiting cardiac output. Major changes in CPR guidelines from the 2005 PALS are reviewed in Table 26-2.

Table 26-1. Dr. Al’s "5 & 2" Rule for High-Quality CPR.
Five critical components when performing chest compressions:

1. Correct hand position—the heel of one hand placed over the sternum at the nipple line in children and one finger breath below the nipple line in infants. When two-rescuer CPR is performed in infants, use the two-thumb-encircling hands technique to compress the sternum with the thumbs and squeeze the infant’s chest with the encircling fingers.

2. Push hard—compress the chest 1/3 to 1/2 the depth of the chest.

3. Push fast—compress at a rate of 100 compressions per min.

   Note: If you perform chest compressions at the same beat as the popular Bee Gee's song Stayin Alive, you will achieve the correct rate of 100 compressions/min.5

4. Allow complete recoil of the chest in order to allow the heart to refill with blood before the next compression.

5. Minimize interruption of chest compressions; perform uninterrupted CPR in 2-min intervals before reassessing the patient.

**Table 26-2. Key Changes and Major Points of Emphasis in the 2005 PALS Guidelines**

<table>
<thead>
<tr>
<th>1. Ventilation to compression ratios for infant and child CPR:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lone rescuer: 30:2.</td>
</tr>
<tr>
<td>Two-rescuer: 15:2.</td>
</tr>
<tr>
<td>CPR with an advanced airway in place: 8–10 breaths/min, and compressions at 100/min.</td>
</tr>
<tr>
<td>Apnea with a pulse: 12–20 breaths/min.</td>
</tr>
<tr>
<td>2. Palpable pulses during compressions assess quality of CPR.</td>
</tr>
<tr>
<td>3. Avoid overzealous ventilations during CPR.</td>
</tr>
<tr>
<td>4. AEDs can be safely and effectively used in infants and children older than 1 year.</td>
</tr>
<tr>
<td>5. Cuffed ETTs may be used under certain circumstances; however, the cuff pressure must be kept &lt;20 cm H₂O.</td>
</tr>
<tr>
<td>6. The vascular route (IV or IO) for medication administration is highly preferred over endotracheal administration.</td>
</tr>
<tr>
<td>7. High-dose epinephrine is no longer routinely recommended and may be harmful.³</td>
</tr>
<tr>
<td>8. VF and PVT (pulseless ventricular tachycardia) are now treated with single defibrillations followed immediately by 2-min cycles of high-quality CPR.</td>
</tr>
</tbody>
</table>

**AIRWAY AND VENTILATION**

A detailed discussion of the assessment and management of respiratory distress, respiratory failure, and advanced airway management are covered in other chapters within this book. Although uncuffed endotracheal tubes (ETTs) have traditionally been used in pediatric patients, the 2005 PALS guidelines also approve the use of cuffed ETTs in children younger than 8 years (except for the newly born). Cuffed ETTs may be safely used in the in-hospital setting in children under certain circumstances such as poor lung compliance, high airway resistance, or a large glottic leak.³ If a cuffed ETT is used, the cuff pressure must be closely monitored and kept <20 cm H₂O.

Although laryngeal mask airways (LMAs) have been extensively used by pediatric anesthesiologist in the operating room, there is currently insufficient evidence to recommend the routine use of LMAs in children during cardiac arrest.³ However, if a child in cardiopulmonary arrest cannot be adequately ventilated and oxygenated via bag-mask techniques and if attempts of an ETT insertion have failed, an LMA can be used as an alternate adjunct of advanced airway management during CPR.

Once an advanced airway has been inserted, confirm proper tube placement and proper ventilation by clinical assessment and confirmatory devices. The best way to determine whether the correct sized advanced airway is properly placed and that the patient is being effectively ventilated is to observe for adequate and symmetric rise and fall of the chest. The most commonly used confirmatory device in both the out-of-hospital and in-hospital setting is the colorimetric carbon dioxide detector device. Although one of the more common colorimetric capnometers registers the presence of carbon dioxide by changing from its initial purple color to yellow, there are many other similar devices on the market by different manufacturers which use different color schemes to detect exhaled carbon dioxide. The clinician should remember that there are various false-positive and false-negative results that may occur when using a colorimetric carbon dioxide detector device.

During cardiopulmonary arrest, the lungs are poorly perfused and therefore the colorimetric capnometer device may not detect sufficient amounts of carbon dioxide despite the advanced airway being correctly positioned within the trachea. If the standard size capnometer is used in smaller infants, carbon dioxide may not be detected by the device (despite proper placement of the advanced airway) because of low lung volumes in infants and smaller children. Therefore, be sure to check the manufacturer's specifications and weight limitations for the various capnometer devices. As an example, one of the manufacturers of a capnometer device recommends that their neonatal/infant device be used if the patient is <15 kg (otherwise the standard adult-sized capnometer device should be sufficient if the patient is >15 kg). A false-positive result (i.e., apparent detection of exhaled carbon dioxide even though the advanced airway was not actually inserted into the trachea) may occur if the capnometer device is contaminated by gastric acid and/or contaminated by acidic medications such as epinephrine that were instilled into the advanced airway. Children who have consumed carbonated beverages just prior to intubation may have enough carbon dioxide present in their stomachs to produce a color change during an accidental esophageal intubation. Therefore to avoid this false-positive result of an esophageal intubation, provide six ventilations prior to attaching a capnometer device to check for the presence of exhaled carbon dioxide.
Once the patient is intubated, avoid hyperventilation by providing 8 to 10 ventilations per minute during CPR. Excessive ventilations during CPR can impede venous return to the heart and thus potentially compromise cardiac output during CPR.

During the resuscitation, the clinician must continuously reassess the adequacy of ventilations via the ETT. ETT complications should always be considered whenever an intubated patient suddenly deteriorates during the resuscitation or during the postresuscitation stages. The complications of ETT intubation can be quickly and systematically assessed via the "DOPE" mnemonic.

- D = Dislodged or displaced ETT (esophageal intubation or right mainstem displacement)
- O = Obstructed ETT (kinked tube or internal obstruction with blood, mucus, and/or emesis)
- P = Pneumothorax (tension)
- E = Equipment failure (disconnected tubing, too small ETT with air leak, and/or inadequate volume of ventilations)

**VASCULAR ACCESS PRIORITIES FOR MEDICATION ADMINISTRATION**

Intravenous (IV) or intraosseous (IO) access is the preferred method of medication administration during any resuscitation. Although a few lipid-soluble medications (i.e., "L-A-N-E" = lidocaine, atropine, naloxone, and epinephrine) can be administered via the ETT during a resuscitation, a review of several human and animal studies have demonstrated lower blood concentrations of medications that were administered via the ETT as compared which the same medication dose administered intravenously. Some animal studies have even suggested that the lower blood epinephrine concentrations that are achieved when the medication is given into the trachea may produce transient β-effects which can produce detrimental effects of hypotension and lowering of the coronary perfusion pressure. Therefore, the IV or IO route is highly preferred over the ETT route for medication administration during a resuscitation. There is no age restriction for placement of an IO line. In infants and younger children the preferred site is the flat-medial portion of the proximal tibia (i.e., 2–3 cm below the tibial tuberosity). An alternative site for IO placement in older children is the distal tibia (i.e., 2–3 cm proximal to the medial malleous). Any medication that can be given via the IV route can also be administrated via the IO route.

**Estimation of a Child’s Weight for Medication Administration**

Difficulties encountered during a pediatric resuscitation include medication calculations, which are always based on a child’s weight, and selection of appropriate size equipment (i.e., ETT, IV catheter sizes, chest tube sizes, etc.). During the stressful situation of a resuscitation, parents may not be able to accurately recall their child’s weight and therefore the emergency physician is often faced with the daunting task of estimating the child’s weight in order to calculate the correct dose of resuscitation medications. One quick method for estimating a child’s weight is based on the child’s age and can be reviewed in Table 26–3.

<table>
<thead>
<tr>
<th>Table 26-3. Estimating a Child’s Weight Based on the Child’s Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-term neonate = 3–3.5 kg.</td>
</tr>
<tr>
<td>Doubles birth weight by 4–6 mo.</td>
</tr>
<tr>
<td>Triples birth weight by 1 year of age (1-year-old child = ~10 kg).</td>
</tr>
<tr>
<td>The target ages according to this formula are the odd numbered years. Start at 10 kg for the 1-year-old and simply increase the weight in increments of 5 kg for each subsequent odd numbered target year until age 11 years. After 11 years of age, increase the weight in 10-kg increments in order to compensate for the rapid growth spurt during the adolescent period.</td>
</tr>
<tr>
<td>Age = weight:</td>
</tr>
<tr>
<td>1 year old = 10 kg</td>
</tr>
<tr>
<td>3 years old = 15 kg</td>
</tr>
<tr>
<td>5 years old = 20 kg</td>
</tr>
<tr>
<td>7 years old = 25 kg</td>
</tr>
<tr>
<td>9 years old = 30 kg</td>
</tr>
<tr>
<td>11 years old = 35 kg</td>
</tr>
<tr>
<td>13 years old = 45 kg</td>
</tr>
<tr>
<td>15 years old = 55 kg</td>
</tr>
<tr>
<td>17 years old = 65 kg</td>
</tr>
</tbody>
</table>

Length-based tapes (i.e., Broselow tape) are recommended by the PALS guidelines in order to estimate a child’s weight during a resuscitation. These length-based tapes also precalculate the appropriate doses of various resuscitation medications and appropriate equipment sizes based on the child’s length. The validity of length-based tapes has been reverified in recent studies. However, there is no perfect method to accurately estimate a child’s weight and the limitation of the currently available length-based tapes is that they do not take the child’s body habitus into account. A recent study claims that a length-based tape inaccurately estimated the actual weight in up to one-third of children.
Although length-based resuscitation systems have reduced the potential for equipment and medication dosing errors, weight estimate error concerns have been raised with regard to the obese child and the cachectic child. Currently, the length-based tapes only take into account the length of the patient and do not take into account the overall body habitus. The addition of body habitus assessments in addition to length-based systems has demonstrated a more accurate means of estimating a child’s true weight.\textsuperscript{13}

\section*{A SYSTEMATIC APPROACH TO ARREST AND PREARREST DYSRHYTHMIAS}

A systematic approach to pediatric dysrhythmia stabilization and management depends on two key clinical factors:

1. Does the child have a pulse?
2. If a pulse is present, is the child hemodynamically stable or unstable and what is the child’s heart rate?

All of the 2005 PALS dysrhythmia treatment algorithms can be summarized into one treatment algorithm. Refer to Figure 26–1 for a simplified and systematic approach to pediatric dysrhythmias. Children who present with a dysrhythmia but who exhibit good perfusion parameters including strong distal pulses, brisk capillary refill and warm extremities, may not require any emergent interventions unless the presenting rhythm has the potential to degenerate into a more serious condition. Children who exhibit ECG evidence of conduction abnormalities (i.e., Mobitz type II second-degree heart blocks, complete heart blocks, prolonged QT intervals or aberrant conduction such as the Wolff-Parkinson-White syndrome) may also warrant more emergent treatment.\textsuperscript{14} In infants, prearrest rhythm disturbances can manifest as fussiness, lethargy, poor feeding, pallor, respiratory distress, or as cardiogenic shock. In older children, it may present as chest pain, palpitations, difficulty breathing, or syncope.

\textbf{Figure 26-1.}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure261.png}
\caption{A simplified and systematic approach to pediatric dysrhythmias.}
\end{figure}

Dr. Al’s simplified and systematic approach to pediatric dysrhythmias.

The most common pediatric arrest rhythms that will confront the emergency physician are asystole and bradyasystole. Ventricular fibrillation (VF) and ventricular tachycardia (VT) are not as common in children as they are in adults. However, the emergency physician must also be aware of a select group of infants and children who are at a higher risk of developing various primary cardiac dysrhythmias\textsuperscript{15} (Table 26–4).

\begin{table}[h]
\centering
\begin{tabular}{|c|}
\hline
\textbf{Table 26-4. Clinical Conditions Associated with a High Risk for Developing Dysrhythmias}\textsuperscript{14} \tabularnewline \hline
Congenital heart defects (uncorrected defects and postoperative complications) \tabularnewline
Congenital complete heart blocks (i.e., maternal systemic lupus erythematosus) \tabularnewline
\hline
\end{tabular}
\end{table}
Myocarditis
Rheumatic heart disease
Kawasaki disease with coronary artery involvement
Prolonged QT syndrome (familial or drug-induced)
Aberrant AV conduction pathways
Commotio cordis
Severe hypoxia
Profound hypothermia
Electrolyte abnormalities (potassium, calcium magnesium disturbances)

The four pulseless rhythms that will be addressed in this chapter can be clinically divided into two general categories based on their similar treatment approaches:

1. Shockable rhythms: VF and pulseless ventricular tachycardia (PVT).

The treatment approach and management priorities for VF and PVT are the same and require defibrillation followed immediately by CPR, while the treatment approach for asystole and PEA will require CPR, epinephrine, and a search for the reversible causes. Regardless of the presenting arrest rhythm, the emergency physician must also place a high priority on finding the underlying etiology or etiologies which may have lead to the arrest rhythm. The 12 reversible causes of cardiopulmonary arrest that are emphasized in the PALS guidelines can remembered as the "six Hs and six Ts". Another useful mnemonic to rapidly remember the most common reversible causes of PEA in children is "P-A-T2-H4" (Table 26–5).

**Table 26-5. Reversible Causes of Cardiopulmonary Arrest in Children**

"P-A-T2-H4":

When confronted with a child in PEA, use the asystole treatment algorithm and "head down the right PATH in the algorithm":

- P = Pneumothorax
- A = Acidosis
- T = Tamponade
- T = Toxins
- H = Hypovolemia
- H = Hypoxemia
- H = Hyper/Hypokalemia
- H = Hypothermia

Note: The most common cause of PEA in children is hypovolemia. Myocardial and pulmonary thromboses are rare in children.

Because atrial fibrillation and atrial flutter are not very common in children, the other dysrhythmias that will be addressed will be limited to paroxysmal supraventricular tachycardia (PSVT), bradycardia and VT. For a more detailed discussion of pediatric dysrhythmias, refer to Chapter 50.

**PAROXYSMAL SUPRAVENTRICULAR TACHYCARDIA**

PSVT is the most common symptomatic dysrhythmia in infants and children. Infants with PSVT typically present with nonspecific symptoms such as fussiness, lethargy, tachypnea, pallor, and/or difficulty feeding. Although infants can generally tolerate PSVT episodes with heart rates in the 200 to 300 beats/min range, if left untreated they may present with signs and symptoms of congestive heart failure and/or shock.

Older children with PSVT typically complain of palpitations, difficulty breathing, and/or vague chest discomfort. The QRS width in pediatric PSVT is most commonly of a narrow complex. Wide complex PSVT is less common but may be seen in a child with a preexisting bundle branch block or in a child with an antidromic reentry phenomenon, in which the conduction from the atria initially goes down to the ventricles via an accessory pathway and then returns retrograde from the ventricles back to the atria from the atrioventricular (AV) node.

The management of PSVT depends on the child's hemodynamic stability and availability of IV access. Refer to Tables 26–6 and 26–7 for the management and medication doses for PSVT. During any conversion attempt such as vagal maneuvers, adenosine or cardioversion, a continuous rhythm strip should be used to monitor and document the response to each conversion attempt and also to capture the initial
resulting rhythm after a conversion. Hemodynamically stable PSVT in infants and young children can be initially treated with ice applied to the face. A plastic bag or surgical glove filled with a slurry of crushed ice and water can be applied over the infant's forehead, eyes, and bridge of the nose for approximately 10 to 15 seconds. Care must be taken to avoid occluding the infant's nostril and mouth during this maneuver. Older children may be asked to submerge their face in a basin of cold water in addition to trying other vagal maneuvers listed in Table 26–6.

Table 26-6. Summary of Pediatric Dysrhythmia Management

<table>
<thead>
<tr>
<th>Dysrhythmia</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asystole and PEA:</td>
<td>CPR (reassess after 2-min intervals). Epinephrine (q 3–5 min). Treat the underlying cause of PEA (Table 26–5).</td>
</tr>
<tr>
<td>VF and PVT:</td>
<td>Defibrillation followed immediately by 2 min of CPR. Defibrillation followed immediately by 2 min of CPR + epinephrine (q 3–5 min). Defibrillation followed immediately by 2 min of CPR + (amiodarone or lidocaine or magnesium).</td>
</tr>
<tr>
<td>VT (with a pulse):</td>
<td>Unstable: Immediate cardioversion. Stable: Amiodarone or lidocaine or procainamide (Note: Avoid concurrent use of amiodarone and procainamide).</td>
</tr>
<tr>
<td>PSVT:</td>
<td>Unstable: If IV access is immediately available administer adenosine while preparing for cardioversion if adenosine fails to convert the PSVT. If IV access is not immediately available and/or if the patient is hemodynamically unstable, perform immediate cardioversion. Stable: Various vagal maneuvers (valsalva maneuver, ice water slurry in a bag applied to the face, blowing on an occluded straw, and/or blowing on the distal end of a syringe in an attempt to blow out the plunger). Adenosine if vagal maneuvers fail to convert the PSVT.</td>
</tr>
<tr>
<td>Bradycardia:</td>
<td>Unstable: Ensure adequate ventilation and oxygenation. CPR (reassess after 2-min intervals). Epinephrine. Atropine if suspect an increase in vagal tone or cholinergic poisoning. Cardiac pacing. Stable: No emergent treatment is required.</td>
</tr>
</tbody>
</table>

Table 26-7. Resuscitation Medications—Defibrillation and Cardioversion Doses

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephrine:</td>
<td></td>
</tr>
<tr>
<td>IV or IO dose (Standard Dose = SD) = 0.01 mg/kg (which equals 0.1 ml/kg of the 1:10,000 epinephrine solution)</td>
<td></td>
</tr>
<tr>
<td>PEDS = SD stands for Pediatric Epinephrine Dosing Story = Slide the Decimals&lt;sup&gt;18&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Starting with the patient's weight in kg slide the decimal point one spot over to the left to determine the correct volume (milliliters) of the 1:10,000 epinephrine solution to draw up. Then after that volume (milliliters) of epinephrine is administered, slide the decimal point one more spot over to the left to document the correct amount (milligram dose) of the 1:10,000 epinephrine that was given.</td>
<td></td>
</tr>
<tr>
<td>ETT dose (High Dose = HD) = 0.1 mg/kg (which equals 0.1 ml/kg of the 1:1,000 epinephrine solution)</td>
<td></td>
</tr>
<tr>
<td>Adenosine:</td>
<td>First dose = 0.1 mg/kg IV/IO (maximum = 6 mg/dose). Second and subsequent doses = 0.2 mg/kg IV/IO (maximum = 12 mg/dose).</td>
</tr>
</tbody>
</table>
Note: Because of the extremely short half-life of adenosine, all doses must be rapidly administered followed by 10–20 mL of NS flush to rapidly get the medication into the central circulation. A proximal vein is preferred over a distal IV site.

Amiodarone (maximum = 300 mg/dose):
- VF and PVT = 5 mg/kg rapid IV/IO bolus.
- Stable VT = 5 mg/kg IV/IO slowly over 20–60 min to avoid the hypotensive effects of amiodarone.
- PSVT unresponsive to adenosine = 5 mg/kg IV/IO slowly over 20–60 min to avoid the hypotensive effects of amiodarone.

Note: Avoid the concurrent use of other medications that can also prolong the QT interval (i.e., procainamide).

Lidocaine (does not cause QT prolongation like amiodarone and procainamide):
- 1 mg/kg IV/IO.

Atropine:
- 0.02 mg/kg IV/IO (minimum of 0.1 mg/dose to avoid paradoxic bradycardia). Maximum single dose of 0.5 mg for a child and 1 mg for an adolescent. May repeat to a total maximum dose of 1 mg in a child and 2 mg in an adolescent.

Dextrose:
- 0.5 g/kg IV/IO (Table 26–8)

Sodium bicarbonate:
- 1 mEq/kg IV/IO (for severe metabolic acidosis, hyperkalemia or cyclic antidepressant toxicity).

Magnesium sulfate (maximum = 2 g/dose):
- 25–50 mg/kg (rapid IV/IO push for PVT because of torsades or slowly over 10–20 min for VT with a pulse because of torsades).

Calcium chloride (10% solution = 100 mg/mL):
- 20 mg/kg IV/IO (equals 0.2 mL/kg of the 10% solution) over 30–60 min.

Note: When calcium and bicarbonate are being infused in an emergent situation flush the IV line with NS after each medication to avoid the formation of an insoluble precipitate in the IV line.

Procainamide:
- 15 mg/kg IV/IO over 30–60 min for stable VT or for PSVT unresponsive to adenosine.

Defibrillation:
- Start at 2 J/kg then double to 4 J/kg for second and subsequent doses.

Cardioversion:
- Start at 0.5–1 J/kg then may increase up to 2 J/kg.

Patients with hemodynamically stable PSVT who fail to convert after several appropriately administered doses of adenosine may require a pediatric cardiology consultation, elective cardioversion, and/or other medications such as amiodarone or procainamide to convert the PSVT. Verapamil should be avoided in infants and younger children because of the high incidence of profound hypotension and cardiovascular collapse when this medication is administered in this age group. Immediate cardioversion should be performed in any infant or child who exhibits PSVT with significant hemodynamic instability.

Symptomatic Bradycardia

Bradysystmmic bradycardia historically have been largely associated with severe hypoxemia, hypotension, and metabolic acidosis. Bradycardia is poorly tolerated in infants and children because they are not physiologically capable of increasing their stroke volume to maintain an adequate cardiac output. Clinically significant bradycardia is defined as a heart rate lower than the normal rate for age associated with signs of poor systemic perfusion. Chest compressions should be initiated for an absolute heart rate <60 beats/min that is associated with signs of poor systemic perfusion.

The first step in the management of symptomatic bradycardia is to ensure adequate oxygenation and ventilation because hypoxia is the most common etiology of bradycardia in children. Children who remain symptomatic despite adequate oxygenation and ventilation will require chest compressions and medications to convert the bradycardia. In contrast to adult where atropine is the first-line medication to treat symptomatic bradycardia, epinephrine is the first medication of choice to treat children. Because the efficacy of epinephrine is reduced in the face of hypoxia and acidosis, ensure adequate ventilation, oxygenation, and chest compressions/perfusion. Atropine would be indicated before epinephrine if the etiology of the child's bradycardia was felt to be because of an increase in vagal tone, cholinergic...
Hypoglycemia can depress neonatal myocardial function. Because glucose is the major metabolic substrate for the neonatal myocardium, untreated hypoglycemia can depress neonatal myocardial function. Consider emergency pacing for Mobitz type II second-degree AV blocks, complete AV blocks, or sick sinus syndrome.

### VENTRICULAR TACHYCARDIA (WITH A PULSE)

VT is an uncommon pediatric dysrhythmia. The majority of children with VT have underlying conditions that predispose them to developing VT such as, postcardiac surgery, myocarditis, cardiomyopathies, and prolonged QT syndrome. Electrolyte abnormalities (hyperkalemia, hypocalcemia, and hyponagmnesia), and drug toxicities (cyclic antidepressants and cocaine) must also be considered. The treatment of a child with VT and a pulse will be dependent on the child’s hemodynamic stability (Tables 26–6 and 26–7). Torsades de pointes is a unique type of polymorphic VT that deserves special consideration. Prolonged QT syndrome, hyponagmnesia, underlying cardiac defects, and various medications (cyclic antidepressants and calcium channel blockers) have all been implicated as known causes of torsades de pointes. Procainamide and amiodarone are both contraindicated in the treatment of torsades because both of these antidysrhythmic agents are capable of prolonging the QT interval, which could then cause a further deterioration of the torsades rhythm. Lidocaine may be the preferred medication to treat VT that is caused by a drug-induced prolongation of the QT interval.

### Ventricular Fibrillation and PVT

VF and PVT were previously thought to occur very rarely in pediatric cardiopulmonary arrest cases. However, in a recent study of in-hospital cardiac arrest, a shockable rhythm was present during some point of the resuscitation in 25% of the cases. VF and PVT should also be suspected as the initial arrest rhythm in cases of commotio cordis and in cases of witnessed sudden cardiac arrest in children. The treatment approach to VF and PVT has been drastically revised in the 2005 PALS guidelines. Once VF or PVT is detected, defibrillation maneuvers are now immediately followed by 2-minute cycles of CPR. Rhythm checks and pulse checks are now only performed after 2-minute cycles of CPR. Although a single shock by a biphasic defibrillator has a high likelihood of terminating VF, the resulting rhythm is typically a nonperfusing rhythm that therefore requires CPR in order to maintain perfusion to the heart and brain until normal cardiac contractility can resume.

Based on the new 2005 guidelines, epinephrine is administered with the second defibrillation maneuver (and can be repeated every 3–5 minutes), and an antidysrhythmic agent is administered with the third defibrillation maneuver.

### ASYSTOLE AND PEA

Asystole is the most common pulseless arrest rhythm presenting to the emergency department (ED). The survival rate for children who present to the ED in asystole is dismal. Tables 26–6 and 26–7 summarize the treatment of asystole and PEA. Children who present to the ED in PEA have a slightly higher chance of survival compared to those children who present in asystole. The key management issue when confronted with a child in PEA is to rapidly and systematically identify and then correct the underlying cause of PEA. If the underlying cause of PEA is not identified and corrected, the child will not survive. The most common etiology of PEA in children is profound hypovolemia. Therefore, one should always consider a rapid fluid bolus when confronted with a child in PEA. The various etiologies of PEA are listed in Table 26–5. In addition to a much focused history and physical examination, a bedside measurement of 

### SPECIAL ETIOLOGIES OF CARDIOPULMONARY ARREST AND POSTRESUSCITATION CONSIDERATIONS

Special circumstances such as trauma, drowning, toxins, and anaphylaxis can all precipitate cardiopulmonary arrest in children. The specific management issues in these special circumstances are covered in other chapters throughout this book. Although a detailed description of postresuscitation care is beyond the scope of this chapter, several key points should be kept in mind. Avoid hyperthermia and treat fever aggressively. Consider the use of vasoactive medications in the postresuscitation phase unless the patient is neurologically benefit from a brief period of hypothermia at 32°C to 34°C for 12 to 24 hours. Avoid the routine use of hyperthermia and treat fever aggressively and search for an underlying etiology such as hypoglycemia and various other electrolyte disturbances. Patients who remain comatose during the postresuscitation period may neurologically benefit from a brief period of hypothermia at 32°C to 34°C for 12 to 24 hours. Hypoglycemia is another common problem encountered in the postresuscitation phase. Because glucose is the major metabolic substrate for the neonatal myocardium, untreated hypoglycemia can depress neonatal myocardial function.

A quick and easy method to rapidly calculate 0.5 g/kg of IV dextrose is listed in Table 26–7 and 26–8.

### Table 26–6. Dr. Al’s “Hawaii Five-O” Rule for the Treatment of Hypoglycemia

A bolus of 0.5 g/kg of dextrose will raise the patient’s serum glucose by approximately 60–100 mg/dL. If the child remains symptomatic after the first dose of 0.5 g/kg, the same dose may be repeated. Although D_{2}W is the most commonly used dextrose solution in pediatrics, a simple method to quickly draw up 0.5 g/kg of dextrose using any of the four available dextrose solutions is as follows:

\[(\text{Dextrose solution concentration}) \times (\text{The number of mL/kg of that particular dextrose solution}) = \text{the number 50 always.}\]

\[\begin{align*}
5\% & \times 10\ \text{mL/kg} \\
10\% & \times 5\ \text{mL/kg}
\end{align*}\]
25% x 2 mL/kg

50% x 1 mL/kg

Note: D50W solutions should first be diluted to a less concentrated solution before administration to infants and younger children.

REFERENCES


