Chapter 109: Resuscitation of Children

William E. Hauda, II

INTRODUCTION AND EPIDEMIOLOGY

The resuscitation of children differs from that of adults in a number of important ways. For example, the most common cause of primary cardiac arrest in adults is coronary artery disease, whereas respiratory failure and shock are more common causes among children and infants; hypoxemia, hypercapnia, and acidosis subsequently lead to bradycardia, hypotension, and secondary cardiac arrest in children. After resuscitation, survival to discharge may be greater among children and adolescents than in infants or adults.[1,2,3,4] The survival rate without devastating neurologic sequelae in children varies by age, ranging from 1% to 2% in infants and young children to 11% for adolescents in whom a shockable rhythm is more common; survival rates as high as 30% have been seen after sudden out-of-hospital witnessed ventricular fibrillation.[5,6,7] The best chance for a good outcome is to recognize impending respiratory failure or shock and intervene to prevent the development of cardiopulmonary arrest.

Age-related differences are important considerations when treating children. An appropriate drug dose for a 6-month-old infant may be excessive for a 1-month-old newborn but inadequate for a 5-year-old child. Other aspects of resuscitation, such as endotracheal tube size, tidal volumes, cardiac compression rates, and respiratory rates, vary with a child's age. Equipment selection and medication dosing are based on age and body weight. Valuable time can be lost in weight estimation, dosage calculations, and equipment selection. Emergency personnel must be able to find the proper equipment rapidly. Equipment can be stored on shelves or in drawers labeled by age and weight, or a system of color codes can be used in which color-coded shelves, carts, or equipment organizers correspond to specific length categories as illustrated in Figure 109-1.

FIGURE 109-1.

The Broselow resuscitation tape. [Broselow® tape; Armstrong Medical Industries, Inc., Lincolnshire, IL.]

Source: J.E. Tintinalli, J.S. Stapczynski, O.J. Ma, D.M. Yealy, G.D. Meckler, D.M. Cline: Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th Edition
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BASIC LIFE SUPPORT

The American Heart Association Guidelines[8] use the following age group delineations: *newborn*, 1 month or less in age; *infant,* 1 month to 1 year of age; and *child*, 1 year of age to the onset of puberty. As in adults, the priorities of resuscitation are airway, oxygenation, ventilation, and shock management. An important change in the 2010 American Heart Association Guidelines is the order of basic life support assessment. Instead of using ABC (airway, breathing, circulation) as a mnemonic, the American Heart Association recommends CAB, emphasizing the importance of chest compressions beginning as rapidly as possible (Figure 109-2). Reasons for this change in approach include the following: (1) starting with chest compressions reduces the delay to the start of the first compression; (2) all rescuers can start chest compressions immediately, because airway management requires manipulation and positioning of the patient; and (3) simplifying the basic life support resuscitation approach is consistent for all patients regardless of the arrest cause.[8,9] Cardiopulmonary arrest should be prevented whenever possible with prompt recognition of and intervention for compromised physiology.[10] International consensus guidelines for basic life support procedures are listed in **Table 109-1**.[8,11]

TABLE 109-1

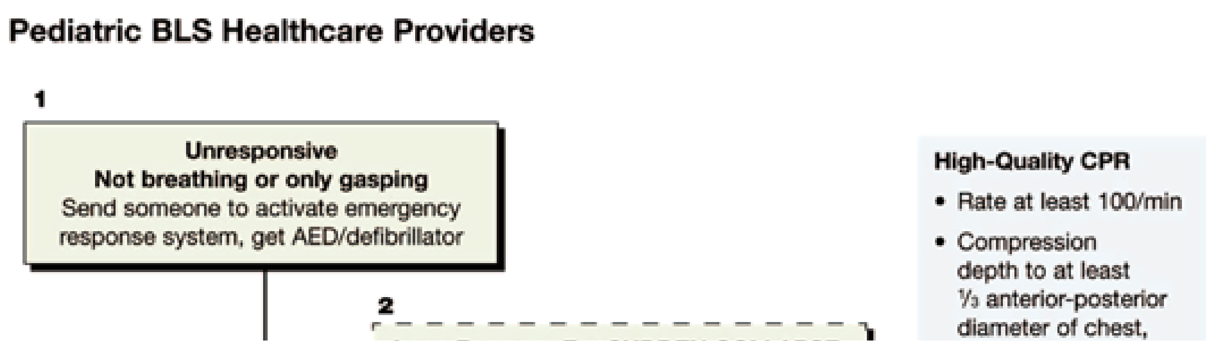
Guidelines for Pediatric Basic Life Support[8]

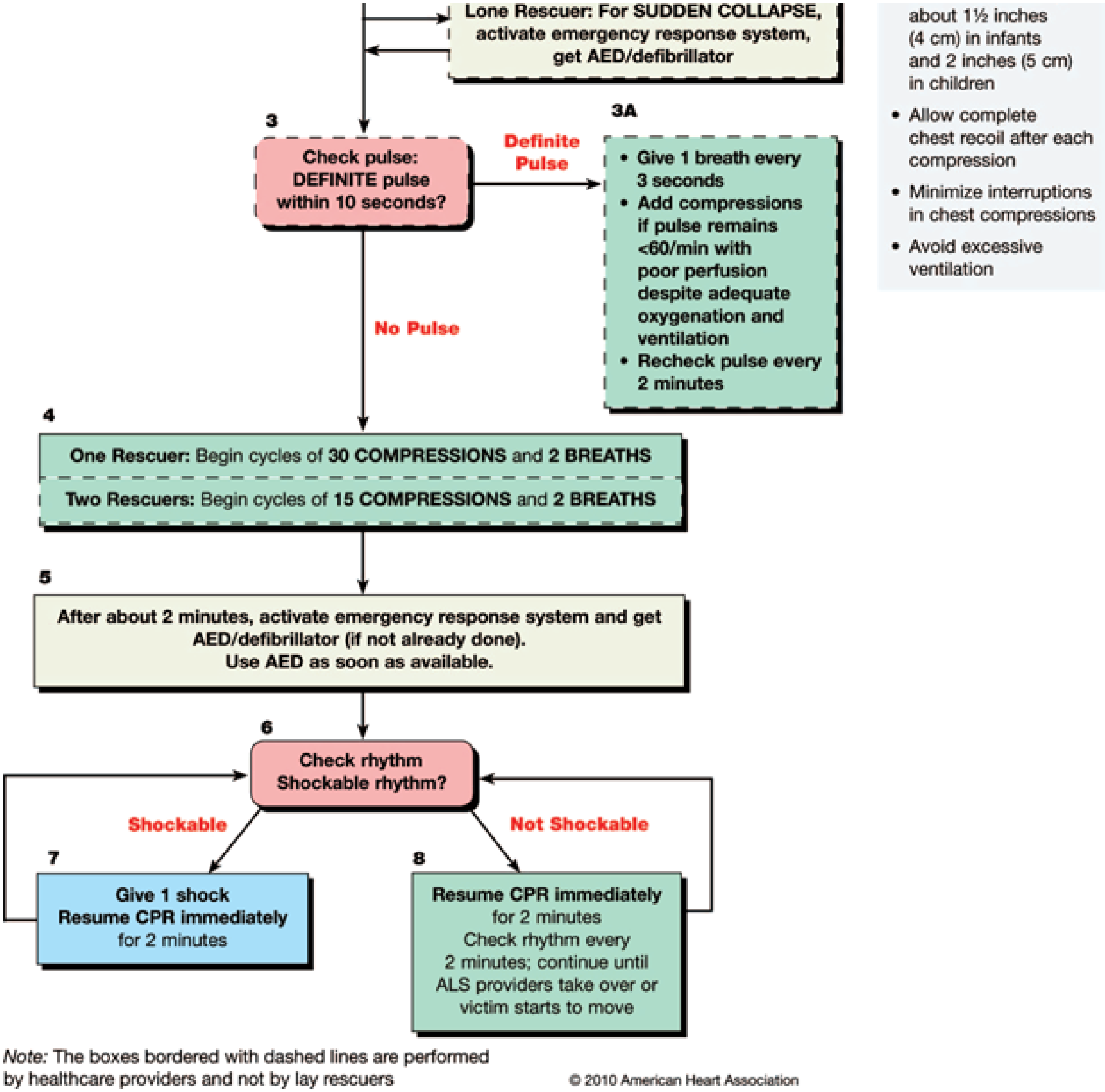
Maneuver	Newborn	Infant <1 Y	Child 1 Y to Puberty	Onset of Puberty to Adult
Airway	Head tilt/chin lift	Head tilt/chin lift	Head tilt/chin lift	Head tilt/chin lift
If trauma	Jaw thrust	Jaw thrust	Jaw thrust	Jaw thrust
If foreign body–conscious	Suction	Back blows and chest thrusts	Abdominal thrusts	Abdominal thrusts
If foreign body–unconscious	Suction	Chest compressions	Abdominal thrusts	Abdominal thrusts
Breathing rate	30–60/min (every 1–2 s)	12–20/min (every 3 s)	12–20/min (every 3 s)	10–12/min (every 5 s)
Circulation Pulse check	Umbilical	Brachial	Carotid or femoral	Carotid or femoral

Maneuver	Newborn	Infant <1 Y	Child 1 Y to Puberty	Onset of Puberty to Adult
Compression Location Method Depth Rate	One finger below intermammary line Two fingers or two thumbs One third of chest 120/min	One finger below intermammary line or lower half of sternum Two fingers or two thumbs One third to one half of chest 100/min	Lower half of sternum Heel of one hand or two hands One third to one half of chest 100/min	Lower half of sternum Two hands One third of chest 100/min
Compression-to-ventilation ratio	3:1	15:2 (single rescuer–30:2)	15:2 (single rescuer–30:2)	30:2

FIGURE 109-2.

Pediatric basic life support (BLS) algorithm. For both single and multiple rescuers, the sequence of approach follows CAB (circulation, airway, breathing): chest compressions are initiated immediately upon recognition of the arrest. AED = automated external defibrillator. [Reprinted with permission 2010 American Heart Association Guidelines For CPR and ECC Part 13: Pediatric Basic Life Support *Circulation.2010;122[suppl 3]:S862-S875* © 2010, American Heart Association, Inc.]





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AIRWAY

ANATOMY

A child's airway is much smaller than an adult's, and airway size varies by age. Anatomic and functional differences are more pronounced in infants and young children. **The airway is higher and more anterior in a child's neck than in an adult's.** The tongue and epiglottis are relatively larger, and, thus, more likely to obstruct the airway. Infants <6 months are primarily nasal breathers, so keeping the nasal passages clear is vital if spontaneous ventilation is present. Infants >6 months are able to breathe through their mouths. During CPR, ventilation by the oral route is sufficient to maintain adequate ventilation.

POSITIONING

When a child is supine, the prominent occiput causes flexion of the neck on the chest and occludes the airway. Correct airway occlusion by mild extension of the neck to the sniffing position. Overextension or hyperextension of the neck, acceptable for adults, causes obstruction and may kink the trachea, because the cartilaginous support is poor.

Maintain the sniffing position by placing a towel or other object beneath the shoulders. Despite good head position, a child's hypotonic mandibular tissues may still allow the relatively large tongue to occlude the airway posteriorly. This condition can be relieved by a chin lift or jaw thrust that elevates the mandible anteriorly and separates the tongue from the posterior pharyngeal wall. Use the jaw thrust technique in a child with a possible cervical spine injury because it minimizes the movement of the neck and allows maintenance of a neutral position of the cervical spine. The jaw thrust may be superior to the standard chin lift and is also useful in maintaining an open airway during bag-valve mask ventilation.[12] If these maneuvers are unsuccessful, consider an oral airway device or endotracheal tube.

BASIC AIRWAY ADJUNCTS

Nasopharyngeal airways can be useful adjuncts for maintaining airway patency during resuscitation, particularly in the awake child; however, nasopharyngeal airway insertion can cause nasal trauma or bleeding due to small nasal passages and hypertrophic adenoid tissue in the posterior nasopharynx. Oral airways should be used only in unconscious children. Oral airways are most useful in children who need a continuous jaw thrust or chin lift to maintain airway patency. Oral airways are inserted with a tongue depressor to push the tongue down into the mandible so that the airway can be inserted under direct vision.

Advanced airway management in neonates and infants and the difficult pediatric airway are discussed in chapter 111.

CHOKING AND FOREIGN-BODY MANAGEMENT

The back blow and chest thrust are recommended maneuvers to clear an infant's airway. The American Heart Association specifically discourages two common maneuvers used with adult patients: (1) **do not use the "Heimlich maneuver" for patients <1 year old**, because of the potential for injury to abdominal organs; and (2) **do not use blind finger sweeps**, because of the possibility of pushing the foreign body farther into the airway.[8,11]

CONSCIOUS CHILDREN

A child who is choking but is able to maintain some ventilation or vocalization should be allowed to clear the airway by coughing. Once a child cannot cough, vocalize, or breathe, a sequence of steps must be instituted immediately. ***Choking infants are treated with an alternating sequence of five back blows and five chest thrusts.***[11] With the infant's torso positioned prone and head down along the rescuer's arm, or the older child draped prone and head down across the rescuer's knees, deliver five blows to the interscapular area. Then reposition the infant supinely along the rescuer's arm, or place the larger infant on the floor, as for external cardiac compression, and deliver five chest thrusts (cardiac compressions) (**Figures 109-3 and 109-4**). Continue this sequence until the airway obstruction is relieved or the child becomes unconscious. In older children, use the obstructed airway ("Heimlich") maneuver, with the rescuer kneeling or standing behind the child. Place the rescuer's clenched fist at the level of the umbilicus, and deliver firm upward thrusts until the obstruction is cleared or the child becomes unconscious.

FIGURE 109-3.

Back blows to clear airway of choking infant. [Image used with permission of Rita K. Cydulka, MD, MS, MetroHealth Medical Center.]

Source: J.E. Tintinalli, J.S. Stapczynski, O.J. Ma, D.M. Yealy, G.D. Meckler, D.M. Cline: Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th Edition
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FIGURE 109-4.

Chest thrusts to clear airway of choking infant. [Image used with permission of Rita K. Cydulka, MD, MS, MetroHealth Medical Center.]

Source: J.E. Tintinalli, J.S. Stapczynski, O.J. Ma, D.M. Yealy, G.D. Meckler, D.M. Cline: Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th Edition
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UNCONSCIOUS CHILDREN

If a child loses consciousness due to a presumed airway obstruction, begin chest compressions immediately. After 30 compressions, open the airway and look for a foreign body in the mouth. Attempt to deliver two rescue breaths. If successful, then check for a pulse. If the obstruction is still present, then continue with alternating cycles of compressions and attempted rescue breaths until the obstruction is relieved. Chest compressions will circulate blood if there is a loss of perfusion (unconsciousness) and may relieve the obstruction. After each cycle and before each attempt at ventilation (lone rescuer: 30 to 2; two rescuers: 15 to 2), inspect the airway to see if an object is present and remove visible objects. **Do not perform blind finger sweeps.**

The foregoing recommendations are directed primarily at first responders or healthcare providers who have neither access to nor the skills to use airway management equipment. For unconscious children in EDs, direct laryngoscopy, visualization, and removal of the foreign body with McGill forceps can be attempted. Until this equipment is ready, use basic life support techniques.

BREATHING

MOUTH TO MOUTH

The size of the child dictates whether to use mouth-to-mouth or mouth-to-mouth-and-nose ventilation. The rate of ventilation is shown in Table 109-1. Perform ventilations slowly to avoid the generation of high airway pressures, which can impede venous return, cause barotrauma, and result in gastric distention and regurgitation.[11]

BAG-VALVE MASK

The self-inflating bag-valve mask system is most commonly used for ventilation. **Ventilation bags used for infants and children should have a minimum volume of 450 mL, and 1000 mL for older children and adolescents.**[11] Pediatric lung compliance is very good, and children can tolerate relatively high pressures. **Pneumothoraces usually result from the administration of excessive tidal volume rather than from high pressures.** The tidal volume necessary to ventilate children is the same as that for adults: 10 to 15 mL/kg. Because it is impractical to calculate the tidal volume in emergency situations, start ventilation with the smallest volume that causes adequate chest rise. Carefully monitor the rate of ventilation to **avoid excessive hyperventilation**.

OXYGEN

It is reasonable to provide 100% oxygen during CPR; however, once circulation has been restored, studies suggest improved outcomes when normal arterial oxygen and carbon dioxide levels are maintained. Wean oxygen to maintain saturations of >93% and assure eucapnia.[11,13,14]

CIRCULATION

Monitor the brachial pulse in infants <1 year old; for older children, the femoral or carotid pulse is most easily accessible.[11] Begin cardiac compression in the absence of pulse or with poor perfusion (heart rate ≤60 beats/min). Perform compressions over the lower sternum, not the midsternum.[8] The depth of compressions should be about one third of the anteroposterior chest diameter.

Place patients on a hard surface to improve the effectiveness of compressions. Palpate pulses during compression to assess the adequacy of the compression depth and rate. With bag-valve mask ventilation, pause chest compressions only long enough to deliver effective ventilations; however, once an advanced airway is established, chest compressions do not need to be paused for ventilations. See chapter 111 for further discussion.

INFANTS

Use the two-thumb technique when two healthcare providers are present. Compress at a rate of at least 100 per minute. The compression-to-ventilation ratio is 15:2 for two healthcare providers performing CPR on an infant.[8] If the patient is intubated, then compressions and ventilations may be performed without synchronization, but the rate of compressions should be maintained at 100 per minute.

CHILDREN 1 YEAR OLD TO THE ONSET OF PUBERTY

Compress the lower half of the sternum with the heel of one hand. If unable to adequately depress the sternum with one hand, then use the two-hand technique. The rate of compression is at least 100 compressions per minute. If there are two healthcare providers, then perform compressions in a series of 15:2 compressions to ventilations. If there is only one healthcare provider, perform 30 compressions for every 2 ventilations. If the patient is intubated, then compressions and ventilations may be performed without synchronization, but keep the rate of compressions at 100 per minute.

CHILDREN AFTER PUBERTY (ADOLESCENTS)

Children who are of pubertal age or older are treated as adults with respect to basic life support.[8] Use the two-hand technique of chest compressions. The compression-to-ventilation ratio and rate of compressions are the same as with children, 15:2 for two-person CPR and 30:2 for one-person CPR with a rate of 100 compressions per minute.

VASCULAR ACCESS

Difficulty in obtaining rapid IV access is certainly one of the major differences between adult and pediatric resuscitation. Keep several important facts in mind. First, a significant portion of children respond to airway management alone because most cardiac arrests in children are secondary to hypoxia from respiratory arrest. Do not waste time securing vascular access in children at the expense of airway management. Intraosseous infusion and fluid administration are quick, safe routes for resuscitation drugs (see chapter 112, "Intravenous and Intraosseous Access in Infants and Children"). If vascular access is needed rapidly, establish an intraosseous site until venous access is obtained. Once the child is intubated, use the tracheal route to administer drugs, such as *l*idocaine, *e*pinephrine, *a*tropine, and *n*aloxone (mnemonic: LEAN). **Although the ideal endotracheal doses for drugs other than epinephrine have never been studied in children, current recommendations support the use of two to three times the respective IV dose.**[8,10]

The most frequently used peripheral sites are the scalp, arm, hand, antecubital veins, and external jugular vein. If central venous access is needed, then the femoral vein is the most familiar and least complicated site. The general order of peripheral venous attempts during resuscitation should be antecubital, then hand or foot.

FLUIDS

If hypotension is due to volume depletion, give isotonic fluid boluses of 20 mL/kg as rapidly as possible and repeat as needed.[10] Use a syringe attached to a three-way stopcock and extension tubing to rapidly deliver aliquots of fluid, until the entire bolus is administered. This method is far superior to the use of gravity or pressure bags.

Deliver the bolus in <20 minutes and more rapidly, if possible. Reassess the child's condition after each bolus. If blood pressure normalizes, maintain fluid administration at the minimum rate to keep the vein open or at a rate to compensate for ongoing fluid losses. Adjust fluids and electrolytes based on calculations or laboratory results after emergency stabilization. If volume depletion is corrected with three to four fluid boluses but hypotension persists, consider a pressor agent.

Always use a pediatric microdrip assembly when resuscitating children to prevent accidental overhydration and for easy monitoring of the total volume given. It is easy to overhydrate infants and children, even when IV lines are set to keep the vein open, if adult equipment is used for children.

WEIGHT ESTIMATION AND MEDICATION CALCULATIONS

Proper dosage of medications in children requires knowledge of the patient's weight, knowledge of the dose (usually given in milligrams per kg), and error-free calculation and delivery. Use a chart with precalculated drug doses to reduce dosage errors (**Tables 109-2 and 109-3**).

TABLE 109-2

Drugs for Pediatric Resuscitation[15,16]

Drug	Pediatric Dosage	Remarks
Adenosine	IV/IO: 0.1 milligram/kg, followed by 2–5 mL NS bolus Double dose and repeat once, if needed	Maximum single dose: 6 milligrams first dose, 12 milligrams second dose.
Amiodarone	IV/IO: 5 milligrams/kg over 20–60 min; then 5–15 micrograms/kg/min infusion	Maximum bolus repetition to 15 milligrams/kg/d. Use lowest effective dose. Bolus may be given more rapidly in shock states.
Atropine	IV/IO: 0.02 milligram/kg, repeat in 5 min (minimum single dose is 0.1 milligram) Endotracheal: 0.04–0.06 milligram/kg diluted with NS to 3–5 mL	Maximum single dose: 0.5 milligram (child) and 1.0 milligram (adolescent). Maximum cumulative dose: 1.0 milligram (child) and 2.0 milligrams (adolescent).
Calcium chloride (10%)	IV/IO: 20 milligrams/kg (maximum dose 2 grams)	*Not routinely recommended.* Use in documented hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia. Administer slowly.

Drug	Pediatric Dosage	Remarks
Epinephrine	Bradycardia: IV/IO: 0.01 milligram/kg (0.1 mL/kg of 1:10,000) Endotracheal: 0.1 milligram/kg (0.1 mL/kg of 1:1000) Pulseless arrest: IV/IO: 0.01 milligram/kg (0.1 mL/kg of 1:10,000) Endotracheal: 0.1 milligram/kg (0.1 mL/kg of 1:1000)	Maximum dose: 1 milligram IV/IO; 2.5 milligrams ETT. Unlike other agents, epinephrine per endotracheal tube is 10× the IV dose. Follow endotracheal dose with several positive pressure ventilations. Maximum dose: 1 milligram IV/IO; 2.5 milligrams ETT. No evidence for high-dose parenteral epinephrine (may worsen outcomes).
Glucose	IV/IO: Newborn: 5 mL/kg $D_{10}W$ Infants and children: 2 mL/kg $D_{25}W$ Adolescents: 1 mL/kg $D_{50}W$	
Lidocaine	IV/IO: 1.0 milligram/kg bolus Endotracheal: double IV dose and dilute with NS to 3–5 mL	
Naloxone	IV/IO: If <5 y or ≤20 kg: 0.1 milligram/kg If >5 y and >20 kg: 2.0 milligrams	Titrate to desired effect.

Drug	Pediatric Dosage	Remarks
Sodium bicarbonate	IV/IO: 1 mEq/kg (1 mEq/mL)	*Not routinely recommended.* Infuse slowly and use only if ventilation is adequate for tricyclic antidepressant overdose and hyperkalemia.

Abbreviation: $D_{10}W$ = 10% dextrose in water; $D_{25}W$ = 25% dextrose in water; $D_{50}W$ = 50% dextrose in water; ETT = endotracheal tube; NS = normal saline.

TABLE 109-3

Calculation for Dosage of Medications Delivered by Constant Infusion Using the Rule of 6

Drug	Continuous Infusion Dose	Conversion Factor	Delivery
Epinephrine	0.1–1.0 microgram/kg/min	0.6 milligram × wt (kg)	1 mL/h = 0.1 microgram/kg/min
Dobutamine	2–20 micrograms/kg/min	6 milligrams × wt (kg)	1 mL/h = 1.0 microgram/kg/min
Dopamine	2–20 micrograms/kg/min	6 milligrams × wt (kg)	1 mL/h = 1.0 microgram/kg/min
Norepinephrine	0.1–2.0 micrograms/kg/min	0.6 milligram × wt (kg)	1 mL/h = 0.1 microgram/kg/min
Lidocaine	20–50 micrograms/kg/min	60 milligrams × wt (kg)	1 mL/h = 10 micrograms/kg/min

Drug	Continuous Infusion Dose	Conversion Factor	Delivery
Nitroprusside	0.5–8 micrograms/kg/min	6 milligrams × wt (kg)	1 mL/h = 1 microgram/kg/min
Isoproterenol	0.1–1.0 microgram/kg/min	0.6 milligram × wt (kg)	1 mL/h = 0.1 microgram/kg/min
Dosage of medications delivered by constant infusions is calculated in terms of micrograms per kg per minute. Actual calculation can be confusing and a source of lethal decimal errors. The rule of 6 can be used for dopamine and dobutamine to simplify dosage calculation:			
The medication is mixed in an IV set with a measured chamber and a microdrip (1 drop/min = 1 mL/h). Rate of administration is best set by an electric pump.	6 milligrams × wt (kg), fill to 100 mL with D_5W		
Example: For a 10-kg infant requiring dopamine	6 milligrams × 10 = 60 milligrams dopamine		

Drug	Continuous Infusion Dose	Conversion Factor	Delivery
In a measured chamber, fill to 100 mL with D_5W. Weight is now factored in so that:	1 mL/h = 1 microgram/kg/min 5 mL/h = 5 micrograms/kg/min 10 mL/h = 10 micrograms/kg/min		
For epinephrine and isoproterenol, the rule of 6 is:	0.6 milligram × wt (kg), fill to 100 mL with D_5W 1 mL/h = 0.1 microgram/kg/min 5 mL/h = 0.5 microgram/kg/min		

Abbreviations: D_5W = 5% dextrose in water; wt = weight.

Reformulating drug preparations so that all children receive 0.1 mL/kg regardless of the medication results in a 50% reduction in time to administration and a significant reduction in dosing errors even compared with the use of a length-based drug calculation device.[17]

To calculate the proper drug dosage from the table, accurately determine the child's weight. Because it is not possible to weigh a child during resuscitation, several alternative methods are available for estimating a child's weight, but each of these has inherent challenges and problems (**Table 109-4**).

TABLE 109-4

Estimating Weight in Infants and Children

Formulas by name	Argall	(Years + 2) × 3
	Luscombe	(Years × 3) + 7
	Advanced Pediatric Life Support	Infants: (age in months × 0.5) + 4 Children 1–5 y: (2 × age in years) + 8 Children 6–12 y: (3 × age in years) + 7
	Nelson	<12 mo: (months + 9)/2 1–6 y: (years × 2) + 8 7–12 y: (years × 7) – 5
	Best Guess	<12 mo: (months + 9)/2 1–4 y: (years + 5) × 2 5–14 y: (years × 4)
Formulas by age	Infants	(months + 9)/2
	1 to 5 or 6 y	(years × 2) + (7, 8, or 10)
		Or
		(years × 3) + 7

	6 or 7 to 12 or 14 y	(years × 2) + 8
		Or
		(years × 3) + 7
		Or
		Years × 4
		Or
		(years × 5) – 5

LENGTH-BASED ESTIMATION

Systems based on a direct measurement of a patient's length have been developed for estimating weight, dosages, and selecting equipment in pediatric emergencies (**Table 109-5**).[18] The use of a length-based system is currently included in the American Heart Association Pediatric Advanced Life Support Course.[10] These systems use a tape measuring device (**Broselow® tape**; Armstrong Medical Industries, Inc., Lincolnshire, IL) to assist in making appropriate selections. Most tapes are two-sided and display emergency resuscitation drug dosage and equipment selection based on length (Figure 109-1). Fluid volumes for resuscitation and appropriate basic life support techniques are often also displayed.

TABLE 109-5

Length-Based Equipment Chart (Length = Centimeters)*

Item	54–70	70–85	85–95	95–107	107–124	124–138	138–155
Endotracheal tube size (mm)	3.5	4.0	4.5	5.0	5.5	6.0	6.5
Lip–tip length (mm)	10.5	12.0	13.5	15.0	16.5	18.0	19.5
Laryngoscope	1 straight	1 straight	2 straight	2 straight or curved	2 straight or curved	2–3 straight or curved	3 straight or curved
Suction catheter	8F	8F–10F	10F	10F	10F	10F	12F
Stylet	6F	6F	6F	6F	14F	14F	14F
Oral airway	Infant/small child	Small child	Child	Child	Child/small adult	Child/adult	Medium adult
Bag-valve mask	Infant	Child	Child	Child	Child	Child/adult	Adult
Oxygen mask	Newborn	Pediatric	Pediatric	Pediatric	Pediatric	Adult	Adult
Vascular access (gauge)							
Catheter	22–24	20–22	18–22	18–22	18–20	18–20	16–20

Item	54–70	70–85	85–95	95–107	107–124	124–138	138–155
Butterfly	23–25	23–25	21–23	21–23	21–23	21–22	18–21
Nasogastric tube	5F–8F	8F–10F	10F	10F–12F	12F–14F	14F–18F	18F
Urinary catheter	5F–8F	8F–10F	10F	10F–12F	10F–12F	12F	12F
Chest tube	10F–12F	16F–20F	20F–24F	20F–24F	24F–32F	28F–32F	32F–40F
Blood pressure cuff	Newborn/infant	Infant/child	Child	Child	Child	Child/adult	Adult

*Directions for use: (1) measure patient length with centimeter tape; (2) using measured length in centimeters, access appropriate equipment column.

Source: Reproduced with permission from Luten RC, Wears RL, Broselow J, et al: Length-based endotracheal tube sizing and emergency equipment for pediatric resuscitation. *Ann Emerg Med* 21: 900, 1992, ©1992, Elsevier, Philadelphia, PA. Copyright Elsevier.

The length-based systems many not be accurate in all populations of children.[19,20,21] Forty-three percent of children 10 to 12 years of age are longer than the tape used for the weight estimation.[22] The Broselow® tape underestimates some weights, resulting in underdosing medications.[20,23] Although there are limitations in using the length-based systems for weight estimation, their use in EDs provides a very rapid tool during a critical resuscitation. Length-based systems also help provide accurate selection of appropriately sized equipment.[24]

AGE-BASED ESTIMATION

There are several formulas based on a child's age to assist in estimating a child's weight. The commonly used estimates of weights based on age noted in **Table 109-6** have never been formally validated. The original Advanced Pediatric Life Support formula, (years + 4) × 2, under-estimates weights of 1-year-old children by 9.7% and underestimates weights of 12-year-olds by 34.2%[25] and has, therefore, been updated to be more accurate, but at the cost of increased complexity (Table 109-4). Luscombe and colleagues suggest that the formula (years × 3) + 7 bears a more consistent relationship to a child's true weight. A large study comparing various formulas to estimate weights in Australian children found the Best Guess and updated Advanced Pediatric Life Support formulas were most accurate overall.[23] No formulas are perfect. The Argall formula was within 10% of actual weight in only 37% of Australian children studied.[26] It also correlates poorly with the weight estimates of the Broselow® tape in whites.[27] Both the Nelson formula and the Best Guess formula would be challenging to apply rapidly from memory in the ED but are accurate when used for white children.[28]

TABLE 109-6

Body Weight Estimation by Age

Age	Weight (kg)	Estimation
Term infant	3.5	Birthweight
6 mo	7	2 × birthweight
1 y	10	3 × birthweight
4 y	16	One-fourth adult weight of 70 kg
10 y	35	One-half adult weight

HEALTHCARE PROVIDER ESTIMATION

Estimations by healthcare providers without using a specific tool are quite variable.[29] Healthcare providers should not rely on a visual estimation of the child's weight, but must use some tool in estimating a child's weight for all resuscitation medications.

PARENTAL ESTIMATION

Parental estimations of a child's weight are often the most accurate estimation compared with formulas and length-based devices.[27] One author has suggested that parental estimations should be used, if available; if not, then use length-based weight estimations.[29]

PHARMACOLOGIC AGENTS

The pharmacology of resuscitation drugs has been well described in other chapters (see chapter 19, "Pharmacology of Antiarrhythmics and Antihypertensives," and chapter 20, "Pharmacology of Vasopressors and Inotropes"), but a few peculiarities pertain to pediatric resuscitation drug use.

EPINEPHRINE

Epinephrine is the one drug universally used in cardiac arrest; however, its beneficial effect on survival remains questionable. It is specifically indicated for hypoxia- or ischemia-induced slow rates that fail to respond to adequate oxygenation and ventilation and for pulseless arrest situations (i.e., asystole, pulseless electrical activity, and ventricular fibrillation). If the initial dose of epinephrine is not effective, give subsequent doses at the same dose. High-dose epinephrine (0.1 milligram/kg of the 1:1000 concentration) for resuscitation in infants and children does not increase survival. The American Heart Association currently recommends that subsequent doses of epinephrine be at the standard dose.[8] High-dose epinephrine may be useful in catecholamine-resistant states, such as anaphylaxis, α- or β-blocker overdose, or severe sepsis. Adverse effects associated with the use of high-dose epinephrine include intracranial hypertension, myocardial hemorrhage, myocardial necrosis, and a postresuscitation hyperadrenergic state.[30]

Epinephrine, rather than dopamine, is the vasopressor infusion of choice in children (Table 109-3**)**, because dopamine requires release of endogenous norepinephrine. In children with cardiac arrest, norepinephrine stores may be low. There is no evidence to recommend use of vasopressin over epinephrine in children.

AMIODARONE

Amiodarone can treat atrial and ventricular arrhythmias and is currently included in the algorithm for ventricular fibrillation and pulseless ventricular tachycardia, although a single study of children found higher rates of return of spontaneous circulation among those treated with lidocaine compared to amiodarone.[31] Amiodarone is a potent vasodilator and a potential proarrhythmic agent. Dosage for pediatric patients is 5 milligrams/kg over 20 to 60 minutes and may be repeated to a maximum of 15 milligrams/kg/d. Administer amiodarone rapidly for ventricular tachycardia or ventricular fibrillation resistant to electrical cardioversion. If the patient has a perfusing rhythm, then consultation with a pediatric cardiologist or critical care specialist is strongly recommended prior to amiodarone administration.[8]

Avoid amiodarone if there is the potential for a long QT syndrome either due to a primary cardiac dysrhythmia or medication administration or overdose, because amiodarone prolongs the QT interval and its administration may cause irreversible dysrhythmias in these circumstances.

ATROPINE

Atropine is the first-line drug for treatment of symptomatic bradycardias **in the absence of reversible causes** (Class IIa). In children, hypoxia and shock are the primary causes of symptomatic bradycardia. Although primary cardiac causes of slow rates are rare in children, atropine is recommended if slow rates persist after adequate oxygenation and ventilation. The recommended dose of atropine is 0.02 milligram/kg IV. The minimum dose is 0.1 milligram, with maximum single doses of 0.5 milligram for children and 1.0 milligram for adolescents. The dose may be repeated once, with maximum total doses of 1.0 milligram for children and 2.0 milligrams for adolescents. There is no particular proscription against additional doses, but the maximum recommended dose is considered fully vagolytic. If no response to atropine is seen, then dosing beyond the vagolytic amount is unlikely to be effective. If an effect is seen but not maintained, give additional doses. **Large doses of atropine are needed to treat exposure to organophosphates or nerve agents.**

SODIUM BICARBONATE

Bicarbonate therapy has a primary role in treating overdoses of sodium channel blocking agents, such as procainamide, flecainide, and tricyclic antidepressants (Class IIa). It has an uncertain utility in calcium channel blocker overdoses (Class Indeterminate). Because other resuscitation drugs are less effective in the face of severe acidosis, sodium bicarbonate may be useful during prolonged resuscitations. Adverse effects of bicarbonate include reducing systemic vascular resistance (thereby lowering coronary perfusion pressure), inhibition of oxygen release (by shifting the oxyhemoglobin dissociation curve), inducing hypernatremia and hyperosmolality, inactivation of simultaneously administered catecholamines, and paradoxical worsening of intracellular acidosis (by the production of carbon dioxide, which diffuses rapidly through cell walls). **An initial dose of 1 mEq/kg IV is given only after adequate ventilation has been established.** Without adequate ventilation, the child cannot compensate for the release of carbon dioxide by buffering the hydrogen ions, and the adverse effects of bicarbonate therapy surpass any beneficial effects. **In neonates or premature infants, dilute sodium bicarbonate 1:1 with sterile water, not saline, to reduce the hyperosmolarity of the solution.**

CALCIUM

Routine calcium administration is not recommended during resuscitation because of lack of proven efficacy and because of possible harmful effects. Calcium should be used for documented and symptomatic hyperkalemia, hypocalcemia, and calcium channel blocker overdose. Whenever possible, follow ionized calcium levels to direct calcium administration (total calcium levels do not correlate with the need for calcium therapy in critically ill patients).[32] Calcium may be given as calcium chloride, 20 milligrams/kg (0.2 mL/kg of a 10% solution), or calcium gluconate, 60 to 100 milligrams/kg (0.6 to 1.0 mL/kg of a 10% solution) via the IV or intraosseous route.

DYSRHYTHMIAS

Dysrhythmia management plays only a small role in the resuscitation of children. **Because rhythm disturbances are usually secondary to hypoxia and not primary cardiac events, first provide ventilation and oxygenation, and correct hypoxia, acidosis, and fluid balance.**

A child with an abnormal cardiac rhythm or rate, coupled with evidence of poor end-organ perfusion (cyanosis, mottled skin, lethargy, etc.) is unstable and requires immediate intervention. The parameters of clinical assessment and expression of instability vary with a child's age. In infants and children, variations in heart rate may be well tolerated clinically, and a blood pressure of 70 plus (age in years) divided by 2 mm Hg or less, coupled with evidence of poor end-organ perfusion, may be used to define instability. **Figures 109-5, 107-6, and 109-7** summarize the approach to unstable cardiac rhythms in children, and **Table**

109-7 lists the weight-based electrical dose when cardioversion or defibrillation is indicated.[8] American Heart Association guidelines for pediatric ALS are available at: http://circ.ahajournals.org/content/122/18_suppl_3.toc.

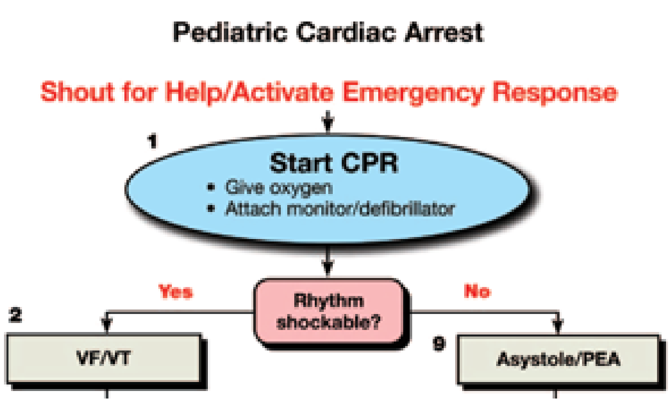
TABLE 109-7

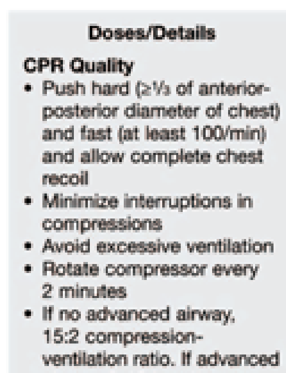
Energy Requirements for Defibrillation and Cardioversion

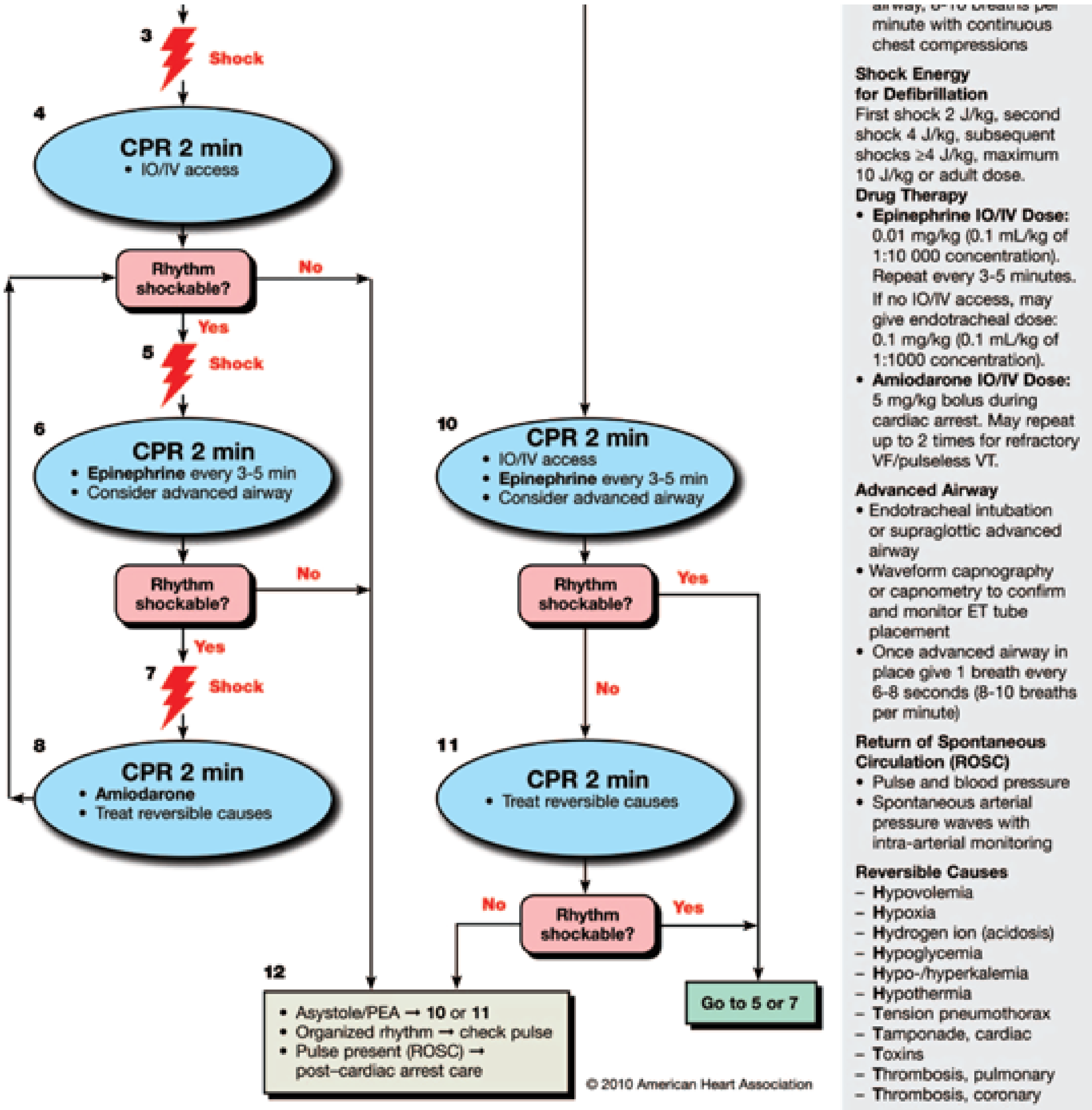
Rhythm	Type of Shock	Initial Dose	Subsequent Doses
Ventricular fibrillation or pulseless ventricular tachycardia	Defibrillation (unsynchronized)	2 J/kg	4 J/kg to maximum of 10 J/kg or adult dose
Unstable supraventricular tachycardia or ventricular tachycardia with pulse but poor perfusion	Synchronized cardioversion	0.5–1 J/kg	2 J/kg

FIGURE 109-5.

Pediatric pulseless arrest decision tree. PEA = pulseless electrical activity; VF = ventricular fibrillation; VT = ventricular tachycardia. [Reprinted with permission 2010 American Heart Association Guidelines For CPR and ECC Part 14: Pediatric Advanced Life Support *Circulation. 2010;122[suppl 3]:S876-S908* © 2010, American Heart Association, Inc.]







Source: J.E. Tintinalli, J.S. Stapczynski, O.J. Ma, D.M. Yealy, G.D. Meckler, D.M. Cline: Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th Edition
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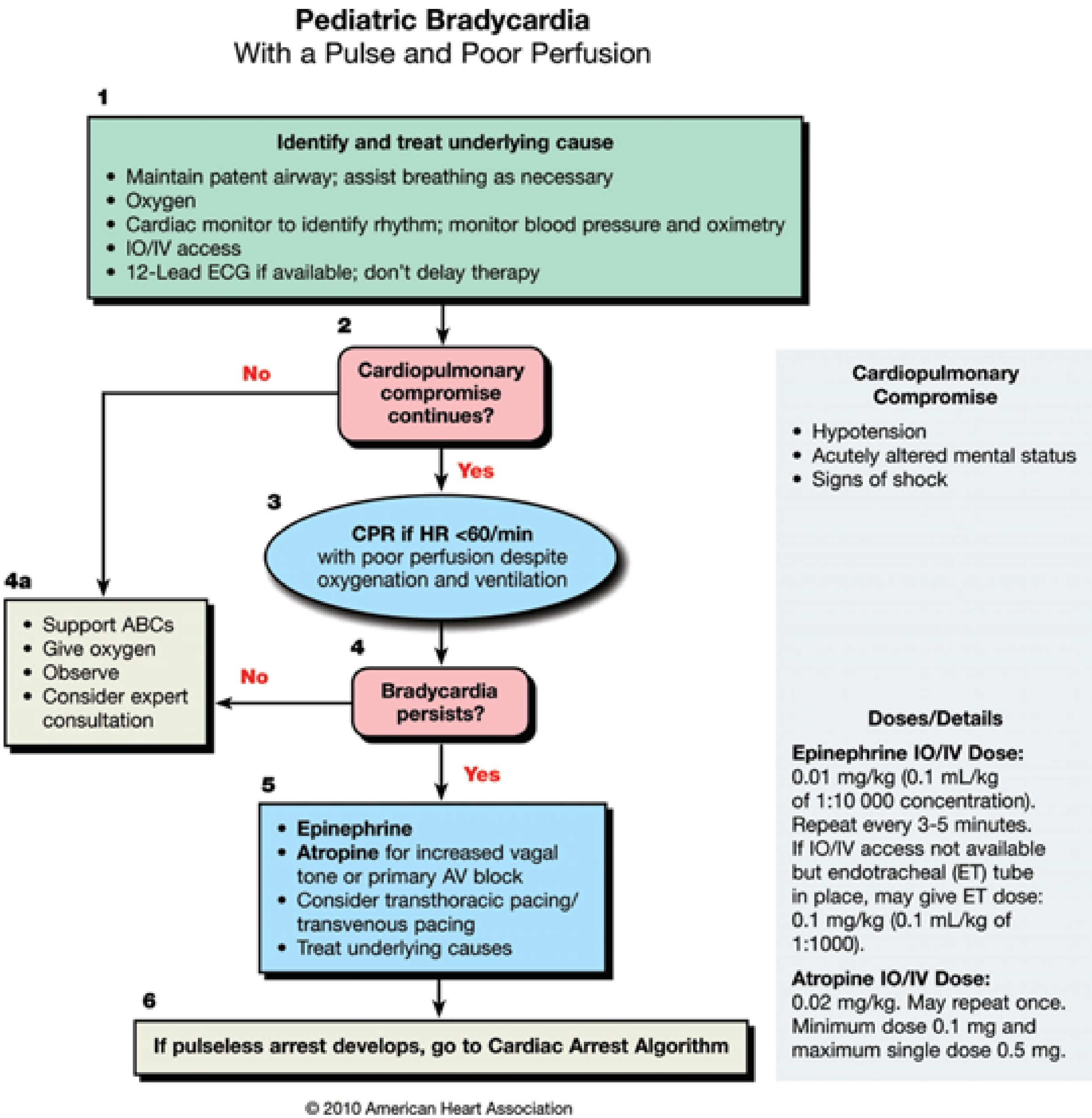
FIGURE 109-6.

Pediatric bradycardia decision tree. ABC = airway, breathing, circulation; AV = atrioventricular; HR = heart rate; ICP = intracranial pressure. [Reprinted with permission 2010 American Heart Association Guidelines For CPR and ECC Part 14: Pediatric Advanced Life Support *Circulation. 2010;122[suppl 3]:S876-S908* ©2010, American Heart Association, Inc.]



Source: J.E. Tintinalli, J.S. Stapczynski, O.J. Ma, D.M. Yealy, G.D. Meckler, D.M. Cline: Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th Edition
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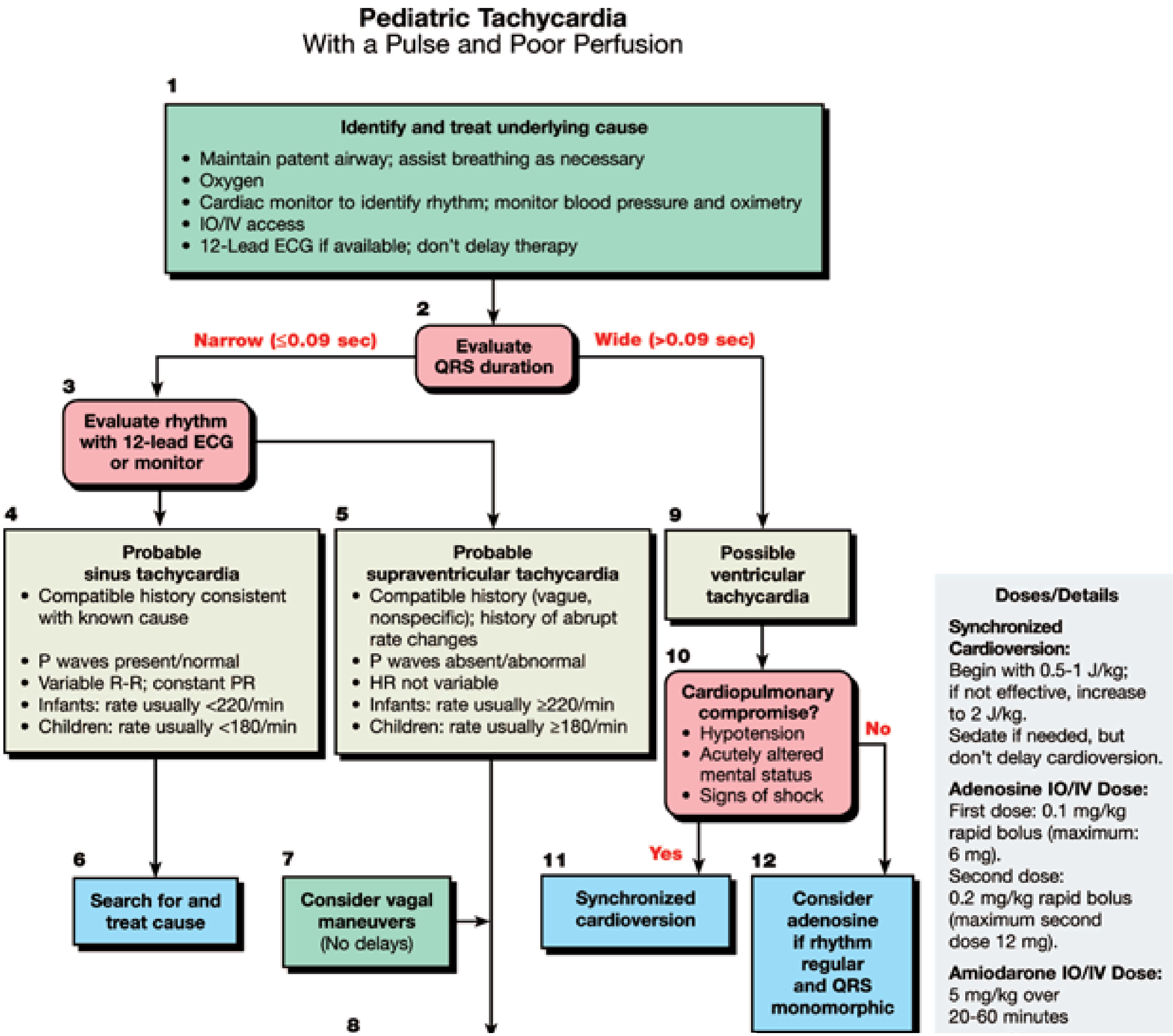
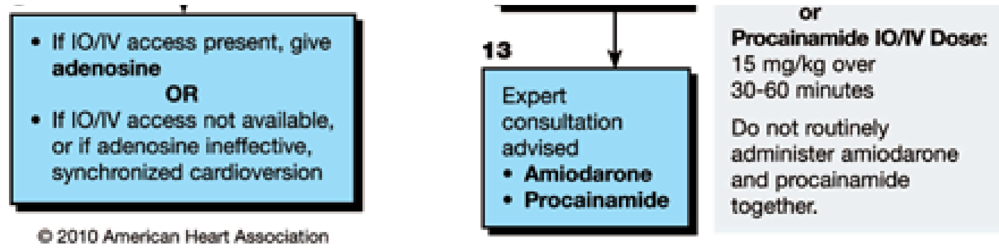
FIGURE 109-7.

Pediatric tachycardia decision tree for infants and children with rapid rhythm and poor perfusion. ABC = airway, breathing, circulation; bpm = beats per minute; HR = heart rate. [Reprinted with permission 2010 American Heart Association Guidelines For CPR and ECC Part 14: Pediatric Advanced Life Support *Circulation.2010;122[suppl 3]:S876-S908* ©2010, American Heart Association, Inc.]





The most common rhythms seen in pediatric arrest are the bradycardias, which lead to asystole if untreated. **Again, treatment consists of maximizing oxygenation and ventilation.** Begin chest compression in children with a heart rate <60 beats/min and signs of poor perfusion.

Paroxysmal atrial tachycardia (supraventricular tachycardia) is seen most commonly in infants and most often presents as a narrow complex tachycardia with rates usually between 250 and 350 beats/min. Treatment of unstable patients consists of rapid synchronized cardioversion. Treatment of stable patients varies. Adenosine, vagal maneuvers, and cardioversion are used to treat stable supraventricular tachycardia. **Adenosine (0.1 milligram/kg) is the current recommended drug for supraventricular tachycardia in children; administer via rapid IV push using a three-way-stopcock setup and normal saline flush in a proximal vein or intraosseous line.** This dose can be doubled if the first dose is unsuccessful.

Differentiating a rapid secondary sinus tachycardia from a rapid primary cardiac tachycardia can be difficult but is critical to patient management. Although heart rates of 150 to 200 beats/min in adults are usually cardiac in origin, small infants and young children not uncommonly have compensatory sinus tachycardias as fast as 200 to 220 beats/min. **A rate of >220 beats/min in an infant or >180 beats/min in a child is likely supraventricular tachycardia.** ECG may not be very helpful, because identifiable P waves may not be readily apparent at very fast rates. History compatible with volume loss suggests sinus tachycardia. Congestive heart failure is more likely associated with a pathologic rhythm than a compensatory sinus tachycardia. Children can tolerate primary cardiac tachydysrhythmias for long periods before congestive heart failure or lethal dysrhythmias develop.

CARDIOVERSION, DEFIBRILLATION, AND PACING

Electric conversion is used on an emergency basis to treat ventricular fibrillation (defibrillation) and symptomatic tachydysrhythmia (cardioversion). Ventricular fibrillation is an unusual presenting rhythm in infants and children, but more common with advancing age, and may be present at some point in up to 27% of children with in-hospital cardiac arrest.[7,8,33] Energy requirements for defibrillation and cardioversion are listed in Table 109-7.

Paddle Size

Paddle size is 4.5 cm for infants (who weigh <10 kg) and 8 cm for children. The paddle should be in contact with the chest wall over its entire surface area. The larger, 8-cm paddles can be used for infants in the anteroposterior position.

Paddle Interface

Electrode cream, electrode paste, and saline-soaked gauze pads are acceptable. Alcohol pads should not be used because serious burns may occur. Make sure that the interface substance from one paddle does not come in contact with the substance from the other paddle. Contact creates a short circuit, and insufficient energy may be delivered to the heart. Many defibrillation devices use cables with integrated adhesive pads for delivery of energy. Adhesive pads are used with the same general guidelines as metal paddles, including the recommendations on sizing and positioning.

Electrode Position

Place one paddle to the right of the sternum at the second intercostal space. Place the other paddle at the left midclavicular line at the level of the xiphoid. The anteroposterior approach also can be used, although improved success with anteroposterior positioning has not been documented.[8]

Defibrillation

Defibrillate as quickly as possible for pulseless ventricular tachycardia or ventricular fibrillation. The first shock success rate during cardiac arrest due to ventricular arrhythmia is 18% to 50%.[8] Initially, use 2 J/kg. Immediately after defibrillation, and before additional attempts at defibrillation, provide 2 minutes of high-quality uninterrupted CPR to restore coronary perfusion and improve delivery of oxygen to the myocardium. If the first defibrillation attempt is unsuccessful, double the defibrillation energy to 4 J/kg, and use this higher energy level for all additional defibrillation attempts; refractory ventricular fibrillation may require higher energy to a maximum of 10 J/kg or the maximum adult dose.[8]

Provide 2 minutes of chest compressions with ventilations after each defibrillation attempt, regardless of the postdefibrillation rhythm. Nearly all patients will be in a low-perfusion state after defibrillation, and external chest compressions (with ventilations) will improve the perfusion of the vital organs.

If medications such as epinephrine are administered, they are probably most effective when given 1 to 2 minutes before repeating a defibrillation attempt.

Cardioversion

Tachydysrhythmias are generally very sensitive to electric conversion. **The initial dose is 0.5 J/kg, in the synchronized mode** (Table 109-7). Double the energy level if the first attempt is unsuccessful. If the device has only a few energy settings available, choose the one closest to the desired energy setting. If the device does not provide the synchronized mode, then obviously the unsynchronized mode must be used.

Transcutaneous Pacing

Severe bradycardia or asystole due to an intrinsic myocardial block may respond to transcutaneous pacing. Oxygenation, chest compressions, and medications should precede attempts at pacing in children with severe symptomatic bradycardia due to heart block or sinus node dysfunction. Pacing is not indicated if the bradycardia is due to hypoxic or ischemic myocardial injury or if due to respiratory failure.

Use adult pacing patches in children who weigh >15 kg.[34] Anterior-posterior positioning does not appear to have an advantage over the standard anterior positioning. If using the anterior-posterior positioning, place the negative electrode patch on the anterior chest at V_3, and place the positive electrode patch on the posterior chest between the shoulder blades at the T4 vertebral level. Ventricular capture is determined by the palpation of a pulse or the appearance of an arterial waveform, if an arterial pressure catheter is present. Maximal energy output is used until ventricular capture occurs, then the energy setting is decreased progressively until the lowest setting is found that allows ventricular capture. Set the pacing rate slightly higher than the normal rate for age.

Transcutaneous pacing has not been associated with greatly improved survival rates, but may be advantageous in a child with sudden asystole or bradycardia due to intrinsic atrioventricular node or sinus node dysfunction and with congenital or acquired heart disease.

Automated External Defibrillators

Because children ≥8 years old may have life-threatening arrhythmias similar to those in adults and because their body weights approach those of adults, an automated external defibrillator (AED) can be used. A child ≥8 years and weighing >25 kg with sudden collapse should have an AED applied as soon as possible. An AED with a pediatric dose attenuator is ideal for a child 1 to 8 years of age because this feature allows the delivery of a lower dose of energy in pediatric patients. More AEDs are available that allow changing the cardioversion energy levels. If an AED with a pediatric dose attenuator is not available, then use a standard AED. AEDs may be used in infants, but a manual defibrillator is preferred.

Because ventricular fibrillation is an uncommon presentation in children, it is uncertain whether there is greater benefit from providing five cycles of CPR before application of the AED or withholding CPR until the AED has completed its analysis of the heart rhythm. Guidelines for adults recommend 2 minutes of chest compressions before allowing the AED to analyze the rhythm in unwitnessed arrests or when the time since collapse is >5 minutes.[10] For witnessed arrests and arrests in the hospital, the AED should be applied and allowed to analyze as soon as possible. Start chest compressions the instant cardiac arrest is confirmed, and continue compressions until the moment the AED is in place and ready to analyze the rhythm. Realistically, with more than one rescuer, a cycle or two of chest compressions can be provided before the AED is able to analyze the rhythm. If the

AED does not recommend defibrillation, then continue CPR. Keep the AED applied until other means of cardiac monitoring become available.

TERMINATION OF EFFORTS

Pediatric cardiopulmonary arrest lasting >20 minutes or with no response to two doses of epinephrine and good CPR is associated with a poor outcome.[1] If hypothermia is thought to be responsible for the arrest, and cardiac electrical activity is present, continue resuscitation until a core temperature of 30°C (86°F) is reached. The likelihood of survival and intact neurologic function diminish as the duration of the resuscitation attempt increases. Unfortunately, no single factor is predictive of outcome, so integrate all the circumstances of the arrest and the patient's premorbid condition before terminating resuscitative efforts. Neurologically intact survival can occur after very prolonged ED resuscitations with high-quality CPR,[8] so developing a strict time for termination of resuscitation efforts is not possible.

FAMILY PRESENCE DURING RESUSCITATION

Family presence during resuscitation efforts continues to increase in acceptance. ED staff may worry about the family's critique of the resuscitation or the family's unwillingness to terminate efforts. Some family members may become distressed or exceedingly emotional while care is being given to a loved one. Positive and negative family responses can occur during resuscitation.[35] Most family members wish to be present during resuscitation.[35] Having family members present during resuscitation is a holistic approach to patient care, with the family's and the patient's needs addressed simultaneously. The current 2010 American Heart Association Guidelines consider family presence during the resuscitation to be a Class I recommendation.[8] A social worker, chaplain, or nurse can assist the family during resuscitative efforts.

COPING WITH THE DEATH OF A CHILD

Both family members and members of the resuscitation team mourn the death of a child.[36] Several *tasks of mourning* have been described that must occur for successful resolution of grieving (**Table 109-8**).[37]

TABLE 109-8

Tasks of Family Mourning a Lost Child

Accept the reality of the loss.
Work through painful grieving.
Adjust to life without the child.
Emotional resolution and return to normal activities.

Physicians and other healthcare providers can shape the way families remember the death of a child. Guidelines for communicating with parents are listed in **Table 109-9**.[38] Parents remember how compassionately the bad news is given, but most families still want the "bottom line" when they are first told of their child's death. They are waiting for it. Saying, "I am very sorry, we did everything we could, but Sally died" is compassionate and direct. Most families do not want all the technical details about the resuscitation efforts. After delivering the bad news, have a chaplain or social worker stay with the family to allow the family time to deal initially with the shocking news. The physician should remain quietly in the room or return after a few minutes (or later, if other duties require) to answer questions. This is also the time to ask whether the family would like to see the child and to prepare them for what they will see. Although parents do not regret organ donation, donation is not associated with a higher likelihood of successful grieving.[38]

TABLE 109-9

Giving Bad News Effectively

Use support staff such as chaplains and social workers.
Early in your delivery of the news, let the family know the child has died.
Use simple, direct, understandable language.
Speak with compassion and caring.
Answer questions from any family members honestly.

REFERENCES

1. Donoghue AJ, Nadkarni V, Berg RA et al.: Out-of-hospital pediatric cardiac arrest: an epidemiologic review and assessment of current knowledge. *Ann Emerg Med* 46: 512, 2006.
[PubMed: 16308066]

2. de Mos N, van Litsenburg RR, McCrindle B et al.: Pediatric in-intensive-care-unit cardiac arrest: incidence, survival, and predictive factors. *Crit Care Med* 34: 1209, 2008.
[PubMed: 16484906]

3. Atkins DL, Everson-Stewart S, Sears G et al.: Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry–Cardiac Arrest. *Circulation* 119: 1484, 2009.
[PubMed: 19273724]

4. Michiels EA, Dumas F, Quan L et al.: Long-term outcomes following pediatric out-of-hospital cardiac arrest. *Pediatr Crit Care Med* 14: 755, 2013.
[PubMed: 23925145]

5. Nitta M, Iwami T, Kitamura T et al.: Age-specific differences in outcomes after out-of-hospital cardiac arrests. *Pediatrics* 128: e812, 2011.
[PubMed: 21890823]

6. Berg MD, Nadkarni VM, Zuercher M, Berg RA: In-hospital pediatric cardiac arrest. *Pediatr Clin North Am* 55: 589, 2008.
[PubMed: 18501756]

7. Morgayzel C, Quan L, Graves JR et al.: Out of hospital ventricular fibrillation in children and adolescents: causes and outcomes. *Ann Emerg Med* 25: 484, 1995.
[PubMed: 7710153]

8. Hazinski MF, Field JM, Sayre MR et al.: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care science. *Circulation* 122 (suppl 3): S640, 2010.
[PubMed: 20956217]

9. Lubrano R, Cecchetti C, Bellelli E et al.: Comparison of intervention during pediatric CPR maneuvers using ABC and CAB sequences: a randomized trial. *Resuscitation* 83: 1473, 2012.
[PubMed: 22579678]

10. American Heart Association: *Pediatric Advanced Life Support Provider Manual*. Dallas, TX: American Heart Association, 2006.

11. Berg MD, Schexnayder SM, Chameides L et al.: Pediatric basic life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 122: s862, 2010.

[PubMed: 20956229]

12. Bingham RM, Proctor LT: Airway management. *Pediatr Clin North Am* 55: 873, 2008.
[PubMed: 18675024]

13. Kilgannon JH, Jones AE, Parrillo JE et al.: Relationship between supranormal oxygen tension and outcome after resuscitation from cardiac arrest. *Circulation* 123: 2717, 2011.
[PubMed: 21606393]

14. Del Castillo J, Lopez-Herce J, Matamoros M et al.: Hyperoxia, hypocapnia and hypercapnia as outcome factors after cardiac arrest in children. *Resuscitation* 83: 1456, 2012.
[PubMed: 22841610]

15. Kleinman ME, Chameides L, Schexnayder SM et al.: Pediatric advanced life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Pediatrics* 126: e1361, 2010.
[PubMed: 20956434]

16. Kleinman ME, Chameides L, Schexnayder SM et al.: Part 14: pediatric advanced life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 122: S876, 2010.
[PubMed: 20956230]

17. Fineberg SL, Arendts G: Comparison of two methods of pediatric resuscitation and critical care management. *Ann Emerg Med* 52: 35, 2008.
[PubMed: 18407376]

18. Luten RC, Wears RL, Broselow J et al.: Length-based endotracheal tube sizing and emergency equipment for pediatric resuscitation. *Ann Emerg Med* 21: 900, 1992.
[PubMed: 1497153]

19. Ramarajan N, Krishnamoorthi R, Strehlow M et al.: Internationalizing the Broselow tape: how reliable is weight estimation in Indian children. *Acad Emerg Med* 15: 431, 2008.
[PubMed: 18439198]

20. Nieman CT, Manacci CF, Super DM et al.: Use of the Broselow tape may result in the underresuscitation of children. *Acad Emerg Med* 13: 1011, 2006.
[PubMed: 17015417]

21. Madhumita S, Lezine MW, Frechette A et al.: Weighing the pediatric patient during trauma resuscitation and its concordance with estimated weight using Broselow Luten Emergency Tape. *Pediatr Emerg Care* 28: 544, 2012.
[PubMed: 22653453]

22. Hashikawa A, Juhn Y, Homme J et al.: Does length-based resuscitation tape accurately place pediatric patients into appropriate color-coded zones? *Ped Emerg Care* 23: 856, 2007.
[PubMed: 18091592]

23. Graves L, Chayen G, Peat J, O'Leary F: A comparison of actual to estimated weights in Australian children attending a tertiary children's hospital, using the original and updated APLS, Luscombe and Owens, Best Guess formulae and the Broselow tape. *Resuscitation* 85: 392, 2014.
[PubMed: 24321321]

24. Hofer CK, Ganter M, Tucci M et al.: How reliable is length-based determination of body weight and tracheal tube size in the paediatric age group? The Broselow tape reconsidered. *Br J Anaesth* 88: 283, 2002.
[PubMed: 11878662]

25. Luscombe M, Owens B: Weight estimation in resuscitation: is the current formula still valid? *Arch Dis Child* 92: 412, 2007.
[PubMed: 17213259]

26. Nguyen KD, Krieser D, Kerr D et al.: Failed validation of the Argall weight formula for estimating children's weight in an Australian emergency department. *Acad Emerg Med* 14: 486, 2007.
[PubMed: 17384408]

27. Krieser KD, Nguyen K, Kerr D et al.: Parental weight estimation of their child's weight is more accurate than other weight estimation methods for determining children's weight in an emergency department? *Emerg Med J* 24: 756, 2007.
[PubMed: 17954827]

28. Tinning K, Acworth J: Make your best guess: an updated method for paediatric weight estimation in emergencies. *Emerg Med Australas* 19: 528, 2007.
[PubMed: 18021105]

29. Greig A, Ryan J: How good are doctors at estimating children's weight? *J Accid Emerg Med* 14: 101, 1997.
[PubMed: 9132182]

30. Kleinman ME, Srinivasan V: Postresuscitation care. *Pediatr Clin North Am* 55: 943, 2008.
[PubMed: 18675028]

31. Valdes SO, Donoghue AJ, Hoyme DB et al.: Outcomes associated with amiodarone and lidocaine in the treatment of in-hospital pediatric cardiac arrest with pulseless ventricular tachycardia or ventricular fibrillation. *Resuscitation* 85: 381, 2014.
[PubMed: 24361455]

32. Cardenas-Rivero N, Chernow B, Stoiko MA et al.: Hypocalcemia in critically ill children. *J Pediatr* 114: 946, 1989.
[PubMed: 2786063]

33. Atkins DL, Everson-Stewart S, Sears GK et al.: Epidemiology and outcomes from out-of-hospital cardiac arrest in children. *Circulation* 119: 1484, 2009.

[PubMed: 19273724]

34. Beland MJ, Hesslein PS, Finlay CD et al.: Non-invasive transcutaneous cardiac pacing in children. *PACE* 10: 1262, 1987.
[PubMed: 2446273]

35. Dingeman RS, Mitchell EA, Meyer EC, Curley MA: Parent presence during complex invasive procedures and cardiopulmonary resuscitation: a systematic review of the literature. *Pediatrics* 120: 842, 2007.
[PubMed: 17908772]

36. Winsten A, Zingmark K: Supportive needs of parents confronted with sudden cardiac death—a qualitative study. *Resuscitation* 74: 68, 2008.
[PubMed: 17353083]

37. Worden J: Attachment, loss, and the tasks of mourning, in *Grief Counselling and Grief Therapy: A Handbook for the Mental Health Practitioner*, 3rd ed. New York: Springer-Verlag, 2003.

38. Oliver RC, Fallat ME: Traumatic childhood death: how well do parents cope? *J Trauma* 39: 303, 1995.
[PubMed: 7674399]

USEFUL WEB RESOURCES

AHA—http://www.americanheart.org/cpr

AHA 2010 Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care—
http://circ.ahajournals.org/content/122/18_suppl_3.toc

AHA 2010 Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Pediatric ALS—http://circ.ahajournals.org/content/122/18_suppl_3/S862.full

American Academy of Pediatrics–*Pediatrics*—http://pediatrics.aappublications.org/content/126/5/e1361.full