Pediatric Anesthesia CME Program

Module 2

This is Module 2 of CSA's Pediatric Anesthesia Continuing Medical Education Program (CME). To receive CME credit, submit your registration page, answers to the questions, and the evaluation to the CSA office by mail or fax (650) 345-3269. Your CME certificate will be mailed to you. Alternatively, the full text of each module will be accessible through the CSA Web Site, **www.csahq.org**, in the Online CME Program section. Instructions to complete Module 2 online are given in the information pages. After completing the assessment, print your CME certificate. Members will need their usernames and passwords to do the modules online.

The following Important Information about Module 2 must be read and acknowledged before proceeding to the rest of the module. Check the acknowledgement box on the registration page.

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Estimated Time to Complete the Module: One hour

Availability

Module 2: Pediatric Resuscitation

Release Date: September 30, 2010
Expiration Date: September 30, 2013

CME Sponsor/Accreditation

The California Society of Anesthesiologists (CSA) is accredited by the Accreditation Council for Continuing Medical Education to sponsor continuing medical education for phy¬sicians. The CSA Educational Programs Division designates this pediatric anesthesia program for *AMA PRA Category 1 Credit(s)*™ (1 credit per module). Physicians should claim credits commensurate with the extent of their participation in the activity.

Fees, Target Audience, Evaluation

The modules are free to CSA members. Nonmembers pay $30 for each module. Each module is worth one *AMA PRA Category 1 Credit™*. This program is intended for all licensed physicians, including residents. An evaluation of each module of this series is offered after the test questions.

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Objectives

Upon completion of this activity, participants will be able to:

1. Discuss relative risk of serious events and factors associated with cardiac arrest based on the ASA Closed Claims Database and Pediatric Perioperative Cardiac Arrest registry.
2. Identify key similarities and differences between Advanced Cardiac Life Support and Pediatric Advanced Life Support with regard to techniques and equipment.
3. Describe appropriate Pediatric Advanced Life Support protocol and drug dosing for pulseless arrest, tachycardia, and bradycardia algorithms.
4. Describe appropriate Neonatal Resuscitation Program protocol and drug dosing.
5. Discuss treatment of local anesthetic toxicity with intralipid in pediatric patients.

Pediatric Resuscitation

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Introduction

The practice of anesthesiology in children is commonly a rewarding and straightforward endeavor for prepared, well-trained personnel. However, evidence proves the stakes are high, and sometimes the worst complications occur in the healthiest children. Therefore, it is imperative that knowledge of pediatric resuscitation techniques are available to every anesthesiologist whose scope of practice includes children or obstetrics, in which case resuscitation of the newborn may be required.

Much of our knowledge about the risk of anesthesia in pediatrics comes from information contained in the ASA Closed Claims Database. While there are limitations to the methodology of applying closed claims data to clinical practice, the information contained in the most recent examination of the data from 1990-2000 gives us important perspective.[1] Despite a significant decrease compared to the previous decades, death and brain death remained the dominant injuries in pediatric anesthesia malpractice claims in the 1990s. This pattern of injury is much more serious compared with adult claims. Of the 532 pediatric patients (less than 16 years) malpractice claims from 1973-2000 reviewed in total, 77 percent were patients with ASA physical status 1–2, which highlights the need for readily applicable resuscitation skills even when caring for healthy children. In earlier decades, respiratory events resulted in the most liability in pediatric anesthesia malpractice claims; however, in the 1990s, cardiovascular events (26 percent) outnumbered respiratory events (23 percent).

In 1994, The Pediatric Perioperative Cardiac Arrest (POCA) Registry was formed to determine the clinical factors and outcomes associated with cardiac arrest in anesthetized children. The initial findings of the registry (1994-1997)[2] suggested that anesthesia-related cardiac arrest occurred most often in patients less than one year of age and in patients with severe underlying disease. Mortality following anesthesia-related cardiac arrest was 26 percent. Patients having emergency surgery or with severe underlying disease were most likely to have

a fatal outcome. Medication-related problems were identified as the most frequent cause of anesthesia-related cardiac arrest. From 1998 to 2004[3] there was a decrease in medication-related arrests from 37 percent to 18 percent. Cardiovascular causes of cardiac arrest became the most common (41 percent of all arrests), with hypovolemia from blood loss and hyperkalemia from transfusion of stored blood the most common identifiable cardiovascular causes. Despite the inherent biases involved in the reporting of events to a registry and the subsequent analysis, data such as this suggest that education about resuscitation is essential.

The American Heart Association (AHA) periodically reviews, updates and changes the scientific evidence behind its Emergency Cardiovascular Care (ECC) resuscitation algorithms and guidelines. A survey of members of the Society of Pediatric Anesthesiologists (SPA) about knowledge of the current (2005) AHA Pediatric Advanced Life Support (PALS)[4] revealed that of the 51 percent of members who responded, 89 percent knew the correct initial dose of epinephrine for asystole, 44 percent knew the subsequent management for asystole if the initial epinephrine dose was ineffective, 49 percent knew the defibrillation sequence to treat pulseless ventricular tachycardia (VT), and 73 percent knew the medication sequence to treat pulseless VT. This CME module is designed to highlight both the changes to the current PALS and Neonatal Resuscitation Program (NRP) guidelines and the current algorithms. It is not designed to replace PALS and NRP certification, which should take place through accredited AHA programs

Pediatric Advanced Life Support

The ECC guidelines were most recently updated in 2005, but a newer version is expected to be released soon. The current[5-6] recommendations about PALS compression rates and ventilation ratios are the same as for Advanced Cardiac Life Support (ACLS). The compression rate is 100/minute and the depth should be approximately 1/3 to 1/2 of the anterior-posterior diameter. Ventilation rate should be delivered 8 to 10 per minute. A cycle of cardiopulminary resuscitation (CPR) is 30 compressions: 2 ventilations. The newest guidelines for both ACLS and PALS also stress the importance of effective compressions with minimal interruptions for defibrillation and rhythm check. Each shock should be followed immediately by CPR. The current PALS drug dosages have undergone minimal changes.[7]

Use adult paddles for defibrillation on children greater than 10 kg if they fit on the chest wall *and* there is at least 3 cm between the paddles. Use infant paddles for infants weighing less than10 kg. The guidelines also suggest that automatic external defibrillators (AEDs) can be used in children in ages 1-8 with a pediatric attenuator system, which are pediatric pads that decrease the delivered energy. If no pediatric pads are available, then use a standard AED with sensitivity and specificity for pediatric shockable rhythms.

Pulseless Arrest (Figure 1)

Similar to ACLS, the Pulseless Arrest Algorithm is divided into arms for shockable ventricular fibrillation (VF)/Pulseless VT and non-shockable pulseless electrical activity (PEA)/Asystole. For VF/Pulseless VT, provide CPR while obtaining a defibrillator. Give one shock of 2 J/kg, followed immediately by five cycles of CPR before a rhythm check is performed. The second shock is 4 J/kg, followed by a dose of intravenous (IV) or intraosseous (IO) epinephrine given during the compressions. The dose of epinephrine is 0.01 mg/kg (0.1 mL/kg 1:10,000) IV/IO *or* 0.1 mg/kg (0.1 mL/kg 1:1,000) endotracheally with a maximum of 1 mg IV/IO and 10 mg via endotracheal tube. The successive shocks are always 4 J/kg, and epinephrine is repeated every 3-5 minutes. Following epinephrine, give antiarrhythmics such as amiodarone (5 mg/kg IV/IO) or lidocaine (1 mg/kg IV/IO) if amiodarone is unavailable. Magnesium (25 to 50 mg/kg IV/IO with a maximum dose of 2 g) should be considered for torsades de pointes.

With VF/Pulseless VT occurring in only 20 percent of pediatric arrests in the hospital setting, asystole and PEA are far more common. The algorithm arm for asystole/PEA involves only CPR and epinephrine. The dose for epinephrine is the same as for VF/pulseless VT, and it can be administered every 3 to 5 minutes. Perform a rhythm check every five cycles of CPR, or every 2 minutes with two rescuers.

Bradycardia with a Pulse

Bradycardia is commonly caused by inadequate oxygenation and ventilation in children, so PALS emphasizes the importance of supporting the airway and ventilating with oxygen, while attaching an electrocardiogram monitor and defibrillator, and then reevaluating if the bradycardia is causing hemodynamic compromise. If cardiovascular compromise persists and the heart rate (HR) is less than 60 beats per minute (bpm) with poor perfusion, then start chest compressions at 100 bpm. If symptomatic bradycardia persists, then give epinephrine boluses every 3 to 5 minutes at the same dose as in the Pulseless Arrest Algorithm: 0.01 mg/kg (0.1 mL/kg 1:10,000) IV/IO, *or* 0.1 mg/kg (0.1 mL/kg 1:1,000) via endotracheal tube. This dose of epinephrine should be repeated every 3 to 5 minutes. An infusion of epinephrine or isoproterenol can be administered if only transient response is noted with boluses. If it is determined that the bradycardia is due to increased vagal stimulation or primary atrioventricular block, then give atropine 0.02 mg/kg, repeating this does if necessary, with a minimum dose of 0.1 mg and a maximum total dose of 1 mg. Transcutaneous pacing may be lifesaving if the bradycardia is due to complete heart block or sinus node dysfunction unresponsive to oxygenation,

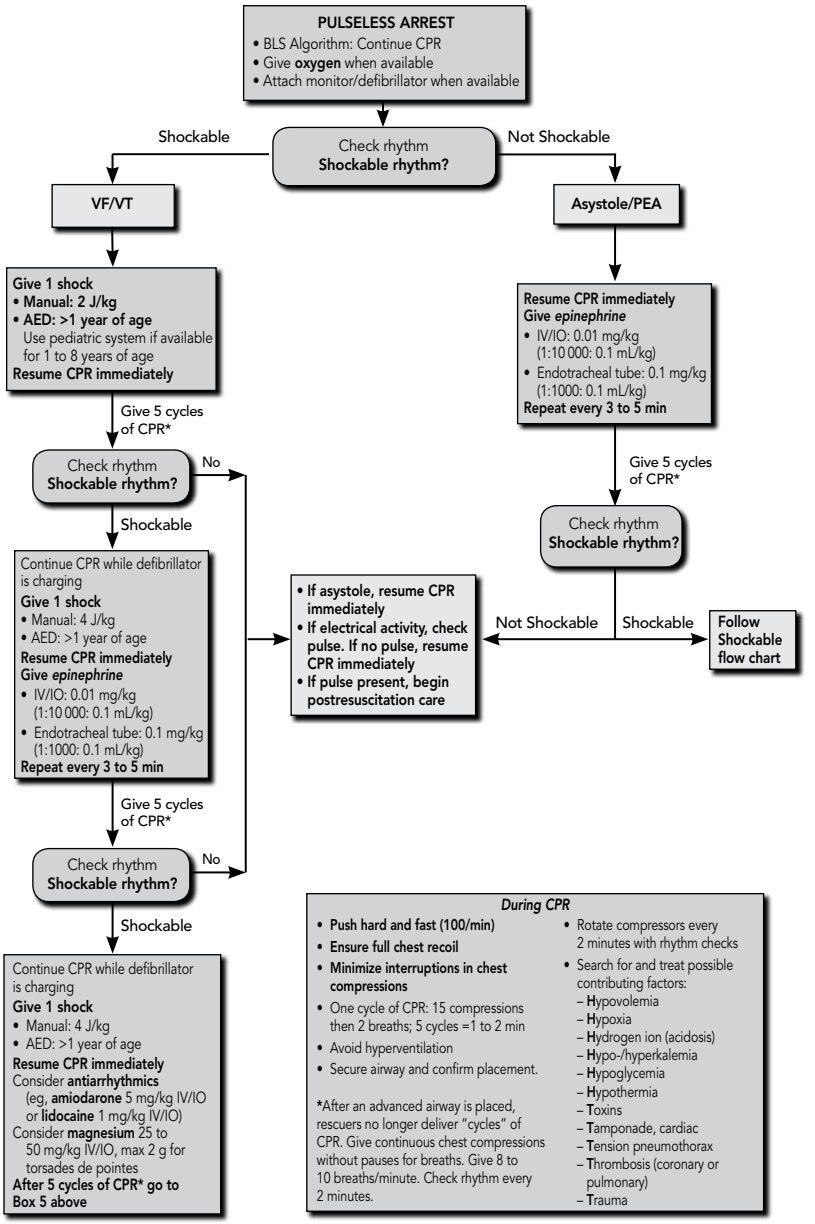

Figure 1. Pulseless Arrest (Reprinted with permission of the 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, Part 12: Pediatric Advanced Life Support Circulation. 2005; 112:IV-173-IV-187) © 2005 American Heart Assoc., Inc.

ventilation, chest compressions and medications. Should a pulseless arrest occur, then proceed to the Pulseless Arrest algorithm.

It may be necessary to seek and treat factors other than hypoxia or ventilation problems that might be contributing to the bradycardia such as: hypovolemia, hypo- or hyperkalemia, hypoglycemia, metabolic acidosis, hypothermia, tension pneumothorax, cardiac tamponade, increased intracranial pressure, cardiac tamponade, and coronary or pulmonary thrombosis.

Tachycardia (Figure 2)

The PALS tachycardia (like ACLS) algorithm is initially divided into narrow- and wide-complex tachycardia. However, it has fewer drug options than ACLS and converging final treatment arms. If the patient has pulses but is having hemodynamic instability from tachycardia, then first ensure adequate oxygenation and ventilation. Next, attach monitors and the defibrillator to determine if the QRS duration is less than than 0.08 second (narrow-complex tachycardia) or greater than 0.08 second (wide-complex tachycardia). For narrow complex rhythms, a 12 lead ECG monitor is recommended for differentiation between sinus tachycardia and supraventricular tachycardia. For sinus tachycardia, search for and treat reversible causes.

For supraventricular tachycardia, attempt vagal stimulation unless the patient is very unstable or it will delay chemical or electrical cardioversion. Chemical cardioversion with adenosine should proceed if the vagal stimulation was ineffective. Administer adenosine in children using two syringes attached to a stopcock so that 5 mL of normal saline can immediately follow the adenosine administration. The dose of adenosine is 0.1 mg/kg with a maximum of 6 mg. The second dose is doubled with a maximum dose of 12 mg. Unlike ACLS, no third dose is given. If the patient is very unstable or the adenosine was not effective, then perform synchronized cardioversion with 0.5 to 1 J/kg. If this is ineffective, increase to 2 J/kg. Consider administering an antiarrhythmic before the third shock. Give either amiodarone or procainamide slowly as an infusion and consult experts. The dosing for amiodarone is 5 mg/kg over 20 to 60 minutes and the dosing for procainamide is 15 mg/kg over 30 to 60 minutes.

Wide-complex tachycardia with poor perfusion is most likely ventricular in origin but may be supraventricular with aberrancy, and in either case it should be treated with synchronized electrical cardioversion with 0.5 to 1 J/kg. If it does not delay cardioversion, then a dose of adenosine may be given first in order to determine if the rhythm is SVT with aberrancy. If unsuccessful, then administer a second shock of 2 J/kg. If this is unsuccessful or if the tachycardia recurs quickly, then give amiodarone or procainamide as in the narrow-complex algorithm before the third shock. Lidocaine has been removed from the tachycardia algorithm.

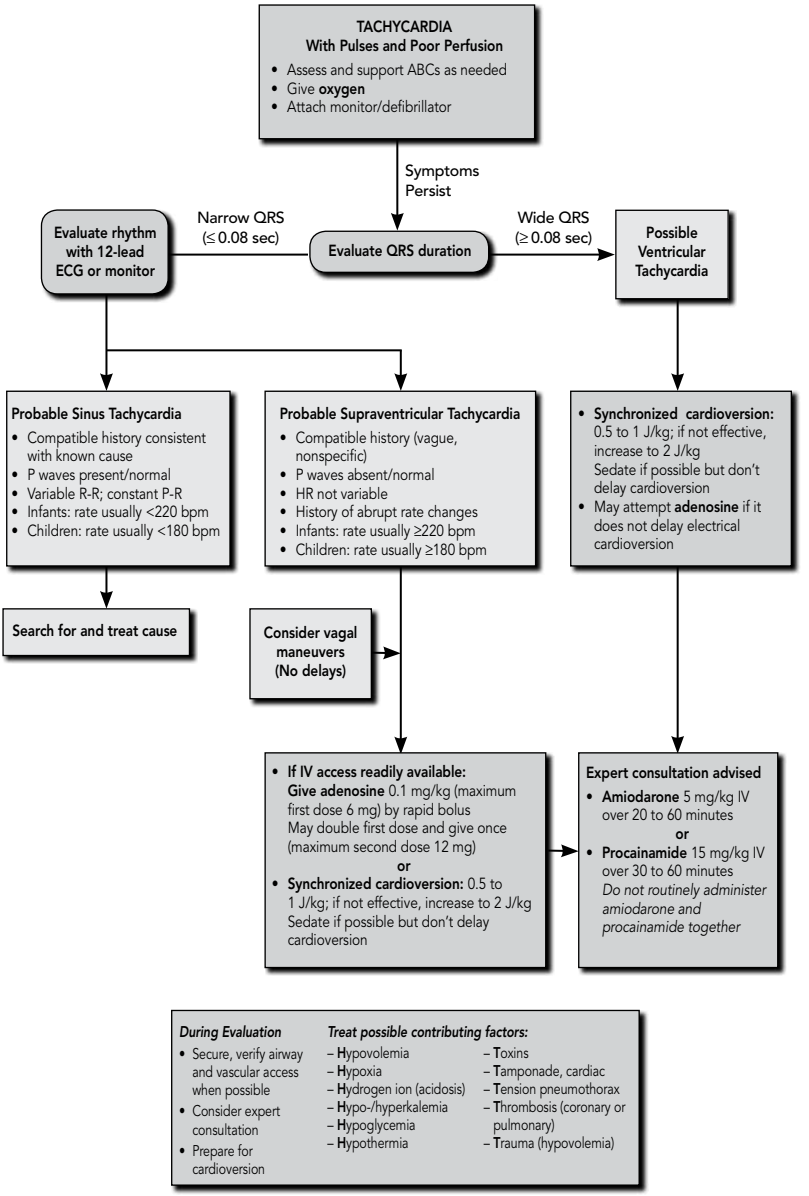

Figure 2. Tachycardia (reprinted with permission of the 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, Part 12: Pediatric Advanced Life Support Circulation. 2005;112:IV-173-IV-187) © 2005 American Heart Assoc., Inc.

Neonatal Resustation Progam (NRP) (Figure 3)

As anesthesiologists in a perinatal unit, we should understand that approximately ten percent of newborns require assistance to start breathing at birth, and one percent needs extensive resuscitative efforts.[8] While initial steps at stabilization often are successful, one should be familiar with the current NRP guidelines. The algorithm proceeds in 30-second intervals.

Beginning with anticipating the need for resuscitation, first ask the following four questions:

1) Was the baby born after a full-term gestation?
2) Is the amniotic fluid clear of meconium and evidence of infection?
3) Is the baby breathing or crying?
4) Does the baby have good muscle tone?

If the answer to any of these questions is "no," then the infant should receive initial steps in stabilization:

1) provide warmth
2) place into the sniffing position
3) clear the airway (endotracheal intubation may be considered)
4) dry
5) stimulate

After these initial maneuvers are completed, then, when indicated, ventilation, chest compressions, and administration of epinephrine and/or volume expanders may become necessary (see below).

Traditionally, all meconium-stained infants had endotracheal intubation with suctioning immediately following birth. However, randomized controlled trials have shown that this practice offers no benefit if the infant is vigorous.[9,10] The NRP defines a vigorous infant as one who has strong respiratory efforts, good muscle tone, and a HR greater than 100 bpm. Conversely, revised recommendations no longer suggest pausing routinely after delivery of the shoulders for oropharyngeal and nasopharyngeal suctioning in meconium stained infants because this was not found to be efficacious. If the [infant] is not vigorous, then they should receive endotracheal suctioning.[7]

The above-described evaluation and initial steps in stabilization can take place for up to 30 seconds, and then one must evaluate HR, respirations, and color. If the infant is breathing, *and* the HR is greater than 100 bpm, *and* the infant is pink, then observational care may proceed.

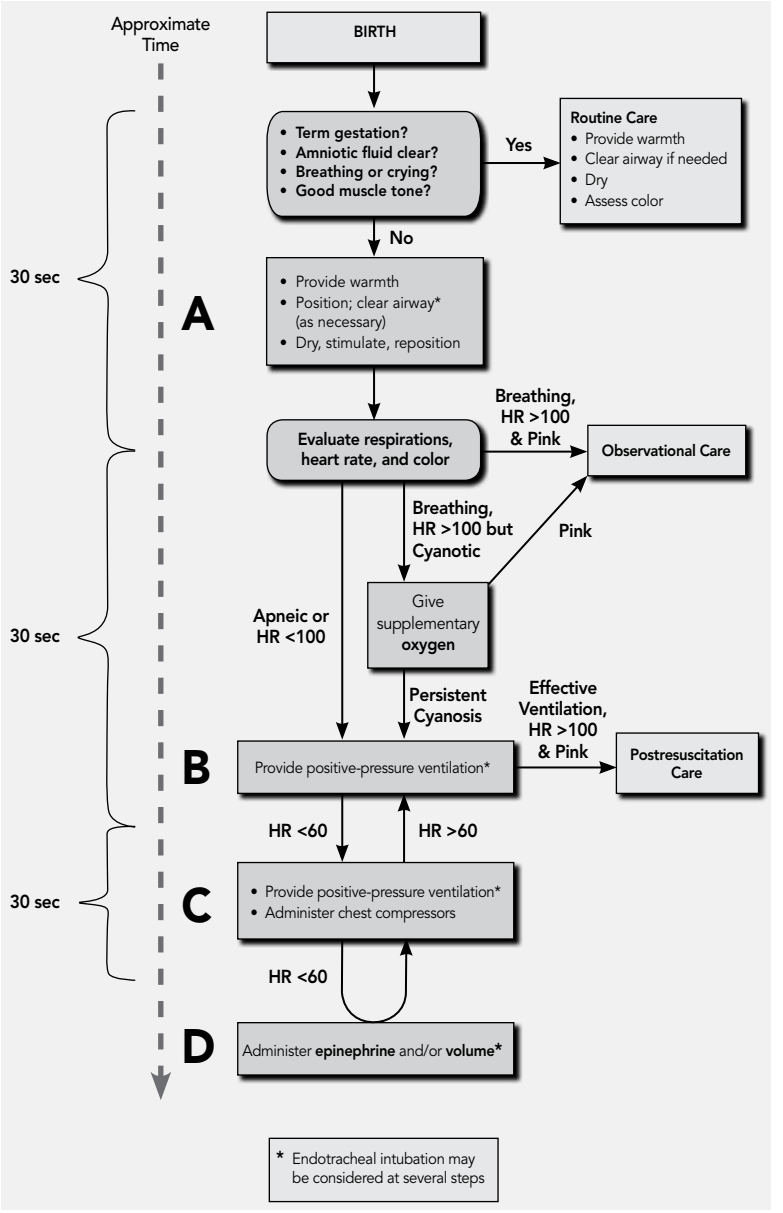

Figure 3. Neonatal Resuscitation Program (reprinted with permission of the 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, Part 13: Neonatal Resuscitation Guidelines Circulation. 2005;112:IV-188-IV-195) © 2005 American Heart Assoc., Inc

If the infant is breathing *and* the HR is greater than 100 bpm, *but* the infant is cyanotic, then give supplemental oxygen. If this successfully eliminates cyanosis, then observational care may proceed.

Within the ensuing 30 seconds, if the infant remains apneic or gasping, *or* the HR remains less than 100 bpm, *or* the infant continues to have persistent central cyanosis despite administration of supplementary oxygen, then start positive-pressure ventilation. The primary measure of adequate ventilation is prompt improvement in heart rate. Ventilation is the most effective action in neonatal resuscitation.

If the HR is *less* than 60 bpm despite adequate ventilation (endotracheal intubation may be considered) with supplementary oxygen for 30 seconds, then start chest compressions. Compressions should be delivered on the lower third of the sternum to a depth of approximately one-third of the anterior-posterior diameter of the chest with the two-thumb, encircling-hands technique. The ratio of compressions to ventilations is 3:1, with 90 compressions and 30 breaths to achieve approximately 120 events per minute in order to maximize ventilation at an achievable rate. Note the difference in *both* compression rate *and* the ventilation-to-compression ratio when compared with ACLS and PALS. Reassess respirations, HR and color every 30 seconds; then continue coordinated chest compressions and ventilations until the spontaneous HR is greater than 60 bpm.

The standard approach to resuscitation is to use 100 percent oxygen. NPR notes that some clinicians may begin resuscitation with an oxygen concentration of less than 100 percent—or even room air—and suggests that evidence supports either of these practices as reasonable. However, it must be emphasized that if one begins resuscitation with room air, then supplementary oxygen should be available to use if there is no appreciable improvement within 90 seconds after birth. Conversely, concerns about potential hyperoxic injury should limit the use of excessive oxygen, especially in the premature infant.

There is insufficient evidence to support the routine use of the LMA as the primary airway device during neonatal resuscitation in the following settings: meconium-stained amniotic fluid, when chest compressions are required, in very low birth weight babies, or for delivery of emergency endotracheal medications. However, a randomized controlled trial found no clinically significant difference between the use of the LMA and endotracheal intubation when bag-mask ventilation was unsuccessful.[11]

While ventilation is required for apnea and HR less than 100 bpm or unresolved cyanosis, the guidelines do not require intubation for ventilation. However, intubation may be indicated in the following situations:

- When tracheal suctioning for meconium is required
- If bag-mask ventilation is ineffective or prolonged
- When chest compressions are performed
- When endotracheal administration of medications is desired
- For special resuscitation circumstances, such as congenital diaphragmatic hernia or extremely low birth weight (less than 1000 g)

Given that ventilation is the most effective action in neonatal resuscitation, drugs are rarely indicated in resuscitation of the newly born infant. However, if the HR remains less than 60 bpm despite adequate ventilation with 100 percent oxygen and chest compressions, then administration of epinephrine or volume expansion, or both, may be indicated. Past guidelines recommended that initial doses of epinephrine be given through an endotracheal tube because the dose can be administered more quickly than when an intravenous route must be established. However, given the lack of data on endotracheal epinephrine, the IV route should be used as soon as venous access is established. The recommended IV dose is 0.01 to 0.03 mg/kg per dose. While access is being obtained, administration of a higher dose (up to 0.1 mg/kg) through the endotracheal tube may be considered. The concentration of epinephrine for either route should be 1:10,000 (0.1 mg/mL). The recommendations stress the avoidance of higher IV doses because animal[12-13] and pediatric[14] studies show exaggerated hypertension, decreased myocardial function, and worse neurologic function after administration of IV doses in the range of 0.1 mg/kg.

One should consider volume expansion when blood loss is suspected or the infant appears to be in shock and has not responded adequately to other measures. Deliver a 10 mL/kg dose of an isotonic crystalloid for volume expansion.

Naloxone is not recommended during the primary steps of resuscitation[15] but should be given IV or IM instead of endotracheal administration if needed. The recommended dose is 0.1 mg/kg, although no studies have examined the efficacy of this dose in newborns. The recommendations suggest that naloxone should be avoided in babies whose mothers are suspected of having had long-term exposure to opioids because one case report showed an association with seizures when naloxone was given to a baby born to an opioid addicted mother.[16]

Lipid Rescue for Local Anesthetic Toxicity

Because the POCA registry suggests that medication-related issues are frequent causes of arrest, it is prudent to discuss the role of lipid therapy in local anesthetic (LA) toxicity. One cannot completely eliminate the risk of local anesthetic toxicity. Tachycardia is not a perfect indicator of an intravascular injection of bupivacaine with epinephrine, occurring in only 83 percent of intravascular injections during general anesthesia.[17] In the initial POCA registry search, all of the cases of cardiac arrest following intravascular injection of local anesthetic during caudal anesthesia had a documented negative aspiration and a negative test dose.

Intravenous lipid emulsion has been shown to be effective for resuscitation of cardiac arrest due to bupivacaine toxicity in animal studies and case reports in humans. Studies in isolated rat heart preparations concluded that lipid treatment promotes the loss of bupivacaine from the myocardium and accelerates the recovery from bupivacaine-induced asystole.[18] The adult literature suggests that 1.5 mL/kg of 20 percent lipid emulsion should be administered over one minute followed by a maintenance infusion rate of 0.25 mL/kg/min and repeated boluses every 3 to 5 minutes until the circulation is restored.[19-20] Maximum total dose has not been established but is suggested to be 8 ml/kg. To date, there are only a few published pediatric reports with this intervention,[21-23] but success was achieved with a single injection of 20 percent lipid emulsion in an infant with 2 ml/kg and in a 13 year old with 3 mL/kg. Therefore, the dose of lipids in children remains tentative. However, there is a growing consensus that 20 percent lipid emulsions should be immediately available in any location where regional anesthesia is performed to permit rapid treatment of cardiac toxicity.

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Questions

1. According to the Pediatric Perioperative Cardiac Arrest (POCA) Registry, the mortality rate for perioperative arrest is 26 percent.
    a. True
    b. False

2. In the ASA Closed Claims Database, pediatric events occurred in ASA status 1-2 patients which percentage of the time?
    a. 22
    b. 55
    c. 66
    d. 77

3. In PALS, the correct initial treatment for pulseless electrical activity (PEA) is which of the following?
    a. Defibrillation at 2 J/kg three consecutive times
    b. Defibrillation at 2 J/kg once
    c. Defibrillation at 4 J/kg once
    d. Epinephrine 0.01 mg/kg IV/IO

4. In PALS, what is the next treatment for wide complex tachycardia with pulses and poor perfusion that responded only briefly to synchronized cardioversion with 1 J/kg then 2 J/kg?
    a. Unsynchronized shock
    b. Amiodarone 5 mg/kg IV push
    c. Amiodarone 5 mg/kg over 20—60 minutes
    d. Vagal maneuvers

5. In PALS, what is the correct sequence of medications for a patient receiving CPR who is in pulseless ventricular tachycardia (VT)?
    a. Epinephrine, amiodarone, epinephrine
    b. Epinephrine, vasopressin, amiodarone
    c. Epinephrine, lidocaine, amiodarone
    d. Epinephrine, adenosine, epinephrine

6. In PALS, what is the correct sequence of defibrillation in a patient with pulseless VT?
    a. Defibrillation at 1 J/kg three consecutive times followed by 5 cycles of CPR
    b. Defibrillation at 2 J/kg three consecutive times followed by 5 cycles of CPR
    c. Defibrillation at 1 J/kg once followed by 5 cycles of CPR, then defibrillation at 2 J/kg once and 5 cycles of CPR
    d. Defibrillation at 2 J/kg once, followed by 5 cycles of CPR, then defibrillation at 4 J/kg once and 5 cycles of CPR

7. In PALS, for a patient receiving CPR for asystole who did not respond to the initial dose of epinephrine 0.01mg/kg, what is your next treatment?
    a. Defibrillation at 2 J/kg once
    b. Defibrillation at 4 J/kg once
    c. Epinephrine 0.01 mg/kg IV/IO
    d. Epinephrine 0.1 mg/kg IV/IO

8. According to the NRP guidelines, a neonate who is meconium-stained needs to be suctioned endotracheally immediately after birth.
    a. True
    b. False

9. In the NRP guidelines, if the heart rate is less than 60 bpm following 30 seconds of positive pressure ventilation, which of the following is the next step?
    a. chest compressions at 100 compressions/min
    b. chest compressions at 120 compressions/min
    c. epinephrine 0.01 mg/kg IV
    d. epinephrine 0.1 mg/kg intratracheally

10. The current suggested dosing for lipid rescue with 20 percent intralipid in adults is a single bolus 1.5 mg/kg. The dosing has not been firmly established in children but it has been used successfully.
    a. True
    b. False

Evaluation of Module 2

As part of the CSA Educational Programs Division's ongoing efforts to offer continuing medical education, the following evaluation of this program is requested. This is a useful tool for the EPD in preparing future CME programs.

1. How well were the learning objectives of this program met?

Very Well	5	Above Average	4
Average	3	Below Average	2
Not Well at All	1		

2. How relevant was the information in this program to your clinical practice?

Very Relevant	5	Above Average	4
Average	3	Below Average	2
Not Relevant	1		

3. How would you rate this program overall?

Excellent	5	Above Average	4
Average	3	Below Average	2
Poor	1		

4. Did you detect any commercial bias in this module? Yes No

Pediatric Resuscitation

By Suzanne L. Strom, M.D.
Assistant Professor, University of California–Irvine

This second module in the Pediatric Anesthesia Bulletin and Online CME Program is now available in this issue. You may complete the module by taking the assessment and faxing a copy to the CSA office at 650.345.3269., or you may go online and take the module in the Online CME section of the CSA Website (http://www.csahq.org)

Registration

Complete this form, the test, and the evaluation, and **mail or fax** to the CSA office at 951 Mariner's Island Boulevard #270, San Mateo, CA 94404 or FAX to 650-345-3269. The CSA CME Bulletin courses also are available on the CSA Web Site at www.csahq.org.

Pediatric Anesthesia CME Course, Module 2

Available November 15, 2010, to November 15, 2013

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❑ **I acknowledge I have read the Introductory Information about Module 2.**