Neonatal Cardiopulmonary Resuscitation

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KEY POINTS

- In newborn resuscitation, simultaneous auscultative assessment of the heart rate and respirations should precede more advanced interventions.
- Because visual determination has been found to be unreliable, pulse oximetry with the minimal oxygen supplementation necessary to maintain adequate oxygen saturation should be used to assess newborns.
- Endotracheal intubation should be considered for tracheal suctioning of meconium, heart rates below 100 beats/min that do not respond to initial bag-valve-mask ventilation, prolonged bag-valve-mask ventilation or chest compressions, administration of medications, and other special considerations such as congenital diaphragmatic hernia and extremely low birth weight.
- If the heart rate remains below 60 beats/min despite respiratory support, chest compressions should be performed at a rate of at least 100 compressions per minute via the two-finger or chest-encircling technique. The chest-encircling technique is preferred for chest compressions. The ratio of compressions to ventilations should be 3:1, with 90 compressions and 30 breaths to achieve approximately 120 events per minute to maximize ventilation at an achievable rate. Each event will be allotted approximately \( \frac{1}{2} \) second, with exhalation occurring during the first compression after each ventilation.

PERSPECTIVE

Approximately 10% of newborns require assistance after birth to achieve spontaneous breathing, and 1% need additional support. The likelihood of survival can be estimated from the gestational age and birth weight (Fig. 12.1).\(^1\)

SURVIVAL WITH COMORBID CONDITIONS

A 2001 study reviewing more than 700 neonatal intensive care unit admissions involving infants born at or before 25 weeks’ gestation found that survivors (63%) had a high incidence of chronic lung disease (51%), high-grade retinopathy of prematurity (32%), intraventricular hemorrhage (44%), nosocomial infection (38%), and necrotizing enterocolitis (11%).\(^2\)

In this same study, only 23% of survivors had no major morbidity, defined as chronic lung disease, necrotizing enterocolitis, at least grade 3 intraventricular hemorrhage, or at least grade 3 retinopathy of prematurity.

ANATOMY

Anatomic considerations for the neonatal airway are similar to those discussed for pediatric patients (see Chapter 13), with the exception that the structures are even smaller and more anterior and superior, thus making visualization of the vocal cords an even greater challenge.

The neonatal chest wall is very flexible and can be notably distorted if vigorous inspiratory efforts are made; such distortion results in inadequate lung expansion and the potential need for positive pressure ventilatory support, particularly in premature infants who lack adequate surfactant production.

PRESENTING SIGNS AND SYMPTOMS

“Yes” answers to the following three questions identify babies who do not require support after birth but can be dried, covered, and kept with the mother if desired.\(^3\)

- Was the baby born after a full-term gestation?
- Is the baby breathing or crying?
- Does the baby have good muscle tone?

INTERVENTIONS AND PROCEDURES: RESUSCITATION STEPS

Figure 12.2 lists the steps in neonatal resuscitation.

If the answer to any of the three questions just listed is “no,” the infant should receive the following in sequence, with 60 seconds allotted for completing and beginning ventilation if needed:

- Stabilization (warm, clear the airway, dry, stimulate)
- Ventilation
- Chest compressions
- Epinephrine, volume expansion, or both
Apgar scores are measured at 1 minute and 5 minutes after delivery. These scores are used to (1) predict which infants will require resuscitation and (2) identify infants who are at higher risk for neonatal mortality. A score of 7 or higher is reassuring (Table 12.1).

**AIRWAY**

The American Heart Association (AHA) no longer recommends routine intrapartum oropharyngeal and nasopharyngeal suctioning because it has been shown to be associated with cardiopulmonary complications in healthy neonates. Oropharyngeal and nasopharyngeal suctioning should be reserved for newborns with obvious upper airway obstruction and associated respiratory distress.3,4

Meconium-stained amniotic fluid occurs in up to 20% of deliveries, and as many as 9% of infants with meconium-stained amniotic fluid experience meconium aspiration syndrome (MAS), which carries a modern-day mortality rate of up to 40%.4

MAS occurs when the fetus aspirates meconium before or during birth, which leads to obstruction of the airways, atelectasis, severe hypoxia, inflammation, acidosis, and infection.5 The AHA guidelines regarding the management of a newborn with potential meconium aspiration make no distinction between thin and thick meconium because both have shown to lead to MAS.

In the absence of randomized controlled trials on routine tracheal suctioning of depressed infants born through meconium-stained amniotic fluid, the 2005 newborn resuscitation guidelines have not changed significantly. Thus, a non-vigorous newborn with meconium-stained amniotic fluid should not be suctioned on the mother’s perineum. Avoiding such suctioning prevents undue stimulation, which would lead to breathing and aspiration of meconium before endotracheal suctioning.6 Endotracheal intubation (ETI) and suctioning of meconium should be performed with a 10 French (F) to 14 F suction catheter and a meconium aspirator attached to an endotracheal tube. If intubation attempts are prolonged, bag-mask ventilation should not be delayed, especially when bradycardia is present.4

A vigorous neonate born with meconium-stained amniotic fluid does not require endotracheal suctioning for any level of meconium staining. Endotracheal suctioning has shown no benefit in this setting because the meconium has already caused irreversible damage to the lower airways. Vigorous is defined as having strong respiratory effort, good muscle tone, and a heart rate higher than 100 beats/min.7

**BREATHING**

Methods to stimulate breathing in neonatal resuscitation are as follows:

- Rubbing the back/spine
- Flicking the soles of the feet
- Vigorously drying the skin
Fig. 12.2 Newborn resuscitation algorithm. CPAP, Continuous positive airway pressure; ET, endotracheal; HR, heart rate; IV, intravenous; PPV, positive pressure ventilation. (Modified from Kattwinkel J, Perlman JM, Aziz K, et al. Part 15: neonatal resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010;122:S909-19.)

If these measures are not stimulating an adequate change in heart rate, oxygenation, or activity, blow-by oxygen (blowing or wafting oxygen) should be administered.

Positive pressure ventilation (PPV) via a bag-valve-mask device at a rate of 40 to 60 breaths/min is indicated for the following situations:

- The infant is apneic or gasping after warming, stimulation, and administration of blow-by oxygen.
- The heart rate remains lower than 100 beats/min after the preceding methods have been applied.
- The infant has persistent hypoxia.
Following pulse oximetry and titration of oxygen as needed, a term infant undergoing PPV should be started on room air and a preterm infant on a blend of air and oxygen. Starting PPV with 100% oxygen should be avoided because it is potentially harmful at the cellular level.

In a term infant, an initial inflation pressure of 20 cm H\(_2\)O may be sufficient and could be increased to 30 to 40 cm H\(_2\)O as needed to achieve adequate movement of the chest wall and elevation of the heart rate; inflation pressures in preterm infants should be 20 to 25 cm H\(_2\)O.

In the absence of meconium-stained amniotic fluid, laryngeal mask airways may be used in a newborn weighing more than 2000 g or delivered at more than 34 weeks’ gestation and requiring assisted ventilation, but not chest compressions.

Continuous positive airway pressure (CPAP) delivered via face mask immediately after delivery may be used in a neonate with respiratory effort but significant distress. Devices that provide some level of CPAP include standard self-inflating bags, flow-inflating bags, and predetermined CPAP devices such as the Neopuff Infant Resuscitator (Fisher and Paykel, Auckland, NZ). Benefits of CPAP include reduced need for intubation, diminished work of breathing, reduced incidence of apnea, decreased inspiratory resistance, and improved oxygenation. Drawbacks include an increased risk for pneumothorax and those related to the risk associated with overdistention, which can result in reduced pulmonary perfusion, diminished cardiac output, and ultimately, ventilation-perfusion mismatch. The current AHA recommendations allow either CPAP or intubation to be used in infants requiring ventilatory support.

Guidelines for ETI in neonatal resuscitation are as follows:

- Tracheal suctioning is needed for nonvigorous newborns with meconium-stained amniotic fluid.
- Bag-valve-mask ventilation is prolonged or ineffective.
- Chest compressions are prolonged.
- Administration of medications by endotracheal tube is desired.
- Special considerations include conditions such as congenital diaphragmatic hernia or extremely low birth weight.

**CIRCULATION**

It is recommended that assessment of the heart rate be performed via auscultation at the anterior surface of the chest. However, if palpation is used, the umbilical pulse should be used while recognizing that this method may underestimate the heart rate. If the heart rate remains below 60 beats/min despite respiratory support, chest compressions (on the lower third of the sternum and at a depth of one third the diameter of the chest) should be performed at a rate of at least 100 per minute with the two-finger or the preferred chest-encircling technique. At this point, the ratio of chest compressions to breaths should be 3:1 unless a cardiac cause is suspected, in which case a 15:2 ratio should be considered.

If an intravenous (IV) line cannot be placed, an umbilical catheter can be used. The umbilical vein (UV) may be used for blood sampling, fluid or drug infusion, and monitoring of blood pressure and central venous pressure. Anatomically, there are typically two umbilical arteries (UAs) and one UV.

The UV is usually in the 12-o’clock position and has a thinner wall and wider lumen than the UAs. The UV is often described as resembling a “smiley face.” In emergency situations the UV is the preferred vessel to access because the UAs are often tortuous and difficult to cannulate. The umbilicus should be prepared with a bactericidal solution and draped, and a silk suture should be placed around the base of the umbilical stomp. The distal end of the stump is cut off, and the vessels are occluded to prevent blood loss. A 3.5 to 5.0 F catheter is flushed with saline and inserted into the lumen of the desired vessel. The UV catheter should be advanced just to the point where good blood return is obtained. Plain radiographs should be taken to confirm placement. Complications of umbilical catheters include hemorrhage, infection, air embolism, and perforation of a blood vessel.

Umbilical vein catheterization can reasonably be attempted up to 1 week after delivery, although the likelihood of cord patency diminishes with time.

Fig. 12.3 Two-finger (A) and chest-encircling (B) techniques. A 3:1 ratio of compressions to ventilations should be used, which results in approximately 90 compressions and 30 ventilations per minute of cardiopulmonary resuscitation performed.
MAINTENANCE OF TEMPERATURE
For a well term infant, temperature can be maintained with standard drying followed by swaddling and placement under warming lights or on the mother’s warm skin.

Very-low-birth-weight infants (<1500 g) require additional warming techniques. The AHA guidelines recommend wrapping the newborn in "food-grade heat-resistant plastic wrapping” and placing the newborn under radiant heat.

Some evidence indicates that induced hypothermia (33.5° C to 34.5° C) may decrease the rate of death or disability (or both) in asphyxiated newborns. Using clearly defined protocols, infants born at greater than 36 weeks’ gestation with suspected severe hypoxic-ischemic encephalopathy should be treated with therapeutic hypothermia within 6 hours. If these protocols are not in place, at the very least, hyperthermia should be strictly avoided.

RESUSCITATION MEDICATIONS AND VOLUME REPLACEMENT
The need for resuscitation medications is rare in the delivery room. Bradycardia is usually secondary to a primary respiratory cause. However, in the rare instance in which ventilatory support does not reverse the bradycardia, standard-dose IV epinephrine at 0.01 to 0.03 mg/kg of a 1:10,000 solution should be administered. Although IV administration is preferred, a higher dose of epinephrine, 0.05 to 0.1 mg/kg of a 1:10,000 solution, can be administered through the endotracheal tube until IV access has been established.

If volume replacement is necessary, isotonic crystalloid is recommended at 10 mL/kg, with repeated dosing as dictated by the clinical situation. Caution should be used when giving fluids because rapid newborn volume expansion has been associated with intraventricular hemorrhage (Tables 12.2 and 12.3). Glucose regulation is particularly important during the poststabilization period in an asphyxiated newborn, whose glycogen stores can be depleted rapidly. Although a target glucose level has not been established, a serum glucose level greater than 40 mg/dL should be maintained with the administration of 10% dextrose in water (D10W).

Table 12.2 Medications to Maintain Cardiac Output and for Postresuscitation Stabilization

<table>
<thead>
<tr>
<th>MEDICATION</th>
<th>DOSE RANGE*</th>
<th>COMMENT</th>
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<tbody>
<tr>
<td>Inamrinone</td>
<td>0.75-1 mg/kg IV/IO over 5 min; may repeat ×2; then 2-20 mcg/kg/min</td>
<td>Inodilator</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>2-20 mcg/kg/min IV/IO</td>
<td>Inotrope, vasodilator</td>
</tr>
<tr>
<td>Dopamine</td>
<td>2-20 mcg/kg/min IV/IO</td>
<td>Inotrope, chronotrope, renal and splanchnic vasodilator in low doses, pressor in high doses</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>0.1-1 mcg/kg/min IV/IO</td>
<td>Inotrope, chronotrope, vasodilator in low doses, pressor in higher doses</td>
</tr>
<tr>
<td>Milrinone</td>
<td>50-75 mcg/kg IV/IO over 10-60 min, then 0.5-0.75 mcg/kg/min</td>
<td>Inodilator</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>0.1-2 mcg/kg/min</td>
<td>Inotrope, vasopressor</td>
</tr>
<tr>
<td>Sodium nitroprusside</td>
<td>1-8 mcg/kg/min</td>
<td>Vasodilator, prepare only in D5W</td>
</tr>
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*Alternative formula for calculating an infusion: Infusion rate (mL/hr) = Weight (kg) × Dose (mg/kg/min) × 60 (min/hr) ÷ Concentration (mg/mL).


D5W, 5% dextrose in water; IO, intraosseously IV, intravenously.
Naloxone administration should generally be avoided in the resuscitation of a newborn at the time of delivery; instead, one should concentrate on support of breathing and the circulation. Administration of naloxone to mothers with known opioid addiction can have adverse outcomes and is not recommended by the AHA.³

Bicarbonate is not routinely recommended in the acute resuscitation of a newborn because of studies showing deleterious effects, including depression of myocardial function, intracellular acidosis, reductions in cerebral blood flow, and risk for intracranial hemorrhage.¹¹

### REFERENCES

References can be found on Expert Consult @ www.expertconsult.com.

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**Table 12.3  Medications for Pediatric Resuscitation and Arrhythmias**

<table>
<thead>
<tr>
<th>MEDICATION</th>
<th>DOSE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenosine</td>
<td>0.1 mg/kg (maximum: 6 mg) Repeat: 0.2 mg/kg (maximum: 12 mg)</td>
<td>Monitor the ECG Rapid bolus IV/IO</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>5 mg/kg IV/IO; repeat up to 15 mg/kg Maximum: 300 mg</td>
<td>Monitor the ECG and blood pressure Adjust the administration rate to urgency (give more slowly when a perfusing rhythm present) Use caution when administering with other drugs that prolong the QT interval (consider expert consultation)</td>
</tr>
<tr>
<td>Atropine</td>
<td>0.02 mg/kg IV/IO 0.03 mg/kg ET* Repeat once if needed Minimum dose: 0.1 mg Maximum single dose: Child: 0.5 mg Adolescent: 1 mg</td>
<td>Higher doses may be used with organophosphate poisoning</td>
</tr>
<tr>
<td>Calcium chloride (10%)</td>
<td>20 mg/kg IV/IO (0.2 mL/kg)</td>
<td>Slowly Adult dose: 5-10 mL</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>0.01 mg/kg (0.1 mL/kg 1:10,000) IV/IO 0.1 mg/kg (0.1 mL/kg 1:1000) ET†</td>
<td>May repeat q3-5min</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.5-1 g/kg IV/IO D₁₀W: 5-10 mL/kg D₂₅W: 2-4 mL/kg D₅₀W: 1-2 mL/kg</td>
<td></td>
</tr>
<tr>
<td>Lidocaine</td>
<td>Bolus: 1 mg/kg IV/IO Maximum dose: 100 mg Infusion: 20-50 mcg/kg/min</td>
<td></td>
</tr>
<tr>
<td>Magnesium sulfate</td>
<td>25-50 mg/kg IV/IO over 10-20 min; faster with torsades de pointes Maximum dose: 2 g</td>
<td></td>
</tr>
<tr>
<td>Naloxone</td>
<td>&lt;5 yr or ≤20 kg: 0.1 mg/kg IV/IO/ET* ≥5 yr or &gt;20 kg: 2 mg IV/IO/ET†</td>
<td>Use lower doses to reverse respiratory depression associated with therapeutic opioid use (1-15 mcg/kg)</td>
</tr>
<tr>
<td>Procainamide</td>
<td>15 mg/kg IV/IO over 30-60 min Adult dose: 20-mg/min IV infusion up to total maximum dose of 17 mg/kg</td>
<td>Monitor ECG and blood pressure Use caution when administering with other drugs that prolong the QT interval (consider expert consultation)</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>1 mEq/kg per dose IV/IO slowly After adequate ventilation</td>
<td></td>
</tr>
</tbody>
</table>

D₁₀W, 10% dextrose in water; ECG, electrocardiogram; ET, via endotracheal tube; IO, intraosseously; IV, intravenously.

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

¹See text for neonatal ET dosing.

²Not recommended in neonates.

REFERENCES