

Neonatal Resuscitation



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Most neonates require only basic supportive care at the time of delivery. Approximately 10% will need brief respiratory support, and 1% will require extensive resuscitative efforts.¹ The vast majority will adapt to extrauterine life with only minimal assistance from delivery personnel.

Physiologic Adaptation to Extrauterine Life

A discussion of physiological adaptations of neonates at the time of delivery is important to understand the goals and techniques of neonatal resuscitation.

Cardiovascular System

Gas exchange occurs in fetus from the mother via the placenta. Ten percent of maternal cardiac output reaches the placenta. Oxygenated blood returns to the fetus via the umbilical vein; 50% of the umbilical vein flow enters the inferior vena cava via the ductus venosus, and the other half enters the hepatoportal system (Fig. 13-1). A streaming phenomenon tends to separate blood with higher oxygen saturation such that it flows preferentially to the left atrium via the foramen ovale, whereas relatively deoxygenated blood enters the right atrium. Blood ejected from the left heart is responsible for supplying oxygenated blood (saturation approximately 65–70%) to the brain and upper extremities. Less oxygenated blood from the right atrium (saturation approximately 55%) flows to the right ventricle and most returns via the ductus arteriosus to the systemic circulation; it perfuses the lower half of the body and approximately 40% returns to the placenta via the umbilical artery where it is reoxygenated. Oxygen saturation, oxygen and carbon dioxide tension, and pH of umbilical venous and arterial blood are shown in Table 13-1. Several factors contribute to ensure adequate oxygenation at the low PO_2 of the fetal blood. First, the relatively fast fetal heart rate and the decreased systemic vascular resistance of the placenta maintain the high fetal cardiac output relative to total body surface area. Second, the fetal hemoglobin concentration is higher than the adult, approximately 16 g/dL. Third, fetal blood will show a higher oxygen saturation as compared with adult blood at the same oxygen tension. This is due to differences in the affinity of fetal hemoglobin for oxygen, in turn due to lower binding of 2,3-diphosphoglycerate (2,3-DPG) to fetal hemoglobin. This shifts the hemoglobin–oxygen dissociation curve to the left (Fig. 13-2). The P_{50} (the PO_2 corresponding to 50% saturation)

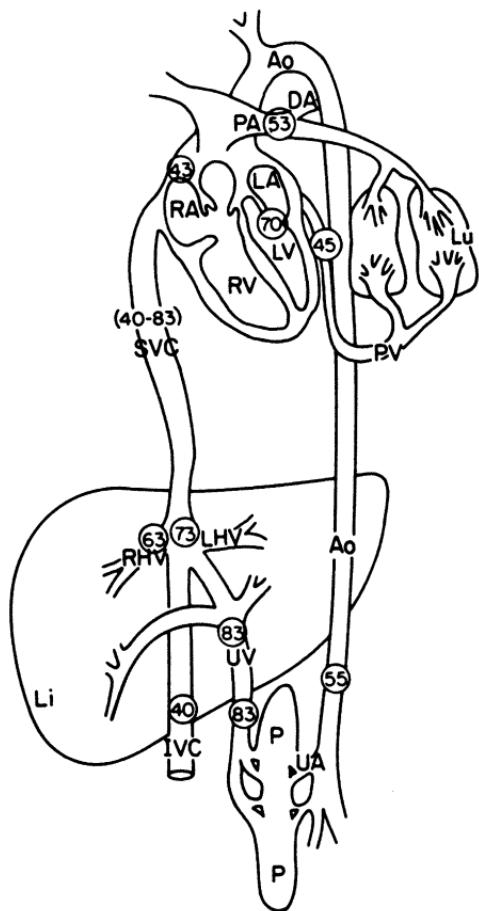


Figure 13-1. Fetal circulation with oxygen saturation in different parts of the fetus (*circled numbers* indicate percent saturation). *P* = placenta; *IVC* = inferior vena cava; *UV* = umbilical vein; *RHV* = right hepatic vein; *LHV* = left hepatic vein; *SVC* = superior vena cava; *RV* = right ventricle; *RA* = right atrium; *LV* = left ventricle; *LA* = left atrium; *PA* = pulmonary artery; *DA* = ductus arteriosus; *Ao* = aorta; *PV* = pulmonary vein; *AO* = aorta; *UA* = umbilical artery. (From Martin.¹¹)

of fetal hemoglobin at term is approximately 19–21 mmHg compared to 26–27 mmHg in the adult.

Table 13-1. Fetal Blood Gas and Acid–Base Values

	pH	PCO ₂	PO ₂	HCO ₃ ⁻
Umbilical artery	7.28 ± 0.05	49.2 ± 8.4 (50)	18.0 ± 6.2 (20)	22.3 ± 2.5
Umbilical vein	7.35 ± 0.05	38.2 ± 5.6 (40)	29.2 ± 5.9 (30)	20.4 ± 2.1

Data from Yeomans et al.¹² from 146 uncomplicated vaginal deliveries. Values are shown as mean ± SD. In parentheses are approximations of the mean values which form a convenient mnemonic: 20-30-40-50.

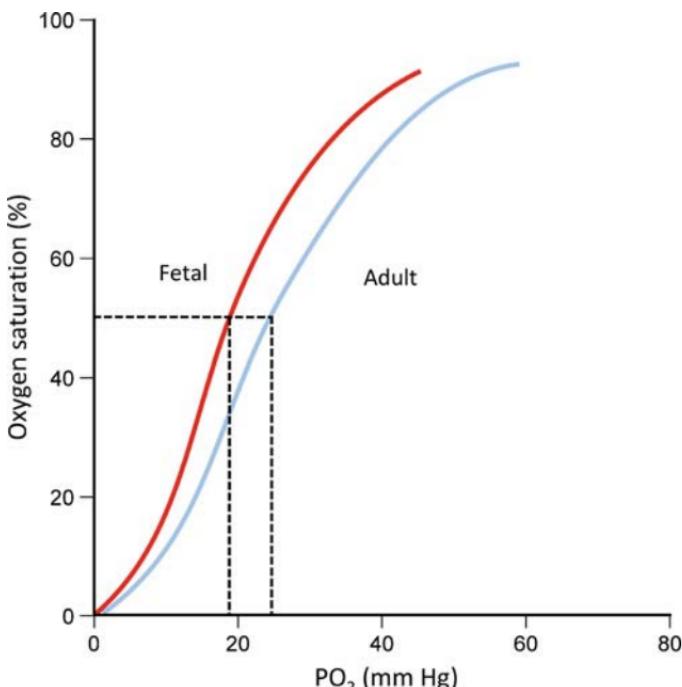


Figure 13-2. Adult and fetal oxyhemoglobin dissociation curves. The dotted line shows the P₅₀, the PO₂ associated with 50% saturation of hemoglobin. Fetal hemoglobin is more avid for oxygen and thus has a lower P₅₀.

At the time of delivery several changes take place: the onset of respiration increases fetal PO_2 and consequently decreases pulmonary vascular resistance; simultaneously, exclusion of the placental circulation by clamping the umbilical cord increases systemic vascular resistance. Increased systemic vascular resistance causes the closure of the foramen ovale, and the ductus arteriosus closes as a result of the increased fetal arterial PO_2 .²

Respiratory System

In intrauterine life the fetal tracheobronchial tree is filled with approximately 30 mL/kg of fluid, which is an ultrafiltrate of plasma. At the time of birth the fetal lung fluid is cleared by several factors: (1) during vaginal delivery the fluid is squeezed out by compression of the thoracic cage, (so babies delivered by cesarean section will have more lung fluid because of the absence of this mechanism), (2) one-third of the lung fluid will be absorbed by lymphatics, (3) some of the fluid will be expelled by the newborns themselves, and (4) some of the fluid is deliberately suctioned out at the time of delivery.

Initiation of respiration is essential for the transition away from the fetal circulation and usually occurs within a few seconds to 1 min after delivery. Regular rhythmic respiration is established within 2–10 min. The exact stimulus responsible for the establishment of neonatal respiration is unknown; however, several factors may be involved: (1) squeezing of the thoracic cage by the vaginal canal and elastic recoil of the chest wall, (2) hypoxia and hypercarbia, (3) tactile stimulation, (4) umbilical cord clamping, and (5) possibly the lower temperature outside the uterus.

The first breath requires an extremely high negative intrathoracic pressure that can vary from 40 cm to 100 cm H_2O . The lungs are expanded with 40–70 mL of air, but expiration is incomplete, and the lungs become completely inflated after the first few breaths. Normal term neonates breathe 30–60 times per minute with a 10–30-mL tidal volume, and the lungs maintain a minute volume of about 500 mL.

During development the fetal lung produces two types of epithelial cells. Type II cells are responsible for the production of surfactant (surface-acting material), which is important for counteracting the surface tension and keeping the alveoli open. Surfactant production by type II cells begins by 22–24 weeks but is not complete until 34–38 weeks, putting preterm infants at risk of respiratory distress syndrome.

Thermoregulation

The neonate is unable to maintain body temperature by shivering, and hence nonshivering thermogenesis becomes an important factor.³ Breakdown of brown fat is the main source of maintenance of fetal body temperature. The term fetus stores abundant brown fat in the neck, interscapular area, back, and axillary area as well as around different abdominal viscera, especially the kidney and adrenals. Brown fat is extremely vascular and receives as much as 25% of the cardiac output in hypothermic conditions. Cold stress will liberate norepinephrine, which is important for the metabolism of brown fat; this complex process involves an exothermic reaction that liberates heat with the utilization of a significant amount of oxygen.⁴ Maintenance of body temperature is extremely important for the neonate because cold temperature will cause pulmonary vasoconstriction, increased right-to-left shunt, hypoxemia, and metabolic acidosis, which will further increase the right-to-left shunt.

General Principles of Neonatal Resuscitation

Several general principles should guide anesthesiologists' participation in newborn resuscitation. First, both ASA and ACOG agree that anesthesiologists should be primarily responsible for maternal well-being; hence, when active neonatal resuscitation becomes necessary, a person other than the anesthesiologist should be responsible for this task.⁵ However, practices in this

regard will necessarily vary among institutions due to availability of staff trained in newborn resuscitation. Second, although most infants require little resuscitation, prior knowledge of a difficult delivery or delivery of a high-risk fetus will help predict the large majority of babies who will. Factors that may predict need for more aggressive resuscitation are listed in Table 13-2. Third, proper preparation includes ready availability of equipments, fluids, and medications (Table 13-3).

Table 13-2. Factors Associated with Need for Neonatal Resuscitation

<i>Maternal factors</i>	<i>Difficult deliveries</i>
Uteroplacental insufficiency	Traumatic
Diabetes mellitus	Intrauterine manipulation
Preeclampsia	Breech extraction
Postmaturity	Forceps delivery
Intrauterine growth retardation	Uterine hyperstimulation
Cocaine addiction	Precipitous labor or delivery
Autoimmune disease	Prolonged labor
Fever and infection	Prolonged second stage
Hemorrhage	Prolonged rupture of membranes
Placenta previa	Nonreassuring fetal heart rate tracing
Abruptio placentae	Shoulder dystocia
Ruptured uterus	
Vasa previa	
Endocrine problems	
Hypothyroidism or hyperthyroidism	
Hypoadrenalinism or hyperadrenalinism	
Pheochromocytoma	
Maternally administered drugs (high dose or overdose)	
Opioids (particularly within 4 h of delivery)	
Sedatives and tranquilizers	
Magnesium sulfate	
Local anesthetics	
Calcium channel blockers	
β-Blockers	
	<i>Fetal factors</i>
	Prematurity
	Small for dates
	Macrosomia
	Polyhydramnios or oligohydramnios
	Abnormal presentation, e.g., breech
	Multiple gestation
	Congenital anomalies
	Intrapartum fetal distress
	Presence of meconium
	Prolapsed umbilical cord

Table 13-3. Equipment and Medications Necessary for Neonatal Resuscitation

-
- I. Radiant warmer
 - II. Equipment for suction
 - A. Bulb syringe
 - B. De Lee mucus trap with a 10-F catheter or mechanical suction
 - C. Suction catheters, 5 F, 6 F, 8 F, and 10 F
 - D. An 8-F feeding tube and a 20-mL syringe
 - E. Adaptor for suctioning via endotracheal tube
 - III. Bag and mask
 - A. Resuscitation bag with a pressure-release valve
 - B. Face masks of different sizes
 - C. Laryngeal mask airway
 - D. Oral airways of different sizes
 - E. Oxygen with a flow meter and tubing
 - IV. Equipment for intubation
 - A. Laryngoscope with straight blades (#0 and 1)
 - B. Endotracheal tubes (2.5 mm, 3.0 mm, 3.5 mm, and 4.0 mm)
 - C. Stylet
 - D. LMA (#1)
 - E. Scissors
 - F. Gloves
 - G. Capnometer or chemical CO₂ detector
 - V. Medication and intravenous fluid
 - A. Epinephrine, 1:10,000
 - B. Naloxone hydrochloride (0.4 or 1 mg/mL)
 - C. Albumin, 5% solution
 - D. Normal saline
 - E. Ringer's lactate
 - F. Sodium bicarbonate (4.2% in 10-mL)
 - G. Dextrose, 10%
 - H. Sterile water
 - I. Normal saline
 - J. 5-F feeding tube or specialized umbilical vein catheterization tray
-

Evaluation of the Neonate: The Apgar Score

In 1953 Dr. Virginia Apgar devised a scoring system for quick evaluation of the neonate immediately after delivery⁶ (Table 13-4). Scores are evaluated by observing five criteria and are recorded at 1 min and 5 min routinely. In severely

Table 13-4. Apgar Scoring System

Mnemonic (APGAR)	Sign	Score		
		0	1	2
Appearance	Color	Blue, pale	Pink body, blue extremity	Pink all over
Pulse	Heart rate	Absent	< 100 BPM	> 100 BPM
Grimace	Reflex irritability	No response	Some response, grimace	Cry, cough
Activity	Muscle tone	Flaccid	Some flexion	Active motion
Respiration	Respiratory effort	Absent	Slow, irregular	Strong cry

depressed infants, scores are recorded every 5 min for 20 min or until two successive scores are ≥ 7 . If the 10-min score is 0, survival is rare (less than 2%).⁷ However, higher scores have relatively weak long-term prognostic significance. Importantly, the Apgar score *should not be a guide to neonatal resuscitative efforts, which often begin well before 1 min of life, but should be viewed instead as a gauge of resuscitation efficacy.*¹

Steps in Neonatal Resuscitation

Neonatal resuscitation proceeds according to a basic algorithm based on ongoing assessment of the newborn's respiration and circulation (Fig. 13-3). Vigorous term infants require little more than drying and warming, clearing of the airway by gentle bulb suctioning, and ongoing assessment. All newborns should be placed under a radiant warmer with a slight head-down tilt and the head slightly extended, and then gently dried. Infants that are not vigorous require progressively aggressive maneuvers to establish and maintain the airway, support respiration, and maintain adequate circulation. The mnemonic "A-B-C-D" (Airway, Breathing, Circulation, Drugs) helps remind the resuscitator of the preferred sequence of steps.

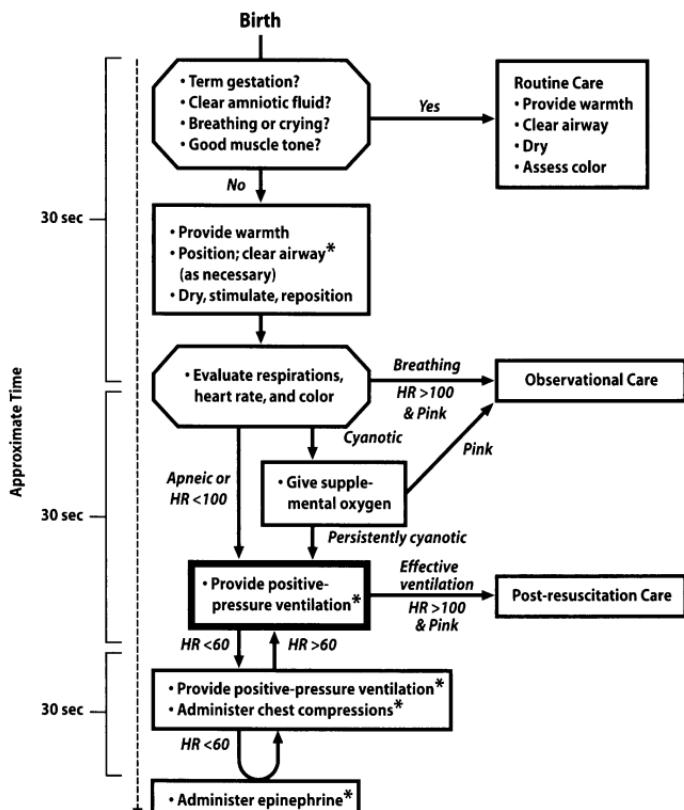


Figure 13–3. Basic algorithm for neonatal resuscitation. (From Tegtmeier.¹ Used with permission.)

Airway

The first important step is clearing and establishing an open airway. Suction should begin shortly after the delivery by the obstetric team. Turning the head to the side will allow better drainage and removal of the secretion. Suction with a bulb syringe will be satisfactory in most cases, but caution should be

used to prevent stimulation of the posterior portion of the pharynx during the first few minutes after delivery to prevent vagally mediated bradycardia. The mouth is suctioned before the nose ("M before N"). In the presence of meconium-stained fluid, thin or thick, modern resuscitation algorithms are much more conservative than in the past, and depend on the overall condition of the neonate (Fig. 13-4). If the infant has absent or depressed respiration, decreased muscle tone and heart rate below 100, direct laryngoscopy should be done for suction of meconium from hypopharynx as well as from trachea. A special adaptor allows suction to be applied directly to the endotracheal tube after intubation of the trachea. Care should be taken to use moderate negative pressure, less than -100 mmHg. Suctioning can be repeated if meconium is aspirated but positive-pressure ventilation should be considered if the heart rate remains below 100. Gastric suction is also recommended after other initial resuscitation efforts are complete. If the infant is vigorous,

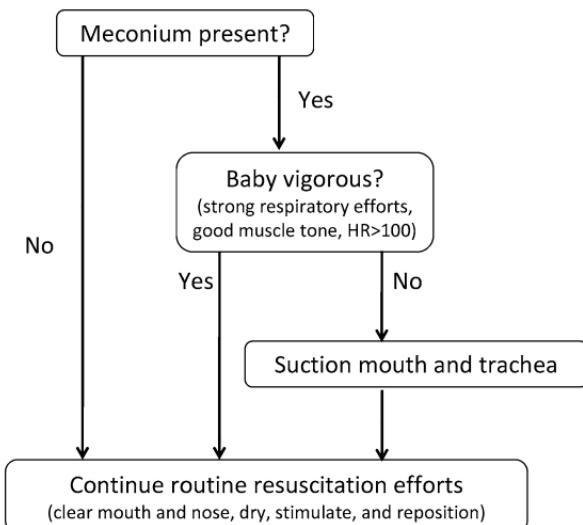


Figure 13-4. Treatment for meconium-stained amniotic fluid. (Redrawn and adapted from Tegtmeier.¹)

regardless of the consistency of meconium, laryngoscopy and tracheal suction should not be performed.^{1,8}

Breathing

Once the oral cavity is cleared, the majority of neonates will start breathing spontaneously, but in a few cases tactile stimulation may be necessary to initiate respiration. In the absence of respiratory effort and movement, positive-pressure ventilation using a bag and mask should be initiated. The heart rate should also be checked at the same time; adequate oxygenation with proper ventilation will improve the heart rate as well as the color. Most neonatal resuscitation bags have a built-in pressure-release valve that is set to release at 30–35 cm H₂O. Neonates should be ventilated at a rate of 40–60 per minute. The adequacy of chest movement should be observed and also be confirmed by listening for bilateral breath sounds. If the heart rate and color do not improve after adequate ventilation or if there is any difficulty in ventilation, endotracheal intubation may be necessary. The laryngeal mask airway can be used for ventilation if bag and mask ventilation is inadequate or endotracheal intubation is not successful or available.

Recent data suggest that the traditional practice of ventilating with 100% oxygen may not be optimal during neonatal respiration. Two recent meta-analyses of randomized trials involving over 3,000 infants receiving room air or oxygen during newborn resuscitation concluded that room air was superior with respect to mortality and trended towards a reduction in ischemic encephalopathy.^{9,10} However, the American Heart Association guidelines do not yet call for substitution of room air for oxygen, but suggest both are acceptable. If room air is used first, and the heart rate does not improve, oxygen is recommended.¹

Circulation

If the heart rate is below 60 beats per minute despite stimulation (rubbing and drying) and 30 s of positive-pressure ventilation, external cardiac compression should be started. Chest compression will compress the heart against the spinal

column, and this will help to maintain circulation in the vital organs. There are two techniques for external cardiac massage. In the thumb technique the fingers encircle the chest, with the thumbs lying over the midsternum and the fingertips lying over the spine. The sternum is compressed one-third of the anterior-posterior diameter of the chest, 90 times per minute. In the two-finger technique the tips of the middle finger and either the index finger or ring finger of the same hand are used to compress the sternum; the other hand can support the back of the neonate in the absence of a rigid surface. The sternum is again compressed one-third of the anterior-posterior diameter of the chest, 90 times per minute. Ventilation should be continued at 30 breaths per minute. Endotracheal intubation should be considered in order to facilitate ventilation during chest compressions. If the heart rate increases to >60 BPM, chest compressions can be stopped and ventilation increased to 40–60 breaths per minute. Ventilation can be gradually withdrawn when the heart rate increases to >100 BPM.

Drug Therapy

In the absence of improvement in the heart rate despite effective ventilation and 30 s of chest compressions, drug therapy is indicated.¹ Epinephrine is the preferred first-line drug, and is given intravenously by umbilical catheter at a dose of 0.1–0.3 mL/kg of a 1:10,000 solution. The umbilical vein should be the preferred route: a catheter is introduced through the umbilical stump until the tip of the catheter is just deep enough to allow free aspiration of blood. Threading the catheter too far will entail the risk of infusion of the solutions into the liver and risk liver damage. If the intravenous route is not available, epinephrine can be given via the endotracheal tube at a higher dose (up to 1 mL/kg). However, lower blood levels are obtained and effectiveness is uncertain.

Indications for Volume Expanders

Volume expanders are rarely indicated but may be considered in the following situations:

1. Persistence of pallor after adequate oxygenation
2. Presence of weak pulses or delayed capillary refill
3. Inadequate response to resuscitative measures
4. History consistent with blood loss (placental abruption or previa, vasa previa, bleeding from umbilical cord)

Normal saline or Ringer's lactate, 10 mL/kg over 5–10 min, is the preferred initial choice.

If there is acute bleeding or suspected anemia, whole blood (O-negative blood, which can be cross-matched with the mother's blood, where any reactive antibodies would originate, if time allows) is given at a similar dose.

Other Drugs

Other drugs are very rarely indicated in neonatal resuscitation. Recommended doses are shown in Table 13-5. Use of bicarbonate is discouraged. If it is used following prolonged arrests unresponsive to other medications, it should be used only after establishment of adequate ventilation and circulation. Continued use of bicarbonate should be associated only with documented fetal metabolic acidosis or hyperkalemia. A 4.2% solution at a dose of 2 mEq/kg is used, and it is given slowly at a rate of 1 mEq/kg/min. The risk of intraventricular hemorrhage following bicarbonate infusion can be minimized by using dilute solution (4.2%) and injecting slowly. Naloxone can be used in the presence of neonatal respiratory depression following maternal opioid administration within 4 h of delivery. It is given in a dose of 0.1 mg/kg intravenously, or intramuscularly; the intratracheal route is no longer recommended. *Naloxone should not be administered to a newborn infant whose mother is a chronic opioid user because of the possibility of precipitating acute withdrawal.*

Unusual Specific Causes of Neonatal Respiratory Problems

These rare conditions are classified by parts of the respiratory system.

Table 13–5. Medications for Neonatal Resuscitation

Medication	Concentration	Dosage route	Rate/ Precautions
Epinephrine	1:10,000	0.1–0.3 mL/kg IV or ET	Give rapidly May dilute with normal saline to 1–2 mL (ET)
Volume expanders	Whole blood 5% Albumin– saline Normal saline Ringer's lactate	10 mL/kg IV	Give over 5–10 min
Sodium bicarbonate	0.5 mEq/mL (4.2% solution)	2 mEq/kg IV	Give slowly, over at least 2 min Give only if infant is being effectively ventilated
Naloxone hydrochlo- ride	0.4 mg or 1 mg/mL	0.1 mg/kg IV, ET, IM, SQ	Give rapidly IV (preferred), IM, ET not recommended
Dopamine	Varies by institution	5 mcg/kg/min may increase to 20 mcg/ kg/min if necessary	Give as a continuous infusion using an infusion pump, monitor heart rate and blood pressure closely, seek consultation

I = intravenous, ET = endotracheal, IM = intramuscular, SQ = subcutaneous.

Choanal Atresia

This condition is associated with anatomic obstruction of the nasal passage. Attempted breathing via the nose will demonstrate an absence of breath sounds, and the newborn will be cyanotic. Breathing via the mouth or crying will make the baby pink, and breath sounds will be present.

There is an inability to pass a soft rubber or plastic catheter through the nose. Imaging after injection of a small amount of contrast media through the nares will confirm the anatomic obstruction. Choanal atresia is treated by insertion of a rubber or plastic oral airway and, if necessary, an endotracheal tube.

Upper Airway Obstruction

The Pierre Robin syndrome can cause neonatal respiratory problems and is a congenital malformation associated with

glossoptosis, micrognathia, and possibly a cleft palate. Clinical findings include sternal retraction, cyanosis, and specific congenital anomalies. Initial treatment may include pulling the tongue anteriorly, insertion of an oral airway or endotracheal tube (which may be very difficult), placement of a small endotracheal tube via the nose into the pharynx, and use of the prone position.

Anomalies of the Larynx

This can include webs, fusions, atresia, and vocal cord paralysis. Clinical findings include stridor, cyanosis, and prolonged inspiration and expiration. Placement of an endotracheal tube distal to the obstruction will alleviate the clinical problems. Expertise in the neonatal airway and facility with fiberoptic techniques may be required.

Anomalies of the Trachea

These include subglottic stenosis, tracheal rings, hemangiomas and webs, vascular rings, and tumors. Clinically, these anomalies may be characterized by inspiratory stridor, retraction, decreased breath sounds, collapse of the trachea during inspiration in the presence of incomplete tracheal rings, or tracheal bleeding in the presence of hemangiomas. An endotracheal tube should be inserted beyond the site of obstruction if possible. If there is pulmonary hemorrhage because of trauma to the hemangioma, the situation can be life-threatening. A neonatal airway expert and thoracic or ENT surgeon should be consulted.

Diaphragmatic Hernia

Diaphragmatic hernia is a congenital defect in the diaphragm with entrance of the gut into the thoracic cavity. It is usually diagnosed antepartum by ultrasound but may be discovered in the immediate neonatal period. Clinical findings include scaphoid abdomen, cyanosis, intercostal retractions, and grunting. Intubation of the trachea and the use of positive-pressure ventilation is usually started immediately after delivery. Careful ventilation is necessary because excessive pressure

may cause pneumothorax. Surgical intervention will be needed in these cases.

Pneumothorax

A collection of air in the pleural cavity (pneumothorax) can occur spontaneously or during ventilation with high pressure in situations like respiratory distress syndrome or meconium aspiration syndrome. Clinical findings include tachypnea, cyanosis, reduced breath sounds on the affected side, displacement of the trachea, and hypotension. An endotracheal tube in the right mainstem bronchus can also cause absent breath sounds on the left side and must be distinguished from pneumothorax in intubated infants. The diagnosis is confirmed by a chest X-ray, transillumination of the chest, or insertion of a needle or chest tube. Removal of air by a chest tube or intravenous catheter will be necessary in symptomatic cases.

Summary

Most deliveries remain uncomplicated and do not require extensive resuscitation of the infant. However, knowledge of neonatal resuscitation may become important, particularly in high-risk situations. Basic techniques centered on maintenance of the airway and ventilation are effective in almost all cases, with cardiovascular support and drug therapy only rarely required.

References

1. Tegtmeier K, Braner D, Halamek L, et al. *Textbook of Neonatal Resuscitation*. 5th ed. Dallas, TX: American Heart Association, American Academy of Pediatrics; 2006.
2. Clyman RI, Heymann MA, Rudolph AM. Ductus arteriosus responses to prostaglandin E1 at high and low oxygen concentrations. *Prostaglandins*. 1977;13:219–223.
3. Dahm LS, James LS. Newborn temperature and calculated heat loss in the delivery room. *Pediatrics*. 1972;49:504–513.
4. Adamson SK, Jr., Gandy GM, James LS. The influence of thermal factors upon oxygen consumption of the newborn human infant. *J Pediatr*. 1965;66:495–508.

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5. ACOG Committee Opinion. Committee on Obstetric Practice. Optimal goals for anesthesia care in obstetrics. *Obstet Gynecol.* 2001;97:suppl 1–3.
6. Apgar V. A proposal for a new method of evaluation of the newborn infant. *Curr Res Anesth Analg.* 1953;32:260–267.
7. Jain L, Ferre C, Vidyasagar D, Nath S, Sheftel D. Cardiopulmonary resuscitation of apparently stillborn infants: survival and long-term outcome. *J Pediatr.* 1991;118:778–782.
8. Wiswell TE, Gannon CM, Jacob J, et al. Delivery room management of the apparently vigorous meconium-stained neonate: results of the multicenter, international collaborative trial. *Pediatrics.* 2000;105:1–7.
9. Rabi Y, Rabi D, Yee W. Room air resuscitation of the depressed newborn: a systematic review and meta-analysis. *Resuscitation.* 2007;72:353–363.
10. Saugstad OD, Ramji S, Soll RF, Vento M. Resuscitation of newborn infants with 21% or 100% oxygen: an updated systematic review and meta-analysis. *Neonatology.* 2008;94:176–182.
11. Martin R. Prepartum and intrapartum fetal monitoring. In: Datta S, ed. *Anesthetic and Obstetric Management of High-Risk Pregnancy.* 3rd ed. New York, NY: Springer; 2004.
12. Yeomans ER, Hauth JC, Gilstrap LC, 3rd, Strickland DM. Umbilical cord pH, PCO₂, and bicarbonate following uncomplicated term vaginal deliveries. *Am J Obstet Gynecol.* 1985;151:798–800.