CHAPTER 32: The Newborn

Normally the newly born child begins to cry almost immediately after its exit from the vulva. This act indicates the establishment of respiration, which is accompanied by important modifications in the circulatory system.

—J. Whitridge Williams (1903)

INTRODUCTION

In most instances at delivery, the newborn is healthy and vigorous, but at times, special care may be needed. For this reason, the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists (2017b) recommend that every birth should be attended by at least one qualified individual. This person should be skilled in the initial steps of newborn care and positive-pressure ventilation, and their only responsibility is management of the newborn. This usually is a pediatrician, nurse practitioner, anesthesiologist, nurse anesthetist, or specially trained nurse. However, in their absence, the responsibility for neonatal resuscitation falls to the obstetrical attendant. Thus, obstetricians should be well versed in measures for immediate care of the newborn.

The number and qualifications of personnel who attend the delivery will vary depending on the anticipated risk, the number of babies, and the hospital setting. A qualified team with full resuscitation skills should be present for high-risk deliveries and immediately available for every resuscitation (Wyckoff, 2015). This team should not be on call at home or in a remote area of the hospital. Moreover, team training through frequent simulation practice is recommended for all who may be called to attend deliveries (Perlman, 2015).

TRANSITION TO AIR BREATHING

Immediately following birth, the newborn must promptly convert from placental to pulmonary gas exchange. Pulmonary vascular resistance must fall, pulmonary perfusion must rapidly rise, and unique fetal vascular shunts must begin to close to separate the systemic and pulmonary circulations (Rudolph, 1979). These shunts include the patent ductus arteriosus and patent foramen ovale, described in Chapter 7 (Cardiovascular System). Lung aeration is not only critical for pulmonary gas exchange. Recent studies suggest that it is significantly responsible for initiating cardiovascular changes at birth (Hooper, 2016).

In utero, the fetal lungs are filled with amnionic fluid, which must be cleared quickly for air breathing. This clearance occurs through various means, and the contributions of these mechanisms may depend on gestational age and mode of delivery. First, a large release of fetal adrenaline late in labor stimulates pulmonary epithelial cells to stop secreting and instead to start reabsorbing lung liquid as a result of sodium-channel activation (te Pas, 2008). The contribution of this mechanism is unlikely to be major, as blockade of the receptors for sodium channel activation reduces or delays but does not prevent lung liquid clearance at birth (O'Brodovich, 1990).

As a second method, mechanical forces aid lung fluid clearance during labor. Early reports described compression of the fetal thorax and abdomen as they passed through the birth canal leading to lung liquid expulsion (Karlberg, 1962; Saunders, 1978). By this mechanism, up to a third of lung liquid is expelled in a jet of fluid from the nose and mouth once the respiratory tract is exposed to the lower outside pressure. However, it may be that uterine contractions force a change in fetal posture leading to compression of the thorax and increased intrathoracic pressures. This prompts expulsion of lung liquid early in labor more so than the "vaginal squeeze" theory (Lines, 1997; te Pas, 2008; Vyas, 1981).

In a third mechanism, a significant amount of lung liquid is cleared after birth (Hooper, 2016). In animal studies, most lung aeration occurs during inspiration—within three to five breaths after birth. But, no liquid clears between breaths (Hooper, 2007). Specifically, the transpulmonary pressure gradient during inspiration promotes movement of fluid into the interstitial tissue. From here, it is gradually cleared, probably by the pulmonary circulation and lymphatic vessls. It is possible for lung interstitial tissue pressure to rise to a point that fluid can actually move back into the airspaces during expiration unless positive end-expiratory pressure opposes liquid reentry (Siew, 2009a,b). This may be a contributing factor in the development

of *transient tachypnea of the newborn.*

As fluid is replaced by air, compression of the pulmonary vasculature is reduced considerably, and in turn, resistance to blood flow is lowered. With the fall in pulmonary arterial blood pressure, the ductus arteriosus normally closes.

High, negative intrathoracic pressures are required to permit the initial entry of air into the fluid-filled alveoli. Normally, from the first breath after birth, progressively more residual air accumulates in the lung. And, with each successive breath, lower pulmonary opening pressure is required. In the normal mature newborn, by approximately the fifth breath, pressure-volume changes achieved with each respiration are very similar to those of the adult. Thus, the breathing pattern shifts from shallow episodic inspirations characteristic of the fetus to regular, deeper inhalations (Chap. 17, Fetal Breathing).

As a last mechanism, surfactant, which is synthesized by the type II pneumocytes, lowers alveolar surface tension and helps maintain lung inflation by preventing alveolar collapse. Insufficient surfactant, which is common in preterm neonates, leads promptly to respiratory distress syndrome (Chap. 34, Respiratory Distress Syndrome).

In utero, umbilical venous return is the main source of preload for the left ventricle, particularly as fetal pulmonary blood flow is very low due to high pulmonary vascular resistance and is unable to provide sufficient venous return to maintain left ventricular output (Hooper, 2015).

Clamping the umbilical cord reduces preload for the left ventricle and thus reduces cardiac output. Until the lungs aerate and pulmonary blood flow increases, the reduced cardiac output will manifest as bradycardia. If cord clamping is delayed until after the lungs have aerated, the transition is smoother and cardiac ouput does not fall (Bhatt, 2013). This understanding has led to interest in delayed (physiological) cord clamping, especially if it can be done after successful inflation of the lung. Randomized trials are currently underway.

CARE IN THE DELIVERY ROOM

The International Liaison Committee on Resuscitation (ILCOR) updated its scientific review for neonatal delivery room care and resuscitation (Perlman, 2015). The ILCOR scientific review is used by the American Academy of Pediatrics and the American Heart Association to develop the neonatal resuscitation guidelines for North America (Wyckoff, 2015).

Immediate Care

Before and during delivery, careful consideration must be given to several determinants of neonatal well-being. These include: (1) maternal health status; (2) prenatal complications, including any suspected fetal malformations; (3) gestational age; (4) labor complications; (5) duration of labor and ruptured membranes; (6) type and duration of anesthesia; (7) difficulty of delivery; and (8) medications given during labor and their dosages, administration routes, and timing.

When risk factors are present, neonatal resuscitation providers should be present for the delivery. This team readies equipment, ensures that adequate personnel are present, delegates roles and responsibilities, and considers contingency plans to stabilize the newborn. Four questions a neonatal provider will ask pertain to expected gestional age, amnionic fluid color, fetal number, and additional fetal risks. Several conditions are associated with a nonvigorous presentation. These may include immaturity, hypoxemia or acidosis from any cause, sepsis syndrome, recent drugs administered to the mother, and central nervous system developmental abnormalities. Those related to the respiratory tract are lung abnormalities, upper airway obstruction, pneumothorax, and meconium aspiration.

Umbilical Cord Clamping

Ideally, obstetrical and pediatric teams discuss plans regarding umbilical cord management. Delayed cord clamping provides transfusion of placental blood to the newborn. In term infants, delay of cord clamping by 30 to 60 seconds raises hemoglobin levels at birth, improves iron stores during infancy, and enhances neurodevelopment at 4 years of age (Katheria, 2017). As discussed in Chapter 33 (Neonatal Abstinence Syndrome), the only reported negative outcome of delayed cord clamping is hyperbilirubinemia, leading to a higher rate of phototherapy (American College of Obstetricians and Gynecologists, 2017a). In preterm neonates, delayed cord clamping reduces rates of blood transfusion, intraventricular hemorrhage, and necrotizing enterocolitis.

Delayed cord clamping should be performed in preterm and term newborns who do not require resuscitation at birth (American Academy of Pediatrics, 2017a; American College of Obstetricians and Gynecologists, 2017a; Perlman, 2015). There should be no delay if a newborn requires resuscitation or if the placental circulation is disrupted by abruption, cord avulsion, or bleeding placenta previa or vasa previa.

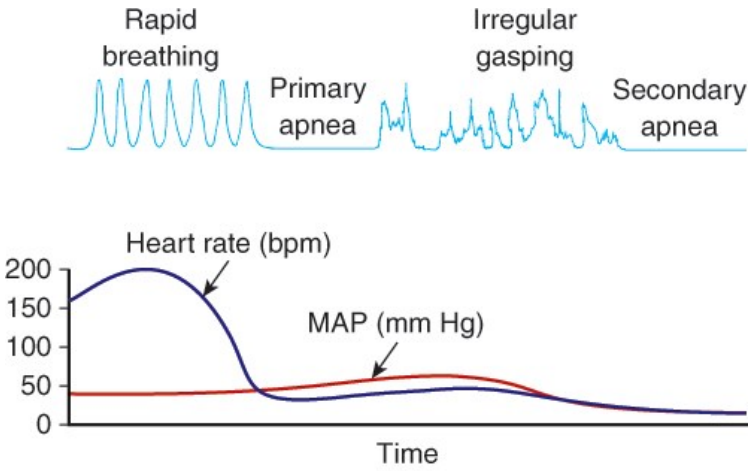
Newborn Resuscitation

Approximately 10 percent of newborns require some degree of active resuscitation to stimulate breathing, and 1 percent need extensive care. Perhaps not coincidentally, the risk of death for newborns delivered at home compared with those delivered in hospitals is increased two- to threefold (American College of Obstetricians and Gynecologists, 2017d).

When deprived of adequate gas exchange, either before or after birth, neonates demonstrate a well-defined sequence of events leading to apnea (Fig. 32-1). With oxygen deprivation and carbon dioxide (CO_2) elevation, there is a transient period of rapid breathing, and if it persists, breathing stops, which is termed *primary apnea.* This stage is accompanied by a fall in heart rate and loss of neuromuscular tone. Simple stimulation will usually reverse primary apnea. If oxygen deprivation and asphyxia persist, however, the newborn will develop deep gasping respirations, followed by *secondary apnea.* This latter stage is associated with a further decline in heart rate, fall in blood pressure, and loss of neuromuscular tone. Neonates in secondary apnea will not respond to stimulation and will not spontaneously resume respiratory efforts. Unless ventilation is assisted, death follows.

FIGURE 32-1

Physiological changes associated with primary and secondary apnea in the newborn. bpm = beats per minute; HR = heart rate; MAP = mean arterial pressure. (Adapted with permission from Kattwinkel J: Textbook of Neonatal Resuscitation, 6th ed. Elk Grove Village, American Academy of Pediatrics and American Heart Association, 2010.)



Source: F. Gary Cunningham, Kenneth J. Leveno, Steven L. Bloom, Catherine Y. Spong, Jodi S. Dashe, Barbara L. Hoffman, Brian M. Casey, Jeanne S. Sheffield: *Williams Obstetrics*, 25th Edition

Clinically, primary and secondary apneas are indistinguishable, and thus, secondary apnea must be assumed. And, when a response to stimulation is not immediate, resuscitation with effective ventilation of the apneic newborn must be started quickly.

Resuscitation Protocol

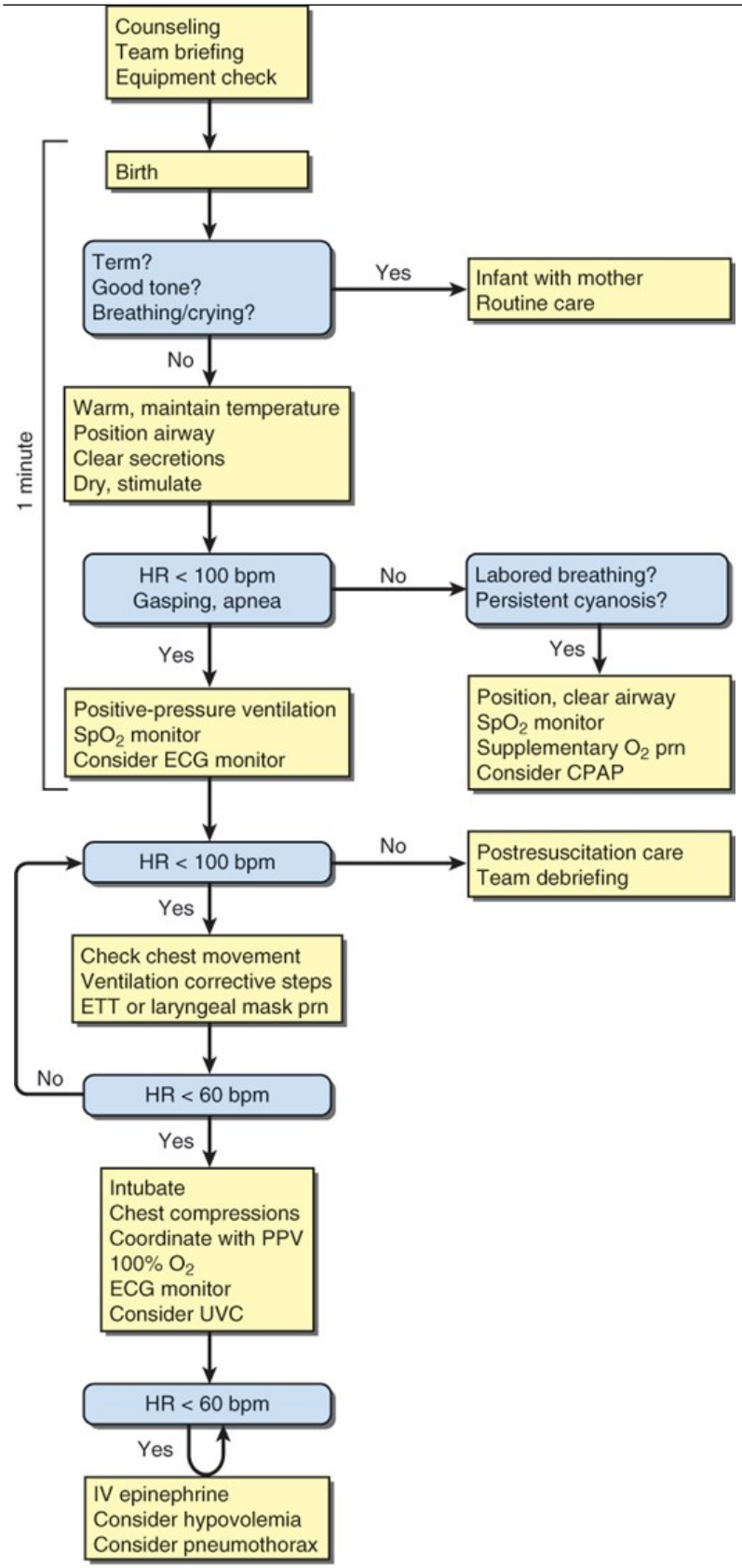
Initial Assessment

Immediately after birth and usually during the delay for umbilical cord clamping, newborn tone, respiratory effort, and heart rate are evaluated (Fig. 32-2). Most term neonates are vigorous by 10 to 30 seconds after birth (Ersdal, 2012). For these, initial steps of warming the newborn can be done on the mother's chest or abdomen. Direct skin-to-skin contact with the mother and drying and covering the newborn with a warm blanket will help maintain euthermia (36.5 to 37.5°C). A vigorously crying newborn does not require routine oral suctioning (Carrasco, 1997; Gungor, 2006). Instead, bulb suctioning to remove secretions is best reserved for those who cannot clear secretions on their own due to apnea or copious secretions. Additional routine care steps include drying, gentle stimulation by rubbing the newborn's back, and continued observation during the transition

period.

FIGURE 32-2

Algorithm for resuscitation of the newborn based on the International Liaison Committee on Resuscitation scientific review and recommended by the American Academy of Pediatrics and American Heart Association (Perlman, 2015; Wyckoff, 2015). bpm = beats per minute; CPAP = continuous positive airway pressure; ECG = electrocardiogram; ETT = endotracheal tube; HR = heart rate; IV = intravenous; PPV = positive-pressure ventilation; SpO_2= peripheral oxygen saturation; UVC = umbilical venous catheter.



Source: F. Gary Cunningham, Kenneth J. Leveno, Steven L. Bloom, Catherine Y. Spong, Jodi S. Dashe, Barbara L. Hoffman, Brian M. Casey, Jeanne S. Sheffield: *Williams Obstetrics*, 25th Edition

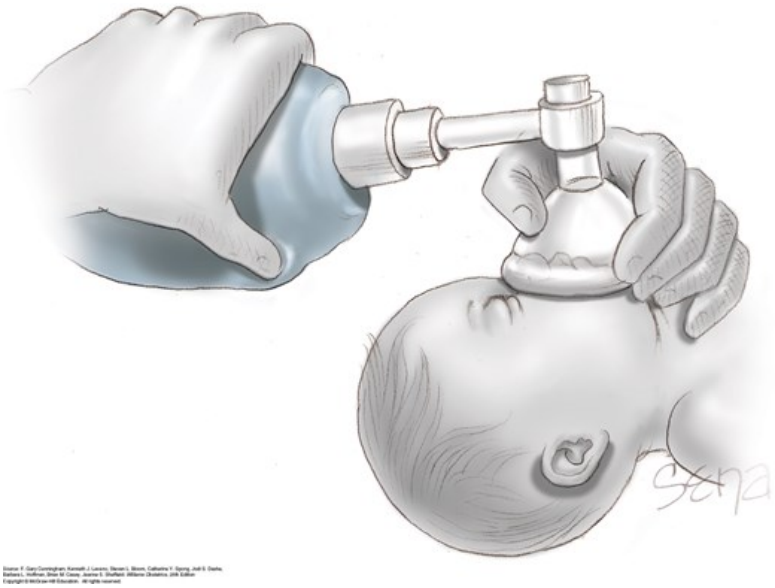
If not vigorous or if preterm, the neonate is carried to a prewarmed radiant warmer for the initial newborn care steps. The initial wet birth blanket is removed to allow newborn drying. Cold stress is associated with multiple neonatal morbidities and mortality. Preterm infants are particularly vulnerable, and special steps to maintain euthermia include providing a warmer delivery room (>25°C), covering the neonatal head with either a plastic or wool hat, application of polyethylene plastic "ponchos" or wraps to slow evaporative heat losses, use of chemically activated thermal mattresses to reduce conductive heat loss, and administration of warm, humidified respiratory gases during respiratory stabilization (Perlman, 2015).

At the radiant warmer, newborns must be positioned to maximally open the airway, with mild extension of the neck. If the newborn is apneic or has copious secretions that it cannot clear, a bulb syringe or suction catheter may be used to clear the mouth and then the nose. Routine intubation and suctioning of meconium-stained amnionic fluid is no longer recommended for the nonvigorous newborn (American College of Obstetricians and Gynecologists, 2017b; Perlman, 2015). Intubation and suction are reserved for suspected airway obstruction.

After completion of the initial stabilization steps, apnea, gasping respirations, or heart rate ≤100 beats per minute (bpm) should prompt immediate administration of positive-pressure ventilation with room air (Fig. 32-3). This should be started by 60 seconds of life, if not sooner, once the initial steps are completed.

FIGURE 32-3

Correct use of bag-and-mask ventilation. The head should be in a sniffing position with the tip of the nose pointing to the ceiling. The neck should not be hyperextended.



Mask Ventilation

Assisted ventilation by facemask at a rate of 40 to 60 breaths per minute is recommended. Oxygen saturation is monitored by pulse oximetry. Supplemental oxygen can be given in graduated, rising percentages to maintain oxygen saturation values within a normal range per minute of life. Adequate ventilation is best indicated by an improved heart rate. Colorimetric end-tidal carbon dioxide ($ETCO_2$) monitoring placed between the positive-pressure device and facemask serves as a helpful adjunct for detection of successful gas exchange during mask ventilation (Weiner, 2016).

If the heart rate remains ≤100 bpm after 5 to 10 positive pressure breaths, the attempted ventilation is inadequate and corrective steps must be taken. These can be remembered by the mnemonic MR. SOPA (Table 32-1). The two most common problems are mask leak due to an ineffective seal and malposition of the airway (Schmolzer, 2011). If corrective steps do not improve the heart rate, either intubation with an endotracheal tube or placement of a laryngeal mask airway is required.

TABLE 32-1

Ventilation Corrective Steps (MR. SOPA)

M—Mask adjustment	Check the seal of the mask and reapply if needed.
R—Reposition airway	Make sure the newborn is truly in the open airway (mild extension) position.
S—Suction mouth and nose	Remove obstructing secretions.
O—Open the mouth	In an effort to achieve a good seal, providers sometimes accidentally close the mouth. The higher resistance of the narrow-diameter nasal passages will limit effective ventilation.
P—Pressure increase	Try increasing the inflation pressure.
A—Advanced airway	If all prior steps fail to achieve chest rise, intubate or place a laryngeal mask.

Data from Weiner, 2016.

Alternative Airway

If mask ventilation is ineffective or prolonged, an alternative airway is placed. For tracheal intubation, a laryngoscope with a straight blade—size 0 for a preterm newborn and size 1 for a term neonate—is used. Gentle cricoid pressure may be useful. An increasing heart rate and $ETCO_2$ detection after several breaths are the primary methods of confirming intubation of the trachea and not the esophagus. One can also look for symmetrical chest wall motion; auscultate for equal breath sounds, especially in the axillae; and auscultate for the absence of breath sounds or gurgling over the stomach.

Once in place, the tube is used for tracheal suctioning only for a suspected obstructed airway. Otherwise, an appropriate positive-pressure device is attached to the endotracheal tube. Air puffs are delivered at a rate of 40 to 60 per minute with a force adequate to stabilize the heart rate. In term infants, opening pressures of 30 to 40 cm H_2O typically will expand the alveoli without causing barotrauma. Once the lung is inflated, less pressure is typically needed (20 to 25 cm H_2O). For preterm infants, pressures of 20 to 25 cm H_2O are typically used. An increase in heart rate and peripheral oxygen saturation (SpO_2) levels within acceptable ranges reflect a positive response.

Chest Compressions

Most commonly, effective ventilation is all that is required to stabilize the newborn in the delivery room. If the heart rate remains <60 bpm despite ventilation corrective steps, including placement of tracheal tube, chest compressions are initiated. Once the tracheal tube has been secured, compressions are done from the head of the bed rather than the side so that space is opened up for a provider to have umbilical venous access. When compressions are initiated, the oxygen concentration is increased to 100 percent. With the two-thumb compression method, hands encircle the chest, while the thumbs depress the sternum. Compressions are delivered on the lower third of the sternum at a depth sufficient to generate a palpable pulse. This is typically one third of the anterior-posterior diameter of the chest. Compared with other techniques, this method offers less provider fatigue over time, yields higher generated perfusion pressures, and lessens hand malpositioning that could cause traumatic injury (Kapadia, 2012).

A 3:1 compressions-to-ventilation ratio is recommended, and 90 compressions and 30 breaths achieve approximately 120 events each minute. Coordinated chest compressions and ventilations should continue until the spontaneous heart rate is ≥60 bpm.

Epinephrine

Intravenously administered epinephrine is indicated if the heart rate remains ≤60 bpm after adequate ventilation and chest compressions. The recommended intravenous dose is 0.01 to 0.03 mg/kg. Epinephrine may be given through the endotracheal tube if venous access has not been established, but its action is less reliable (Kapadia, 2017). If given through the endotracheal tube, higher doses are employed—0.05 to 0.1 mg/kg.

Discontinuation of Resuscitation

ILCOR concludes that it is reasonable to discontinue resuscitative efforts for a neonate who remains without a heartbeat despite at least 10 minutes of continuous and adequate resuscitative efforts. Notably, the decision to continue or discontinue resuscitative efforts must be individualized (Perlman, 2015).

EVALUATION OF NEWBORN CONDITION

Apgar Score

The scoring system described by Dr. Virginia Apgar in 1953 remains a useful clinical tool to classify newborn health immediately after birth and to assess the effectiveness of resuscitative measures (American Academy of Pediatrics, 2017). As shown in Table 32-2, each of five easily identifiable characteristics—heart rate, respiratory effort, muscle tone, reflex irritability, and color—is assessed and assigned a value of 0, 1, or 2. In the currently recommended expanded form, concurrent resuscitation interventions are also recorded over time. The total score, based on the sum of the five components, is determined in all neonates at 1 and 5 minutes after delivery. In those with a score <7, the score may be calculated at further 5-minute intervals until a 20-minute Apgar score is assigned or resuscitation efforts are halted.

TABLE 32-2

20-Minute Expanded Apgar Score

Sign	0 point	1 point	2 point	1 min	5 min	10 min	15 min	20 min
Color	Blue or pale	Acrocyanotic	Completely pink					
Heart rate	Absent	<100/min	>100/min					
Reflex irritability	No response	Grimace	Cry or active withdrawal					
Muscle tone	Limp	Some flexion	Active motion					
Respiration	Absent	Weak cry; hypo- ventilation	Good, crying					
			Total					
Comments:			**Resuscitation**					
			Minutes	1	5	10	15	20
			Oxygen					
			PPV/CPAP					
			ETT					
			Chest compressions					
			Epinephrine					

CPAP = continuous positive airway pressure; ETT = endotracheal tube; PPV = positive-pressure ventilation.

Data from Weiner, 2016.

In an analysis of more than 150,000 newborns delivered at Parkland Hospital, Casey and associates (2001b) assessed the significance of the 5-minute score for predicting survival during the first 28 days of life. They found that in term neonates, the risk of neonatal death was approximately 1 in 5000 for those with Apgar scores of 7 to 10. This risk compares with a mortality rate of 25 percent for term newborns with 5-minute scores ≤3. Low 5-minute scores were comparably predictive of neonatal death in preterm neonates. These investigators concluded that the Apgar scoring system remains relevant for the prediction of neonatal survival.

There have been attempts to use Apgar scores to define asphyxial injury and to predict subsequent neurological outcome—uses for which the Apgar score was never intended (Chap. 33, Neuroimaging Studies in Encephalopathy and Cerebral Palsy). Such associations are difficult to measure with reliability given that both asphyxial injury and low Apgar scores are infrequent outcomes. For example, according to United States birth certificate records for 2010, only 1.8 percent of newborns had a 5-minute score below 7 (Martin, 2012). Similarly, in a population-based study of more than 1 million term newborns in Sweden between 1988 and 1997, the incidence of 5-minute Apgar scores of ≤3 approximated 2 per 1000 (Thorngren-Jerneck, 2001).

Previously, many groups established erroneous definitions of asphyxia based solely on low Apgar scores. These prompted the American College of Obstetricians and Gynecologists and American Academy of Pediatrics (2017f) to issue a series of joint opinions with important caveats regarding Apgar score limitations. Certain elements of the Apgar score are partially dependent on the physiological maturity of the newborn, and a healthy, preterm

neonate may receive a low score only because of immaturity. Other influencing factors include fetal malformations, maternal medications, and infection. Therefore, it is inappropriate to use an Apgar score alone to diagnose asphyxia. Moreover, the Apgar score alone cannot establish hypoxia as the cause of cerebral palsy, as discussed in Chapter 33 (Neuroimaging Studies in Encephalopathy and Cerebral Palsy).

Umbilical Cord Blood Acid–Base Studies

Blood taken from umbilical vessels may be used for acid–base studies to assess the metabolic status of the neonate. Blood collection is performed following delivery by immediately isolating a 10- to 20-cm segment of cord with two clamps placed near the neonate and another two clamps positioned nearer the placenta. The cord is then cut between the two proximal clamps and then the two distal clamps (Blickstein, 2007).

Arterial blood is drawn from the isolated cord segment into a 1- to 2-mL commercially prepared plastic syringe containing lyophilized heparin or a similar syringe that has been flushed with a heparin solution containing 1000 U/mL. Once sampling is completed, the needle is capped and the syringe transported, on ice, to the laboratory. Although efforts should be made for prompt transport, neither the pH nor partial pressure of CO_2 (pCO_2) values change significantly in blood kept at room temperature for up to 60 minutes (Lynn, 2007). Mathematical models have been developed that allow reasonable prediction of birth acid–base status in properly collected cord blood samples analyzed as late as 60 hours after delivery (Chauhan, 1994). Acid–base measurements can show significant variances between different analyzing devices (Mokarami, 2012).

Fetal Acid–Base Physiology

The fetus produces both carbonic and organic acids. Carbonic acid (H_2CO_3) is formed by oxidative metabolism of CO_2. The fetus usually rapidly clears CO_2 through the placental circulation. If CO_2 clearance is lowered, then carbonic acid levels rise. This often follows impaired placental exchange. When H_2CO_3 accumulates in fetal blood and organic acids do not concurrently rise, the result is *respiratory acidemia*.

In contrast, organic acids primarily include lactic and β-hydroxybutyric acids. Levels of these increase with persistent placental exchange impairment, and they result from anaerobic glycolysis. These organic acids are cleared slowly from fetal blood. When they accumulate, without a concurrent increase in H_2CO_3, the result is *metabolic acidemia*. With the development of metabolic acidemia, bicarbonate (HCO_3^-) levels drop because it is used to buffer the organic acid. A rise in H_2CO_3 concentrations accompanied by greater organic acid levels, reflected by decreased HCO_3^- levels, causes *mixed respiratory-metabolic acidemia*.

In the fetus, respiratory and metabolic acidemia and ultimately tissue acidosis are most likely part of a progressively worsening continuum. This is different from adult pathophysiology, in which distinct conditions result either in respiratory acidosis—for example, pulmonary disease, or in metabolic acidosis—for example, diabetes. In the fetus, the placenta serves as both the lungs and, to a certain degree, the kidneys. One principal cause of fetal acidemia is a drop in uteroplacental perfusion. This creates retention of CO_2, that is, respiratory acidemia, and if protracted and severe enough, yields a mixed or metabolic acidemia.

Assuming that maternal pH and blood gases are normal, the actual pH of fetal blood is dependent on the proportion of carbonic and organic acids and the amount of bicarbonate, which is the major buffer in blood. This can best be illustrated by the Henderson–Hasselbalch equation:

$$\mathrm{pH} = \mathrm{pK} + \log\frac{[\mathrm{base}]}{[\mathrm{acid}]} \text{ or, } \mathrm{pH} = \mathrm{pK} + \log\frac{\mathrm{HCO_3^-}}{\mathrm{H_2CO_3}}$$

For clinical purposes, HCO_3^- represents the metabolic component and is reported in mEq/L. The H_2CO_3 concentration reflects the respiratory component and is reported as the pCO_2 in mm Hg. Thus:

$$\mathrm{pH} = \mathrm{pK} + \log\frac{\text{metabolic } (\mathrm{HCO_3^-} \text{ mEq/L})}{\text{respiratory } (\mathrm{Pco_2} \text{ mm Hg})}$$

The result of this equation is a pH value. Because pH is a logarithmic term, it does not give a linear measure of acid accumulation. For example, a change in hydrogen ion concentration associated with a fall in pH from 7.0 to 6.9 is almost twice that which is associated with a fall in pH from 7.3 to 7.2. For this reason, the change in base—termed delta base— offers a more linear measure of the degree of accumulation of metabolic acid (Armstrong, 2007). The delta base is a calculated number used as a measure of the change in buffering capacity of bicarbonate (HCO_3^-). The formula for calculating

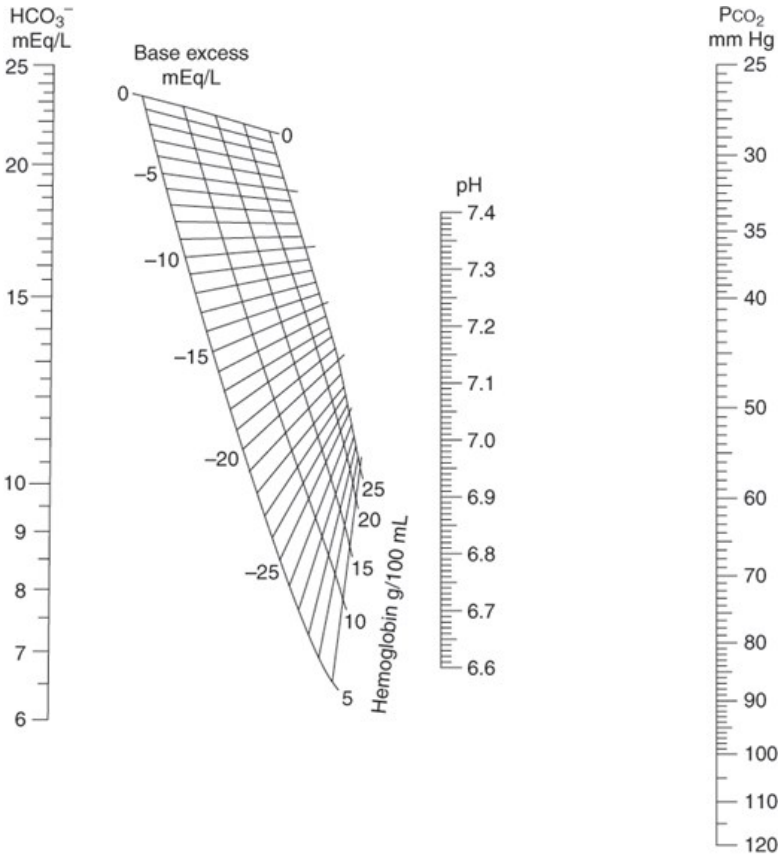
the base excess (BE) is as follows:

$$BE = 0.02786 \times pCO_2 \times 10^{(pH-6.1)} \times 13.77 \times pH - 124.58$$

Shown in Figure 32-4 is a nomogram developed from which these can be calculated if only two parameters are known. For example, the HCO_3^- concentration declines with a metabolic acidemia as it is consumed to maintain a normal pH. A base deficit develops when the HCO_3^- concentration drops below normal levels, and a base excess occurs when HCO_3^- values are above normal. Importantly, a mixed respiratory–metabolic acidemia with a large base deficit and a low HCO_3^-, for example 12 mmol/L, is more often associated with a depressed neonate than is a mixed acidemia with a minimal base deficit and a more nearly normal HCO_3^- level.

FIGURE 32-4

Nomogram for determining the delta base. (Adapted with permission from Siggaard- Anderson O: Blood acid–base alignment nomogram, Scand J Clin Lab Invest. 1963;15:211–7.)



Clinical Significance of Acidemia

Fetal oxygenation and pH generally decline during the course of normal labor. Normal umbilical cord blood pH and blood gas values at delivery in term newborns are summarized in Table 32-3. Similar values have been reported for preterm neonates (Dickinson, 1992; Ramin, 1989; Riley, 1993). The lower limits of normal pH in the newborn have been found to range from 7.04 to 7.10 (Thorp, 1996). Thus, these values should be considered to define neonatal acidemia. Even so, most fetuses will tolerate intrapartum acidemia with a pH as low as 7.00 without incurring neurological impairment (Freeman, 1988; Gilstrap, 1989). That said, in a study of newborns with a pH <7.0 from Parkland Hospital, there were inordinate proportions of neonatal deaths—8 percent, intensive care admissions—39 percent, intubations—14 percent, and seizures—13 percent (Goldaber, 1991). And, in a

study from Oxford of more than 51,000 term newborns, the incidence of neonatal encephalopathy in those with a birth pH <7.0 was 3 percent (Yeh, 2012). Even those with who had normal 5-minute Apgar scores but an arterial cord pH values <7.0 had a significantly higher risk of morbidity that included respiratory distress, neonatal intensive care unit admission, and sepsis (Sabol, 2016). The speed of acidemia resolution after birth is associated with outcome (Casey, 2001a).

TABLE 32-3

Umbilical Cord Blood pH and Blood Gas Values in Normal Term Newborns

Values	Ramin, 1989[a] Spontaneous Delivery n = 1292[c]	Riley, 1993[b] Spontaneous Delivery n = 3522[c]	Kotaska, 2010[b] Spontaneous Delivery n = 303[d]	Kotaska, 2010[e] Cesarean Delivery n = 189[d]
Arterial Blood				
pH	7.28 (0.07)	7.27 (0.069)	7.26 (7.01–7.39)	7.3 (7.05–7.39)
P_{CO_2} (mm Hg)	49.9 (14.2)	50.3 (11.1)	51 (30.9–85.8)	54 (37.5–79.5)
HCO_3^- (mEq/L)	23.1 (2.8)	22.0 (3.6)	—	—
Base excess (mEq/L)	−3.6 (2.8)	−2.7 (2.8)	—	—
Venous Blood				
pH	—	7.34 (0.063)	7.31 (7.06–7.44)	7.34 (7.10–7.42)
P_{CO_2} (mm Hg)	—	40.7 (7.9)	41 (24.9–70.9)	44 (29.1–70.2)
HCO_3^- (mEq/L)	—	21.4 (2.5)	—	—
Base excess (mEq/L)	—	−2.4 (2)	—	—

[a]Newborns of selected women with uncomplicated vaginal deliveries.

[b]Newborns of unselected women with vaginal deliveries.

[c]Data shown as mean (SD).

[d]Data shown as range with 2.5 or 97.5 percentile.

[e]Cesarean delivery—labor not stated.

From Centers for Disease Control and Prevention, 2012; Watson, 2006.

Respiratory Acidemia

Acute interruption in placental gas exchange is accompanied by subsequent CO_2 retention and respiratory acidemia. The most common antecedent factor is transient umbilical cord compression. Generally, respiratory acidemia is not harmful to the fetus (Low, 1994).

The degree to which pH is affected by pCO_2—the respiratory component of the acidosis—can be calculated. First, the upper normal neonatal pCO_2 of about 50 mm Hg is subtracted from the cord blood gas pCO_2 value. Each additional 10 mm Hg pCO_2 increment will lower the pH by 0.08 units (Eisenberg, 1987). Thus, in a mixed respiratory–metabolic acidemia, the benign respiratory component can be calculated. As an example, acute cord prolapse during labor prompts cesarean delivery of a neonate 20 minutes later. The umbilical artery blood gas pH was 6.95 and the pCO_2 was 90 mm Hg. The degree to which the cord compression and subsequent impairment of CO_2 exchange affected the pH is calculated using the relationship given earlier and shown below.

$$90 \text{ mm Hg} - 50 \text{ mm Hg} = 40 \text{ mm Hg excess } CO_2$$

$$\text{To correct pH: } (40 \div 10) \times 0.08 = 0.32;\ 6.95 + 0.32 = 7.27$$

Therefore, the pH before cord prolapse was approximately 7.27, well within normal limits. Thus, the low pH resulted from respiratory acidosis.

Metabolic Acidemia

The fetus begins to develop metabolic acidemia when oxygen deprivation is sufficiently long and severe to require anaerobic metabolism for cellular energy needs. Low and associates (1997) defined fetal acidosis as a base deficit ≥12 mmol/L, and severe fetal acidosis as a base deficit ≥16 mmol/L. In the Parkland study of more than 150,000 newborns cited earlier, metabolic acidemia was defined using umbilical cord blood gas thresholds that were two standard deviations below the mean (Casey, 2001b). Thus, metabolic acidemia was an umbilical artery blood pH <7.00 accompanied by a pCO_2 ≤76.3 mm Hg, with higher values indicating a respiratory component; HCO_3^- concentration ≤17.7 mmol/L; and base deficit ≥10.3 mEq/L. From the standpoint of *possible* neurological injury, the American College of Obstetricians and Gynecologists (2014) defines metabolic acidosis as umbilical arterial pH <7.0 and a base deficit ≥12 mmol/L.

Metabolic acidemia is associated with a high rate of multiorgan dysfunction. In rare cases, such hypoxia-induced metabolic acidemia may be so severe that it causes subsequent neurological impairment—*hypoxic-ischemic encephalopathy* (Chap. 33, Neonatal Encephalopathy). In fact, a fetus without such acidemia cannot by definition have suffered recent hypoxic-induced injury. That said, severe metabolic acidosis is poorly predictive of subsequent neurological impairment in the term neonate (King, 1998; Socol, 1994). In very-low-birthweight neonates, that is, those <1000 g, newborn acid–base status may be more closely linked to intraventricular hemorrhage and possibly long-term neurological outcome (Lavrijsen, 2005; Salhab, 2005; Victory, 2003).

Casey and coworkers (2001b) described the association between metabolic acidemia, low Apgar scores, and neonatal death in term and preterm newborns. Regarding term neonates, the risk of neonatal death was more than 3200-fold greater in term neonates with metabolic acidemia and 5-minute scores ≤3 compared with those with a 5-minute Apgar score ≥7.

Recommendations for Cord Blood Gas Determinations

In some centers, cord gas analysis is performed in all neonates at birth (Casey, 2001b; Sabol, 2016). Cost-effectiveness analysis for universal cord blood gas measurements suggest benefit and potential cost savings (White, 2010, 2016). It seems reasonable to obtain cord blood gas determinations for intrapartum cases of cesarean delivery for fetal compromise, abnormal fetal heart rate tracing, fever, and low 5-minute Apgar score. Multifetal gestation and severely growth-restricted fetuses are others.

Although umbilical cord acid–base blood determinations are poorly predictive of either immediate or long-term adverse neurological outcome, they provide the most objective evidence of the fetal metabolic status at birth.

PREVENTIVE CARE

Eye Infection Prophylaxis

Ophthalmia neonatorum is mucopurulent conjunctivitis of newborns. Some form of conjunctivitis affects 1 to 12 percent of all neonates, and gonococcal and chlamydial infections are among the most common (Zuppa, 2011).

Neisseria gonorrhoeae infection acquired at birth was a common cause of childhood blindness in the past. However, the practice of instilling a 1-percent ophthalmic solution of silver nitrate largely eliminated this. Various other antimicrobial agents have also proven effective, and gonococcal prophylaxis is now mandatory for all neonates in most states (American Academy of Pediatrics, 2017b). For *prophylaxis* soon after delivery, recommendations include a single application of either 1-percent silver nitrate solution or 0.5-percent erythromycin ointment. In North America, a previously used 1-percent tetracycline ophthalmic ointment is no longer available (Mabry-Hernandez, 2010; Moore, 2015).

For a neonate born to a mother with untreated gonorrhea, *treatment* of presumptive neonatal gonococcal conjunctivitis is a single ceftriaxone dose, 100 mg/kg, given either intramuscularly or intravenously. Before treatment, testing for both gonococcal and chlamydia infections should be obtained.

With *chlamydial conjunctivitis,* adequate neonatal prophylaxis is complex. Ideally, prenatal screening and treatment for *Chlamydia trachomatis* obviates conjunctival infection (Hammerschlag, 2011). In neonates delivered vaginally of mothers with an active chlamydial infection, 12 to 25 percent will develop conjunctivitis up to 20 weeks after birth (Teoh, 2003). *Prophylactic topical eye treatments do not reliably reduce the incidence of chlamydial conjunctivitis.* In a study from Kenya, 2.5-percent povidone-iodine solution was reported to be superior to either 1-percent silver nitrate solution or 0.5-percent erythromycin ointment in preventing chlamydial conjunctivitis (Isenberg, 1995). In another study from Iran, povidone-iodine eye drops were twice as effective in preventing clinical conjunctivitis as erythromycin drops—9 versus 18 percent failure rate, respectively (Ali, 2007).

Conjunctivitis in a newborn up to age 3 months should prompt consideration for chlamydial infection (Moore, 2015). Treatment for pediatric chlamydial infection is with oral azithromycin for 5 days or oral erythromycin for 14 days.

Hepatitis B Immunization

Routine immunization with thimerosal-free vaccine against hepatitis B before hospital discharge is standard practice for all medically stable newborns with birthweights greater than 2000 g (American Academy of Pediatrics, 2017b). If the mother is seropositive for hepatitis B surface antigen, then the neonate is also passively immunized with hepatitis B immune globulin. As discussed in Chapter 55 (Pregnancy and Hepatitis B), some advocate treatment of high-risk or even all seropositive women with antiviral nucleoside or nucleotide analogues during pregnancy to minimize fetal transmission (Dusheiko, 2012; Tran, 2012).

Zika Virus

This virus is primarily spread by mosquito bites. Infection is asymptomatic in most people but can cause severe birth defects (Chap. 64, Coronavirus Infections). Screening begins with an interrogation for recent travel to endemic areas. For women at risk, serological screening is then completed. All newborns of mothers who have laboratory evidence of Zika virus infection during pregnancy should receive a comprehensive examination, a neurological assessment, postnatal head ultrasound, standard newborn hearing screen before hospital discharge, and Zika virus laboratory testing (Reynolds, 2017).

Vitamin K

Supplemental vitamin K injection will prevent vitamin K-dependent hemorrhagic disease of the newborn (Chap. 33, Polycythemia and Hyperviscosity). A single intramuscular dose of vitamin K, 0.5 to 1 mg, is given within 1 hour of birth (American Academy of Pediatrics, 2017b).

Newborn Screening

Numerous mass-screening tests are now available for 29 newborn conditions. Shown in Table 32-4, many are mandated by various state laws (American College of Obstetricians and Gynecologists, 2017c). Most states require that all tests in the core panel be performed. Supplemental conditions—*secondary targets*—are also listed on the Maternal and Child Health Bureau website. Some states require some of these in addition to their mandated core panel. Each practitioner should be familiar with their individual state requirements, which are available at http://genes-r-us.uthscsa.edu/resources/consumer/statemap.htm.

TABLE 32-4

Newborn Screening Core Panel

Acylcarnitine Disorders[a]				
Organic Acid Metabolism	**Fatty Acid Metabolism**	**Amino Acid Metabolism[a]**	**Hemoglobin Disorders**	**Others**
Isovaleric Glutaric type I 3-Hydroxy-3-methylglutaric Multiple carboxylase Methylmalonic mutase 3-Methylcrotonyl-CoA carboxylase Methylmalonic acid (cobalamin A, B) Propionic β-Ketothiolase	Medium-chain acyl-CoA dehydrogenase Very long-chain acyl-CoA dehydrogenase Long-chain 3-OH acyl-CoA dehydrogenase Trifunctional protein Carnitine uptake	Phenylketonuria Maple syrup (urine) Homocystinuria Citrullinemia Arginosuccinic Tyrosinemia I	SS disease S-β-thalassemia SC disease	Congenital hypothyroidism Biotinidase Congenital adrenal hyperplasia Galactosemia Hearing loss Cystic fibrosis Critical congenital heart disease[b] Severe combined immunodeficiency[b]

[a]Determined by tandem mass spectrometry.

[b]Added after 2006.

From Centers for Disease Control and Prevention, 2012; Watson, 2006.

ROUTINE NEWBORN CARE

Gestational-Age Estimation

Newborn gestational age can be estimated very soon after delivery. The relationship between gestational age and birthweight can identify neonates at risk for complications. For example, neonates who are either small or large for gestational age are at greater risk for hypoglycemia and polycythemia, and measurements of blood glucose and hematocrit are indicated.

Care of Skin and Umbilical Cord

All excess vernix, blood, and meconium is gently wiped off after delivery while keeping the newborn warm. Any remaining vernix is readily absorbed and disappears within 24 hours. The first bath is postponed until the neonate's temperature is stable.

Aseptic precautions are observed in the immediate care of the cord. The American Academy of Pediatrics has concluded that keeping the cord dry is sufficient care (Stewart, 2016). The umbilical cord begins to lose water from Wharton jelly shortly after birth. Within 24 hours, the cord stump loses its characteristic bluish-white, moist appearance and soon becomes dry and black. Within several days to weeks, the stump sloughs and leaves a small, granulating wound, which after healing forms the umbilicus. Separation usually takes place within the first 2 weeks. The range is 3 to 45 days (Novack, 1988). The umbilical cord dries more quickly and separates more readily when exposed to air. Thus, a dressing is not recommended.

In resource-poor countries, local antimicrobial prophylaxis is reasonable (Salam, 2014). Triple-dye applied to the cord was reported to be superior to soap and water care in preventing colonization and exudate formation (Janssen, 2003). In a Nepalese study, cleaning the cord stump with 4-percent chlorhexidine reduced severe infection by 75 percent compared with soap and water (Mullany, 2006). Likewise, 0.1-percent chlorhexidine powder was superior to dry cord care (Kapellen, 2009). The World Health Organization (2014) recommends cleansing with chlorhexidine.

Despite precautions, a serious umbilical infection—*omphalitis*—sometimes develops. In a German study of more than 750 newborns with aseptic cord care, 1.3 percent suffered such infections (Kapellen, 2009). The most likely offending organisms are *Staphylococcus aureus, Escherichia coli,* and group B streptococcus. Typical signs of cellulitis and stump discharge usually aid diagnosis. Mild erythema and some bleeding at the stump site with cord detachment is also common, but some cases present with no outward signs.

Feeding and Weight Loss

In 2016, 81 percent of U.S. newborns were initially breastfed, 52 percent were still breastfed at 6 months, and 31 percent at 1 year (Centers for Disease Control and Prevention, 2016). According to the American College of Obstetricians and Gynecologists (2017e), exclusive breastfeeding is preferred until 6 months. In many hospitals, breastfeeding begins in the delivery room. Most term newborns thrive best when fed 8 to 12 times daily for approximately 15 minutes each episode. Preterm or growth-restricted newborns require feedings at shorter intervals. Breastfeeding is discussed further in Chapter 36 (Lactation And Breastfeeding).

Because most neonates actually receive little nutriment for the first 3 or 4 days of life, they progressively lose weight until the flow of maternal milk is established or other feeding is instituted. Preterm neonates lose relatively more weight and regain their birthweight more slowly. Conversely, growth-restricted but otherwise healthy newborns regain their initial weight more quickly than those born preterm. With proper nourishment, birthweight of term newborns usually is regained by 10 days.

Stools and Urine

For the first 2 or 3 days after birth, the colon contains soft, brown-green meconium. This consists of desquamated epithelial cells from the intestinal tract, mucus, epidermal cells, and lanugo (fetal hair) that have been swallowed along with amnionic fluid. The characteristic color results from bile pigments. During fetal life and for a few hours after birth, the intestinal contents are sterile, but bacteria quickly colonize the bowel contents.

Meconium stooling is seen in 90 percent of newborns within the first 24 hours, and most of the rest within 36 hours. Usually, newborns first void shortly after birth but may not until the second day. Meconium and urine passage indicates patency of the gastrointestinal and urinary tracts, respectively. Failure of the newborn to stool or urinate after these times suggests a congenital defect, such as Hirschsprung disease, imperforate anus, or posterior urethral valve. After the third or fourth day, as a result of milk ingestion, meconium is replaced by light-yellow, softer, homogenous feces.

Neonatal Hyperbilirubinemia

Between the second and fifth day of life approximately one third of all neonates develop physiological jaundice of the newborn. It has special significance considering most hospitals have policies for early discharge. Guidelines regarding standard phototherapy equipment and monitoring, as well as treatment recommendations per gestational age, hour of life, and risk factors are used (Bhutani, 2011; Maisels, 2009). Hyperbilirubinemia is discussed further in Chapter 33 (Polycythemia and Hyperviscosity).

Male Circumcision

Indications

Neonatal circumcision of male infants has been a controversial topic in the United States for at least 30 years. Even so, scientific evidence supports several medical benefits that include prevention of phimosis, paraphimosis, and balanoposthitis. Circumcision also lowers the incidence of penile cancer and of cervical cancer among their sexual partners. Previously, the American Academy of Pediatrics Task Force on Circumcision (1999) concluded that existing evidence was insufficient to recommend *routine* neonatal circumcision. It seems that this policy has had only a negligible effect on practices in this country. Specifically, the Centers for Disease Control and Prevention (2011) estimated that the newborn male circumcision rate declined during a 12-year period from approximately 60 percent in 1999 to only 55 percent in 2010.

Other studies have endorsed health benefits of circumcision. In large randomized trials from regions of Africa with a high prevalence of human immunodeficiency virus (HIV), male circumcision was found to lower the risk of HIV acquisition in the adult by half (Bailey, 2007; Gray, 2007). And, male circumcision was also reported to decrease adult incidences of HIV, HPV, and herpes infections (Tobian, 2009). In its subsequent policy statement, the American Academy of Pediatrics Task Force on Circumcision (2012) concluded that health benefits of newborn male circumcision outweigh the risks.

Thus, access to the procedure is justified for families who choose it. The Task Force stopped short of recommending circumcision for *all* newborns.

Surgical Technique

Circumcision is performed only in a healthy neonate. Other contraindications include any genital abnormalities such as hypospadias and a family history of a bleeding disorder, unless excluded in the newborn.

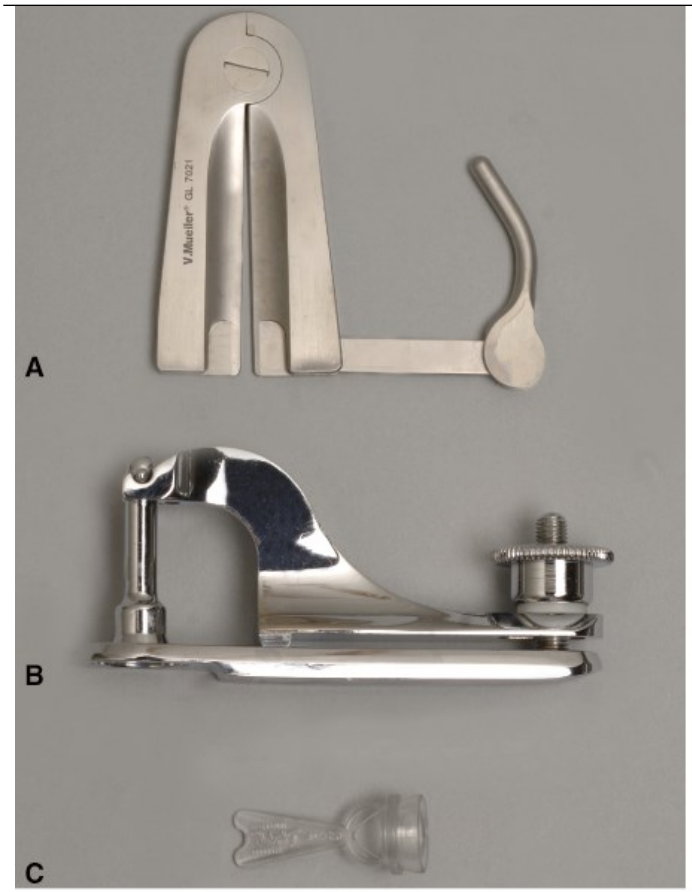
The Task Force (2012) recommends procedural analgesia. Various pain relief techniques include lidocaine-prilocaine topical cream, local analgesia infiltration, dorsal penile nerve block, or ring block (Arnett, 1990; Stang, 1988). The dorsal penile nerve block or the ring block is superior to topical analgesia (Hardwick-Smith, 1998; Lander, 1997; Taddio, 1997). The use of a pacifier dipped in sucrose is a useful adjunct to these methods (Kaufman, 2002).

After appropriate penile cleansing, the ring block places a wheal of 1-percent lidocaine at the base of the penis and then advances the needle in a 180-degree arc around the base of the penis. The needle is advanced first to one side and then to the other to achieve a circumferential ring of analgesia. The maximum dose of lidocaine is 1.0 mL. *No vasoactive compounds such as epinephrine should ever be added to a local analgesic agent for circumcision.*

The most commonly used instruments are shown in Figure 32-5 and are Gomco and Mogen clamps and the Plastibell device. Compared with the Gomco procedure, Kaufman and colleagues (2002) reported that the Mogen technique required less time to perform and was associated with less apparent discomfort for the newborn. Regardless of the method used, the goal is to remove enough shaft skin and inner preputial epithelium so that the glans is exposed sufficiently to prevent phimosis. In all techniques: (1) the amount of external skin to be removed must be accurately estimated, (2) the preputial orifice must be dilated to visualize the glans and ensure that it is normal, (3) the inner preputial epithelium must be freed from the glans epithelium, and (4) the circumcision device must be left in place long enough to produce hemostasis before amputating the prepuce (Lerman, 2001).

FIGURE 32-5

Three different tools used for circumcision. **A.** Mogen clamp. The arms of the clamp open to a 3-mm maximum width. **B.** Gomco clamp, assembled. **C.** Plastibell device.



Source: F. Gary Cunningham, Kenneth J. Leveno, Steven L. Bloom, Catherine Y. Spong, Jodi S. Dashe, Barbara L. Hoffman, Brian M. Casey, Jeanne S. Sheffield: *Williams Obstetrics*, 25th Edition

The risks for bleeding, infection, and hematoma formation are low (Christakis, 2000). Unusual complications include distal glans amputation, acquisition of HIV infection or other sexually transmitted disease, meatal stenosis, penile denudation, penile destruction with electrosurgical coagulation, subsequent epidermal inclusion cyst and urethrocutaneous fistula, and ischemia following the inappropriate use of lidocaine with epinephrine (Amukele, 2003; Neulander, 1996; Nicoll, 1997; Pippi-Salle, 2013; Upadhyay, 1998).

Rooming In and Hospital Discharge

Hospital *rooming in* places newborns in their mothers' rooms instead of central nurseries. This practice attempts to make all phases of childbearing as natural as possible and to foster early mother-child relationships. By 24 hours, the mother is generally fully ambulatory. Thereafter, with rooming-in, she can usually provide routine care for herself and her newborn. An obvious advantage of this is her ability to assume full care when she arrives home.

Traditionally, the newborn is discharged with its mother, and in most cases, maternal stay has determined that of the neonate. From 1970 to the mid-1990s, average maternal postpartum length of stay declined steadily, and many mothers were discharged before 48 hours. The World Health Organization (2014) cites a minimal stay of only 24 hours. Although it is clear that most newborns can be safely discharged within 48 hours, this is not uniformly true. For example, in more than 2.1 million neonates in Canada, Liu and associates (2000) examined readmission rates following initial neonatal discharge. As the length of hospital stay dropped from 4.2 days in 1990 to 2.7 days in 1997, the readmission rate rose from 27 to 38 per 1000. Dehydration and jaundice accounted for most of these readmissions. Using Washington state data, Malkin and coworkers (2000) found that the 28-day mortality rate was increased fourfold in newborns discharged within 30 hours of birth, and the 1-year mortality rate grew twofold. Safe discharge for late-preterm newborns has special concerns (Whyte, 2012).

Because of the increased scrutiny regarding short hospital stays, federal legislation—*The Newborns' and Mothers' Health Protection Act of 1996*—was enacted to prohibit insurers from restricting hospital stays for mothers and newborns to less than 2 days for vaginal delivery or 4 days for cesarean

delivery. In an analysis of more than 662,000 births in California, Datar and Sood (2006) found that readmission rates declined by 9, 12, and 20 percent, respectively, at 1, 2, and 3 years after the legislation was implemented.

REFERENCES

Ali A, Khadije D, Elahe A, et al: Prophylaxis of ophthalmia neonatorum comparison of Betadine, erythromycin and no prophylaxis. J Trop Pediatr 53(6):388, 2007

American Academy of Pediatrics: Delayed umbilical cord clamping after birth. Pediatrics 139(6), 2017a

American Academy of Pediatrics, American College of Obstetricians and Gynecologists: Care of the newborn. In Guidelines for Perinatal Care, 8th ed. Elk Grove Village, AAP, 2017b

American Academy of Pediatrics Task Force on Circumcision: Circumcision policy statement. Pediatrics 103:686, 1999

American Academy of Pediatrics Task Force on Circumcision: Circumcision policy statement. Pediatrics 130(3):585, 2012

American College of Obstetricians and Gynecologists: Executive summary: neonatal encephalopathy and neurologic outcome, second edition. Report of the American College of Obstetricians and Gynecologists' Task Force on Neonatal Encephalopathy. Obstet Gynecol 123(4):896, 2014

American College of Obstetricans and Gynecologists: Delayed umbilical cord clamping after birth. Committee Opinion No. 684, January 2017a

American College of Obstetricians and Gynecologists: Delivery of a newborn with meconium-stained amniotic fluid. Committee Opinion No. 689, April 2017b

American College of Obstetricians and Gynecologists: Newborn screening and the role of the obstetrician-gynecologist. Committee Opinion No. 616, January 2015, Reaffirmed 2017c

American College of Obstetricians and Gynecologists: Planned home birth. Committee Opinion No. 697, April 2017d

American College of Obstetricians and Gynecologists: Optimizing support for breastfeeding as part of obstetric practice. Committee Opinion No. 658, February 2016, Reaffirmed 2017e

American College of Obstetricians and Gynecologists. American Academy of Pediatrics: The Apgar score. Committee Opinion No. 644, October 2015, Reaffirmed 2017f

Amukele SA, Lee GW, Stock JA, et al: 20-year experience with iatrogenic penile injury. J Urol 170:1691, 2003

Apgar V: A proposal for a new method of evaluation of the newborn infant. Curr Res Anesth Analg 32:260, 1953

Armstrong L, Stenson BJ: Use of umbilical cord blood gas analysis in the assessment of the newborn. Arch Dis Child Fetal Neonatal Ed 92:430, 2007

Arnett RM, Jones JS, Horger EO III: Effectiveness of 1% lidocaine dorsal penile nerve block in infant circumcision. Am J Obstet Gynecol 163:1074, 1990

Bailey RC, Moses S, Parker CB, et al: Male circumcision for HIV prevention in young men in Kismu, Kenya: a randomized controlled trial. Lancet 369:643, 2007

Bhatt S, Alison BJ, Wallace EM, et al: Delaying cord clamping until ventilation onset improves cardiovascular function at birth in preterm lambs. J Physiol 591(8):2113, 2013

Bhutani VK, Committee on Fetus and Newborn, American Academy of Pediatrics: Phototherapy to prevent severe neonatal hyperbilirubinemia in the

newborn infant 35 or more weeks of gestation. Pediatrics 128(4):e1046, 2011

Blickstein I, Green T: Umbilical cord blood gases. Clin Perinatol 34(3):451, 2007

Carrasco M, Martell M, Estol PC: Oronasopharyngeal suction at birth: effects on arterial oxygen saturation. J Pediatr 130(5):832, 1997

Casey BM, Goldaber KG, McIntire DD, et al: Outcomes among term infants when two-hour postnatal pH is compared with pH at delivery. Am J Obstet Gynecol 184:447, 2001a

Casey BM, McIntire DD, Leveno KJ: The continuing value of the Apgar score for the assessment of newborn infants. N Engl J Med 344:467, 2001b

Centers for Disease Control and Prevention: Breastfeeding report card: progressing toward national breastfeeding goals-United States 2016. Available at: http://www.cdc.gov/breastfeeding/data/reportcard2.htm. Accessed June 2017

Centers for Disease Control and Prevention: CDC grand rounds: newborn screening and improved outcomes. MMWR 61(21)390, 2012

Centers for Disease Control and Prevention: Trends in in-hospital newborn male circumcision—United States, 1999–2010. MMWR 60(34):1167, 2011

Chauhan SP, Cowan BD, Meydrech EF, et al: Determination of fetal acidemia at birth from a remote umbilical arterial blood gas analysis. Am J Obstet Gynecol 170:1705, 1994

Christakis DA, Harvey E, Zerr DM, et al: A trade-off analysis of routine newborn circumcision. Pediatrics 105:246, 2000

Datar A, Sood N: Impact of postpartum hospital-stay legislation on newborn length of stay, readmission, and mortality in California. Pediatrics 118:63, 2006

Dickinson JE, Eriksen NL, Meyer BA, et al: The effect of preterm birth on umbilical cord blood gases. Obstet Gynecol 79:575, 1992

Dusheiko G: Interruption of mother-to-infant transmission of hepatitis B: time to include selective antiviral prophylaxis? Lancet 379(9830):2019, 2012

Eisenberg MS, Cummins RO, Ho MT: Code Blue: Cardiac Arrest and Resuscitation. Philadelphia, Saunders, 1987

Ersdal HL, Mduma E, Svensen E, et al: Early initiation of basic resuscitation interventions including face mask ventilation may reduce birth asphyxia related mortality in low-income countries: a prospective descriptive observational study. Resuscitation 83(7):869, 2012

Freeman JM, Nelson KB: Intrapartum asphyxia and cerebral palsy. Pediatrics 82:240, 1988

Gilstrap LC III, Leveno KJ, Burris J, et al: Diagnosis of birth asphyxia on the basis of fetal pH, Apgar score, and newborn cerebral dysfunction. Am J Obstet Gynecol 161:825, 1989

Goldaber KG, Gilstrap LC III, Leveno KJ, et al: Pathologic fetal acidemia. Obstet Gynecol 78:1103, 1991

Gray RH, Kigozi G, Serwadda D, et al: Male circumcision for HIV prevention in Rakai, Uganda: a randomized trial. Lancet 369:657, 2007

Gungor S, Kurt E, Teksoz E, et al: Oronasopharyngeal suction versus no suction in normal and term infants delivered by elective cesarean section: a prospective randomized controlled trial. Gynecol Obstet Invest 61(1):9, 2006

Hammerschlag MR: Chlamydial and gonococcal infections in infants and children. Clin Infect Dis 53(3):S99, 2011

Hardwick-Smith S, Mastrobattista JM, Wallace PA, et al: Ring block for neonatal circumcision. Obstet Gynecol 91:930, 1998

Hooper SB, Kitchen MJ, Wallace MJ, et al: Imaging lung aeration and lung liquid clearance at birth. FASEB J 21(12):3329, 2007

Hooper SB, te Pas AB, Kitchen MJ: Respiratory transition in the newborn: a three-phase process. Arch Dis Child Fetal Neonatal Ed 101(3):F266, 2016

Hooper SB, te Pas AB, Lang J, et al: Cardiovascular transition at birth: a physiological sequence. Pediatr Res 77(5):608, 2015

Isenberg SJ, Apt L, Wood M: A controlled trial of povidone-iodine as prophylaxis against ophthalmia neonatorum. N Engl J Med 332:562, 1995

Janssen PA, Selwood BL, Dobson SR, et al: To dye or not to dye: a randomized clinical trial of a triple dye/alcohol regime versus dry cord care. Pediatrics 111:15, 2003

Kapadia V, Wyckoff MH: Chest compressions for bradycardia or asystole in neonates. Clin Perinatol 39(4):833, 2012

Kapadia VS, Wyckoff MH: Epinephrine use during newborn resuscitation. Front Pediatr 5:97, 2017

Kapellen TM, Gebauer CM, Brosteanu O, et al: Higher rate of cord-related adverse events in neonates with dry umbilical cord care compared to chlorhexidine powder. Results of a randomized controlled study to compare efficacy and safely of chlorhexidine powder versus dry care in umbilical cord care of the newborn. Neonatology 96(1):13, 2009

Karlberg P, Adams FH, Geubelle F, et al: Alteration of the infant's thorax during vaginal delivery. Acta Obstet Gynecol Scand 41:223, 1962

Katheria AC, Lakshminrusimha S, Rabe H, et al: Placental transfusion: a review. J Perinatol 37(2):105, 2017

Kattwinkel J: Textbook of Neonatal Resuscitation, 6th ed. Elk Grove Village, American Academy of Pediatrics and American Heart Association, 2010

Kaufman GE, Cimo S, Miller LW, et al: An evaluation of the effects of sucrose on neonatal pain with 2 commonly used circumcision methods. Am J Obstet Gynecol 186:564, 2002

King TA, Jackson GL, Josey AS, et al: The effect of profound umbilical artery acidemia in term neonates admitted to a newborn nursery. J Pediatr 132(4):624, 1998

Kotaska K, Urinovska R, Klapkova E, et al: Re-evaluation of cord blood arterial and venous reference ranges for pH, pO_2, pCO_2, according to spontaneous or cesarean delivery. J Clin Lab Anal 24(5):300, 2010

Lander J, Brady-Fryer B, Metcalfe JB, et al: Comparison of ring block, dorsal penile nerve block, and topical anesthesia for neonatal circumcision: a randomized controlled trial. JAMA 278:2157, 1997

Lavrijsen SW, Uiterwaal CS, Stigter RH, et al: Severe umbilical cord acidemia and neurological outcome in preterm and full-term neonates. Biol Neonate 88(1):27, 2005

Lerman SE, Liao JC: Neonatal circumcision. Pediatr Clin North Am 48:1539, 2001

Lines A, Hooper SB, Harding R: Lung liquid production rates and volumes do not decrease before labor in healthy fetal sheep. J Appl Physiol (1985)82(3):927, 1997

Liu S, Wen SW, McMillan D, et al: Increased neonatal readmission rate associated with decreased length of hospital stay at birth in Canada. Can J Public Health 91:46, 2000

Low JA, Lindsay BG, Derrick EJ: Threshold of metabolic acidosis associated with newborn complications. Am J Obstet Gynecol 177:1391, 1997

Low JA, Panagiotopoulos C, Derrick EJ: Newborn complications after intrapartum asphyxia with metabolic acidosis in the term fetus. Am J Obstet Gynecol 170:1081, 1994

Lynn A, Beeby P: Cord and placenta arterial gas analysis: the accuracy of delayed sampling. Arch Dis Child Fetal Neonatal Ed 92(4):F281, 2007

Mabry-Hernandez I, Oliverio-Hoffman R: Ocular prophylaxis for gonococcal ophthalmia neonatorum: evidence update for the U.S. Preventive Services Task Force reaffirmation recommendation statement. AHRQ Publication No. 10–05146. Rockville, Agency for Healthcare Research and Quality, 2010

Maisels MJ, Bhutani VK, Bogen D, et al: hyperbilirubinemia in the newborn infant ≥35 weeks' gestation: an update with clarifications. Pediatrics 124(4):1193, 2009

Malkin JD, Garber S, Broder MS, et al: Infant mortality and early postpartum discharge. Obstet Gynecol 96:183, 2000

Martin JA, Hamilton BE, Ventura SJ, et al: Births: final data for 2010. Natl Vital Stat Rep 61(1), 2012

Mokarami P, Wiberg N, Olofsson P: An overlooked aspect on metabolic acidosis at birth: blood gas analyzers calculate base deficit differently. Acta Obstet Gynecol Scand 91(5):574, 2012

Moore DL, MacDonald NE, Canadian Paediatric Society Infectious Disease and Immunization Committee: Preventing ophthalmia neonatorum. Paediatr Child Health 20(2):93, 2015

Mullany LC, Darmstadt GL, Khatry SK, et al: Topical applications of chlorhexidine to the umbilical cord for prevention of omphalitis and neonatal mortality in southern Nepal: a community-based, cluster randomized trial. Lancet 367:910, 2006

Neulander E, Walfisch S, Kaneti J: Amputation of distal penile glans during neonatal ritual circumcision—a rare complication. Br J Urol 77:924, 1996

Nicoll A: Routine male neonatal circumcision and risk of infection with HIV-1 and other sexually transmitted diseases. Arch Dis Child 77:194, 1997

Novack AH, Mueller B, Ochs H: Umbilical cord separation in the normal newborn. Am J Dis Child 142:220, 1988

O'Brodovich H, Hannam V, Seear M, et al: Amiloride impairs lung water clearance in newborn guinea pigs. J Appl Physiol (1985)68(4):1758, 1990

Perlman JM, Wyllie J, Kattwinkel J, et al: Part 7: neonatal resuscitation: 2015 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Pediatrics 136 Suppl 2:S120, 2015

Pippi-Salle JL, Jesus LE, Lorenzo AJ, et al: Glans amputation during routine neonatal circumcision: mechanism of injury and strategy for prevention. J Pediatr Urol 9:763, 2013

Ramin SM, Gilstrap LC, Leveno KJ, et al: Umbilical artery acid–base status in the preterm infant. Obstet Gynecol 74:256, 1989

Reynolds MR, Jones AM, Petersen EE, et al: Vital signs: update on Zika virus-associated birth defects and evaluation of all U.S. infants with congenital Zika virus exposure—U.S. Zika Pregnancy Registry, 2017 MMWR 66(13):366, 2017

Riley RJ, Johnson JW: Collecting and analyzing cord blood gases. Clin Obstet Gynecol 36:13, 1993

Rudolph AM: Fetal and neonatal pulmonary circulation. Annu Rev Physiol 41:383, 1979

Sabol BA, Caughey AB: Acidemia in neonates with a 5-minute Apgar score of 7 or greater—what are the outcomes? Am J Obstet Gynecol 215(4):486 e481, 2016

Salam RA, Mansoor T, Mallick D, et al: Essential childbirth and postnatal interventions for improved maternal and neonatal health. Reprod Health 11 Suppl 1:S3, 2014

Salhab WA, Perlman JM: Severe fetal acidemia and subsequent neonatal encephalopathy in the larger premature infant. Pediatr Neurol 32(1):25, 2005

Saunders RA, Milner AD: Pulmonary pressure/volume relationships during the last phase of delivery and the first postnatal breaths in human subjects. J Pediatr 93:667, 1978

Schmolzer GM, Dawson JA, Kamlin CO, et al: Airway obstruction and gas leak during mask ventilation of preterm infants in the delivery room. Arch Dis Child Fetal Neonatal Ed 96(4):F254, 2011

Siew ML, te Pas AB, Wallace MJ, et al: Positive end-expiratory pressure enhances development of a functional residual capacity in preterm rabbits ventilated from birth. J Appl Physiol (1985)106(5):1487, 2009a

Siew ML, Wallace MJ, Kitchen MJ, et al: Inspiration regulates the rate and temporal pattern of lung liquid clearance and lung aeration at birth. J Appl Physiol (1985)106(6):1888, 2009b

Siggaard-Anderson O: Blood acid–base alignment nomogram. Scand J Clin Lab Invest 15:211, 1963

Socol ML, Garcia PM, Riter S: Depressed Apgar scores, acid–base status, and neurologic outcome. Am J Obstet Gynecol 170:991, 1994

Stang HJ, Gunnar MR, Snellman L, et al: Local anesthesia for neonatal circumcision: effects on distress and cortisol response. JAMA 259:1507, 1988

Stewart D, Benitz W, AAP Committee on Fetus and Newborn: Umbilical cord care in the newborn infant. Pediatrics 138(3):e20162149, 2016

Taddio A, Stevens B, Craig K, et al: Efficacy and safety of lidocaine-prilocaine cream for pain during circumcision. N Engl J Med 336:1197, 1997

Teoh D, Reynolds S: Diagnosis and management of pediatric conjunctivitis. Pediatr Emerg Care 19:48, 2003

te Pas AB, Davis PG, Hooper SB, et al: From liquid to air: breathing after birth. J Pediatr 152(5):607, 2008

Thorngren-Jerneck K, Herbst A: Low 5-minute Apgar score: a population-based register study of 1 million term births. Obstet Gynecol 98:65, 2001

Thorp JA, Dildy GA, Yeomans ER, et al: Umbilical cord blood gas analysis at delivery. Am J Obstet Gynecol 175(3 Pt 1):517, 1996

Tobian AA, Serwadda D, Quinn TC, et al: Male circumcision for the prevention of HSV-2 and HPV infections and syphilis. N Engl J Med 360(13):1298, 2009

Tran TT: Hepatitis B: treatment to prevent perinatal transmission. Clin Obstet Gynecol 55(2):541, 2012

Upadhyay V, Hammodat HM, Pease PW: Post circumcision meatal stenosis: 12 years' experience. N Z Med J 111:57, 1998

Victory R, Penava D, da Silva O, et al: Umbilical cord pH and base excess values in relation to neonatal morbidity for infants delivered preterm. Am J Obstet Gynecol 189(3):803, 2003

Vyas H, Milner AD, Hopkins IE: Intrathoracic pressure and volume changes during the spontaneous onset of respiration in babies born by cesarean section and by vaginal delivery. J Pediatr 99(5):787, 1981

Watson MS, Mann MY, Lloyd-Puryear MA, et al: Newborn screening: towards a uniform screening panel and system. Executive summary. Genet Med 8(Suppl 5):1S, 2006

Weiner GM: Textbook of Neonatal Resuscitation. 7th ed. Elk Grove Village, American Academy of Pediatrics, 2016

White CR, Doherty DA, Cannon JW, et al: Cost effectiveness of universal umbilical cord blood gas and lactate analysis in a tertiary level maternity unit. J Perinat Med 44(5):573, 2016

White CR, Doherty DA, Henderson JJ, et al: Benefits of introducing universal umbilical cord blood gas and lactate analysis into an obstetric unit. Aust

N Z J Obstet Gynaecol 50(4):318, 2010

Whyte RK: Neonatal management and safe discharge of late and moderate preterm infants. Semin Fetal Neonatal Med 17(3):153, 2012

World Health Organization: Postnatal care of the mother and newborn, 2013. Geneva, WHO, 2014

Wyckoff MH, Aziz K, Escobedo MB, et al: Part 13: neonatal resuscitation: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Pediatrics 136 Suppl 2:S196, 2015

Yeh P, Emary K, Impey L: The relationship between umbilical cord arterial pH and serious adverse neonatal outcome: analysis of 51,519 consecutive validated samples. BJOG 119(7):824, 2012

Zuppa AA, D'Andrea V, Catenazzi P, et al: Ophthalmia neonatorum: what time of prophylaxis? J Matern Fetal Neonatal Med 24(6):769, 2011