Most newborns with complications are identified and cared for in community hospitals or level II perinatal centers (American Academy of Pediatrics [AAP], 2012). Perinatal nurses must have a thorough understanding of pathophysiologic and clinical signs of illness during the immediate newborn period. The length of stay limits the time to identify behavioral cues or subtle changes that could potentially compromise newborn well-being.

Conditions discussed in this chapter include common complications such as respiratory distress, congenital heart disease (CHD), hypoglycemia, hyperbilirubinemia, and sepsis. Less common but important topics include neonatal resuscitation, perinatal HIV-1 exposure, neonatal substance exposure, and hypoxic ischemic encephalopathy (HIE). The target population is term and preterm newborn infants, including the late preterm infant born between 34 0/7 and 36 6/7 weeks’ gestational age. This chapter concludes with a discussion of neonatal transport because, in some cases, the severity of the disease process necessitates transfer to a tertiary care center.

**NEONATAL RESUSCITATION AND STABILIZATION**

Most newborns transition from fetal to extraterine life uneventfully. However, approximately 1 in 10 will require some assistance after delivery to initiate or sustain respiratory effort, and 1% will require extensive measures to survive. In keeping with the “ABCs” of resuscitation, providers must ensure that the airway is clear and unimpeded, breathing is spontaneous and unassisted, and that circulation is maintained to adequately perfuse tissues and organs. The AAP and the American Heart Association (AHA) (2011) recommend that all births be attended by someone capable of initiating resuscitation and those resources for sustained resuscitation efforts be available as needed.

Prior to birth, the fetus receives oxygen by diffusion from the mother’s blood across the placental membranes. Since the fetal lungs do not participate in oxygenation, only a small fraction of fetal blood passes through them. The fetal alveoli, although round and expanded, are fluid filled, and the surrounding arterioles are constricted. The increase in pulmonary vascular resistance (PVR) favors blood flow in a manner which bypasses the lungs through a series of fetal shunts, allowing delivery of optimally oxygenated blood through the ductus arteriosus to the body. After birth, the placenta no longer supports fetal needs, and the newborn must quickly establish ventilation, clear fluid from the alveoli, and dilate the pulmonary vasculature to support ongoing oxygenation. Failure to do so results in hypoxemia and acidosis. The newborn may respond briefly to hypoxia with compensatory tachypnea, although this is quickly followed by primary apnea and a fall in heart rate (HR). If breathing is not quickly established, secondary apnea occurs, and assisted ventilation must be provided to reverse the process (AAP & AHA, 2011).

Certain antepartum and intrapartum risk factors are associated with the need for resuscitation. Maternal factors may be chronic or acute and include such conditions as diabetes, hypertension, cardiopulmonary disease, substance exposure, late trimester bleeding, and infection. Intrapartum factors may also complicate fetal transition, including assisted delivery, cesarean delivery, abnormal fetal lie, presence of meconium, and placental complications. Newborns who are postterm, premature, or who have size-date
discrepancies pose additional risks for poor transition. An anticipated compromised birth warrants the presence of personnel who can initiate and sustain resuscitation, including use of ventilatory support, chest compressions, and selected medications. However, risk factors are not always apparent, and providers must be able to anticipate and intervene quickly to support the compromised newborn. Three assessment prompts will assist with quick identification of newborns who will require support: Is the baby term? Is the baby breathing? Is there good muscle tone? (AAP & AHA, 2011).

The Neonatal Resuscitation Program (NRP) was developed in 1987 to provide a systematic method for managing the compromised newborn. It supports consistent and appropriate actions to address ventilation and circulation needs, which are continually evaluated using an algorithm containing action blocks. The resuscitation sequence begins with positioning the newborn infant on his back or side to open the airway, and then proceeding to drying and stimulating. It is important to ensure resuscitation occurs in a warm environment. Following this initial 30-second block (“A”), the infant is assessed. If the infant responds with a sustained heart rate above 100 beats per minute and sustained breathing or crying, additional measures are unnecessary. However, an infant who does not establish sustained breathing is presumed to be exhibiting secondary apnea, and the next block (“B”) commences with assisted ventilation. The infant is continually assessed, and additional maneuvers are applied according to infant response (AAP & AHA, 2011).

Effective neonatal resuscitation for at-risk infants requires not only dexterity with maneuvers such as ventilation and compressions but also collaboration among a neonatal team to ensure timely and organized support. Poor communication and lack of teamwork have been identified as factors in poor outcomes following neonatal resuscitation, and the most recent edition updates recommendations to increase focus on team building and collaborating, and alternate learning strategies such as more effective use of simulation and debriefing (AAP & AHA, 2011; Perlman et al., 2010; Zaichkin & Weiner, 2011).

An additional neonatal education program endorsed by the AAP is S.T.A.B.L.E., which reinforces key stabilization skills via an acronym: **S**ugar, **T**emperature, **A**irway, **B**lood pressure, **L**ab work assessment, and **E**motional support of families. This program supports nursery staff who participate in postresuscitation stabilization and pretransport care of the neonate requiring intensive care and encourages a systematic approach to management (Taylor & Price-Douglas, 2008). Both S.T.A.B.L.E. and the NRP have been disseminated worldwide as stabilization programs for at-risk neonates.

**RESPIRATORY DISTRESS**

Respiratory distress is a major cause of neonatal morbidity and mortality despite significant technological and pharmacologic advances during the past 30 years. Respiratory distress is one of the most common neonatal complications seen by the perinatal and neonatal nurse and is a principal indication for neonatal transfer to tertiary care units. The pathophysiology and etiology of respiratory distress varies, but the result is decreased ability to exchange the oxygen and carbon dioxide necessary to ensure delivery of well-oxygenated blood to vital organs. Respiratory distress may be an isolated finding or occur in association with other medical or systemic problems. It may be due to structural or functional abnormality or as a consequence of acute lung injury and result in prolonged transition to extrauterine life. Five of the most common respiratory diseases...
occurring during the neonatal period are respiratory distress syndrome (RDS), MAS, pneumonia, transient tachypnea of the newborn (TTNB), and persistent pulmonary hypertension of the newborn (PPHN).

**RESPIRATORY DISTRESS SYNDROME**

RDS primarily occurs in preterm newborns. In the United States, approximately 24,000 newborns develop RDS each year. The incidence of RDS is inversely related to gestational age: 60% of infants are born at less than 28 weeks, 30% of those are born at 28 to 34 weeks' gestation, and less than 5% of those born after 34 weeks are affected (Warren & Anderson, 2009). The mortality rate for RDS across all gestational ages is about 10%, attributable to improved prenatal and postnatal management (Dudell & Stoll, 2007; Warren & Anderson, 2009). RDS is caused by insufficient amounts of surfactant or delayed or impaired surfactant synthesis. Surfactant is a mixture of phospholipids and proteins synthesized, packaged, and excreted by alveolar type II cells that lowers surface tension in the alveoli and functions as a stabilizer to prevent atelectasis and alveolar collapse at end expiration (Cole, Nogee, & Hamvas, 2006). Without surfactant, atelectasis (alveolar collapse) occurs, resulting in a series of events that progressively increase disease severity. These events include hypoxemia (decreased concentration of oxygen), hypercapnia (increased concentration of carbon dioxide), mismatch of ventilation with perfusion, acidosis, pulmonary vasoconstriction, alveolar endothelial and epithelial damage, and subsequent protein-rich interstitial and alveolar edema. This cascade of events further decreases surfactant synthesis, storage, and release and leads to pulmonary failure (Dudell & Stoll, 2007; Warren & Anderson, 2009).

**MECONIUM ASPIRATION SYNDROME**

Passage of meconium in utero or perinatally is primarily seen in term and postterm infants and those experiencing stress such as growth-restricted infants or those with cord complications compromising uteroplacental circulation (Dudell & Stoll, 2007). Meconium passage occurs as a response to hypoxia, as relaxation of the anal sphincter allows passive escape of meconium into the amniotic fluid. Under normal intrauterine conditions, amniotic fluid does not enter the fetal lung. However, when the fetus experiences hypoxemia, gasping may result in aspiration of meconium-stained amniotic fluid. Of newborns, 8% to 20% are exposed to amniotic fluid stained by meconium; of these, 5% to 10% will go on to develop MAS (American College of Obstetricians and Gynecologists [ACOG], 2006; Dudell & Stoll, 2007; van Lerland & de Beaufort, 2009).

Preventive strategies have been evaluated for cases at risk for MAS, including amniinfusion and direct tracheal suctioning of the neonate. Although amniinfusion appears to be a reasonable treatment for repetitive variable decelerations, its sole use as a technique to prevent MAS is not warranted (ACOG, 2006; Xu, Wei, & Fraser, 2008). When aspirated by the fetus before or during birth, meconium can obstruct the airways, leading to severe hypoxia, inflammation, and infection and cause significant respiratory difficulties. Past evidence suggested that intrapartum suctioning before the first breath would decrease the risk of MAS; however, subsequent evidence from a large multicentered randomized trial did not show benefit from routine intrapartum oropharyngeal and nasopharyngeal suctioning (Velaphi & Vidyasagar, 2006; van Lerland & de Beaufort, 2009). Currently, the NRP no longer recommends that all meconium-stained babies routinely receive intrapartum suctioning (AAP & AHA, 2011; Vain, Szyl, Prudent, & Aguilar, 2009).

Pneumonitis is an inflammatory response likely secondary to bile salts present in aspirated meconium. Pneumonitis results in acute lung injury with protein-rich interstitial and alveolar edema. In situations where meconium only partially obstructs the airway, a ball-valve effect results. Air enters the lower airways on inspiration but cannot escape on expiration. This causes overdistension of alveoli, leading to alveolar rupture and pulmonary air leaks. Pneumonitis and airway obstruction result in hypoxemia and acidosis, which cause increased PVR and subsequent PPHN (Steinhom & Farrow, 2007).

**PNEUMONIA**

Pneumonia is acquired through vertical or horizontal transmission of a pathogenic organism and may present clinically as early-onset sepsis develops in the neonate. Vertical transmission occurs in utero in association with chorioamnionitis, intraamniotic infection, transplacental transmission of organisms, or aspiration of infected amniotic fluid. It may also occur following prolonged rupture of the membranes due to loss of the bacteriostatic protection of amniotic fluid. Horizontal transmission occurs in the nursery as pathogenic organisms spread from hospital personnel, equipment, or families or present as secondary infections as the result of some other primary infection. Pneumonia causes an inflammatory process, disrupting the normal barrier function of the pulmonary endothelium and epithelium, leading to abnormal protein permeability and edema of lung tissue. Hypoxemia and acidosis result, causing increased PVR and potential sequelae such as PPHN (Stoll, 2007a).

**TRANSIENT TACHYPNEA OF THE NEWBORN**

TTNB occurs in approximately 0.3% to 0.5% of newborns, although the exact incidence is unknown.
cular system. In approximately 1/500 to 1/1,500 live births, severe, prolonged hypoxemia (decreased oxygen in the blood) progresses to hypoxia (decreased oxygen in the tissues) and results in metabolic acidosis and worsening pulmonary vasoconstriction. A vicious cycle ensues. PPHN may be idiopathic, caused by abnormal development of pulmonary vessels, or may result from pathophysiologic events such as asphyxia, MAS, pneumonia, and RDS (Dudell & Stoll, 2007; Lapointe & Barrington, 2011; Stayer & Liu, 2010; Steinhom & Farrow, 2007). Infants with PPHN are typically labile and often require sedation to control competing respiratory effort, vasodilators to overcome pulmonary vasoconstriction, and vasopressors to support systemic blood pressure. A small percentage with refractory hypoxemia may require extracorporeal membrane oxygenation (ECMO) for survival (Dudell & Stoll, 2007).

**ASSESSMENT OF RESPIRATORY DISTRESS**

Clinical signs of respiratory distress may be present at birth or occur at any time in the early neonatal period. These signs include tachypnea, grunting, retractions, nasal flaring, and cyanosis. Tachypnea is defined as a sustained respiratory rate greater than 60 to 70 breaths per minute (Gardner, Enzman-Hines, & Dickey, 2011). Tachypnea develops when the newborn attempts to improve ventilation. Because of the very compliant chest wall, especially in the preterm newborn, it is more energy efficient for the newborn to increase the respiratory rate rather than the depth of respirations. However, persistent tachypnea results in muscular fatigue and, over time, further compromises pulmonary status.

On exhalation, a grunting sound is sometimes heard in newborns with respiratory distress. Grunting is the result of forceful closure of the glottis in an attempt to increase intrapulmonary pressure, keep alveoli open, and create residual lung gas volume (functional residual capacity). Keeping alveoli open during exhalation is a compensatory response to decreased partial pressure of oxygen (PO$_2$) and allows more time for gas exchange to occur (Gardner et al., 2011).

Retractions are depressions observed between the ribs, above the sternum, or below the xiphoid process during inhalation. Retractions are the result of a very compliant chest wall and noncompliant lung. Compliance refers to the stiffness or distensibility of the chest wall and lung parenchyma. As the amount of negative intrathoracic pressure increases on inspiration, the rib cage expands until the soft tissue of the thorax and weak intercostal muscles are pulled inward toward the spine. The result is worsening atelectasis with marked oxygenation and ventilation abnormalities (Cifuentes, Segars, & Carlo, 2003; Gardner et al., 2011).

Nasal flaring occurs with respiratory distress as the newborn attempts to decrease airway resistance and increase the inflow of air through dilation of the alae nasi (Gardner et al., 2011).
Cyanosis results from inadequate oxygenation caused by atelectasis, poor lung compliance, and right-to-left shunting. Although the newborn’s color may be an indicator of oxygenation, variables such as skin temperature and perfusion affect the accuracy of this finding. Precise measurement of oxygen and acid–base status may be necessary for the management of respiratory distress using tools such as pulse oximetry and blood gases (Gardner et al., 2011; Rohan & Golembek, 2009).

INTERVENTIONS FOR RESPIRATORY DISTRESS

Care for newborns with respiratory distress focuses on oxygenation and ventilation as well as controlling factors that increase oxygen demands such as hypothermia or stress. Adequate oxygenation and ventilation requires supportive mechanisms ranging from supplemental oxygen only to application of assisted ventilation with techniques such as continuous positive airway pressure (CPAP) or mechanical ventilation. Pulse oximetry and direct arterial blood gas monitoring are methods used to ensure adequate gas exchange. In a preterm newborn, delivery of oxygen should be sufficient to maintain arterial oxygen tension at 50 to 70 mm Hg, corresponding to a pulse oximetry reading of approximately 85% to 95% (Dudell & Stoll, 2007). Because oxygen may be toxic to some tissue, care should be taken to avoid excessive tissue oxygenation, which might have toxic effects such as chronic lung disease or retinopathy of prematurity. In a term newborn at risk for PPHN, oxygen delivery should be sufficient to maintain normoxemia yet avoid hypoxia, which is a potent stimulus for vasoconstriction (Lapointe & Barrington, 2011). Infants with suspected PPHN will need to be transferred to a tertiary care center for further evaluation and management, including potential use of high-frequency ventilation (HFOV), inhaled nitric oxide (i-NO), or ECMO for severe hypoxemia (Stayer & Liu, 2010).

Select pharmacologic agents may be used in the prevention or management of neonatal respiratory distress. Prenatally, at-risk mothers may receive antenatal steroids to stimulate surfactant synthesis in an effort to prevent RDS. Postnatally, commonly used preparations include airway-instilled surfactant (for RDS prophylaxis or treatment), antibiotics (for pneumonia prophylaxis or treatment), and inhaled or vascularly delivered pulmonary vasodilators (for PPHN treatment) (Konduri & Kim, 2009; Warren & Anderson, 2009).

A neutral thermal environment (NTE) is crucial in the care of a newborn with respiratory distress. Hypothermia or hyperthermia both increase metabolic demands, leading to decreased oxygenation, metabolic acidosis, and worsening respiratory distress (Cifuentes et al., 2003). Newborns with respiratory distress are cared for under a radiant warmer or in an incubator.

Adequate nutrition frequently requires the administration of intravenous (IV) fluids during the early neonatal period. Care is taken to prevent hypoglycemia that may occur from respiratory distress and increased metabolic demands (Rohan & Golembek, 2009).

CONGENITAL HEART DISEASE

CARDIOVASCULAR SYSTEM

The cardiovascular system begins to develop in the third week of gestation and is fully developed by the end of the eighth week. It is the first major organ system to develop in the embryo. In the United States, an estimated 32,000 infants are expected to be affected with CHD annually. Of these, an approximate 25% require invasive treatment in the first year of life (AHA, 2012). Heart defects are among the most common birth defects and are the leading cause of birth defect-related deaths. However, the overall mortality has significantly declined over the past few decades (AHA, 2012). The cause of CHD cannot be ascribed to any single factor. Most cases are multifactorial, involving genetic predisposition, familial recurrence, and environmental factors. A family history of CHD is significant; if the mother has a history of a child with CHD, her risk of recurrence increases by threefold (Kenney, Hoover, Williams, & Iskersky, 2011).

CHD can also be associated with chromosomal abnormalities (i.e., trisomies 21, 18, 13; chromosome deletion syndromes; DiGeorge deletion 22q; Turner syndrome; and Cornelia de Lange) and maternal–environmental factors, such as drugs (i.e., thalidomide, anticonvulsants, lithium, retinoic acid) and alcohol exposure, or diseases (e.g., insulin-dependent diabetes, maternal lupus erythematosus) and infections (e.g., rubella, Coxsackie B, and enteroviruses) (Kenney et al., 2011).

Cardiac lesions are classified as cyanotic, acyanotic, or according to the hemodynamic characteristics related to pulmonary blood flow. Five of the most commonly occurring cardiac lesions presenting in the early neonatal period include ventricular septal defect (VSD), tetralogy of Fallot (TOF), PDA, atrial septal defect (ASD), and d (dextro)-transposition of the great arteries (d-TGA).

The assessment to exclude CHD includes the following:

- Close observation of cardiorespiratory status
- Palpation of peripheral pulses
- Blood pressures of the four extremities
- Chest radiograph to evaluate heart size and pulmonary vascularity
- Blood gas determinations to evaluate oxygenation and metabolic status
- Evaluation of response to 100% oxygen (a hyperoxia test is used to differentiate respiratory disease from cyanotic heart disease)
The newborn with CHD or persistence of a fetal shunt may present shortly after birth or within the first weeks of life with cyanosis or symptoms of congestive heart failure (CHF). The newborn becomes cyanotic when gas exchange is impaired by pulmonary edema, blood flow to the lungs is restricted as a result of a structural abnormality, or blood flow is shunted away from the lungs. In the newborn with CHD, central cyanosis (bluish discoloration of the skin, nail beds, and mucous membranes) is one of the most common presenting signs and is generally not visible until there is 4 to 5 g/dL of deoxygenated hemoglobin in the arterial system (Mahle et al., 2009). Both the severity of hypoxemia and the hemoglobin concentration determine the degree of cyanosis (Kenney et al., 2011). It is important to differentiate central cyanosis from acrocyanosis (cyanosis of the extremities is commonly seen in newborns because of reduced blood flow through the small capillaries), which is considered a normal finding (Lott, 2007; Kenney et al., 2011).

When the heart is unable to meet the metabolic demands of the tissues, CHF ensues. Unlike infants with CHD, infants with CHF typically present with significant respiratory distress. Common clinical signs associated with CHF (Kenney et al., 2011; Lott, 2007):

- Tachypnea (due to pulmonary edema)
- Respiratory distress
- Gallop rhythm (caused by dilation of the ventricles)
- Decreased peripheral pulses and mottling of the extremities (decrease in peripheral tissue perfusion)
- Tachycardia (in an attempt to compensate for a decrease in cardiac output [CO], the heart either increases the rate or the stroke volume [SV])
- Hepatomegaly (right ventricle does not adequately empty, leading to an elevated right atrium pressure, resulting in hepatic venous congestion)
- Poor feeding (due to high respiratory rate and increases in basal metabolic rate demands)

A murmur, if present, varies in quality and intensity, depending on the particular cardiac lesion present. If a VSD or ASD is present, allowing mixing of oxygenated and unoxygenated blood, only mild cyanosis occurs. If there is no intracardiac shunt, severe cyanosis is observed. With the exception of cyanosis, the physical examination is often otherwise unremarkable. In the newborn with a large VSD or ASD, signs of CHF develop over time as the PVR falls and the pulmonary blood flow increases. In newborns without an intracardiac shunt, severe hypoxemia and metabolic acidosis develop, followed by a rapid demise if emergency measures are not instituted.

Routine newborn screening for critical congenital heart disease (CCHD) using pulse oximetry is recommended to prevent mortality and morbidity (Secretary’s Advisory Committee on Heritable Disorders in Newborns and Children, 2011). Hypoplastic left heart syndrome, pulmonary atresia (with intact septum), transposition of the great arteries, truncus arteriosus, tricuspid atresia, tetralogy of Fallot, and total anomalous pulmonary venous return are among the seven CCHDs that are primary targets for the routine screening in the well infant and intermediate nurseries (Mahle et al., 2009; Kemper et al., 2012).

**VENTRICULAR SEPTAL DEFECT**

**Pathophysiology**

The partitioning of the embryonic heart into chambers of the atria and ventricles begins near the fourth week of gestation and is completed by the end of the seventh week (Auckland, 2010). A VSD is present when there is an incomplete division of the right and left ventricles. VSDs are classified by their anatomic location; perimembranous and muscular are the two most common types. A perimembranous VSD is located just below the aortic valve and accounts for 80% of all VSDs. A muscular VSD is located in the muscular septum. Of membranous and muscular VSDs, 75% to 80% close spontaneously. A VSD is considered an acyanotic lesion with increased pulmonary blood flow. The size and location of the defect, as well as the pulmonary-to-systemic vascular resistance ratio, determine the degree of left-to-right shunt. The timing of the onset of symptoms is directly related to the normal fall in the PVR after birth (Kenney et al., 2011).

**Assessment**

The onset of symptoms resulting from a VSD is related to the size of the defect and PVR. A newborn with a small defect has minimal left-to-right shunting at the ventricular level and may appear well with few or no symptoms other than a holosystolic systolic murmur heard best at the lower left sternal border. The murmur develops as the PVR falls. A newborn with a large defect may present with symptoms of CHF but not until approximately 2 to 4 weeks of life. As with the smaller defects, the murmur is holosystolic and heard over the left lower sternal border. Preterm newborns with large VSDs may present sooner and be more symptomatic compared to their term counterparts because preterm infants have lower PVR at birth, resulting in greater left-to-right shunting (Kenney et al., 2011).

**TETRALOGY OF FALLOT**

**Pathophysiology**

TOF consists of a large perimembranous VSD, pulmonary artery stenosis, an overriding aorta, and right ventricle hypertrophy (Kenney et al., 2011). This lesion is a result of disordered embryonic cardiac functioning. TOF occurs during the embryonic stage of development, when some unknown factor influences...
functioning of the heart at the cellular level. This alteration in cellular function is partly responsible for determining development. TOF is generally considered a cyanotic lesion with decreased pulmonary blood flow, but the hemodynamics vary widely, depending on the severity of pulmonary stenosis, the size of the VSD, and the pulmonary and systemic vascular resistance. Most newborns with TOF present with cyanosis because of the right-to-left intracardiac shunt. However, if the intracardiac shunt is mainly left to right due to a mild or moderate right ventricular outflow obstruction, the infant will not be cyanotic (Kenney et al., 2011). Typically, the course worsens over the first year of life.

**Assessment**

TOF is the most common cyanotic heart disease seen in the first year of life. Newborns with TOF are most often diagnosed in the first few weeks of life due to either a loud murmur or cyanosis. Newborns with TOF often present with cyanosis, hypoxia, and dyspnea. However, newborns who are symptomatic typically have severe right ventricular outflow tract obstruction (Kenney et al., 2011). The timing and degree of cyanosis depend on the severity of the pulmonary stenosis and may not be noticed until closure of the ductus arteriosus. In the case of pulmonary atresia and hypoplasia of the pulmonary arteries, marked cyanosis may be observed immediately after birth. The clinical signs of right-sided heart failure, resulting from right ventricular outflow tract obstruction, include hepatomegaly, tricuspid valve regurgitation, and a grade II to IV/VI harsh systolic ejection murmur best heard over the mid to upper left sternal border.

**PATENT DUCTUS ARTERIOSUS**

**Pathophysiology**

The ductus arteriosus is a normal pathway of fetal circulation. The ductus arteriosus connects the pulmonary artery to the aorta, allowing blood to bypass the lungs directly into the placenta. During fetal life, PVR is greater than systemic vascular resistance. After birth, with spontaneous respiration, the arterial oxygen level increases and PVR decreases, causing the ductus to close. Functionally, the PDA closes within hours to several days after birth, but closure is often delayed in premature infants. If the ductus arteriosus does not close, blood begins to flow left to right through the patent ductus as the PVR decreases. A PDA is an acyanotic lesion with increased pulmonary blood flow. It presents with signs and symptoms of CHF. It occurs much more commonly in preterm newborns, with the incidence inversely proportional to gestational age (Kenney et al., 2011).

**Assessment**

The manifestation of PDA depends on the gestational age and the degree of lung disease. Preterm newborns generally develop signs associated with CHF at 3 to 7 days of life, but it can develop sooner in the smaller preterm newborn treated with surfactant. The development of clinical signs is related to the normal fall in the PVR, resulting in increased blood flow to the pulmonary circulation and volume overload of the left ventricles. In newborns, a grade I through III systolic ejection murmur will likely develop; if left untreated, a classic machinery-like continuous murmur may result in older infants and children. PDA murmurs are best heard at the upper left sternal border (over the first and second intercostal spaces to the left of the sternum) and may radiate to the back, between the scapulae. However, with a right-to-left shunt, a murmur may be absent (Kenney et al., 2011).

**ATRIAL SEPTAL DEFECT**

**Pathophysiology**

The separation of the atrium begins near the middle of the fourth week of gestation and is completed by the sixth week, leaving the foramen ovale open between the two atria. An abnormality occurring during atrial separation can result in an ASD. An ASD is considered an acyanotic lesion with increased pulmonary blood flow. Approximately 10% of newborns with very large ASDs develop CHF as the PVR decreases and a left-to-right shunt develops with concomitant right ventricular volume overload and hypertrophy (Sadowski, 2010). Three major types of ASDs occur and are differentiated from each other by whether they involve other structures of the heart and how they are formed during fetal development (Lott, 2007). The first type is ostium secundum, the most common yet least serious type of ASD, and is caused when a part of the atrial septum fails to close completely while the heart is developing. The second type is an ostium primum defect, part of the spectrum of atrioventricular (AV) canal defects, which is often associated with a cleft in the leaflet of the mitral valve. The third type is the sinus venosus defect, which occurs at the superior vena cava and right atrium junction and is most often associated with partial anomalous pulmonary venous connection.

**Assessment**

Newborns with an uncomplicated ASD are generally asymptomatic. However, about 10% present with signs of CHF, poor feeding, and poor growth. These symptoms develop as the PVR falls over the first few weeks of life. Associated with an ASD is a soft, systolic murmur best heard over the second intercostal space at the left upper sternal border.
d-TRANSPOSITION OF THE GREAT ARTERIES

Pathophysiology

The truncus arteriosus begins to divide during the fifth week of gestation. As the cardiac tube folds, the vessel twists on itself and divides into two separate vessels. The exact etiology of transposition remains unknown. Historically, transposition was thought to occur because of a failure of the aorticopulmonary septum to grow in a spiral fashion, resulting in inappropriate migration of the vessels. However, additional causes continue to be explored (Sankaran & Brown, 2007). The d (dextro)transposition of the great arteries (d-TGA) occurs when the aorta arises from the right ventricle and the pulmonary artery arises from the left ventricle, resulting in pulmonary and systemic circulations functioning in parallel. When these two arteries are transposed, unoxygenated blood returning from the body enters the right side of the heart and returns to the body, and oxygenated blood returning from the lungs enters the left side of the heart and returns to the lungs. d-TGA is considered a cyanotic lesion with increased pulmonary blood flow. d-Transposition can occur in isolation or can be associated with other defects (e.g., PDA, ASD, VSD, pulmonary stenosis). The degree of cyanosis depends on the mixing of oxygenated and unoxygenated blood between the parallel systemic and pulmonary circulations through the associated lesions (e.g., patent foramen ovale [PFO], VSD, ASD, PDA, or collateral circulation) (Kenney et al., 2011).

Assessment

d-TGA is the most common cyanotic heart lesion that presents in the newborn period and is more prevalent in males (Kenney et al., 2011). The newborn with d-TGA presents with cyanosis typically within the first hours of life, and the degree of cyanosis varies depending on the amount of intracardiac mixing. For instance, if the mixing occurs through a large VSD or PDA, the cyanosis may be mild. If the ventricular septum is intact or the PDA is closing, the cyanosis is profound since there is no intracardiac shunt. With the exception of cyanosis, the physical examination findings are often otherwise unremarkable. With a large VSD or ASD, signs of CHF develop over time as the PVR falls and the pulmonary blood flow increases. In the absence of an intracardiac shunt, severe hypoxemia and metabolic acidosis develop, followed by a rapid demise if emergency measures are not instituted.

INTERVENTIONS FOR CONGENITAL HEART DISEASE

Newborns with known or suspected CHD usually require transfer to a tertiary center for treatment and follow-up. The complete diagnostic workup and subsequent repairs or palliative surgery are performed in centers with pediatric cardiac capabilities. Before transport, close observation and supportive care and treatment are warranted. Nursing care for newborns with known or suspected CHD includes the following:

- Cardiorespiratory monitoring
- Pulse oximetry
- Blood work, including blood gas determinations
- Ongoing assessment of color, perfusion, and degree of respiratory distress
- Maintaining a neutral thermal environment
- IV hydration and nutrition
- Oxygen therapy, if appropriate, and mechanical ventilation, if required

Metabolic acidosis is treated with sodium bicarbonate, pulmonary edema with respiratory distress is treated with diuretics, and shock is treated with vasopressors and calcium gluconate. A lesion such as d-TGA without an intracardiac shunt is treated with prostaglandin E1 to maintain patency of the ductus arteriosus until surgical correction takes place (Kenney et al., 2011).

HYPOGLYCEMIA

During the neonatal period, transient low glucose levels are not only common but also likely a normal adaptation to extrauterine life (Williams, 2005). Blood glucose as low as 30 mg/dL may occur during the first hours following birth (Committee on Fetus and Newborn & Adamkin, 2011). One of the major difficulties associated with defining hypoglycemia is the lack of correlation between a given blood glucose level and clinical signs. Whether producing symptoms or asymptomatic, hypoglycemia can result in either normal neonatal outcome or serious neurologic sequelae, such as brain injury, learning disabilities, and cerebral palsy. The clinical effects of hypoglycemia remain poorly defined. Neuropathology is available in only a few infants who have died after severe hypoglycemia, although follow-up studies of high-risk infants suggest that adverse neurodevelopmental outcomes are more prevalent when there is a history of asymptomatic hypoglycemic in the newborn period (McGowan & Perlman, 2006). Although the exact incidence is elusive due to inconsistent definitions, hypoglycemia is estimated to occur in 1 to 3/1,000 live births and up to 15% of those who are born growth restricted (McGowan, Rozance, Price-Douglas, & Hay, 2011; Stoll, 2007b).

Rather than identifying strict definitions of hypoglycemia, most authors suggest the use of operational thresholds. There is no absolute threshold applicable to all babies, and there is no glucose concentration that absolutely determines clinical risk or predicts sequelae. A glucose value must be assessed in conjunction with other clinical data, and treatment should be based upon this integrated input (Cornblath et al., 2000).
CHAPTER 21 / Common Neonatal Complications

PATHOPHYSIOLOGY

During fetal life, insulin is secreted by the fetal pancreas in response to glucose that readily crosses the placenta. At birth, the newborn’s blood glucose level is approximately 70% to 80% that of the mother. After removal of placental circulation, the newborn must maintain glucose homeostasis. This requires initiation of various metabolic processes, including gluconeogenesis (e.g., forming glucose from noncarbohydrate sources such as protein and fat) and glycogenolysis (e.g., conversion of glycogen stores to glucose), as well as an intact regulatory mechanism and an adequate supply of substrate (Kayiran & Gurakan, 2010; Sperling & Menon, 2004). While this is effective for the well or term infant, the sick or preterm infant is constrained in effectively mobilizing or utilizing fuel sources.

Hypoglycemia can occur at variable times in neonatal life, depending on its cause. Hypoglycemia during the first few hours of life can be a transient result of developmental immaturity or perinatal stress and may occur in preterm or small-for-gestational-age (SGA) infants. Beyond the first few hours of life, hypoglycemia is more common due to hyperinsulinemia, as with the infant of a diabetic mother. Persistent hypoglycemia, a rare event, may represent inborn metabolic errors of metabolism or endocrine disorders (Sperling & Menon, 2004).

Early feeding will contribute to stabilization of newborn blood sugar. Breastfed term infants have lower blood glucose levels but higher concentrations of ketone bodies than formula-fed infants (Hawdon, Ward Platt, & Aynsley-Green, 1992). Utilization of this alternate fuel source may allow them to tolerate lower serum glucose levels without sequelae (Committee on Fetus and Newborn & Adamkin, 2011; Cornblath et al., 2000).

ASSESSMENT

Identification of those infants at risk for developing hypoglycemia facilitates planning and implementation of appropriate nursing care. This process begins with a review of maternal prenatal and intrapartum history for risk factors associated with neonatal hypoglycemia and a careful physical examination. Symptoms of hypoglycemia are nonspecific and not easily differentiated from many other common neonatal conditions (Display 21–1).

Universal blood glucose screening before clinical signs develop is not currently recommended by the AAP (Committee on Fetus and Newborn & Adamkin, 2011). Selective screening of at-risk newborns is more appropriate and does not appear to decrease quality of care or result in adverse outcomes.

Newborns at risk should be screened within 30 to 60 minutes after birth. Use of proper screening techniques is one of the most important nursing functions. Point-of-care testing (POCT), performed using a bedside glucose oxidase stick method, will provide an expedient estimation of glucose values. Although glucose oxidase sticks are widely used, accuracy of the results from these screening tests depends on the hematocrit, blood source, and operator’s skill. They have been shown to have considerable variance from actual blood glucose levels, which may be due to the source of blood used for testing. Venous blood samples have glucose levels that are approximately 10% less than capillary or arterial specimens (Deshpande & Ward Platt, 2005). Other factors limiting accuracy are improper storage, outdated shelf life of test strips, or contamination with isopropyl alcohol, which falsely elevates the glucose result. It is also important to remember that these POCT use whole blood, which will affect the ability to accurately detect glucose at extremes of hematocrit. The timing of glucose measurements may also result in inaccurate values, as failure to run the test promptly after sampling may result in red blood cell (RBC) oxidation of glucose and produce falsely low values. Blood samples should be transported on ice and analyzed quickly.

INTERVENTIONS

Newborns with asymptomatic hypoglycemia should be fed immediately and then retested. Invasive interventions on the basis of low values detected by screening are not warranted as long as infants are assessed and are found to be without clinical findings attributable to hypoglycemia. A low glucose in the asymptomatic newborn may initially be managed by offering breastfeeding or providing expressed breast milk or formula. The infant should be reassessed within 2 to 4 hours and, if the glucose remains low for a second measurement, should be fed again or have IV therapy started (Cornblath et al., 2000).
Newborns with symptomatic hypoglycemia, particularly those with neurologic signs and low POCT bedside blood glucose, should be treated immediately with an IV infusion of glucose, and a blood sample should be drawn and sent to the laboratory for glucose evaluation. Infusion rates should be similar to that expected with endogenous hepatic glucose production (approximately 5 mg/kg/min depending on maturity and weight for gestation—equivalent to 10% dextrose at approximately 70 to 80 mL/kg/day or 3 mL/kg/hr and titrated based on response) (Williams, 2005). Gradual increases in glucose infusion rate should not exceed 2 mg/kg/min each hour. Newborns who are unable to nipple feed and those whose blood glucose levels do not respond to oral feedings or have very low glucose levels (e.g., <20 mg/dL) should receive a 200 mg/kg (2 mL/kg) bolus of 10% dextrose in water intravenously over 1 minute, followed by a continuous infusion at the rates given previously until the blood glucose is stabilized (Cornblath et al., 2000; Rozance & Hay, 2010). Correction of hypoglycemia should result in resolution of the symptoms. IV administration is tapered off slowly, and the blood glucose level is monitored frequently, every 1 to 2 hours initially, and then intermittently before feedings until stable (Williams, 2005).

Newborns who experience persistent hypoglycemia may require an increased concentration of glucose, such as 12.5%, 15%, or 20%; dextrose solutions with concentrations greater than 12.5% require placement of a central line because of the risk of tissue extravasation. Other treatments for persistent or refractory hypoglycemia include glucagon, which promotes glycogenolysis and requires adequate stores, and corticosteroids, which induce gluconeogenic enzyme activity (Jain et al., 2010).

Hypoglycemia severe enough to warrant IV therapy, or which persists or recurs, requires further investigation to rule out underlying pathology, particularly infection or metabolic and endocrine disease (Deshpande & Ward Platt, 2005). The focus of nursing care is to prevent hypoglycemia when possible. Newborns should be fed within the first 2 hours of life. Care is taken to avoid cold stress and to recognize signs of respiratory distress and sepsis, which can increase the newborn’s risk for developing hypoglycemia.

### Hyperbilirubinemia

Hyperbilirubinemia resulting in clinical jaundice is detected in up to 60% of term and in 80% of preterm newborns (Juretschke, 2005; Piazza & Stoll, 2007). Typically, healthy newborns are discharged from the hospital before the usual peak of total serum bilirubin (TSB) (72 to 120 hours). Most jaundice is benign and resolves within 7 to 10 days in term newborns. However, severe hyperbilirubinemia may develop in 8% to 9% of all newborns during the first postnatal week (Kamath, Thilo, & Hernandez, 2011). Jaundice is a common indication for hospital readmission, affecting 1 in 100 term or late preterm infants (Alkalay, Bresee, & Simmons, 2010). Because of the potential for bilirubin toxicity, newborns require assessment to identify those at risk for severe hyperbilirubinemia or, in rare cases, bilirubin encephalopathy or kernicterus. Unconjugated hyperbilirubinemia results from physiologic mechanisms (Display 21–2) or pathologic causes (Display 21–3).

### Pathophysiology

Bilirubin is produced from the breakdown of heme-containing proteins (Juretschke, 2005). The major heme-containing protein is hemoglobin, which is the source of approximately 75% of the bilirubin produced. Heme is acted on by the enzyme heme oxygenase, releasing carbon monoxide and biliverdin. Biliverdin is then reduced to bilirubin through the activity of the enzyme biliverdin reductase. The degradation of every 1 g of hemoglobin produces 34 to 35 mg of bilirubin. Bilirubin binds with albumin for transport to the liver. Bilirubin, but not albumin, diffuses into the liver.
cytoplasm, where it is transported to the endoplasmic reticulum for conjugation. Bilirubin combines with glucurionate with the help of glucuronyl transferase, the conjugating enzyme. Conjugated bilirubin is water soluble and excreted into bile and subsequently into the small intestine through the common bile duct. In the gut, conjugated bilirubin is excreted from the body through stool or converted to unconjugated bilirubin by a gut enzyme (beta-glucuronidase) that renders it reabsorbable. In fetal life, this reabsorption facilitates transport of bilirubin to the placenta for maternal excretion; however, postnatally, this pathway adds to the infant’s bilirubin load (Kamath et al., 2011; Piazza & Stoll, 2007; Thilo, 2005).

Excretion of conjugated bilirubin is facilitated by bacteria in the gut. Meconium contains large amounts of bilirubin, but excretion is inhibited in the newborn because of the sterility of the gut. Normal colonization of bacteria occurs over time and is facilitated by early and frequent feeding. Feeding introduces bacteria into the gut. Lack of bacterial flora allows conversion of conjugated bilirubin back to an unconjugated form. This, along with greater red cell mass per kilogram in the newborn than in the adult and a shortened red cell life span, sets the stage for development of physiologic unconjugated hyperbilirubinemia. Newborns produce twice as much bilirubin as adults (Halamek & Stevenson, 2002; Piazza & Stoll, 2007; Thilo, 2005).

In a term newborn, physiologic unconjugated hyperbilirubinemia is characterized by a progressive increase in serum bilirubin to a peak of 6 to 8 mg/dL at 72 hours of age and a steady decline over the next week. In a preterm newborn, bilirubin continues to rise until the fourth to seventh postnatal day, reaching a peak of 8 to 12 mg/dL and decreasing thereafter as the processes of metabolism and excretion mature (Halamek & Stevenson, 2002). When jaundice is evident within the first 24 to 36 hours of life, bilirubin levels rise >5 mg/dL/day or peak in excess of 12 to 14 mg/dL; or if jaundice persists beyond 2 weeks of life, it is less likely to represent a physiologic process and warrants assessment (Burgos, Flaherman, & Newman, 2011; Piazza & Stoll, 2007).

Hyperbilirubinemia may result from three mechanisms: increased bilirubin production, increased bilirubin reabsorption, or decreased bilirubin excretion and may be attributed to physiologic or pathologic causes. Conditions contributing to physiologic unconjugated hyperbilirubinemia include normal bilirubin load from a large fetal RBC mass with a shortened life span, as well as delayed stooling. Breastfed infants may experience exaggerated jaundice related to initial decreased caloric intake, decreased stooling with subsequent increase of enterohepatic circulation, or effects of substances within the milk, which interfere with conjugation and excretion (Kamath et al., 2011). Pathologic hyperbilirubinemia is most commonly associated with conditions, which acutely increase the bilirubin load, such as isoimmune hemolytic disease in cases of Rh, ABO, or other minor blood group incompatibility between fetus and mother. Other causes contributing to excess bilirubin load or impaired excretion include extravascular blood, polycythemia, intestinal obstruction, prematurity, infection, infant of a diabetic mother, and rare metabolic or inherited conditions (Kamath et al., 2011; Juretschke, 2005; Thilo, 2005). Table 21–1 lists maternal and newborn risks for hyperbilirubinemia.

No absolute safe bilirubin level has been determined, and hyperbilirubinemia has the potential for leading to injury such as encephalopathy of kernicterus. Reports indicate that kernicterus, although rare, is still occurring and is almost always preventable (AAP, 2004a). The term kernicterus is used interchangeably with the acute and chronic findings of bilirubin encephalopathy. The AAP Subcommittee on Hyperbilirubinemia recommends acute bilirubin encephalopathy to be used when describing the acute manifestations of toxicity seen in the first weeks after birth and kernicterus reserved for the chronic and permanent clinical sequelae (AAP, 2004a; Schwartz, Haberman, & Ruddy, 2011). Permanent damage to the central nervous system (CNS) results from deposition of bilirubin in the brain, specifically in the basal ganglia, hippocampal cortex, subthalamic nuclei, and cerebellum (Juretschke, 2005).

During the early phase of acute bilirubin encephalopathy, severely jaundiced infants become lethargic and hypotonic and have a poor suck. The intermediate phase is characterized by moderate stupor, hypertonia,
and irritability. The infant may also develop a fever and a high-pitched cry that alternates with drowsiness and hypotonia. The hypertonia is characterized by backward arching of the trunk (opisthotonos) and of the neck (retrocollis). CNS damage may, in some cases, be reversed during this phase with a combination of intensive phototherapy and an emergent exchange transfusion. The advanced phase is characterized by pronounced retrocollis and opisthotonos, shrill cry, inability to feed, apnea, fever, deep stupor to coma, seizures, and death. In the chronic form, kernicterus, surviving infants may develop severe athetoid cerebral palsy, auditory dysfunction, dental enamel dysplasia, paralysis of upward gaze, as well as intellectual and other handicaps (AAP, 2004a). There is no absolute level at which bilirubin encephalopathy occurs in all newborns. Gestational age, postnatal age, clinical condition, and the pathophysiologic process involved all play a part in determining what level of unconjugated bilirubin causes encephalopathy in a particular newborn (Juretschke, 2005).

**ASSESSMENT**

Clinical jaundice is apparent at serum bilirubin levels of 5 to 7 mg/dL. (Juretschke, 2005; Kamath et al., 2011) and progresses cephalocaudally from head to the lower extremities. Visual recognition of jaundice is inaccurate, unreliable, and unsafe and varies with the experience and level of training of the observer (AAP, 2004a). A careful physical examination of any newborn presenting with jaundice aids in determining the cause of hyperbilirubinemia. The newborn should be assessed for risks including prematurity, low birth weight, indicators of bleeding or extravascular blood collections such as bruising, cephalhematoma or petechiae, and hepatosplenomegaly. In conjunction with the clinical examination, transcutaneous bilirubin (TcB) assessment and a number of laboratory tests including serum bilirubin may be done to quantify the bilirubin level and determine potential causes (Display 21–4). Any infant with jaundice presenting within the first 24 hours of life should have a bilirubin assessment (Burgos et al., 2011).

The AAP established new guidelines in 2004 for the management of hyperbilirubinemia in the newborn infant ≥35 weeks’ gestation (AAP, 2004a). These guidelines stress the importance of universal systematic assessment while the newborn is hospitalized, close follow-up, and prompt intervention when indicated. The key elements of the recommendation suggest that the clinician should:

1. Promote and support successful breastfeeding.
2. Establish nursery protocols for the identification and evaluation of hyperbilirubinemia.
3. Measure the TSB or TcB level on infants jaundiced in the first 24 hours.
4. Recognize that visual estimation of the degree of jaundice can lead to errors, particularly in darkly pigmented infants.
5. Interpret all bilirubin levels according to the infant’s age in hours.
6. Recognize that infants at less than 38 weeks’ gestation, particularly those who are breastfed, are at higher risk of developing hyperbilirubinemia and require closer surveillance and monitoring.
7. Perform a systematic assessment on all infants before discharge for the risk of severe hyperbilirubinemia.
8. Provide parents with written and verbal information about newborn jaundice.
9. Provide appropriate follow-up based on the time of discharge and the risk assessment.
10. Treat newborns, when indicated, with phototherapy or exchange transfusion.

**INTERVENTIONS**

In supporting adequate breastfeeding, clinicians should instruct mothers to nurse their infants 8 to 10 times per day over the first several days (Thilo, 2005). This not only promotes adequate hydration and caloric intake but also decreases the likelihood of subsequent significant hyperbilirubinemia. Nurseries should have established protocols for the assessment of jaundice. Newborns should be assessed with vital signs but no less than every 8 to 12 hours. Assessment should be done in a well-lit room; however, it is important to remember that visual assessment of jaundice is unreliable and potentially unsafe (Piazza & Stoll, 2007). A low threshold should be used for assessing bilirubin. Noninvasive TcB devices have been proven to be very useful as screening tools. It has also been recommended that protocols allow nurses to access bilirubin testing, either TcB or TSB, without a physician’s order.
Every newborn should be assessed for the risk of developing severe hyperbilirubinemia before discharge. As serum bilirubin rises >19 mg/dL, the risk of kernicterus increases incrementally (Smitherman, Stark, & Bhutani, 2006). In the Pilot Kernicterus Registry, the causes for kernicterus were attributed to the following three categories in equal proportions: hemolytic disorders (mostly ABO immunization), glucose-6-phosphate dehydrogenase (G6PD) deficiency (associated with hemolysis and impaired bilirubin conjugation), and idiopathic causes (presumably from delayed or impaired function of the glucuronyl transferase enzyme system), coupled with breastfeeding and inadequate nutritional intake (Bhutani, Johnson, & Shapiro, 2004). All nurseries should establish protocols for assessing this risk. This is particularly important if the infant is discharged before 72 hours of age. This risk can be assessed by predischARGE measurement of bilirubin and/or assessment of clinical risk factors. Regardless of how risk is assessed, appropriate follow-up is essential. An hour-specific nomogram is a useful tool for determining the need for and appropriate timing of repeated TcB or TSB measurements. The assigned low-, intermediate-, or high-risk zone in which the individual bilirubin level falls (Fig. 21–1) will indicate the risk for developing clinically significant hyperbilirubinemia (Bhutani, Johnson, & Sivievri, 1999). Reassuring predischarge bilirubin levels do not eliminate the risk of developing significant hyperbilirubinemia, and careful follow-up of even “low risk” newborns is warranted (Bromiker, Bin-Nun, Schimmel, Hammerman, & Kaplan, 2012).

The risk factors most frequently associated with severe hyperbilirubinemia are predischarge TSB or TcB levels in the high-risk zone of the nomogram; jaundice within the first 24 hours of life, blood group incompatibility, or other known hemolytic disease with a positive direct antiglobulin test; gestational age of 35 to 36 weeks; previous sibling who received phototherapy; cephalhematoma or significant bruising; East Asian race; and exclusive breastfeeding, particularly if nursing is not going well and weight loss is excessive (AAP, 2004a; Burgos et al., 2011). Written and verbal information must be provided to parents at discharge. This should include an explanation of jaundice, the need to monitor infants for jaundice, and advice on how monitoring should be done. Newborn jaundice resource materials are available for parents in multiple languages (English, Spanish, Chinese, and Italian) and include a frequently asked question sheet from the AAP (2004b). All infants should be examined by a qualified healthcare professional in the first days after discharge, and those with jaundice should be evaluated within 24 hours (AAP, 2004a).

PHOTOTHERAPY

In the late 1940s, exchange transfusion was the only available treatment for newborns with hyperbilirubinemia. In the mid-1950s, an observant nurse noticed that newborns exposed to sunlight had less clinical jaundice over exposed areas and decreased serum bilirubin levels. This observation led to the use of phototherapy, which remains the primary treatment for hyperbilirubinemia. In nearly all newborns, phototherapy decreases or blunts the rise in serum-unconjugated bilirubin regardless of gestational age, race, or presence or absence of hemolytic disease. Phototherapy is used for treatment and prophylaxis of hyperbilirubinemia. No serious long-term side effects have been reported. Recommendations for treatment in infants born at ≥35 weeks’ gestation are found in Figure 21–2. There is no consensus or recommendation regarding the discontinuation of phototherapy.

The goal of phototherapy is to decrease the level of unconjugated bilirubin. Phototherapy accomplishes this goal by means of the following:

- Absorption of light by bilirubin molecule
- Photoconversion of bilirubin by photochemical reaction, restructuring the molecule into an isomer
- Excretion of bilirubin through urine and bile, bypassing the conjugation process (Maisels & McDonagh, 2008; Schwartz et al., 2011).

Effectively used phototherapy can decrease bilirubin levels at a rate of 0.5 to 1.0 mg per hour (Kamath et al., 2011). For phototherapy to be effective, there must be illumination of an adequate area of exposed skin at a sufficiently short distance. Several types of phototherapy lamps are available: daylight, cool white fluorescent, fluorescent green, special blue fluorescent, quartz halogen, and high-intensity gallium nitride light-emitting diodes (AAP, 2004a). Phototherapy can also be delivered using a fiber-optic blanket (McFadden, 1991). Although any light source with irradiance between 400 and 500 nm can be used, the most effective light sources currently available are those that use special blue fluorescent tubes or a specially designed light-emitting diode light (AAP, 2004a). There is a direct relationship between the irradiance used and the rate of bilirubin decline with phototherapy. Irradiance should be monitored and is measured with a radiometer as μW/cm²/nm. Standard phototherapy units deliver 8 to 10 μW/cm²/nm (AAP, 2004a). A fiber-optic blanket generally delivers irradiance of 15 to 20 μW/cm²/nm (McFadden, 1991). Intensive phototherapy requires >30 μW/cm²/nm. Intensive phototherapy can be provided with special blue tubes placed 10 to 15 cm above the infant (AAP, 2004a). To expose the maximum surface area of the infant, overhead phototherapy can be used with a fiber-optic blanket. The newborn is placed naked under the phototherapy light and repositioned at least every 2 hours to ensure adequate light exposure to all areas. If a fiber-optic blanket is used, the blanket is wrapped around the newborn’s trunk, and clothing is placed over the blanket.
Common Neonatal Complications


**FIGURE 21–2.** Algorithm for the management of jaundice in the newborn nursery. (From American Academy of Pediatrics Clinical Practice Guideline Subcommittee on Hyperbilirubinemia. [2004]. Management of hyperbilirubinemia in the newborn infant 35 or more weeks’ gestation. Pediatrics, 114[1], 297–316.)
Although phototherapy has not been associated with any serious long-term effects, important short-term side effects include temperature instability, increased insensible fluid losses, and rash. The focus of nursing care is to prevent or minimize side effects. Newborns receiving phototherapy from phototherapy lamps are placed in a bassinet or under a radiant heat source, and axillary temperature is monitored at least every 2 hours to assess for hyperthermia. Hyperthermia can result in tachycardia and increased insensible water loss and dehydration. Loose stools are an unavoidable effect of phototherapy and can also result in increased insensible water loss and dehydration. Intake, output, and urine-specific gravity are measured accurately and documented. Meticulous skin care is necessary to prevent skin breakdown resulting from loose stools. A generalized macular rash frequently develops and resolves spontaneously when phototherapy is discontinued (Stokowski, 2006).

The newborn’s eyes are covered at all times while under phototherapy lamps to prevent potential retinal damage. An advantage of the fiber-optic blanket is that eye protection is unnecessary. Eye patches should be removed during feedings or at least every 4 hours to observe for drainage and to promote social stimulation and visual development. Corneal injury can result from eye patches that apply excessive pressure to the eyes or which are loose enough to allow eye opening under the patch (Piazza & Stoll, 2007; Thilo, 2005). Although human studies have not confirmed irradiance effects on the developing gonads, animal studies have shown DNA strand breaks and chromatid exchanges and mutations. Diapers or small diaperlike devices are used as a shield for the testicles or ovaries (Maisels, 1990).

For infants with severe hyperbilirubinemia, treatment may also include use of a double-volume exchange transfusion to directly remove excess unconjugated bilirubin from the bloodstream. This procedure is reserved for severe cases in whom phototherapy or other treatments have proved ineffective or whose rate of bilirubin production is escalating rapidly. This procedure involves vascular access and vigilant monitoring, necessitating transfer to the intensive care nursery setting (Kamath et al., 2011). Techniques are being investigated to aid in the identification of rising bilirubin levels, especially in those patients with hemolysis. Carbon monoxide is a known byproduct of bilirubin metabolism, and noninvasive monitoring of exhaled or serum carbon monoxide is being studied as an indicator of heme degradation (Cohen, Wong, & Stevenson, 2010; Juretschke, 2005). Another research focus is on replacing traditional treatment or augmenting therapy for those who do not respond to phototherapy. Metalloporphyrins, a family of compounds to which heme belongs, are known to interfere with heme degradation and bilirubin production. Two such compounds, tin-protoporphyrin and tin-mesoporphyrin, are potent inhibitors of heme oxygenase, an essential step in the degradation process. There is current evidence that hyperbilirubinemia may be effectively treated or even prevented with tin-mesoporphyrin; however, this agent is not yet approved by the U.S. Food & Drug Administration (FDA) (AAP, 2004a; Schwartz et al., 2011; Thilo, 2005).

### NEONATAL SEPSIS

The incidence of neonatal sepsis is approximately 1 to 5 cases per 1,000 live births (Puopolo, 2008; Stoll, 2007a). Neonatal bacterial sepsis is the sixth leading cause of infant mortality in the United States across all races and genders (Kochanek, Xu, Murphy, Minino, & Kung, 2011). Risks for and subsequent morbidity and mortality from neonatal sepsis is affected by factors such as adequacy of perinatal care and infant gestational age and birth weight. Diagnosis of neonatal sepsis is based on clinical signs and supported by a positive blood culture (Bentlin, Suppo, & Rugolo, 2010). Display 21–5 identifies maternal and perinatal factors that may pose risks for neonatal sepsis.

### PATHOPHYSIOLOGY

Many microorganisms are responsible for infection during the neonatal period. The most common causative bacterial agents in the United States are group B Streptococcus (GBS) and Escherichia coli (Puopolo, 2008). In contrast to preterm infants, in whom the most significant bacterial pathogen is Escherichia coli, GBS is the most common pathogen affecting term newborns (Stoll et al., 2011). Infection occurs as a result of the following conditions:

- Intrauterine exposure by means of ascending infection from one or more of the endogenous flora of the cervix or vagina or, less commonly, by a transplacental route from maternal circulation

### DISPLAY 21–5

**Maternal and Perinatal Factors Predisposing Newborns to Sepsis**

- Preterm labor
- Premature rupture of the membranes
- Prolonged rupture of membranes
- Maternal sepsis
- Chorioamnionitis
- Intraamniotic infection
- Vaginal colonization with group B streptococci (GBS)
- Perineal colonization with *Escherichia coli*
- Prior birth of an infant with GBS
- Chemical dependency or substance abuse
- Urinary tract infection
- Foul-smelling amniotic fluid
• Cutaneous transmission as the fetus passes through the birth canal
• Environmental contamination after the birth

Two presentations of infection, early versus late onset, are observed in neonates. Early-onset sepsis occurs within 7 days of life (Oh, 2013; Shane & Stoll, 2012). Frequently, inoculation occurred in utero. If symptoms are not present immediately after birth, most newborns become asymptomatic within 12 hours with respiratory distress and nonspecific findings such as feeding intolerance, abdominal distension, apnea, or bradycardia (Ohlin, Bjorkqvist, Montgomery, & Schollin, 2010). Late onset sepsis may occur as early as 72 hours of age (Bentlin et al., 2010) but is more common after the first postnatal week. This presentation is likely due to exposure during the birth process or nosocomial transmission after birth from caregivers or invasive procedures and results in findings such as septicemia, pneumonia, and meningitis. Unrecognized sepsis may progress rapidly to hypotension and septic shock.

GBS is an important source of morbidity and mortality in the perinatal setting (Shane & Stoll, 2011). Of pregnant women, 20% to 30% are colonized with GBS; 50% of their infants will be colonized with GBS; and 1% to 2% will develop invasive disease (Oh, 2013; Puopolo, 2008). Most of these infections could be prevented by use of prophylactic antimicrobials in at-risk women. The CDC, AAP, the American College of Nurse Midwives, the American Academy of Family Physicians, the American Society for Microbiology, and ACOG endorse protocols to prevent early-onset infection (Verani, McGee, & Schrag, 2010). The 2010 recommendations state:

• All pregnant women should be screened at 35 to 37 weeks’ gestation for vaginal and rectal colonization.
• Women with GBS bacteriuria during the current pregnancy should automatically receive chemoprophylaxis; no screening culture is needed. Bacteriuria is a marker for genital colonization.
• Women who have had a previous infant with invasive GBS disease should automatically receive intrapartum chemoprophylaxis; no screening culture is needed.
• At the onset of labor or rupture of membranes (ROM), chemoprophylaxis should be given to all women identified as GBS carriers.
• Chemoprophylaxis should be given at the onset of labor or ROM if the GBS status is unknown and there are risk factors and in women <37 weeks, with ROM ≥18 hours and/or temperature ≥38°C.

ASSESSMENT

As with all neonatal complications, early identification of newborns at risk and prompt recognition of developing signs decreases morbidity and increases the chances of survival. Recognizing multiple risk factors is the first step in identifying newborns whose early days may be complicated by infection. Risk factors can be categorized as maternal, neonatal, and environmental. A thorough review of antepartum and intrapartum history should specifically look for conditions that increase the risk of early-onset sepsis. If different nurses care for the mother and newborn, communication among healthcare team members is essential to ensure that maternal complications with potential impact on the newborn are not overlooked. The nurse caring for the mother during the postpartum period should notify the neonatal care provider if fever or other symptoms of infection develop.

The primary neonatal factors influencing development of sepsis are gestational age and birth weight. Gestational age and birth weight vary inversely with morbidity and mortality from sepsis. Preterm newborns may be exposed to the same organisms as term newborns, but their ability to fight infection is lessened. Other factors associated with increased risk of sepsis are resuscitation at birth and low Apgar scores. Congenital anomalies in which the skin or mucous membrane is not intact increase the risk of sepsis because a cutaneous port of entry is available for microorganisms. A history of a nonreassuring fetal HR pattern during labor, with or without meconium in the amniotic fluid, may identify fetuses at risk for infection. More male than female newborns develop sepsis, suggesting that the susceptibility may be sex linked (Stoll, 2007a). Maternal factors include premature rupture of membranes (PROM), chorioamnionitis, intrapartal fever, and GBS colonization (Puopolo, 2008; Shane & Stoll, 2012).

The most obvious environmental risk for developing sepsis is admission to a neonatal intensive care unit (NICU). Newborns in the NICU are compromised because of the original reason for admission along with being subjected to manipulation and invasive procedures that frequently puncture the skin, the first line of defense against infection. Environmental risks of nosocomial infection include use of equipment, indwelling catheters and chest tubes, inadequate hand washing or cleaning procedures, breaks in skin integrity, oxygen therapy, mechanical ventilation, surgical procedures, and possibly cohorting. Overcrowding in the nursery or inadequate attention to isolation precautions increases the risk of cross-contamination.

In addition to reviewing antepartum and intrapartum history, identifying the newborn with neonatal sepsis requires a thorough physical examination, evaluation of vital signs and laboratory data, and recognition of signs consistent with the diagnosis of sepsis. Like many conditions complicating the newborn period, the early signs of neonatal sepsis are vague and frequently nonspecific. Clinical indicators such as apnea, tachypnea, temperature instability, tachycardia, lethargy, and poor feeding may be early symptoms of sepsis.

A diagnostic evaluation includes a complete blood cell (CBC) count with a differential cell count, aerobic
and anaerobic blood cultures, and supportive cultures such as tracheal aspirate, cerebrospinal fluid, or urine as clinically indicated. For best yield, cultures should be obtained before the initiation of antibiotic therapy from any newborn suspected of being septic. A positive blood culture remains the gold standard for the diagnosis of sepsis. Other studies may include evaluation of acute-phase reactants such as C-reactive protein (CRP). Acute-phase reactants increase in response to inflammation or tissue necrosis, which may indirectly support the diagnosis of infection (Shane & Stoll, 2012; Stoll, 2007a).

**INTERVENTIONS**

Many institutions have developed protocols for evaluations to exclude sepsis, including laboratory data and frequency of vital signs and clinical assessment. The CDC, AAP, and ACOG have also published certain recommendations for the management of a neonate born to a mother who received intrapartum antimicrobial prophylaxis for GBS. If there are signs of sepsis, the newborn should receive a full diagnostic evaluation and antimicrobial therapy. If there are no signs of sepsis and the newborn is less than 35 weeks’ gestation, a CBC and blood culture should be obtained and the newborn observed for 48 hours or longer. If the newborn is greater than or equal to 35 weeks’ gestation and the mother received antibiotic prophylaxis less than 4 hours before delivery, a CBC and blood culture should also be obtained and the newborn observed for 48 hours or longer. If the mother received two or more doses of an antimicrobial agent, no evaluation or therapy is required, although the newborn must still be observed for 48 hours or longer. This approach would preclude an early discharge. Figure 21–3 is an algorithm for management of infants born to mothers who received intrapartum chemoprophylaxis for GBS infection.

After the diagnostic evaluation has been completed, antimicrobial agents are initiated. For early-onset sepsis, ampicillin, a broad-spectrum antimicrobial that is bactericidal for gram-positive and gram-negative bacteria, is used in combination with an aminoglycoside such as gentamicin. The usual dosage of ampicillin is 50 to 100 mg/kg every 8 to 12 hours for 7 to 10 days. When sepsis is complicated by meningitis, the dosage is increased and the duration of treatment is extended to 14 days. The choice of antibiotics is ultimately determined by the particular sensitivity of a recovered organism. If, however, after 48 to 72 hours, cultures are negative and the infant is clinically stable, antimicrobials may be discontinued (Stoll, 2007a).

PERINATAL HUMAN IMMUNODEFICIENCY VIRUS (HIV) INFECTION

Despite great strides in the prevention of perinatal and early childhood transmission of HIV infection, it remains an important source of mortality worldwide. Accounting for both developed and developing countries, it is estimated that 1,800 children will become infected with HIV daily, primarily from maternal-to-child transmission. In developed countries, however, the rate of maternal–child transmission has fallen from 15% to 30% to as low as 2%, attributable to the use of preventive strategies, including antiretroviral therapy (Committee on Obstetric Practice, 2008; Davis & Yawetz, 2012; Thorne & Newell, 2007).

ACOG and the CDC recommend offering all women of childbearing age the opportunity for preconception counseling and care as a component to routine medical care (ACOG, 2005; CDC, 2006a). ACOG, AAP, and the Canadian Paediatric Society recommend HIV testing and counseling, with consent, for all pregnant women in North America and advocate preconception counseling as part of a comprehensive healthcare program for all women (ACOG, 2003; CDC, 2006b; Davis & Yawetz, 2012; King, 2004; Public Health Service Task Force, 2006). HIV testing must be voluntary and free from coercion. No woman should be tested without her knowledge, and each woman has the option to decline or opt out of the HIV screening (CDC, 2006b). Early identification of the HIV-infected pregnant woman is essential for her health and that of her exposed infant (Panel on Antiretroviral Therapy and Medical Management of HIV-Infected Children, 2010). It has been demonstrated that rates of perinatal HIV transmission can be reduced significantly with prenatal testing and antiviral treatment (Davis & Yawetz, 2012).

Many women with HIV infection enter pregnancy with a known diagnosis and are already receiving antiretroviral therapy, although adjustment to their regimen may be necessary (Davis & Yawetz, 2012; Public Health Service Task Force, 2006). Decisions regarding therapy should be the same for pregnant and nonpregnant women with HIV infection, with the additional consideration of the potential impact of therapy on the fetus and infant. Discussions regarding the treatment of HIV should not be coercive, and the woman is ultimately responsible for the final decision. Staging of HIV infection and establishment of an appropriate management plan is essential to optimize both maternal and neonatal care. Assessment should include evaluation of prior HIV-related infections and need for prophylaxis against opportunistic infections. Prior antiretroviral therapy and past CD4-cell counts and plasma HIV viral load, as well as current antiretroviral agents, CD4-cell counts, and plasma HIV RNA copy numbers, will provide necessary data to craft a management plan (Panel on Antiretroviral Therapy and Medical Management of HIV-Infected Children, 2012).

Healthcare providers who treat HIV-infected pregnant women and their newborns are strongly advised to report all instances of prenatal exposure to antiretroviral drugs to the Antiretroviral Pregnancy Registry. This is an observational epidemiologic project assessing the potential teratogenicity of these drugs (Public Health Service Task Force, 2006).

Antiretroviral Pregnancy Registry
Research Park
1011 Ashes Dr.
Wilmington, NC 28405
1-800-258-4263
1-800-800-1052 (fax)
http://www.APRegistry.com

CHEMOPROPHYLAXIS FOR PERINATAL HIV TRANSMISSION

The patient who presents in labor without documented HIV status should receive rapid HIV antibody testing; and those with positive antibody results as well as those with pending HIV RNA copy number or CD4-cell count assessments should commence antiretroviral prophylaxis promptly. Repeat testing is recommended in the third trimester for the pregnant woman with a previous negative HIV antibody test if she remains in a high-risk category (e.g., engages in risky behavior or lives in a high prevalence area). For the patient in whom acute infection is suspected, virologic testing (e.g., plasma HIV RNA assay) should be obtained because serologic testing may be negative at early stages of infection (Davis & Yawetz, 2012; Panel on Antiretroviral Therapy and Medical Management of HIV-Infected Children, 2010, 2012).

Although intrapartum antiretroviral therapy will not prevent perinatal transmission that occurs before
labor, most transmission occurs near or during labor and delivery. Therefore, preexposure prophylaxis is recommended to give antiretroviral drug levels in the fetus during the intensive exposure to HIV-1 in maternal genital secretions and blood during birth (Public Health Service Task Force, 2006).

**MODE OF DELIVERY**

Optimal medical management should focus on minimizing the risk of both perinatal transmission of HIV-1 and the potential for maternal and neonatal complications (Public Health Service Task Force, 2006). Use of instruments such as forceps or vacuum devices poses risks for HIV transmission and should be discouraged when possible. Previous data suggested that elective cesarean delivery at 38 weeks decreased perinatal transmission; however, as combination therapy has become more widely used, the added benefit of cesarean delivery became less clear. Current guidelines do not support routine cesarean delivery to prevent perinatal HIV transmission but rather recommend counseling patients regarding the potential benefits in cases where the HIV RNA is >1,000 copies/ml” (Davis & Yawetz, 2012).

**CARE OF THE NEWBORN**

HIV-exposed infants should be identified early. Viral diagnostic testing is recommended at birth for infants at high risk for HIV infection, including those born to HIV-positive mothers without prenatal care, those without prenatal antiretroviral prophylaxis, and those with an HIV viral load ≥1,000 copies per milliliter near the time of delivery. Repeated viral testing should occur at 14 to 21 days, 1 to 2 months, and 4 to 6 months postnatally (Panel on Antiretroviral Therapy and Medical Management of HIV-Infected Children, 2010).

Immediate care of the newborn should limit exposure to maternal fluids. A bath should be given once the infant’s temperature is stable. Infants born to HIV-infected mothers should have an HIV DNA polymerase chain reaction (PCR) and CBC with manual differential as part of their admission labs (King, 2004; Public Health Service Task Force, 2006). Breastfeeding is a known risk for HIV transmission and is not recommended when suitable alternatives such as infant formula are available (Davis & Yawetz, 2012; King, 2004; Public Health Task Force, 2006).

Antiretroviral therapy has been shown to decrease seroconversion, and current recommendations support initiating treatment in newborns as close as possible to birth, but less than 12 hours of age. Once initiated, chemoprophylaxis should continue for 6 weeks. Zidovudine is currently recommended in infants, with a dose adjusted for gestational age. The dose for term newborns is 2 mg/kg twice daily, which can be given orally (Davis & Yawetz, 2012: Public Health Task Force, 2006).

Anemia is the primary complication of the 6-week course of zidovudine in the neonate. Therefore, at a minimum, a hemoglobin level should be obtained at the initiation and completion of the treatment course (Davis & Yawetz, 2012). Infants with negative virologic test results during the first 6 weeks of life should have a repeat HIV DNA PCR after completion of antiretroviral treatment. Routine infant immunizations should be administered to HIV-exposed infants utilizing specific Red Book guidelines when HIV infection is confirmed (King, 2004). To prevent Pneumocystis carinii pneumonia, all infants born to HIV-infected mothers should begin prophylaxis after completion of the ZDV prophylaxis regimen (Public Health Service Task Force, 2006).

**NEONATAL SUBSTANCE EXPOSURE**

Any drug that enters the mother’s system has the potential for an effect on the fetus, and certain drugs (specifically opiates) may result in low birth weight or create effects such as neonatal intoxication or withdrawal. The incidence of neonatal abstinence syndrome (NAS) has been reported to be a range of 3% to 50%, depending on the population, community setting, and individual hospital sampling practices. Even though studies show that drug use among women of childbearing age is declining, a recent survey found that 5.5% of women use illicit drugs during pregnancy (Rosen & Bateman, 2002). Commonly abused drugs include alcohol, marijuana, cocaine and crack, heroin, amphetamine and methamphetamine, inhalants, and the “club drugs” (Rosen & Bateman, 2002). Drugs associated with NAS can be divided into four groups: CNS depressants, opioids, CNS stimulants, and hallucinogens.

**PATHOPHYSIOLOGY**

Maternal drug use in pregnancy has been associated with higher rates of fetal distress and demise, lower Apgar scores, growth retardation, adverse neurodevelopmental outcomes that may not manifest until later in infancy, and acute withdrawal during the neonatal period (Rosen & Bateman, 2002). It is difficult to know whether substance abuse alone or (more likely) the multifactorial influence of drug abuse and social problems is responsible. Many pregnant women who use illicit drugs also use tobacco and alcohol, which also pose risks to unborn babies, making it difficult to determine which health problems are caused by a specific substance. Drug abuse in pregnancy is frequently associated with poverty and family disruption, increasing the risk that women will place less value on seeking early and consistent prenatal care. The general health
of these women may be poor, predisposing them to suboptimal weight gain and anemia.

Although addressed less extensively in substance abuse literature, there can be effects on the fetus and infant from tobacco exposure during pregnancy. Of pregnant women, 13% to 20% admit to smoking during pregnancy, which poses risks to the parturient as well. Some evidence suggests that tobacco exposure increases rates of placental pathology, ectopic pregnancy, and spontaneous abortion. Infants of smokers have smaller birth weights, are at risk for complications such as sudden infant death syndrome (SIDS), and may be at heightened risk for preterm birth or neurobehavioral effects due (at least partially) to the effects of multiple metabolites in tobacco smoke (Law et al., 2003; Rogers, 2008). It has been suggested that smoking cessation among childbearing women would reduce stillbirths more than 10% and newborn death by approximately 5% (Rogers, 2008).

Complete information on transmission of illicit drugs to the fetus is unavailable, but most appear to pass easily through the placenta. Based on animal studies, it is known that rates of transmission and metabolism vary from drug to drug and depend on fetal age. Increased maternal blood flow in later gestation appears to increase transport of substances to the fetus. The vasoconstricting effects of these substances cause abruptio placentae, elevated blood pressure, precipitous labor, inadequate contraction patterns, decreased fetal oxygenation, and decreased length and head circumference. Use of cocaine and heroin, amphetamine, and marijuana is associated with intrauterine growth restriction. Some studies have shown a higher incidence of genitourinary abnormalities in infants of cocaine-using mothers. Cocaine is also thought to increase fetal vasoconstricting hormones, leading to increased blood pressure and an elevated HR. These physiologic responses increase risk of cerebral ischemia and hemorrhagic lesions (Rosen & Bateman, 2002).

**ASSESSMENT**

NAS describes a range of symptoms the newborn experiences during withdrawal from exposure to a dependency-producing substance (Kuschel, 2007). It is often a multisystem disorder that frequently involves the central nervous and gastrointestinal (GI) systems. Although the most severe withdrawal symptoms are seen in the newborn exposed to opioids, symptoms can also occur after exposure to other drugs. Depending on the chemical agent the mother used, after several weeks or months, symptoms no longer represent withdrawal but rather the long-term effects of intrauterine drug exposure.

Clinical signs of opioid withdrawal usually begin 24 to 48 hours after birth, but they may not appear for as long as 10 days. Symptoms generally last for less than 2 weeks, but some infants show mild signs for up to 6 months (Fike, 2003). The severity of the abstinence syndrome is affected by the drug or combination of drugs used, although it may not correlate predictably with dose or duration of substance exposure (Burgos & Burke, 2009). Withdrawal symptoms are more severe when the drug exposure is closer to the time of birth. Methadone withdrawal is more severe than any other narcotic (Rosen & Bateman, 2002). Approximately 75% of newborns with prenatal exposure to methadone develop withdrawal symptoms. Time of onset is variable and is affected by last prenatal dose, gestational age, and mode of delivery (Liu, Jones, Murray, Cook, & Nanan, 2010). The newborn may have early withdrawal beginning at 24 to 48 hours or may have one or two types of late withdrawal, in which symptoms may appear shortly after birth, improve, and then reappear in 2 to 4 weeks, or there may be no symptoms until 2 to 3 weeks of age. Opioid withdrawal affects multiple systems including CNS (e.g., tremors, hypertonia, hyperreflexia, restlessness, irritability, high-pitched cry), GI (diarrhea, vomiting, poor feeding, or swallow), or autonomic nervous system (sweating, fever, nasal stuffiness, yawning, or motting) (Burgos & Burke, 2009).

Heroin withdrawal begins within the first 2 weeks after birth, with an average onset at 72 hours. The incidence of withdrawal has been associated with maternal dosage of heroin, duration of maternal addiction, and time of the last maternal dose (Rosen & Bateman, 2002). Neonates who are exposed to barbiturates present with symptoms similar to opioids, although the onset is delayed until day 4 to 7 of life, and may persist up to 4 months of age (Burgos & Burke, 2009).

There is no clearly defined abstinence syndrome associated with in utero cocaine exposure (Fike, 2003); however, because it easily crosses the placenta, it may contribute to some neonatal behaviors. A significant perinatal effect of cocaine exposure is related to its potent vasoconstrictive activity, which may result in impaired placental blood flow to the fetus. This has been associated with findings such as growth restriction or asphyxia, which may be further complicated by polydrug exposure (Burgos & Burke, 2009). Several neurobehavioral abnormalities frequently occur after intrauterine cocaine exposure, including hypertonia, irritability, tremulousness, tachypnea, state disorganization, loose stools, and poor feeding. These findings usually occur on day 2 or 3 and are more consistent with the stimulant effect itself rather than withdrawal. Other stimulants such as methamphetamines less commonly create NAS, and fewer than 6% of exposed infants will require pharmacologic management for symptoms (Burgos & Burke, 2009).
Alcohol exposure in utero can be associated with a range of complications including growth restriction, birth defects, mental retardation, and lifelong behavioral problems. Fetal alcohol syndrome (FAS) and alcohol-related neurobehavioral disorders (ARND) refer to clustered findings attributed to in utero alcohol exposure and together affect approximately 0.9 per 100 live births (Langendoerfer, Johnson, & Thureen, 2005). Recently, an alcohol withdrawal syndrome has been described with onset at less than 12 hours after delivery, and findings include irritability, restlessness, inconsolability, and poor feeding (Burgos & Burke, 2009).

Preterm newborns may exhibit less severe or later onset effects from intrauterine substance exposure, either due to decreased risks from shorter term in utero exposure or their CNS immaturity and consequent decreased ability to manifest clinical signs (Kuschel, 2007). It is difficult to accurately assess the severity of abstinence in preterm newborns because the tools available were originally developed for use with term newborns. Many of the characteristics seen in neonatal drug withdrawal are common in preterm newborns, such as tremors, high-pitched cry, tachypnea, and poor feeding.

**INTERVENTIONS**

Appropriate care of drug-exposed newborns begins with early identification and recognition of maternal drug abuse. Careful prenatal and postnatal maternal screening for substance abuse is essential. All women, regardless of racial or social background and perceived risk status, should be asked directly in a nonjudgmental manner about drug and alcohol use during pregnancy. Illicit drug use should be considered as potentially complicating all pregnancies. The level of suspicion should increase when the pregnant woman:

- Has received little or no prenatal care
- Has a history of sexually transmitted diseases
- Insists on leaving the hospital shortly after birth
- Demonstrates signs of drug use such as needle marks and malnutrition
- Demands medication frequently and in large doses

Laws regulating toxicology screens without maternal consent vary regionally, and the perinatal nurse should be aware of local regulations. When indicated, a maternal urine toxicology screen can be included as part of laboratory tests routinely ordered during the hospital admission process. If results are positive or not obtained, a urine toxicology screen or meconium assay is performed with a sample collected from the newborn’s first void or stool (Rosen & Bateman, 2002). The potential yield from newborn screening is affected by a limited diagnostic window following exposure (Kuschel, 2007); thus, all newborns should be observed for signs of NAS.

Many withdrawal symptoms can be successfully treated with basic supportive care. These interventions increase the newborn’s ability to regulate behavioral state, improve neuromotor control, and promote maternal newborn attachment. Minimal handling, swaddling, and a variety of positioning interventions have been used in an attempt to console and quiet the irritable, narcotic-withdrawn newborn. They can easily become overstimulated during the acute period of withdrawal (Fike, 2003). Using a neonatal abstinence scoring system (NASS), narcotic-withdrawn newborns placed in a prone position demonstrated lower scores than narcotic-withdrawn newborns placed in other positions (Fike, 2003). Display 21–6 depicts nonpharmacologic interventions to support the newborn experiencing withdrawal.

Newborns who do not respond to symptomatic treatment alone may need medication. Ideally, the decision to begin medication is based on an objective assessment of symptoms such as the NASS (Fig. 21–4). The newborn is assessed and scored every 2 hours for the first 48 hours and then every 8 hours while symptoms of withdrawal persist. Points are given for all behaviors or symptoms observed during the scoring interval. The newborn must be awake and calm to assess muscle tone, respirations, and Moro reflex. Observations should be made after feeding whenever possible because hunger can mimic withdrawal. Temperatures recorded on the scoring sheet should be obtained rectally, although an axillary temperature 2°F cooler may also indicate withdrawal. If the average of any three successive scores exceeds 8 points and is not reduced by nursing interventions, medications are initiated (Weiner & Finnegan, 1998). A simplified scoring system, the Neonatal Withdrawal Inventory (NWI), has been developed based on the NASS (Zahorodny et al., 1998).
### CENTRAL NERVOUS SYSTEM DISTURBANCES

<table>
<thead>
<tr>
<th>SIGNS AND SYMPTOMS</th>
<th>SCORE</th>
<th>AM</th>
<th>PM</th>
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</thead>
<tbody>
<tr>
<td>Excessive High-Pitched Cry</td>
<td>2</td>
<td></td>
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<tr>
<td>Continuous High-Pitched Cry</td>
<td>3</td>
<td></td>
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<tr>
<td>Sleeps &lt;1 Hour After Feeding</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Sleeps &lt;2 Hours After Feeding</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Sleeps &lt;3 Hours After Feeding</td>
<td>1</td>
<td></td>
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<tr>
<td>Hyperactive Moro Reflex</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Markedly Hyperactive Moro Reflex</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Mild Tremors Disturbed</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Moderate–Severe Tremors Disturbed</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Mild Tremors Undisturbed</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate–Severe Tremors Undisturbed</td>
<td>4</td>
<td></td>
<td></td>
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<tr>
<td>Increased Muscle Tone</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Excoriation (Specify Area):</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myoclonic Jerks</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Generalized Convulsions</td>
<td>5</td>
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### METABOLIC/VASOMOTOR /RESPIRATORY DISTURBANCES

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<tbody>
<tr>
<td>Sweating</td>
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<tr>
<td>Fever &lt;101°F (99.8°F/37.2─38.2°C)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fever &gt;101°F (38.2°C and Higher)</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Frequent Yawning (≥3–4 times/interval)</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Mottling</td>
<td>1</td>
<td></td>
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<tr>
<td>Nasal Stiffness</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Sneezing (≥3–4 times/interval)</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Nasal Flaring</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Respiratory Rate &gt;60/Min.</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory Rate &gt;60/Min. with Retractions</td>
<td>2</td>
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### GASTROINTESTINAL DISTURBANCES

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<tr>
<td>Excessive Sucking</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Poor Feeding</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regurgitation</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projectile Vomiting</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Loose Stools</td>
<td>2</td>
<td></td>
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</tr>
<tr>
<td>Watery Stools</td>
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**TOTAL SCORE**
A variety of medications are used to treat NAS, and the choice of medication varies with individual nurseries. In a recent Cochrane review, opiates (used with caution) are the preferred initial therapy for NAS, especially for infants of mothers who used opioids during pregnancy (Osborn, Cole, & Jeffery, 2005), and the AAP recommends diluted tincture of opium (Kuschel, 2007). Naloxone use is contraindicated in infants born to narcotic-addicted mothers due to the risk of seizures and/or the precipitiation of severe signs and symptoms of withdrawal (Rosen & Bateman, 2002). Sedation is the most common potential complication related to treatment. Tapering and discontinuation of medications are best achieved using the NASS. After medication has been initiated, the newborn should be scored every 8 hours and reevaluated on a daily basis. If all scores are 8 or less, or the mean of any three successive scores is 7 or less, the dose should be maintained for 72 hours. If, after 72 hours, the scores are consistently 8 or less, or the mean of three successive scores is 7 or less, the dose should be decreased by 10%. This dose is maintained for 24 hours. If the mean score remains less than 8, the dose is decreased by 10% every 24 hours. After the medication has been discontinued, scoring continues until scores are 8 or less for 72 hours.

As symptoms of neonatal abstinence may not be completely resolved at the time of discharge, the parents need education to successfully care for the newborn. Parents should spend extended periods observing and interacting with their newborn in the presence of the nurse. These opportunities can be used by the nurse to observe parental interaction. Because drug-exposed newborns are discharged into an environment where drug use may still be a factor, families are followed after discharge to ensure that growth and development is adequate and that parents are aware of and receive available community resources. Breastfeeding is not contraindicated, unless there is evidence of ongoing use of agents such as heroin, cocaine, or amphetamines; methadone use is not a contraindication (Kuschel, 2007).

A component of perinatal substance exposure care is prevention, and evidence suggests that counseling should be directed early at all types of substances that can affect the health of mother and infant, both legalized and illicit. It has been shown that cessation interventions initiated during pregnancy can have a positive effect on both fetus and mother, but they must be sustained for optimal effect (Bailey, McCook, Hodge, & McGrady, 2011).

**LATE PRETERM INFANTS**

Prematurity is the major determinant of neonatal mortality and morbidity. In 2008, 12.3% of the births in the United States were premature (<37 completed weeks of gestation), representing a 3% decline from 2007 (12.7%) and a 4% decline from 2006 (12.8%). Despite the recent rate of decline, the premature rate has steadily increased by nearly 30% for more than two decades (Martin et al., 2010). This dramatic rise in prematurity has largely been due to the increase in the deliveries between 34 and 36 completed weeks of gestation. Nearly three fourths, or 8.8% of the total U.S. births in 2008, are between 34 and 36 completed weeks of gestation (Martin et al., 2010). There has been a shift from higher to lower gestational ages, leading to the most frequent length of gestation in the United States to shift from 40 to 39 weeks (Davidoff et al., 2006; Martin et al., 2010). These NTIs are often referred to as late preterm infants, the latter referring to the vulnerability of this unique population. This population of infants is often treated like full-term newborns. However, they have the same risk of complications as infants born prematurely. The magnitude of their morbidities and their impact on public health has not been well studied. Professional organizations including the Association of Women’s Health, Obstetric and Neonatal Nurses (AWHONN), the National Institutes of Child Health and Human Development (NICHD) of the National Institutes of Health, and the AAP have led the way in defining and educating healthcare providers and the public on the distinct needs of the late preterm infant. In 2005, the NICHD convened a multidisciplinary task force, which summarized the current state of knowledge on late preterm births and published a special, two-part supplement summarizing the findings from the meetings in Seminars in Perinatology (NICHD Workshop, 2005; Raju, Higgins, Stark, & Leveno, 2006). This multidisciplinary team of experts discussed the definition and terminology, epidemiology, etiology, biology of maturation, clinical care, surveillance, and public health aspects of late preterm infants. Knowledge gaps were identified and research priorities listed. The NICHD panel recommended that births between 34 completed weeks (34 0/7 weeks or day 239) and less than 37 completed weeks (36 6/7 weeks or day 259) of gestation be referred to as late preterm (Raju et al., 2006). Also, in 2005, AWHONN (Medoff-Cooper, Bakewell-Sachs, Buus-Frank, & Santa-Donato, 2005) launched a multiyear initiative to address the unique physiologic and developmental needs of the late preterm infant that resulted in the development of a conceptual framework for optimizing the health of late preterm infant. In 2010, AWHONN released an evidence-based clinical practice guideline (EBG) to provide nurses and other healthcare professionals with state-of-the-science recommendations to accurately assess and manage this high-risk population. Additionally, in a clinical report defining and describing late preterm infants and their unique characteristics,
the AAP has published guidelines for care of these at-risk infants (Engle, Tomashek, & Wallman, 2007).

OBSTETRIC AND NEONATAL ISSUES

Obstetricians face many challenges when managing a woman in preterm labor (Mi Lee, Cleary-Goldman, & D’Alton, 2006; Sibai, 2006; Hankins & Longo, 2006). Continuous assessment of anticipated risks for both the mother and the fetus is crucial. Although a baby born prematurely increases neonatal morbidity and mortality, a fetus left in a suboptimal intrauterine environment can lead to fetal demise. There are specific medical indications for delivering prior to 39 weeks’ gestation (placental abruption, placenta previa, bleeding, infection, hypertension, preeclampsia, idiopathic preterm labor, preterm premature rupture of membranes [PPROM], intrauterine growth restriction, and multiple gestation); however, up to 15% of all births in the United States are currently performed electively (without identifiable medical or obstetric indication) (Clark et al., 2009; Clark et al., 2010; Clark, Knox, Simpson & Hankins, 2010). Early elective induction of labor and elective primary and repeat cesarean delivery resulting in late preterm births has contributed to the overall neonatal morbidity (Clark et al., 2009; Tita et al., 2009). ACOG (2009) have cautioned against elective delivery prior to 39 weeks’ gestation. Nursing and medical leadership need to adopt strategies to reduce elective deliveries prior to 39 completed weeks. Specific evidence-based strategies and resources are available for clinicians to use in discouraging elective births prior to 39 completed weeks with the goal of improving both perinatal and infant mortality (March of Dimes Foundation, 2010a, 2010b).

PATHOPHYSIOLOGY

Late preterm infants are often referred to as great imposters because their initial size and presentation closely resemble the term newborn (Buus-Frank, 2005). Many times within hours of birth, the late preterm infant will appear to be functionally at term, allowing for management decisions to be made accordingly. Despite the fact that these infants are biologically and functionally premature by 3 to 8 weeks, they are often transferred to the regular nursery.

The third trimester is a critical period of rapid growth, development, and biologic maturation. The last few weeks of gestation are vital for fetal development and maturation including surfactant production, control and regulation of breathing, and brain maturation resulting in the infant’s ability to coordinate sucking, swallowing, and breathing. Also, during the last trimester, dramatic growth ensues with an increase in body mass and fat stores, which enhance thermal and glucose regulation.

Late preterm infants, compared to term, have a higher frequency of respiratory distress, temperature instability, hypoglycemia, hyperbilirubinemia, kernicterus, apnea, seizures, feeding difficulties, symptoms prompting a sepsis evaluation, need for IV infusions, and higher rates of rehospitalization and a potential increase risk for long-term behavior and learning problems (Engle et al., 2007; Raju et al., 2006; Wang, Dorer, Fleming, & Catlin, 2004). Compared to term infants, late preterm infants have not only significantly more medical problems but also increased hospital costs (Bird et al., 2010; McLaurin, Hall, Jackson, Owens, & Mahadevia, 2009; Wang et al., 2004).

Hypothermia and Hypoglycemia

Late preterm infants are at risk for hypothermia and early hypoglycemia. Of the fetal energy consumption, 80% is provided by glucose. The fetus is solely dependent on maternal glucose that is supplied transplacentally by a process of facilitative diffusion (Garg & Devaskar, 2006). Once the cord is clamped, newborns are required to swiftly adapt to a life of independence and learn to produce endogenous glucose. The risk of hypoglycemia increases for late preterm infants because metabolic reserves are low, and further energy demands increase because of coexisting conditions of sepsis, birth asphyxia, or cold stress (Laptook & Jackson, 2006). Late preterm infants have less brown fat compared to term newborns, resulting in a higher risk of developing hypothermia. Cold stress and hypoglycemia are very common in late preterm infants, especially soon after birth during the early transitional period of adaptation (Engle et al., 2007; Laptook & Jackson, 2006; Vachharajani & Dawson, 2009).

Hyperbilirubinemia

Late preterm infants are more prone to developing hyperbilirubinemia and its sequelae and to require hospital readmission for treatment (Engle et al., 2007; Wang et al., 2004). These vulnerable infants are 2.4 times more likely to develop significant hyperbilirubinemia and to have significantly higher TSB levels. Elevated bilirubin levels are primarily due to immature liver function and diminished capacity for bilirubin conjugation. These physiologic risks, coupled with more difficult feeding patterns and lower oral intake, exacerbate increased enterohepatic recirculation of bilirubin and may explain the correlation among decreased postmenstrual age, hyperbilirubinemia, and the increased risk for kernicterus (Sarici et al., 2004). Although the incidence of kernicterus in late preterm infants is unknown, compared to term infants, these infants are at increased risk for bilirubin neurotoxicity and kernicterus (Bhutani et al., 2004; Sarici et al., 2004).
Respiratory Distress

Studies have shown the high incidence of respiratory distress and NICU admissions in late preterm infants (Clark, 2005; Consortium on Safe Labor, 2010; Escobar et al., 2005; Roth-Kleiner, Wagner, Bachmann, & Pfenninger, 2003). These infants have a higher incidence of TTNB, pneumonia, RDS, PPHN, and hypoxic respiratory failure than term infants (Consortium on Safe Labor, 2010). Nearly 50% of infants born at 34 weeks’ gestation require intensive care; this number drops to 15% at 35 weeks’ and 8% at 36 weeks’ gestation (Dudell & Jain, 2006). The last few weeks of gestation are critical for fetal development and maturation specifically related to surfactant and lung maturity. Biochemical and hormonal changes that accompany spontaneous labor and vaginal delivery also play an important role in the newborn’s ability to transition smoothly to an extrauterine environment (Dudell & Jain, 2006). For effective gas exchange to occur, alveolar spaces must be cleared of excess fluid and ventilated, and pulmonary blood flow must be increased to match ventilation with perfusion. Failure of either of these events may jeopardize neonatal transition and cause respiratory distress. A significant number of late preterm infants are delivered by cesarean section, and this number continues to rise steadily, reported at an all-time high in the United States at 32.3% in 2008 (Martin et al., 2010). A higher occurrence of respiratory morbidity in late preterm and term infants delivered by cesarean section has been observed (Jain & Dudell, 2006; Hansen, Wisborg, Uldbjerg, & Henricksen, 2007; Levine et al., 2001). These infants are known to develop PPHN and become seriously ill and require significant clinical interventions such as i-NO, HFOV, vasopressor support, and ultimately may progress to ECMO (Ramachandrappa & Jain, 2008). The inability to clear lung fluid, the relative deficiency of pulmonary surfactant, and birth in the absence of labor all contribute to pulmonary dysfunction (Jain & Eaton, 2006; Ramachandrappa & Jain, 2008).

Apnea of Prematurity

Late preterm infants are three times more likely to experience apnea than their term counterparts (Engle et al., 2007). Between 32 and 34 weeks of gestation, the fetus develops synchrony and control of breathing. This period of breathing pattern maturation decreases the risk of apnea of prematurity. The pathogenesis of apnea is multifactorial and includes immature lung volume and upper airway control, ventilatory responses to hypoxia and carbon dioxide, and feeding as well as physiologic and iatrogenic anemia (Darnall, Ariagno, & Kinney, 2006). It is important to remember that infants born between 33 and 38 weeks’ gestation continue to have apnea and are at risk for the resulting periods of bradycardia and hypoxia and are at higher risk for SIDS (Hunt, 2006; Ramanathan et al., 2001).

Brain and Long-term Outcomes

Compared to term newborns, late preterm infants have a more immature brain. It is estimated that an infant at 35 weeks’ gestation has fewer sulci and that the weight of the brain is approximately 65% that of the term infant. Periventricular leukomalacia is a known predictor of adverse neurologic outcomes in preterm infants. Late preterm infants are at risk for developing periventricular leukomalacia; however, the exact incidence is unknown (Kinney, 2006). Brainstem development of infants born between 33 and 38 weeks’ gestation is less mature than that of a term newborn, although more research on this specific population of infants is needed (Darnall et al., 2006). There is a paucity of data on the long-term neurodevelopmental outcome in late preterm infants. Few studies have examined the long-term neurodevelopmental status of late preterm infants and the prevalence rates for subtle neurologic abnormalities, learning and behavioral difficulties, and scholastic achievement (Raju et al., 2006). However, there is a growing concern that these infants are more vulnerable to brain injury and long-term neurologic sequelae (Adams-Chapman, 2006; Morse, Zheng, Tang, & Roth, 2009; Petrini et al., 2009; Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008) and are at more than a threefold increased risk for developing cerebral palsy compared to term newborns (Wang et al., 2004). In contrast to these studies, no significant differences in neurologic outcomes were found in school-aged children (between the ages of 4 and 15 years) who were born late preterm compared to children born at term (Gurka, LoCasale-Crouch, & Blackman, 2010).

Gastrointestinal Tract

The GI tract continues to develop throughout gestation, but the late preterm infant adapts quickly to enteral feedings, including the digestion and absorption of lactose, protein, and fats (Neu, 2006). However, peristaltic functions and sphincter controls in the esophagus, stomach, and intestines are less likely to be mature and fully functional in late preterm infants, which may lead to difficulty in coordinating suck and swallowing, gastroesophageal reflux, a delay in successful breastfeeding, poor weight gain, and dehydration during early postnatal weeks (Escobar et al., 2002; Neu, 2006; Tomashek et al., 2006). The physiologic organization of sucking is almost fully organized by 36 weeks’ gestation, whereas swallow rhythm is established by 32 weeks’ gestation.
(Gewolb, Vice, Schweiter-Kenney, Taciak, & Bosma, 2001). Precise timing for the activation of several upper airway muscles is critical for suck-swallow coordination, but unlike sucking, swallowing interrupts breathing, allowing protection of the airway and decreasing the risk for aspiration (Thach, 2005). It is likely that the etiology of the frequent feeding issues encountered by late preterm infants stems from the immaturity of the coordination of sucking, swallowing, and breathing (Darnall et al., 2006). It is important to remember that less energy is required to feed from the breast than from the bottle, as the peristaltic activity of the tongue provokes the peristaltic movement of the GI tract and stimulates swallowing (Aguayo, 2001).

**Pharmacology and Drug Therapy**

Few studies exist describing the drug clearance of a late preterm infant. Despite the limited evidence, many dosing guidelines used to treat late preterm infants are based on term data, allowing for inappropriate drug dosing because of the immaturity of the liver and kidney, which can reduce drug clearance in late preterm infants (Ward, 2006). Additional drug clearance studies are needed.

**Immunologic System**

Late preterm infants do have unique susceptibilities to infection including the closed setting of a NICU, and the immunologic immaturity of premature infants sets the stage for development of nosocomial infections (Benjamin & Stoll, 2006). Late preterm infants are more likely to be evaluated for sepsis and treated with a 7-day course of antibiotics compared to term newborns (Wang et al., 2004). There are little data on the host defense capabilities of late preterm infants. Recent advances provide a framework for understanding the mechanisms underlying the propensity of infections in this at-risk population. Compared with term and extremely preterm infants, late preterm infants are intermediate with regard to immunologic maturity (Clapp, 2006).

**CARE ENVIRONMENT**

Late preterm infants masquerade as term newborns, making it difficult to determine their potential immediately following delivery. Pathologic signs and symptoms of late preterm infants transitioning to extraterrestrial life may be subtle or may be considered normal transition. Depending on their presentation at delivery, an astute assessment of the late preterm infant is critical since many of these infants may be triaged to the newborn nursery and/or room in with their parents where policies, staffing, and care models focus on normal term newborns, resulting in little time for nurses to perform vigilant assessments, establish lactation, and provide detailed discharge instruction (Pappas & Walker, 2010).

**PHYSIOLOGIC FUNCTION AND NURSING ASSESSMENT AND CARE**

Until recently, EBGs for this vulnerable group of infants were nonexistent. However, new recommendations for assessment and care have emerged (AWHONN, 2010; Engle et al., 2007) along with discharge preparation criteria (Engle et al., 2007). AWHONN’s (2010) clinical practice guideline provides a detailed systematic approach to assessing and managing late preterm infants and focuses on specific parent support and teaching recommendations. Table 21–2 outlines AWHONN’s late preterm infant practice recommendations.

When managing these high-risk infants, it is important to focus on their gestational age and behavior rather than on weight and Apgar scores. Immediately following birth, late preterm infants need to be carefully assessed for respiratory issues and signs and symptoms related to hypothermia or cold stress, hypoglycemia, and sepsis. Following the initial resuscitation and stabilization, assessment of the late preterm infant needs to concentrate on feeding challenges, jaundice and hyperbilirubinemia, and parent education for discharge teaching. It is imperative for nurses to recognize the increased risks associated with breastfeeding late preterm mother–infant dyads, including hyperbilirubinemia, poor milk transfer, and rehospitalization. While more research is needed to examine the causes of poor breastfeeding establishment and associated outcomes among late preterm mother–infant dyads (Radtke, 2011), few published breastfeeding guidelines or recommendation exist to assist healthcare providers caring for the breastfed late preterm infant (Academy of Breastfeeding Medicine, 2008; Meier, Furman, & Degenhardt, 2007; Smith, Donze, & Schuller, 2007; Walker, 2008; Wight, Morton, & Kim, 2008).

Discharge teaching should include information about safe sleep environment that can reduce the risk of all sleep-related infant deaths, including SIDS. Compared to term infants, late preterm infants are at a two-fold higher risk of developing SIDS (Darnall, Ariagno, & Kinney, 2006). Healthcare providers need to educate families about infants’ increased risk for SIDS and demonstrate appropriate SIDS prevention strategies within the nurseries prior to discharge so families can mimic appropriate caregiving behaviors. The AAP Task Force on Sudden Infant Death Syndrome (2011) recommends:

- Infants be placed supine (wholly on the back) for every sleep
- The use of firm sleep surfaces (soft materials or objects should not be placed under a sleeping infant)
### Table 21–2. ASSESSMENT AND CARE OF THE LATE PRETERM INFANT (LPI)

<table>
<thead>
<tr>
<th>Goal</th>
<th>Nursing Assessment and Care Interventions</th>
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| **Determine accurate gestational age** | • Review prenatal records to confirm gestational age from prenatal assessment  
  • Perform postnatal gestational assessment within 12 hr of age (e.g., New Ballard Score)  
  • Obtain infant’s length, weight, and head circumference and plot on validated growth curve to determine size/dates (i.e., AGA, SGA, or LGA) |
| **Cardiopulmonary stability** | • VS within 30 min of age, every 30 min until 2 hr of age, then every 2–4 hr as stable  
  • Assess respiratory rate (normal 30–60 breaths/min); note: LPI may exhibit periodic breathing or brief tachypnea during transition  
  • Assess and document signs of respiratory distress; note: Normal newborns may exhibit grunting during the first 2 postnatal hours  
  • If work of breathing is increased, implement appropriate interventions: Notify healthcare provider, apply pulse oximeter probe to determine saturation, consider supplemental oxygen (monitored and heated/humidified) to achieve pulse oximetry target of 85%–95% saturation  
  • Assess heart rate (normal 120–160 bpm) and perfusion (normal capillary refill time up to 3 secs)  
  • Assess muscle tone and overall activity as indicator of oxygenation  
  • If infant is without distress, may initiate kangaroo care (KC) |
| **Thermal stability** | • Assess temperature within 30 min of age, followed by every 30 min until 2 hr of age, then every 2–4 hr as stable  
  • Review perinatal history to identify risks for heat loss/cold stress  
  • Thoroughly dry infant; provide prewarmed linens and dry cap for head  
  • Preheat radiant warmer or incubator and utilize temperature controls  
  • Target infant temperature: 97.7°–99.3°F (36.5°–37.4°C)  
  • Avoid heat loss through conduction, convection, evaporation, and radiation  
  • Initiate measures to support thermoneutrality, such as KC or swaddling  
  • Postpone bath until thermal and cardiopulmonary stabilities are evident (typically 2–4 hr after birth), then bathe, incorporating measures such as short bath duration, sponge or swaddled bath, bath water temperature of 100°–104°F, minimized room drafts, room temperature set between 79° and 81°F, prewarmed towels for drying, immediate cap and wrap in warm blankets  
  • If infant becomes hypothermic, place in KC, incubator, or under radiant warmer and monitor temperature every 30 min until normalized; review history for risk factors or other indicators of illness |
| **Glucose stability** | • Review antenatal/perinatal history to identify risks for glucose instability  
  • Perform screening point-of-care glucose assessment within the first 2 hr of life and thereafter as indicated if infant is displaying symptoms suggesting hypoglycemia  
  • Provide early, frequent feedings on demand, with interval between feedings no longer than 2–3 hr if breastfed and 3–4 hr if formula fed  
  • If hypoglycemia is suspected, immediately assess glucose level; in general, for glucose <40–45 mg/dL (2.2–2.6 mmol/L), immediately send confirmatory serum glucose; note: No exact definition of hypoglycemia exists  
  • For plasma glucose ≥40–45 mg/dL (2.2–2.6 mmol/L), establish frequent feedings and follow clinically  
  • For plasma glucose <40–45 mg/dL, immediately feed per breast or formula per gavage or bottle and repeat glucose level within 30 min of feeding  
  • If the infant exhibits signs of hypoglycemia and the glucose is <40–45 mg/dL and feedings are not tolerated, provide IV bolus of 10% dextrose in water (2 mL/kg) and establish IV maintenance at 4 to 6 mg/kg/min; repeat glucose testing within 30 min of bolus and thereafter every 1–2 hr until stabilized  
  • For persistent hypoglycemia, consider transferring infant to a higher acuity unit or facility for supportive care |
| **Feeding readiness and tolerance** | • Assess readiness for feeding prior to initiating oral feedings, including infant’s ability to coordinate sucking/swallowing and breathing; LPI may have weak suck, immature feeding pattern, and limited ability to display robust feeding cues  
  • Monitor for stability during feedings; LPI may easily fatigue and lose stamina during feedings at bottle and breast  
  • Evaluate maternal position for breastfeeding, latch, and milk transfer  
  • Facilitate early and frequent breastfeeding (8–12 times/day)  
  • Observe, educate, and validate maternal knowledge about feeding behaviors seen in the LPI, including need to wake before feedings, feeding frequently, and continually assessing coordination of sucking/swallowing/breathing  
  • Encourage adequate milk supply and transfer with strategies such as prepumping breast prior to breastfeeding attempt and utilizing support of lactation consultant; extended lactation support, education, and frequent follow-up are warranted in this population to ensure successful lactation and to avoid potentially dangerous complications related to insufficient lactation (Radtke, 2011) |

(continued)
Common Neonatal Complications

- Breastfeeding
- Room-sharing without bed-sharing
- Routine immunizations
- Consideration of using a pacifier at naptime and bedtime
- Supervised, awake tummy time to facilitate development and minimize development of positional plagiocephaly (e.g., asymmetrical skull)
- Healthcare professionals, newborn nursery and NICU staff, and childcare providers should endorse the SIDS risk-reduction recommendations from birth

In addition, the Task Force (AAP, 2011) recommends avoiding:
- Soft objects and loose bedding out of the crib
- Overheating
- Commercial devices marketed to reduce the risk of SIDS

- Exposure to tobacco smoke, alcohol, and illicit drugs
- Home cardiorespiratory monitors as a strategy for reducing the risk of SIDS

These recommendations were expanded to ensure a safe sleeping environment and ways to reduce the risks of all sleep-related infant deaths, including SIDS, suffocation, and other accidental deaths.

READMISSION RISK AND NEWBORN FOLLOW-UP

In general, late preterm infants are at greater risk of neonatal morbidity and are two to three times more likely to be readmitted to the hospital compared to term newborns (Burgos, Schmitt, Stevenson, & Phibbs, 2008; McLaurin et al., 2009; Tomaszek et al., 2006). Hospital readmission risk factors include...
maternal complications during labor and delivery, families receiving support from a public payer, parents who are of Asian/Pacific Islander ethnicity, a firstborn infant, male gender, use of assisted ventilation, and an infant being breastfed at discharge (Escobar, Clark, & Green, 2006; Escobar et al., 2002; National Center for Health Statistics, 2005; Shapiro-Mendoza et al., 2006; Tomashek et al., 2006). Jaundice, proven or suspected infections, feeding and respiratory difficulties (including gastroesophageal reflux disease), sepsis, and failure to thrive were the most common diagnoses at readmission (Escobar et al., 2006; Jain & Cheng, 2006).

The AAP has established specific criteria for discharging late preterm infants (Engle et al., 2007). According to these guidelines, late preterm infants must be medically stable and able to spontaneously breathe room air without apnea, bradycardia, or episodes of significant desaturation prior to discharge. These infants must be able to maintain a normal body temperature without the use of adjunctive heating devices and should be assessed closely for immature feeding behaviors. Parents need to be confident and competent in their ability to care for their baby prior to discharge and need to be equipped and empowered with the knowledge to appropriately and effectively care for this population of infants and their potential risks after discharge. Specifically, parent education needs to include the increased risk that their child has hyperbilirubinemia, feeding difficulties, apnea, sepsis, respiratory problems, and hypothermia. It is imperative that a follow-up visit 24 to 48 hours after discharge is scheduled with an identified primary care provider prior to discharge.

**SUMMARY**

Research is still needed to understand the etiology of late preterm births. As the rate of preterm births increase, so does the impact on the burden of disease and the healthcare cost to society. The estimated economic burden caused by preterm births in the United States is $26.2 billion, or $51,600 per preterm infant (Berhman & Butler, 2006). Any decrease in the rate of prematurity, at any gestation, would reduce the burden of disease and lead to a significant cost savings. Late preterm infants require diligent evaluation, monitoring, referral, and early return appointments, not only for postneonatal evaluation but also for long-term follow-up (Raju et al., 2006).

**HYPOXIC ISCHEMIC ENCEPHALOPATHY**

HIE is the leading cause of neonatal encephalopathy (NE) in term and late preterm newborns and is a major cause of death and disability (Pfister & Soll, 2010). Typically, HIE ensues after a disruption in cerebral blood flow and oxygen delivery to the brain secondary to insufficient placental blood flow and gas exchange. The progression of HIE and degree of injury are dependent on the timing, duration, and severity of the insult (Pfister & Soll, 2010). The estimated incidence of HIE is 1.5 per 1,000 live births (Kurinczuk, White-Koning, & Badawi, 2010). Perinatal factors associated with the risk of HIE include maternal diabetes, fever, chorioamnionitis, placental abruption, umbilical cord prolapse, uterine rupture, tight nuchal cord, or an acute blood loss (Rutherford et al., 2005; Selway, 2010).

**PATHOPHYSIOLOGY**

Physiologic consequences of hypoxic ischemia evolve over hours to days, resulting in a biphasic pattern of energy failure leading to brain injury, separated by a brief recovery or “latent phase” (Gluckman & Williams, 1992). Primary cell death (necrosis) results if the oxygen deprivation is not corrected. In an effort to sustain functional ability, the neonate’s brain converts to anaerobic metabolism leading to rapid depletion of adenosine triphosphate, accumulation of lactic acid, and failure of normal metabolic activity (Perlman, 2006; Selway, 2010). Loss of ionic homeostasis results in an accumulation of sodium, calcium, and water within brain cells. Once the cerebral blood flow and oxygenation are reestablished, the initial metabolic impairments resolve over 30 to 60 minutes. After reperfusion, during the “latent phase,” complete recovery or development of a secondary phase may occur. The latent phase institutes the “therapeutic window.” Whether injury reversal occurs depends on several factors (severity of the primary phase, body temperature, substrate availability, preconditioning, and simultaneous disease process), and some evidence suggests that it does not appear to extend more than 6 hours from the primary injury (Shankaran & Laptook, 2007).

In an attempt to restore brain function, the secondary phase of energy failure (apoptosis) begins about 6 to 15 hours after the initial injury and extends over several days (Williams, Gunn, & Gluckman, 1991). During this phase of energy failure, mitochondrial dysfunction results from excitatory neurotransmitters, an influx of calcium into the cells, oxygen free radicals, or nitric oxide formation (Cooper, 2011; Mathur, Smith, & Donze, 2008). This secondary phase is clinically associated with seizures, worsening neurologic examination, and is proportional to adverse neurodevelopmental outcomes at 1 and 4 years of age (Mathur et al., 2008; Roth et al., 1992, 1997). The degree of neuronal injury can be assessed using Sarnat and Sarnat’s (1976) clinical staging of encephalopathy criteria. These criteria describe the evolution of the clinical encephalopathy over the first several days of life and emphasize that this encephalopathy is a dynamic clinical state that warrants close monitoring.
neuroprotection is limited, early initiation of cooling is often unclear, and since the therapeutic window for
the secondary phase of energy failure is the single most promising intervention for infants with moder-
ate-to-severe HIE (Azzopardi et al., 2009; Eicher et al., 2005; Gluckman et al., 2005; Lin et al., 2006; Shankaran et al., 2005). Induced hypothermia initiated within 6 hours of birth is significantly associated with fewer deaths and less neurodevelopmental disability at 18-month follow-up in infants born at highest risk for brain injury (as defined by specific protocols) (Edwards et al., 2010). Both total body and selective head cooling methods have been shown to be effective (Jacobs, Hunt, Tarnow-Mordi, Inder, & Davis, 2007).

According to the AAP’s and the AHA’s NRP, therapeutic hypothermia is the treatment of choice in the delivery room for term or late preterm infants with evolving moderate encephalopathy (Perlman et al., 2010). Whole body or selective head cooling should be initiated and conducted in the context of rigorous and clearly defined protocols within NICUs with provisions for monitoring side effects and long-term follow-up.

Intervening with a neuroprotective intervention, such as therapeutic hypothermia (cooling), prior to the secondary phase of energy failure is the single most promising intervention for infants with HIE (Fairchild, Sokora, Scott, & Zanelli, 2010; Mathur et al., 2008; Pfister & Soll, 2010). Although the exact mechanism by which hypothermic neuroprotection works is unknown, it does seem to attenuate the secondary phase of neuronal injury. Most clinical trials have induced therapeutic hypothermia for hypoxic-ischemic neonates within 6 hours of birth. However, evidence that the duration of the latent phase is inversely proportional to the severity of the ischemic insult suggests that the therapeutic window for starting hypothermia therapy may be much shorter, within 2 hours of the suspected insult and no later than 6 hours (Iwata et al., 2007; Pfister & Soll, 2010). Therefore, early identification of hypoxic-ischemic neonates who meet the criteria for hypothermia therapy is critical. These infants have complex needs and are typically managed in tertiary centers with the availability of subspecialty evaluation and treatment. However, many of these at-risk infants are born in hospitals that do not provide neonatal intensive care, requiring transports that often take hours. Additionally, the timing of the onset of injury is often unclear, and since the therapeutic window for neuroprotection is limited, early initiation of cooling is often warranted. Induced hypothermia should be only provided under strict protocols in nontertiary centers under guidance of the regional NICU and transport team. If a cooling protocol is not available, every effort to avoid overheating the infant should be made. Cooling protocols may vary; typically, passive cooling is initiated (if portable cooling equipment is unavailable) and achieved by turning off the radiant warmer, and the infant is cooled to a rectal temperature between 34°C and 35°C. Close monitoring of the rectal or esophageal temperature is required with the appropriate probe or low-reading thermometer (at least every 15 minutes or continuously, if possible) (Azzopardi et al., 2009; Fairchild et al., 2010; Kendall, Kapetanakis, Ratnavel, Azzopardi, & Robertson, 2010). Potential adverse effects of passive overcooling have been reported, highlighting the need for vigilant continuous or intermittent rectal temperature monitoring, ongoing education, and continuous collaboration among all members of the healthcare team (Hallberg, Olson, Bartocci, Edqvist, & Blennow, 2009; Thoresen, 2008).

Criteria for Cooling

Criteria for cooling should be discussed between the referring center and the neonatologist who is accepting the responsibility of the infant’s care. Cooling criteria are fairly consistent among many of the RCTs for therapeutic hypothermia and include the following infants:

- Gestational age at least 36 weeks or more
- Weight of ≥1,800 g
- ≤6 hours of age at time of cooling
- pH ≤7 or base deficit > 12 mEq/L within 1 hour following delivery
- Apgar score of ≤5 at 10 minutes following birth
- Moderate or severe encephalopathy as defined by Sarnat and Sarnat (1976)
- Moderate-to-severe electroencephalography (EEG) amplitude reduction (lower margin <5 microvolts and/or upper margin <10 microvolts) on a 20-minute amplitude-integrated EEG (aEEG) or evidence of seizures.

OR

- Evidence of perinatal metabolic compromise in the setting of a known event. Metabolic compromise is defined as at least two of the following:
  - Umbilical cord blood gas or blood gas within 1 hour of delivery showing a pH of 7.01 to 7.15 or base deficit of 10 to 15.9 mEq/L or no blood gas available within first hour; and
  - The need for respiratory support at 5 minutes of life or 10-minute Apgar score ≤ 5; and
  - Moderate or severe encephalopathy; or
  - Seizures
Exclusion criteria include infants with major congenital defects such as diaphragmatic hernia requiring ventilation, suspected chromosomal anomalies (e.g., trisomies 13 or 18), congenital disorders of the CNS, uncontrolled active bleeding, or parental refusal (Cooper, 2011; Mathur et al., 2008). It is extremely important to investigate other causes of NE, including infection and metabolic disorders, and institute specific treatment.

**CARE AND ASSESSMENT**

Nurses are key to the early identification of infants who are at risk for developing HIE as a result of an acute perinatal event. Nurses in the delivery room need to be knowledgeable and astute of the clinical signs associated with neonatal asphyxia, seizures, and the criteria for therapeutic hypothermia. Utilizing a standard checklist for the neurologic examination provides optimal documentation of the stage and evolution of encephalopathy. Supportive nursing care is an essential element of cooling. Continuous monitoring of oxygenation, ventilation, perfusion, CO, strict intake and output, and glucose levels is essential to avoid additional adverse effects. Infants who are cooled typically have lower HRs (e.g., HR <100 bpm); however, prolonged bradycardia (e.g., HR <80 bpm) may indicate the need for slight warming (Selway, 2010). It is important to remember that vigilant monitoring and documentation of body temperatures are essential in these high-risk infants. Additionally, infants who are cooled need to be monitored and closely assessed for pain, and appropriate pharmacologic and nonpharmacologic therapies should be implemented (Cooper, 2011). Nurses are also key to providing emotional support to parents. Parents and family members need to know what to expect over the course of the next hours and days, the rationale for implementing therapeutic hypothermia, and the importance of further evaluation and management at a tertiary center with subspecialty availability.

**TRANSPORT AND RETURN TRANSPORT**

Many conditions complicating the neonatal period do not begin with dramatic clinical symptoms. Experience and well-developed assessment skills allow perinatal nurses to recognize subtle changes and intervene before the newborn’s condition worsens. Occasionally, the condition of the newborn and services available at a particular perinatal center require transport to a level III/IV NICU. The goal of neonatal transport is to bring a sick newborn to a tertiary center in stable condition. The availability of neonatal intensive care has improved outcomes in high-risk newborns; although no standard definitions exist for graded levels of complexity of care that NICUs provide, thus making it difficult to compare outcomes (AAP, 2012). However, a uniform definition and classification of neonatal resources according to the different levels of care as recommended by AAP provides a framework for the development and implementation of consistent standards of service provided (AAP, 2012). Stabilization is an ongoing process, which begins with the referring hospital through consultation with the tertiary center as needed until the arrival and eventual departure of the transport team. Because of the diversity in the disease process and gestational age, stabilization takes on many forms. Basic care needs of newborns requiring transport to a tertiary center include adequate oxygenation, prevention of hypothermia, prevention of hypoglycemia, conservation of energy, and maintenance of physiologic integrity.

After the newborn’s condition is no longer critical, in the event that an extended hospitalization is anticipated, the decision may be made to move the newborn back to the hospital in which he or she was born. This decision is made with input from neonatology staff at the level III/IV center, the newborn’s primary care provider, the nursing staff in the level II hospital, and the parents. The decision also is influenced by the parents’ insurance carrier or managed care providers. In order to make informed decision, the healthcare team and individual families need to consider the advantages and disadvantages associated with transporting convalescing infants back to their community hospital before return transport (Bowen, 2010). Return transport offers many advantages to family members of the high-risk newborn, although it requires involvement of personnel from the transferring and the receiving hospital as well as adequate parent preparation to be successful. Family involvement is essential to success of return transport. Ideally, the prospect of a return transport is introduced when the infant is initially transferred to the level III/IV center. Return transports should be celebrated as a milestone and a positive step toward discharge.

To provide newborns with the best care possible, healthcare professionals within the referring hospital and between the referring hospital and the tertiary center must communicate and work together as a team. The decision to transport back to the level II hospital first depends on whether the care needs of the newborn can be met at that institution. Communication between the level III/IV and the level II hospitals when a return transport is anticipated should begin several days before the actual transfer. This assists in preparing the parents, and the receiving hospital has time to anticipate staffing and equipment needs. Using a formal documentation system provides the receiving hospital with information about the current condition of the newborn.
SUMMARY

Most newborns are born in level II hospitals. They are healthy at birth, develop no complications during the neonatal period, and are discharged to their homes with their mothers. A small group of newborns are born with complications or develop complications immediately after birth. It is the newborn who develops complications that poses the challenge to the perinatal nurse. The nurse in a level II hospital must strive to identify complications in a timely fashion, care for the infant appropriately, stabilize the infant before transport to a level III/IV facility, and be prepared to accept the patient as a return transfer when he or she is no longer in need of intensive care.

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