Evaluation and Management of the Sick Neonate

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INTRODUCTION

Few clinical scenarios are as anxiety provoking as a severely ill child. Infants under 2 months of age represent a unique category of patients with concerns and differential considerations not commonly seen in other age groups. The most important differential considerations for a sick-appearing neonate can be grouped into 5 general categories: infectious etiologies, congenital heart disease, gastrointestinal disorders, inborn errors of metabolism, and other less common causes (Table 1). Successful management ultimately requires knowledge of both normal and abnormal fetal physiology as well as a systematic approach to evaluating the neonate. This manual provides a concise review of the most important issues related to the diagnostic and therapeutic management of the sick neonate in the emergency department (ED).

DIFFERENTIAL CONSIDERATIONS IN SICK NEONATES

INFECTIOUS ETIOLOGIES

Overwhelming sepsis is the most common cause of serious illness in neonates. Infants at this age are relatively immunocompromised and are unable to partition off and localize infection due to impaired cell-mediated immunity. Neonatal infections may be acquired from the mother, either during pregnancy or at the time of delivery. Signs of infection include apnea, respiratory distress, feeding intolerance, abdominal distension, lethargy, and hypotension.³ Fever may or may not be present. Mortality may be as high as 40%.⁴ All toxic-appearing neonates require a full sepsis evaluation, intravenous antibiotics, and admission. Reasonable antibiotic choices during the first 2 months of life include ampicillin and either gentamicin or cefotaxime. In cases where infants are sick or toxic-appearing, antibiotics should be started as soon as possible and not be delayed until positive laboratory results have returned.

Early-onset neonatal sepsis (EONS) presents as a systemic illness within the first 7 days of life and is associated with high rates of morbidity and mortality. EONS occurs at a rate of 1 to 2 cases per 1000 live births in the United States.⁵ The organisms most commonly associated with EONS include group B streptococcus (GBS) and Escherichia coli, which together account for 70% to 80% of positive cultures.⁶ Other less common enterococci, such as Listeria monocytogenes, also are known to cause disease. Most infants with EONS present within the first 3 days of life, but by definition, there is a range of up to 7 days. The early-onset form accounts for 75% of cases. Less common is the late-onset form of the disease that does not manifest until 2 to 4 weeks of life (range, 1 week–3 months). The median age of onset for late-onset sepsis is 17 days, and it occurs at a rate that is inversely proportional to gestational age and birth weight.²,⁶

In 1996, the Centers for Disease Control and Prevention, in collaboration with the American College of Obstetricians and Gynecologists and the American Academy of Pediatrics, developed EONS prevention guidelines advocating intrapartum antibiotics for women at high risk for delivering an infant with GBS-related EONS infection.⁴ Following the implementation of these guidelines, there has been an 80% reduction in the rate of GBS-related EONS infection.³ Fortunately, this reduction has not been accompanied by an increase in the incidence of EONS caused by non-GBS or ampicillin-resistant organisms.⁵,⁶

Other noteworthy congenitally acquired infections that may be associated with an acutely ill-appearing neonate include toxoplasmosis, syphilis, rubella, cytomegalovirus, and herpes (TORCH). Of these, disseminated herpes infections are perhaps the greatest concern because they have the highest morbidity and mortality. It should be noted that many neonates infected with herpes are born to asymptomatic mothers or to mothers without a history of herpes who are having their first outbreak. Affected infants classically present as a febrile, seizing 7-day-old child with elevated liver enzymes and numerous erythrocytes in the cerebral
spinal fluid. Other viral infections of concern include adenovirus, enterovirus, and respiratory syncytial virus.

Omphalitis is a rare but potentially life-threatening infection involving the umbilical cord and surrounding abdominal wall. The disease begins with a foul-smelling purulent discharge from the umbilical stump, followed by erythema and induration of the surrounding abdominal wall that often progresses rapidly (over 12–24 hours). This entity should not be confused with a simple cellulitis. Due to a neonate’s inability to partition off the spread of infection and the proximity of the umbilicus to the peritoneal cavity and vascular structures, there is a risk for the development of necrotizing fasciitis and sepsis. *Streptococcus pyogenes* (group A streptococci), *Staphylococcus aureus*, and GBS are the most common infectious agents; however, gram-negative enteric rods and mixed flora also may be found. Oxacillin and gentamicin are the antibiotics of choice.

**CONGENITAL HEART DEFECTS**

Diagnosing congenital heart disease is complex. Most congenital heart defects are diagnosed prenatally or in the nursery or neonatal intensive care unit prior to discharge. Rather than attempting to remember a compendium of all possible defects, the emergency medicine physician is best served by developing a systematic approach that emphasizes a thorough understanding of the physiologic changes that occur during the transition between fetal and adult circulation and the potential pathophysiologic results that may occur with certain cardiac defects as a result of these changes.

The transition from fetal to adult circulation involves 2 key components. First, there exists a free-flowing connection of blood between the aorta and the pulmonary artery, the ductus arteriosus. Following birth, the ductus arteriosus gradually closes and becomes the ligamentum arteriosum. If it remains open, it becomes known as the patent ductus arteriosus (PDA). Second, in normal fetal circulation, there is a pressure-resistance pattern that is characterized by high pulmonary vascular resistance and correspondingly low systemic vascular resistance. During normal transition from fetal to adult circulation, the ductus arteriosus closes (range, 2 days–3 weeks) and the pulmonary vascular resistance falls as the systemic vascular resistance increases (range, 2–18 weeks). As these normal changes occur, previously well-appearing infants with certain congenital heart defects may decompensate and present to the ED. These infants may exhibit shock, cyanosis, or congestive heart failure (CHF).

As entities with poor left-sided function or flow gradually lose the boost of ductus arteriosus flow, there is a progressive decline in systolic blood flow that may result in shock. We refer to these entities as defects with ducital-dependent systolic blood flow. They include most notably hypoplastic left heart syndrome (HLHS), coarctation of the aorta, and critical aortic stenosis. HLHS is perhaps the most dramatic lesion and accounts for 25% of all neonatal congenital heart defect

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 deaths occurring in the first week of life. If HLHS is left untreated, the mortality is 100%. HLHS is characterized by underdevelopment of the left side of the heart with hypoplastic ascending aorta, hypoplastic or atretic aortic valve, hypoplastic or atretic mitral valve, and endocardial fibroelastosis. Acute management is dependent on maintaining the ductus arteriosus open with prostaglandin E₁. Surgical palliation may be accomplished with the modified Norwood procedure. It involves a series of staged surgeries that include formation of a neoaoorta, bidirectional cavopulmonary shunt, and a modified Fontan procedure. Definitive treatment requires cardiac transplantation and lifelong immunosuppressive therapy.

Lesions with limited pulmonary flow (ductal-dependent pulmonary blood flow lesions) may cause cyanosis as a result of the loss of PDA flow. As the ductus arteriosus closes, there is a corresponding decrease in the amount of blood traveling to the lungs to be oxygenated and a consequent increase in cyanosis. Classic entities in this category include Tetralogy of Fallot (TOF), transposition of the great vessels, pulmonary stenosis, and tricuspid atresia with restrictive ventriculo- septal defect. TOF is perhaps most common and accounts for approximately 8% to 10% of all congenital heart disease. TOF includes the following 4 abnormalities: ventriculo-septal defect, overriding aorta, right ventricular hypertrophy, and pulmonary stenosis.

CHF is the third possibility and occurs most notably due to changes in pressure and resistance. There is a fall in pulmonary vascular resistance and a corresponding rise in systemic vascular resistance, which may result in left-to-right shunting of blood flow and, consequently, CHF. Lesions in this category include most notably large lesions related to single ventricle physiology (TOF), transposition of the great vessels, pulmonary hypertension, and tricuspid atresia with restrictive ventriculo-septal defect. TOF is perhaps most common and accounts for approximately 8% to 10% of all congenital heart disease. CHF is the third possibility and occurs most notably due to changes in pressure and resistance. There is a fall in pulmonary vascular resistance and a corresponding rise in systemic vascular resistance, which may result in left-to-right shunting of blood flow and, consequently, CHF. Lesions in this category include most notably large lesions related to single ventricle physiology (TOF), transposition of the great vessels, pulmonary hypertension, and tricuspid atresia with restrictive ventriculo-septal defect. TOF is perhaps most common and accounts for approximately 8% to 10% of all congenital heart disease.

Infants present with feeding intolerance and emesis that may be bilious or nonbilious. On physical examination, individual loops of bowel may be distended with air and be palpable on examination of the abdomen. As the disease progresses, infants become acutely ill with marked abdominal distention, hematemesis, hematochezia, metabolic acidosis, disseminated intravascular coagulation, and shock. Intramural air (pneumatosis intestinalis) is pathognomonic for NEC and is present in 75% of patients.

Hypertrophic Pyloric Stenosis

Hypertrophic pyloric stenosis occurs in 1 of every 250 live births and is the most common cause of infantile gastrointestinal obstruction beyond the first month of life. Males are affected 4 times more frequently than females. There is an incidence rate of 1 in 14 in patients whose father was diagnosed with hypertrophic pyloric stenosis, and the rate is even higher if the mother was affected (1 in 5 if the neonate is male and 1 in 10 if the neonate is female). The exact etiology is unknown. Infants are born with a normal pylorus and only develop hypertrophy over time. As hypertrophy of the pylorus progresses, there is increased gastric outlet obstruction that causes emesis of gastric juices and the consequent loss of both hydrogen and chloride ions. In order to compensate for the alkalosis, the kidney substitutes K⁺ for H⁺, which results in classic hypochloremic, hypokalemic, metabolic alkalosis.

Infants classically present in the fourth to sixth week of life, with gradually progressive and continuous nonbilious emesis. Infants remain vigorous with a ravenous appetite and rapidly finish an entire feeding only to projectile vomit the entire volume. In the later stages of the disease, children may exhibit visible waves of abdominal peristalsis in response to intense contractions against an obstruction. On abdominal examination, children may
have a palpable pylorus, often described as an “olive.” Plain radiographs of the abdomen may reveal varying degrees of gastric outlet obstruction and dilation (Figure 1). Hypertrophic pyloric stenosis is confirmed by ultrasonography, or alternatively, an upper gastrointestinal series.\(^1\)\(^1\)\(^2\) It should be noted, however, that neonates generally are not toxic with this disease unless it has been allowed to progress to a fairly advanced stage, at which time they may present with severe dehydration complicated by hypochloremic, hypokalemic, metabolic alkalosis.

**Malrotation with Midgut Volvulus**

Malrotation occurs in 1 in 500 live births, with a male-to-female predominance of approximately 2:1.\(^1\)\(^3\) Of those with malrotation, 75% will eventually develop volvulus, and 75% of those with volvulus will present within the first month of life.\(^1\)\(^4\) Bilious emesis is the hallmark of a malrotation presentation and occurs in more than 75% of cases.\(^1\)\(^5\)

In cases of malrotation, the duodenum and cecum do not completely rotate during normal embryonic development and become suspended in close proximity to each other in the midgut region by a vascular attachment containing the superior mesenteric artery. This unusually close proximity results in a short stalk of mesentery that easily twists upon itself, resulting in obstruction of the distal duodenum and compression of the superior mesenteric artery.

Bilious emesis in the neonate should always suggest the possibility of malrotation with midgut volvulus.\(^1\)\(^5\) If the child has a distended abdomen or appears ill, then the volvulus should be considered present until proven otherwise. Midgut volvulus represents a true surgical emergency and requires a thorough diagnostic evaluation that includes an urgent surgical consultation.

Plain radiographs of the abdomen may reveal air-fluid levels suggestive of obstruction, dilated loops overlying the liver, or a paucity of small bowel gas distally, depending on the degree and duration of obstruction (Figure 2). The diagnostic procedure of choice is an upper gastrointestinal series revealing an abnormal position of the duodenal C-loop and characteristic corkscrew appearance of the proximal small bowel.\(^1\)\(^1\)

**Intussusception**

Intussusception is the most common cause of intestinal obstruction in children younger than 2 years of age and occurs most commonly in infants between 5 and 12 months of life.\(^1\)\(^6\)\(^–\)\(^1\)\(^8\) The estimated incidence is 1 per 2000 children under age 15 years, with a distinct male predominance.\(^1\)\(^7\) Siblings of affected children have a relative risk 15 to 20 times higher than the general population.\(^1\)\(^6\)\(^–\)\(^1\)\(^8\) Mortality estimates for untreated intussusception vary but generally are considered high.\(^1\)\(^6\)\(^–\)\(^1\)\(^8\) The exact etiology remains unclear but is probably...
related to a lead point that causes telescoping of one segment of intestine into another such that as the process continues and intensifies, edema develops and obstructs venous return, resulting in ischemia of the bowel wall.

Although the classic triad of symptoms includes abdominal pain, vomiting, and bloody stools, infants may present without a history of pain and instead have profound lethargy. This is also known as the “neurologic” presentation. Of patients with intussusception, three quarters have at least 2 findings, less than one third have all 3, and 13% have either none or only 1.18 Palpation of the abdomen may reveal a sausage-like mass in the right upper quadrant, representing the intussusception, and a corresponding empty space in the right lower quadrant, representing the movement of the cecum out of its normal position. Known as Dance’s sign, this finding is pathognomonic for intussusception.

Loose stools containing mucus and blood constitute the classic “currant jelly” stool most often associated with intussusception.

Although plain radiographs of the abdomen are often nonspecific, findings suggestive of intussusception include evidence of a soft-tissue mass or abrupt cut-off sign in the right upper quadrant, absence of the liver edge, and dilated loops of small bowel with multiple air-fluid levels (Figure 3). The diagnosis of intussusception may be confirmed by ultrasonography, or alternatively by contrast enema, which may be therapeutic as well.

**Hirschsprung’s Disease**

Hirschsprung’s disease accounts for approximately 20% of cases of partial intestinal obstruction in early infancy and occurs at a rate of 1 in 5000 live births. It is 4 to 5 times more common in boys and may be associated with Down’s syndrome or a variety of other anomalies of the gastrointestinal, genitourinary, or nervous systems.19 Hirschsprung’s disease represents congenital aganglionosis of the colon and is characterized by an absence of ganglion cells in the myenteric plexus of the distal colon. Absence of colonic ganglion cells interferes with that segment’s ability to relax and creates a functional obstruction. Stool accumulates proximal to the level of obstruction and produces dilation of the colon (ie, megacolon).

Neonates with Hirschsprung’s disease usually present in the nursery with failure to pass meconium. Vomiting, irritability, and abdominal distention may subsequently occur. Symptoms may be subtle and involve a history of chronic constipation and poor weight gain or failure to thrive. Hirschsprung’s disease usually is diagnosed in infancy; however, there is a wide spectrum of disease and presentations may occur later in life with waxing and waning constipation and obstipation. Hirschsprung’s enterocolitis also may occur and is characterized by abdominal distention, bloody stools, fever, and an elevated white blood cell count.

**Incarcerated Inguinal Hernia with Obstruction**

Inguinal hernias are a common condition of infancy, and repair of these hernias is the most frequently performed general surgical operation in childhood. The incidence of congenital inguinal hernias in full-term infants is 3.5% to 5.0%, and 9.0% to 11.0% in preterm infants.20 An incarcerated hernia is defined as an entrapped irreducible mass associated with the risk of vascular compromise. The overall risk of incarceration of an inguinal hernia is between 12% and 17%.20 Of those hernias that will become incarcerated, one third occur during the first 6 months of life and two thirds occur during the first year of life.20 Unless reduced, an incarcerated inguinal hernia may lead to perforation, sepsis, and shock. Inguinal hernias may be overlooked during a cursory examination, particularly if the infant is not completely undressed or if the possibility of the condition is not initially considered as part of the routine examination.
INBORN ERRORS OF METABOLISM

Although individually rare, inborn errors of metabolism (IEMs) are collectively frequent. The 3 classes of IEMs most likely to be seen in the ED include fatty acid oxidation disorders (FAO), organic acidurias, and urea cycle defects. Affected infants may present acutely ill with marked hypoglycemia, ketoacidosis, or hyperammonemia (Table 2).

Patients with FAO disorders most commonly present with hypoketotic hypoglycemia, altered mental status, seizures, and mild hyperammonemia. They often present during an intercurrent illness some time within the first 2 years of life, during which they appear ill out of proportion to the duration of the illness. Of the FAO disorders, medium-chain acyl-coenzyme dehydrogenase deficiency is most common, affecting 1 in 8000 to 15,000 live births. Recent evidence suggests that 5% to 7% of children presenting with sudden unexpected death under the age of 1 year and 30% of children presenting with unexplained hypoglycemia have findings consistent with a FAO disorder.

Organic acidurias most commonly present with severe high anion gap ketoacidosis, whereas urea cycle defects most commonly present with marked hyperammonemia. Urea cycle defects and organic acidurias tend to present earlier (roughly 50% in the first month of life and 90% within the first year), whereas FAO disorders tend to present somewhat later (roughly 50% in the first year and 90% by the age of 3 years). Most newborn screening programs include detection of the more common organic acidurias and urea cycle defects but usually do not include FAO disorders. As testing becomes more cost-efficient, screening programs are beginning to include more FAO disorders. Prospective studies are needed to determine if more widespread screening of at risk or symptomatic children in the ED is warranted.

OTHER LESS COMMON CAUSES

Child Maltreatment

Child maltreatment is defined as intentional harm or threat of harm to a child by someone acting in the role of caregiver. The term “battered child” was first used in 1962 to describe young children (usually under the age of 3 years) who had been repeatedly beaten or neglected by their caregivers. The term “shaken baby syndrome” refers to acute brain injuries, most commonly in the form of subdural or subarachnoid hemorrhages, occurring in infants without obvious external evidence of head trauma. Newer designations also include the term “shaken-impact” syndrome.

Nonaccidental head injury is the most common cause of traumatic death in infancy. An estimated 1.4 million children under the age of 18 years (2%–3%) experience some form of maltreatment every year, and of these, 160,000 suffering from a serious or life-threatening injury. Approximately 2000 children die of maltreatment every year, 40% in the first year of life. Risk factors for nonaccidental injuries include young parents, unstable family situations, low socioeconomic status, and disability or prematurity of the child. According to at least 1 study, perpetrators, in descending order of frequency, are fathers, boyfriends, female babysitters, and mothers.

Subdural hemorrhage, usually localized to the posterior interhemispheric fissure, is the most consistent autopsy finding in shaken baby syndrome. Diffuse axonal injury is the most important pathophysiologic mechanism related to shaken baby syndrome. Diffuse axonal

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injury occurs as a result of the sudden angular deceleration forces experienced by the brain and blood vessels and results in the subsequent intracranial injury. Diffuse axonal injury is more likely responsible for the immediate and long-term neurologic sequelae.\(^\text{32}\)

In cases of child maltreatment, histories are notoriously inaccurate, vary with time, and include a description of how the injury occurred that is incompatible with either the injury or the developmental ability of the child. One half of all patients presenting to the ED with shaken baby syndrome have severe impairment and are either unresponsive or moribund.\(^\text{29}\) Seizures are common and occur in 40% to 70% of cases. Retinal hemorrhages are found in 65% to 95% of cases but are nonspecific and cannot be dated with precision.\(^\text{28}\) For example, they have been found in up to 40% of normal vaginally delivered newborns and may not resolve for up to 1 month of age.\(^\text{32}\) In addition, other nontraumatic causes must be excluded, including sepsis, coagulopathy, galactosemia, osteogenesis imperfecta, and severe hypertension. If abuse is suspected, a thorough, unbiased evaluation is essential. The law in most states requires that appropriate child welfare agencies be notified. Caregivers should be informed that investigative procedures are in progress and that further questioning will be forthcoming.

### Methemoglobinemia

Methemoglobinemia occurs whenever there is an excess of oxidized hemoglobin in relationship to the systems that reduce it to the ferrous state. Although methemoglobinemia can occur at any age, infants are predisposed to developing it because fetal hemoglobin is more easily oxidized as compared to adult hemoglobin. Also, the amount of cytochrome b5 reductase at birth is only half that of adults and does not reach full adult levels until at least 4 months of age.

The 3 most common etiologic categories of methemoglobinemia are exogenous (toxin-induced), endogenous (related to diarrhea, infection, or systemic acidosis), and genetic.\(^\text{35}\) Diarrhea-associated methemoglobinemia in infancy is the most common syndrome associated with neonates and is likely due to a combination of factors.\(^\text{34}\) One theory proposes that the diarrhea-related methemoglobinemia in infants is linked to an idioopathic hypersensitivity reaction caused by a particular protein contained within formula and to subsequent increased nitrite formation caused by colonicoyte inflammation.\(^\text{35}\) In an alternative theory, gram-negative intestinal bacteria may convert nitrates to nitite and potentiate methemoglobinemia, and acidosis due to dehydration may potentiate its formation.\(^\text{34}\)

Treatment is based on inducing reduction of the oxidized iron within the hemoglobin back to its ferrous state. The treatment of choice is methylene blue 1 to 2 mg/kg given intravenously over 3 to 5 minutes. Methylene blue is recommended for symptomatic patients with methemoglobin levels greater than 20%, or for asymptomatic patients with levels greater than 30%.\(^\text{23}\) Symptoms usually improve within 1 hour of administration. If no improvement occurs after 30 minutes, a dose of 1 mg/kg may be repeated. It is usually well tolerated. Methylene blue is itself an oxidizing agent and may cause hemolytic anemia, particularly when given either in higher amounts (4 mg/kg) or to patients with glucose-6-phosphate deficiency.\(^\text{36}\)

### Congenital Adrenal Hyperplasia

Congenital adrenal hyperplasia (CAH) comprises a group of autosomal recessive disorders involving defects in cortisol synthesis.\(^\text{37–39}\) In such cases, chronically low levels of cortisol cause oversecretion of adrenocorticotrophic hormone by the pituitary gland, resulting in adrenal hyperplasia. The 3 main classes of steroids produced by the adrenal gland include glucocorticoids (cortisol), mineralocorticoids (aldosterone), and androgens. Variations in clinical presentations depend on the affected enzyme, relative deficiencies of end products, and hormonal effects of precursors.

More than 90% of cases of CAH involve 21-hydroxylase (OH) deficiency and are associated with decreased levels of cortisol and aldosterone and elevated levels of 17-OH progesterone and androgens.\(^\text{37–39}\) Absence of cortisol results in adrenal crisis with hypotension, hypoglycemia, and refractory shock. Decreased levels of aldosterone are associated with salt wasting, hyponatremia, and hyperkalemia. Excess androgens result in ambiguous genitalia in females and excess virilization in both genders.

Classic CAH, also known as the “salt-wasting form,” occurs in 1 in 14,000 infants. Salt wasting occurs due to the lack of aldosterone production. Salt-wasting crisis typically occurs in the first few weeks of life and is characterized by poor weight gain, vomiting, and lethargy, associated with the laboratory findings of marked hyponatremia and hyperkalemia. Nonclassic CAH does not manifest until later in life due to residual enzyme activity (typically in the range of 20%–50%) and the masking of the usual manifestations of virilization and decomposition from lack of cortisol.\(^\text{37–39}\)

CAH should be suspected in infants with ambiguous genitalia, including isolated bilateral cryptorchidism, males or females with signs of inappropriate virilization, or neonates presenting with shock and dehydration.
particularly if there is concomitant hyponatremia and hyperkalemia. Most females with the salt-wasting form are diagnosed at birth due to their relatively obviously abnormal genitalia, and therefore do not present later in life with an acute adrenal crisis because they are already on appropriate therapy. Males, however, are more easily missed due to their relatively normal appearing (andro-genized) genitalia and are much more likely to present at the age of 5 to 30 days of life in acute adrenal crisis. Treatment in the ED involves stress doses of steroids with hydrocortisone (50 mg/m² or 1–2 mg/kg), generous fluid resuscitation with normal saline, and close monitoring for hypoglycemia.

**HISTORY AND PHYSICAL EXAMINATION**

A detailed description of the infant’s general appearance is an important component of the physical examination but is often overlooked. Simple visual inspection should enable the experienced clinician to determine whether the infant is sick. Infants who are well are pink, flexed, and interactive and cry with noxious stimuli but are consolable. Sick infants are gray or cyanotic, flaccid with limbs extended, and may be either lethargic or excessively irritable and are poorly consoled. Measurement of vital signs (temperature, blood pressure, heart rate, respiratory rate, and oxygen saturation on room air [pulse oximetry]) is mandatory. Although vital signs in children vary considerably with age and may be a bit more challenging to obtain in infants, they are equally as important in a 1-month-old neonate as in an adult.

Assuming that rapid assessment of the airway and breathing has already occurred during the initial visual inspection of the infant, the next critical step is determination of perfusion. This step may be easily accomplished by determining peripheral extremity temperature and the time required for capillary refill in the hands and feet of the child. Normal capillary refill time is less than 2 s. All 4 extremity pulses should be sequentially assessed to determine symmetry. Symmetric decreased pulses indicate shock; asymmetric pulses suggest coarctation. If there is any question about blood pressure, then measurements should be obtained in all 4 extremities.

Key historical features to obtain include birth history as well as recent events. Estimated gestational age at birth, method of delivery, birth weight, and complications should be determined. Ask specifically whether the mother had any infections during pregnancy, whether she remembers ever being told that she had GBS, and whether she or the baby ever received any antibiotics. It also may be helpful to ask whether she has ever had vaginal herpes.

Determining the specifics regarding feeding is important, including the quantity, frequency, and type. Ask whether the baby has been awakening on his or her own to feed, and whether the baby has been “feeding as usual.” In addition, history such as recent vomiting and whether it has been bilious or nonbilious, large or small, spitting up or projectile, continuous or intermittent can also be helpful. It is important to determine the number and frequency of wet and dirty diapers and whether there have been any unusual colors, smells, or odors. Frequency of wetting diapers is an important indication of the fluid status of the neonate.

Examination of the skin can be particularly helpful and requires that the neonate be completely undressed. Clinicians should look for any evidence of trauma such as bruising, deformities, or swelling. In infants, cyanosis may be associated with congenital pulmonary abnormalities, acquired pulmonary infections, congenital heart defects, and hemoglobinopathies. In infants with cyanosis and diarrhea, methemoglobinemia must be a consideration, particularly if the blood is unusually dark in appearance. Petechiae or purpura may be associated with severe infection or bleeding dyscrasias. Dehydration may be noted by abnormal skin turgor, dry mucous membranes, and an absence of tears.

Beginning a head-to-toe physical examination of the infant, important findings include a description of the fontanelle, pupillary response to light, and resistance to neck flexion. The chest examination includes important findings related to both pulmonary and cardiac function. Detailed descriptions of the work of breathing that are helpful include the use of accessory muscles, paradoxical thoracoabdominal excursions, presence of adventitial lung sounds, and the relative amount of air entry and exchange. The cardiac examination provides evidence of rate, regularity, and the presence or absence of extra heart sounds.

The abdominal examination should evaluate for the presence of distension, signs of abdominal tenderness, and any evidence of palpable loops of bowel, masses, or hepatosplenomegaly. Rectal examinations are helpful to determine the presence of stool in the vault as well as the presence of blood in the stool or the possibility of an occult mass. A basic neurologic examination should be performed to assess whether the neonate has an active flexor tone, symmetric movements, and vigorous reflexes and responses to stimuli.
**Diagnostic Evaluation**

Diagnostic evaluation begins with a rapid cardiopulmonary assessment and obtaining a rapid bedside glucose measurement, while simultaneously obtaining intravenous access, placing the infant onto continuous cardiopulmonary and pulse oximetry monitors, and initiating a work-up that includes at minimum a complete blood count, blood culture, electrolytes, urinalysis, and urine culture (Figure 4). Full sepsis evaluation includes performance of a lumbar puncture, but this procedure may be delayed until the child is stable. Antibiotics should not be delayed and should be ordered early in course of the resuscitation.

All toxic-appearing children who have no readily apparent etiology for their illness should undergo basic screening for IEM, particularly in the presence of prolonged altered mental status or inappropriate ketosis (either excess or inadequate). In addition to measurement of glucose, serum electrolytes, urinalysis, and blood pH routinely performed in this situation, consider measuring the serum ammonia level.

Chest radiography provides much information regarding the structural and functional components of the neonate’s cardiopulmonary status, such as cardiac size and silhouette, pulmonary vascularity, and parenchymal lung changes (interstitial disease). Electrocardiography also may be helpful but is probably best reserved for patients in whom a cardiac defect is suspected. Detailed interpretation of pediatric electrocardiograms is beyond the scope of this article but may be diagnostic in certain cases. Echocardiography, however, has become the gold standard for diagnosing cardiac defects in infants.

If there is evidence of gastrointestinal pathology, initial screening radiographs should be obtained with a minimum of 2 views of the abdomen (flat plate and left lateral decubitus). Radiographs should be examined for evidence of a soft tissue mass or mass effect, obstruction,
free air, and presence of air in the rectosigmoid region.\textsuperscript{11,15} Obstruction is signified by dilated loops of bowel and air-fluid levels. The presence of pneumatosis intestinalis is specific for NEC. In cases of Hirschsprung’s disease, plain radiographs of the abdomen may reveal evidence of fecal impaction with proximal obstruction, air/fluid levels, and dilated colon. Ultrasound is the least invasive and most commonly used modality for diagnosing hypertrophic pyloric stenosis and, in many centers, intussusception. An upper gastrointestinal series is required to confirm or rule out the presence of malrotation.

**THERAPEUTIC MANAGEMENT**

First and foremost, from an initial resuscitation standpoint, infants should be treated like adults: ABCD. The airway is secured, breathing and circulation are assessed, and a defistick is obtained. When present, hypoglycemia in a neonate should be treated with 2 to 4 mL/kg of 10% dextrose and periodically reassessed. In cases of impaired perfusion, repeated fluid boluses using normal saline 20 mL/kg should be given until adequate circulatory volume has been achieved. As long as the lungs remain clear, up to 3 fluid boluses may be safely given in rapid succession. If the infant remains in shock, consideration must be given to adding other pharmacologic adjuncts, such as dopamine, dobutamine, epinephrine, hydrocortisone, or prostaglandin E\textsubscript{1}. Epinephrine is the drug of choice for most types of shock. Hydrocortisone is indicated specifically for suspected CAH. Prostaglandin E\textsubscript{1} is indicated for cases in which reopening of the ductus arteriosus may be helpful and is desired. Following normalization of blood glucose and circulatory volume, a continuous glucose energy source and maintenance fluids should be provided.

Sick neonates should generally be considered to be septic until proven otherwise. Antibiotics of choice are ampicillin and either gentamicin or cefotaxime. Consideration may also be given to adding acyclovir or vancomycin. Acyclovir is the drug of choice for suspected herpes, and vancomycin is indicated for resistant gram-positive organisms.

Infants in whom there is suspicion of a gastrointestinal emergency, such as those with sudden onset of bilious emesis who are ill appearing or have a distended abdomen, require immediate consultation with a pediatric surgeon. A nasogastric or orogastric tube should be placed to decompress the abdomen, and ill-appearing infants should be given broad-spectrum triple antibiotic coverage with ampicillin, gentamicin, and either clindamycin or metronidazole.

**CONCLUSION**

Successful management of the sick neonate requires a thorough understanding of the most common causes of serious illness that may occur in this unique age-group. In addition, although many of the chief priorities remain the same (ABCD), diagnostic and therapeutic strategies involve uncommonly encountered clinical scenarios that require in-depth, repeated review by the general emergency medicine physician.

**REFERENCES**

11. Hernanz-Schulman M. Imaging of neonatal gastrointestinal

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