

Pediatric Critical Care

Part 1—Diagnostic Interventions

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Neonatal and pediatric critical care is markedly different from adult critical care because of the physiologic and hemodynamic dissimilarities between immature and adult animals. Clinicians are often wary of treating these patients because of their small size and the presumptive limitations in diagnostic and therapeutic interventions. Nevertheless, we have the ability to treat these young animals aggressively. In doing so, however, we must be cognizant of the unique distinctions among pediatric patients with regard to normal physiologic variables that affect physical examination findings and diagnostic test results (see **Pediatrics by the Age**).

Common Causes of Pediatric Illness

Ill neonates can quickly become critically ill. In fact, more than half of all deaths in puppies occur within the first 3 days of life.¹ Any of several disease states, problems with basic animal husbandry, or lack of maternal care can result in a debilitated puppy or kitten that requires critical care.

Common causes of neonatal illness include poor mothering, failure to nurse, and failure of the mother to produce adequate milk. These conditions often manifest in the first week of life but may be delayed if the mother becomes ill in the days or weeks after whelping. Excellent guides are available for the care of orphaned kittens and puppies (see **Resources**, next page).

Infection is another important cause of critical illness; the juvenile immune system is not fully functional.² Bacterial infection with *Escherichia coli*, β -hemolytic *Streptococcus* spp, or *Pasteurella* spp, which may gain access through the umbilical stump, is particularly likely in neonates.

Although some infections occur shortly after birth, others are more common in older puppies or kittens (see **Important Infectious Agents in Puppies and Kittens**, next page). Assuming the mother is healthy and the offspring nurse colostrum, many viral infections (especially those whose antigens are contained in routine vaccines) become more likely after maternal antibodies have waned (eg, parvovirus in dogs, panleukopenia in cats).

Other rule-outs for fading puppy or kitten syndrome include poor environmental conditions, congenital defects (eg, congenital heart disease, cleft palate), thyroid dysfunction, thymic disorders, undetected trauma, neonatal isoerythrolysis, and taurine deficiency. Animals with low birth weight are especially susceptible to illness.¹



Pediatrics by the Age^{3,20}

The term *pediatric* is often used to refer to puppies and kittens younger than 6 months of age; however, many clinicians break down the age groups even further:

- Neonate: 0–2 weeks of age
- Infant: 2–6 weeks of age
- Juvenile: 6–12 weeks of age

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Important Infectious Agents in Puppies & Kittens

Puppies

- *Bordetella bronchiseptica*
- *Brucella canis*
- Distemper
- Endoparasites and ectoparasites
- Canine herpesvirus
- *Mycoplasma* and *Ureaplasma* spp
- *Neospora caninum*
- Parvovirus
- Rotavirus

Kittens

- *Bordetella bronchiseptica*
- Endoparasites and ectoparasites
- Feline leukemia virus
- Feline infectious peritonitis
- *Mycoplasma* and *Ureaplasma* spp
- Feline panleukopenia
- Feline herpesvirus type 1
- *Toxoplasma gondii*

IO = intraosseous infusion

Historical Findings

As soon as the patient is stabilized, the client should be questioned thoroughly about the condition of the mother, previous medical problems (of the patient, mother, sire, littermates, former litters, or particular breeding line), history of abortion, litter size, condition of littermates, nurturing by the mother, vaccine status and routine care of the mother, appropriate blood typing and breeding (for cats), and history of previous blood transfusion. Questioning should also include husbandry, environmental conditions, and nutritional status (eg, whether alternate feeding methods have been implemented via tube or bottle feeding, specific volume and type of supplementation with milk replacement products, feeding frequency, suckle response). The client should also be questioned about signs such as constant crying, failure to gain weight, and

reluctance to nurse, all of which indicate inadequate food intake.

Physical Examination Findings

In the emergent evaluation of unstable neonates, initial therapy should focus on the primary survey—the ABCDs (ie, airway, breathing, circulation, dysfunction). Immediate life-saving therapy should then be initiated as necessary, including oxygen therapy, IV or IO catheter access, blood glucose monitoring, dextrose supplementation (if hypoglycemic), temperature support, and volume resuscitation.

Once the patient has been stabilized, a more thorough and systematic physical examination can be pursued. Patients should be weighed 4–6 times per day to allow for careful assessment of hydration and weight gain. Use of a gram scale is

Resources

The following resources on the care of newborn and orphaned puppies and kittens can provide insight into at-home care and are especially useful to share with clients.

Websites

- **ASPCA:**
 - Newborn Puppy Care: aspc.org/pet-care/dog-care/newborn-puppy-care
 - Newborn Kitten Care: aspc.org/pet-care/cat-care/newborn-kitten-care
- **Koret Shelter Medicine Program (University of California–Davis):**
 - Canine: Guide to Raising Orphan Puppies: sheltermedicine.com/node/33
 - Feline: Guide to Raising Orphan Kittens: sheltermedicine.com/node/39
- **Maddie's Fund:**
 - Orphaned Kitten Care: How-to Videos: maddiesfund.org/maddies_institute/videos/orphaned_kitten_care_how_to.html

Literature

- **Neonatal and pediatric care of the puppy and kitten.** Lawler DF. *Theriogenology* 70:384-392, 2008.
- **Playing mum: Successful management of orphaned kittens.** Little S. *J Feline Med Surg* 15:201-210, 2013.

important to obtain an accurate weight measurement. The neonate should be examined in sternal recumbency while receiving supplemental oxygen. To minimize additional heat loss, the neonate should be kept warm during the examination (eg, avoid placing the animal on a cold examination table).

Respiratory pattern, rate, effort, and lung sounds should be evaluated. Because respiratory sounds are more subtle in neonates than in adults, evaluation is best performed in a quiet room using a pediatric stethoscope. Mucous membrane color, capillary refill time, heart rate, rectal temperature, and pulse quality should be assessed to evaluate perfusion parameters. Clinical signs of sepsis, hypovolemia, or shock in neonates include pale mucous membranes, decreased urine output, cold extremities, limp body tone, constant crying, and reluctance to suckle.^{3,4}

Unique congenital abnormalities should be identified, including umbilical hernia, cleft palate, open fontanel, patent urogenital opening, heart murmur, or atresia ani. Signs of underlying disease may include

nasal and ocular discharge, umbilical discharge or discoloration, abnormal lung sounds, or abnormal temperature. The unique finding of tail tip necrosis in neonatal kittens suggests isoerythrolysis.^{5,6}

It is important to know the normal neonatal physiologic parameters for puppies and kittens and when physiologic milestones are typically achieved (Tables 1 and 2). If the clinician is unaware of these values, low normal temperature or fast normal heart rate could be misinterpreted as signs of illness.

A strong suckle reflex and adequate rooting behavior (ie, ability to move the head in search of milk) should be present shortly after birth. Because neonates nurse and sleep almost constantly for the first 2–3 weeks of life, responsiveness and strength may be difficult to assess. This can be evaluated based on strength of suckle response, ability of the neonate to right itself when placed on its back, and rooting response (ie, the neonate strongly pushes its muzzle forward into circled fingers).

Neonates should show evidence of adequate muscling on examination, and weight gain should be evaluated. Kittens should weigh approximately 100 g at birth, while puppy birth weights vary by breed (eg, Pomeranian, 120 g; beagle, 250 g; greyhound, 490 g; Great Dane, 625 g; Table 1).⁷ Kittens should gain 7–10 g/day, whereas puppies should gain 1 g/lb of anticipated adult weight per day.

Assessment of hydration status by measuring skin turgor may be inaccurate because of increased water content and decreased fat content in neonatal skin.³ Likewise, assessing dehydration by looking for hypersthenuria is inaccurate because of decreased glomerular filtration rate in the neonate.³ Hence, prerenal azotemia and concentrated urine specific gravity may not be present in neonates despite profound dehydration.

Neonates have an immature autonomic nervous system, altering their response to shock. Monitoring parameters such as heart rate and blood pressure are not reliable in assessing hypovolemia in the youngest patients. The traditional evaluation of an adult patient with hypovolemic shock is based on tachycardia, weak pulses, and a low–normal central venous pressure (ie, ≤ 0 cm H₂O). In neonates, normal resting heart rate is higher (180–200 bpm), while mean arterial pressure is lower (50 mm Hg) than that in adults.⁸ The decrease in mean arterial pressure is believed to be a result of the immaturity of the muscular component of the arterial wall at birth.⁸

In addition, central venous pressure is 75% higher in neonates (~8 cm H₂O) than in adults, possibly the result of low venous compliance and increased plasma volume.⁸ Therefore, neonatal and pediatric critical care monitoring must be based on serial physical examinations, weight

Table 1. Normal Physiologic Parameters for Neonates^{1,7,21}

Parameter	Value
Birth weight	Dogs: Varies with breed; most range from 100–650 g Cats: 90–110 g
Rectal temperature	Newborn: 36°C–37°C (96.8°F–98.6°F) 1 month: 38°C (100°F)
Heart rate	180–200 bpm
Respiratory rate	Neonate: 10–18 bpm 1 week: 15–35 bpm
Urine specific gravity	<1.020
Water requirement	Output: 2.5 mL/100 g BW/day
Caloric requirement	Dogs: 20–26 kcal/100 g BW/day Cats: 15–25 kcal/100 g BW/day
Stomach capacity	4–5 mL/100 g BW
BW = body weight	

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Table 2. Normal Neonatal Physiologic Milestones*^{1,2,7,21-23}

Milestone	Age of Occurrence
Pain reflex	At birth
Flexor tone	1–4 days
Umbilical cord loss	2–3 days
Extensor tone	5–8 days
Eyes open	5–14 days
External ear canals open	6–14 days
Capable of crawling	7–14 days
Withdrawal reflex	7–19 days
Capable of walking, urinating, and defecating spontaneously	14–21 days
Ambulation	16 days
Normal vision	21–30 days
Menace reflex	21–30 days
Voluntary voiding	3 weeks
Deciduous incisor/canine teeth erupt	<i>Dogs:</i> 3–6 weeks <i>Cats:</i> 3–4 weeks
Normal hearing	4–6 weeks
Testes descended	4–6 weeks
Deciduous premolars erupt	<i>Dogs:</i> 5–6 weeks <i>Cats:</i> 4–6 weeks
Permanent canines	<i>Dogs:</i> 12–16 weeks <i>Cats:</i> 12–20 weeks
Permanent molars	<i>Dogs:</i> 16–24 weeks <i>Cats:</i> 20–24 weeks
Renal function approximates that of adult	8 weeks
Hepatic function approximates that of adult	4–5 months

* Some differences exist between dogs and cats or between breeds (eg, Abyssinian kittens may open their eyes much sooner than other breeds).

gain, improved heart and lung sounds, improved mentation, nursing ability, chest radiographs, blood glucose, extremity temperature, serial packed cell volume (PCV)/total solids (TS), urine output, and, potentially, increased trends in central venous pressure (provided a jugular catheter is in place).

Laboratory Data

Performing venipuncture on neonates can be physically challenging. The jugular vein should be the primary area for venipuncture, provided there is no evidence of coagulopathy (eg, ecchymoses, petechiae), no history of anticoagulant rodenticide toxicity, and no known hereditary disorder of coagulation or platelets.

Only a limited blood volume can be drawn safely because of the neonate's small size; no more than 1% of the neonate's body weight should be taken in a 24-hour period. It is thus imperative that each blood sample be used efficiently and effectively. A minimum database (ie, PCV, TS, blood glucose, blood urea nitrogen as measured by Azostix) and blood smear should be obtained first, with remaining blood used for other tests (eg, chemistry panel). Recheck venipuncture (eg, spot blood glucose checks) should be performed as necessary, but the *minimum* amount of blood necessary for the test should be drawn. If small volumes of blood are placed in tubes designed for larger volumes, liquid anticoagulant can lead to both sample dilution and false results. Use of tubes designed for very small volumes is ideal. Collection tubes containing ethylenediaminetetraacetic acid (EDTA) or heparin anticoagulant are available in 0.3-, 0.5-, and 1-mL sizes.

Neonatal diagnostic test results (eg, CBC, chemistry panel, coagulation testing, urinalysis) vary from adult parameters as well.^{1,9-14} In neonatal puppies, PCV

decreases by one-third as fetal RBCs meant for the hypoxic uterine environment are replaced; neonatal cells are often macrocytic, and polychromasia, nucleated RBCs, and Howell–Jolly bodies are common in these patients.¹⁰ In puppies, the PCV is typically 47% at birth but drops to approximately 29% at 28 days.¹¹ In neonatal kittens, PCV is approximately 35% at birth and drops to its nadir of about 27% at 28 days.¹⁵ This becomes important when assessing PCV/TS as a parameter for hydration status; if a 3-week-old puppy presents with a PCV of 38% and a TS of 6%, the puppy is hemoconcentrated and should be treated aggressively with IV fluid therapy. At the same time, a puppy with a PCV of 25% and a TS of 4.5% does not need a colloid, as this may be normal for the neonate.

Whereas the RBC count and PCV decreases from birth through the first month, the WBC count increases. What would be considered mild to moderate leukocytosis in an adult may be normal for a 1-month-old puppy. In many pediatric patients, leukocytosis may result from lymphocytosis and eosinophilia caused by initial response to antigen exposure and parasite load, respectively.

Neonatal and pediatric chemistry values include increased alkaline phosphatase and gamma-glutamyltransferase (from bone growth), along with increased bilirubin, calcium, and phosphorus.^{1,7,9,16} Neonates have lower total protein than adults, but globulin values increase almost linearly with age because of antigenic stimulation.¹⁴ Glucose, blood urea nitrogen, and cholesterol may also be lower than in adult animals because of decreased hepatic synthesis. In pediatric patients, serum thyroxine concentrations may be elevated as compared with adults.^{7,14} Finally, urine is isosthenuric until approximately 9 to 10 weeks of age.⁹ Nephrogenesis is incomplete at birth, and tubular maturation occurs later than glomerular



maturation.¹⁷ As a result, glucosuria can be normal in puppies up to 8 weeks of age.⁹

Radiography

Radiograph acquisition is unique in neonatal medicine.^{18,19} Because of the small size of these animals, fine-screen radiographs should be used. In neonates, the quality of the radiograph can be enhanced by decreasing the kilovolt peak (kVp) to one-half that used in the adult. Most studies in puppies and kittens are radiographed using the range of 40–60 kVp.¹⁸ Alternatively, in puppies, 2 kVp can be used for each 1 cm of soft tissue measured.⁷

Pediatric radiographic findings differ from adult findings in several ways. Thoracic radiographs should show the thymus sail sign in neonates, and the pulmonary interstitium may appear more opaque because of increased water content in interstitial lung parenchyma.¹⁶ In addition, costochondral mineralization will be absent, open growth plates will be present, and abdominal detail will be lost from a lack of body fat and normal scant abdominal effusion. Often, the heart appears relatively large in puppies and kittens in proportion to the thoracic cavity.¹⁶

No more than 1% of the neonate's body weight should be taken in a 24-hour period.

Important disease entities to look for on radiographs include structural defects (eg, diaphragmatic hernia, peritoneopericardial diaphragmatic hernia, pectus excavatum), cardiomegaly (eg, congenital heart defect), megaesophagus (eg, congenital or persistent right aortic arch), or lung pathology (eg, bacterial or viral pneumonia, aspiration pneumonia, noncardiogenic pulmonary edema).

Conclusion

With appropriate knowledge of normal physiologic parameters, we can improve our ability to diagnose critical illness in neonatal and pediatric patients. Size should not prevent us from caring for these tiny patients. ■ **cb**

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