

Understanding the pediatric patient and basics of pediatric emergencies



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Stages of development

- Neonatal period
 - from birth till 3rd-4th week
- Weaning period
 - from period when puppy or kitten able to walk and urinate alone (3rd week) until weaned of the dam (8th week)
- Adolescent period
 - ending with puberty
 - > dogs: 6 months in toy breeds
12-15 months in giant breeds
 - > cats: 6 months
- Pediatric refers to animals between 2 weeks and 6 months of age.



Timing of significant events in development



TIMING OF SIGNIFICANT EVENTS IN PEDIATRIC DEVELOPMENT	
EVENT	AGE AT OCCURRENCE
Umbilical cord dries and falls off	2 to 3 days
Eyelids open	5 to 14 days
External ear canals open	6 to 14 days
Extensor dominance	5 days
Capable of crawling	7 to 14 days
Capable of walking, urinating and defecating spontaneously	14 to 21 days
Hematocrit / RBC number stabilize near that of adult	8 weeks
Renal function nears that of adult	8 weeks
Hepatic function nears that of adult	4 to 5 months



Physical examination

Physical examination

- **Body temperature**
 - Large surface area to body mass
 - Lack of insulating body fat
 - Shivering mechanism not developed in neonates
 - In the 1st week of life $35.6 \pm 0.7^{\circ}\text{C}$
 - 2nd – 3rd week of life – $37.0\text{-}38.2^{\circ}\text{C}$
 - At later age approaches the temperature of adults



Physical examination



- **Cardiovascular system**
 - Greater heart rate, cardiac output, plasma volume and CVP
 - Low stroke volume, peripheral resistance and low blood pressure
 - Heart murmurs can be functional (I-III/VI)
 - Sinus arrhythmia not commonly reported in neonates
 - Low blood pressure (mean BP 20-40 mmHg lower than in adults)

Kustritz, 2011

McMichael, 2005

Peterson & Kutzler, 2011: Small Animal Pediatrics: First 12 months of life

Physical examination



- **Respiratory system**
 - Twofold to threefold higher tissue oxygen body demand per BW compared to adults
 - The work of breathing increased (narrow airway passages)
 - Diagnostic imaging -> mild interstitial pattern in puppies can be normal!
 - ✦ Overinterpretation of thymus and brown fat deposits in cranial mediastinum (CT and MRI useful in interpretation of mediastinal structures)

Kustritz, 2011

McMichael, 2005

Peterson & Kutzler, 2011: Small Animal Pediatrics: First 12 months of life

Mistakes in evaluating hydration status in neonates



- Do not assess hydration status in the same manner as in adults!
- Skin turgor unreliable in neonates
- Tachycardia unreliable
- Mucous membranes often remain moist until dehydration is severe
- Urine concentration unreliable
- Hct only stable by 8 weeks of age can be used for evaluation only in adolescents



How do we make it right?



- Ventral abdomen is best place to evaluate hydration status
- Mucous membrane color and capillary refill time are good indicators of perfusion in neonates
- Pale mucous membranes and slow capillary refill time (> 1.5 sec) = severe dehydration enough to cause hypovolemic shock

Physical examination



- **GI tract / abdomen**
 - Examination of oral cavity and teeth -> check for a cleft palate
 - Check for umbilical hernia
 - Some abdominal fluid can be present in normal pediatric patient
 - Spleen and margins of liver lobes should not be palpable -> suggestive of enlargement



Physical examination



- **Skin and haircoat**
 - Check for fleas and dermatophytosis
 - Littermates suckling on each other's appendices
- **Neurologic examination**
 - Possible when neurologic functions mature (6-8 weeks)
 - Postural reactions only develop fully at 6-8 weeks (front limbs first)
- **Musculoskeletal system**
 - Evaluation of movement and palpation of bones and joints
 - Locomotion is present by 3 weeks of age -> assessment of gait and muscle tone

Kustritz, 2011

McMichael, 2005

Peterson & Kutzler, 2011: Small Animal Pediatrics: First 12 months of life



Laboratory data

Puppy

TABLE 30-2 Puppy biochemical parameters from birth to approximately 8 weeks of age

	Days 1-3	Days 8-10	Weeks 4-5 Days 28-33	Weeks 7-8 Days 50-58
Albumin (g/dl)	1.76-2.75	1.71-2.5	2.17-2.97	2.38-3.22
ALP (U/L)	452-6358	195-768	153-490	153-527
ALT (U/L)	9.1-42.2	4.1-21.4	4.3-17.4	10.3-24.3
Bilirubin (mg/dl)	0.04-0.38	0.01-0.18	0.02-0.15	0.01-0.11
BUN (mg/dl)	29.5-118	29.1-66.7	13.1-46.2	16.8-61.4
Calcium (mg/dl)	10.4-13.6	11.2-13.2	10.4-13.2	10.8-12.8
Cholesterol (mg/dl)	90-234	158-340	177-392	149-347
Creatinine (mg/dl)	0.37-1.06	0.28-0.42	0.25-0.83	0.26-0.66
GGT (U/L)	163-3558	-	-	-
GLDH (U/L)	1.8-17.0	0.2-17.7	1.2-9.0	1.6-7.3
Glucose (mg/dl)	76-155	101-161	121-158	122-159
TP (g/dl)	3.7-5.77	3.26-4.37	3.71-4.81	4.04-5.33
Triglycerides (mg/dl)	45-248	52-220	36-149	39-120
Phosphorus (mg/dl)	5.26-10.83	8.35-11.14	8.66-11.45	8.35-11.14

Adapted from Center SA et al: Effect of colostrum ingestion on gamma-glutamyltransferase and alkaline phosphatase activities in neonatal pups, *Am J Vet Res* 52(3):499-504, 1991; Kuhl S et al: Reference values of chemical blood parameters for puppies during the first 8 weeks of life, *Dtsch Tierärztl Wschr* 107:438-443, 2000; Harper EJ et al: Age-related variations in hematologic and plasma biochemical test results in Beagles and Labrador retrievers, *J Am Vet Med Assoc* 223(10):1436-1442, 2003.

TABLE 30-3 Puppy biochemical parameters up to 12 months of age

	2-3 Months	4-6 Months	7-12 Months
Albumin (g/dl)*	2.6-3.7	2.6-3.7	2.6-3.7
ALP (U/L)	88-532	126-438	4-252
ALT (U/L)	≤29	≤32	5-45
Amylase (U/L)*	≤1683	≤1683	≤1683
AST (U/L)	7-19	3-23	2-26
Bilirubin (mg/dl)	0.01-0.13	0.01-0.13	≤0.3
BUN (mg/dl)*	9.8-37.3	9.8-37.3	9.8-37.3
Calcium (mg/dl)	10.4-13.6	10-13.2	10.4-12
Chloride (mEq/L)*	99-120	99-120	99-120
Cholesterol (mg/dl)	99.6-499.6	99.6-499.6	135-278
CK (U/L)	31-255	40-192	≤134
Creatinine (mg/dl)	0.39-0.49	0.27-0.88	0.21-0.89
GGT (U/L)	≤6.2	≤4.3	≤3.2
Globulins (g/dl)	1.9-2.5	2.2-3.5	2.2-4.5
Glucose (mg/dl)	97.1-166.2	97.1-166.2	76-119
GLDH (U/L)	1.6-9.6	1.9-8.7	1.2-8.0
LDH (U/L)	68-290	≤442	9-269
Lipase (U/L)	≤241	≤139	≤154
Magnesium (mEq/L)*	1.4-5.2	1.4-5.2	1.4-5.2
Phosphorus (mg/dl)	6.4-11.3	5.6-9.6	3.5-7.8
Potassium (mEq/L)	4.5-6.3	3.9-6.1	4.2-5.6
Sodium (mEq/L)	140-156	139-159	138-158
Total protein (g/dl)	4.3-5.8	4.5-7.3	4.9-6.7
Triglycerides (mg/dl)	19.1-205.5	19.1-205.5	40-169
TLI (μg/L)	5-35		

Adapted from the following sources:

Harper EJ et al: Age-related variations in hematologic and plasma biochemical test results in Beagles and Labrador retrievers, *J Am Vet Med Assoc* 223(10):1436-1442, 2003.

Kley S et al: Establishing canine clinical chemistry reference values for the Hitachi 912 using the international federation of clinical chemistry (IFCC) recommendations, *Comp Clin Path* 12:106-112, 2003.

Kraft W, Hartmann K, Dereser R: Dependency on age of laboratory values in dogs and cats. Part I: Activities in serum enzymes, *Tierärztl Prax* 23:502-508, 1995.

Kraft W, Hartmann K, Dereser R: Age dependency of laboratory values in dogs and cats. Part II: serum electrolytes, *Tierärztl Prax* 24:169-173, 1996.

Laroute V et al: Quantitative evaluation of renal function in healthy Beagle puppies and mature dogs, *Res Vet Sci* 79(2):161-167, 2005.

Vajdovich P et al: Changes in some red blood cell and clinical laboratory parameters in young and old beagle dogs, *Vet Res Commun* 21(7):463-470, 1997.

* Parameters for which significant age variation was not found in puppies.

Kitten



TABLE 30-4 Kitten biochemical parameters from birth to 8 weeks of age

	Day 0	Day 1	Day 7	Week 4 Day 28	Week 8 Day 56
Albumin (g/dl)	2.5-3.0	1.9-2.7	2.0-2.5	2.4-4.9	2.4-3.0
ALP (U/L)	184-538	1348-3715	126-363	97-274	60-161
ALT (U/L)	7-42	29-77	11-76	14-55	12-56
Amylase (U/L)	310-837	310-659	187-438	275-677	407-856
AST (U/L)	21-126	75-263	15-45	15-31	14-40
Bilirubin (mg/dl)	0.1-1.1	0.1-1.6	0.0-0.6	0.0-0.3	0.0-0.1
BUN (mg/dl)	26-45	34-94	16-36	10-22	16-33
Calcium (mg/dl)	9.4-13.9	9.6-12.2	10.0-13.7	10.0-12.2	9.8-11.7
Cholesterol (mg/dl)	65-141	48-212	119-213	173-253	124-221
CK (U/L)	91-2300	519-2654	107-445	125-592	102-1512
Creatinine (mg/dl)	1.2-3.1	0.6-1.2	0.3-0.7	0.4-0.7	0.6-1.2
GGT (U/L)	0-2	0-9	0-5	0-1	0-2
Glucose (mg/dl)	55-290	65-149	105-145	117-152	94-143
LDH (U/L)	176-1525	302-1309	117-513	98-410	62-862
Lipase (U/L)	12-43	21-131	8-46	4-86	6-70
Phosphorus (mg/dl)	5.9-11.2	4.9-8.9	6.7-11.0	6.7-9.0	7.6-11.7
TP (g/dl)	3.8-5.2	3.9-5.8	3.5-4.8	4.5-5.6	4.8-6.5
TS (g/dl)	3.1-4.4	3.2-5.2	3.0-4.6	4.0-6.0	4.1-6.2
Triglycerides (mg/dl)	23-132	30-644	129-963	43-721	16-170

Adapted from Levy JK, Crawford PC, Werner LL: Effect of age on reference intervals of serum biochemical values in kittens, *J Am Vet Med Assoc* 228(7):1033-1037, 2006.

Kitten



TABLE 30-5 Kitten biochemical parameters up to 12 months of age

	<3 Months	4-6 Months	7-12 Months
ALT (U/L)	10-50	≤77	≤85
ALP (U/L)	≤564	37-333	21-197
Amylase (U/L)*	≤1800	1800	≤1800 (≤2200 Oriental breeds)
AST (U/L)	≤20	≤30	≤30 (≤40 Oriental breeds)
Bilirubin (mg/dl) [†]	≤4	≤4	≤4
BUN (mg/dl) [‡]	17-35	17-35	17-35
Calcium (mg/dl)*	9.2-12.0	9.2-12.0	9.2-12.0
Chloride (mEq/L)	97-125	102-122	104-124
Creatinine (mg/dl)	0.16-1.26	0.33-1.21	— [§]
CK (U/L)	≤188	≤160	≤128
GGT (U/L)*	≤4	≤4	≤4
GLDH (U/L)*	≤7	≤7	≤7 (≤16 Oriental breeds)
Glucose (mg/dl) [‡]	70-150	70-150	70-150
LDH (U/L)	68-280	≤442	9-269
Lipase (U/L)	≤280	≤280	≤280
Magnesium (mEq/L)*	1.2-5.2	1.2-5.2	1.2-5.2
Potassium (mEq/L)	3.7-6.1	4.2-5.8	3.7-5.3
Phosphorus (mg/dl)	6.5-10.1	6-10.4	4.5-8.5
Sodium (mEq/L)*	143-160	143-160	143-160
Total protein (g/dL) [¶]	—	3.3-7.5	3.3-7.5
TLI (μg/L)	17-49 [¶]		

Adapted from Kraft W, Hartmann K, Dereser R: Dependency on age of laboratory values in dogs and cats. Part I: Activities in serum enzymes, *Tierärztl Prax* 23:502-508, 1995; Kraft W, Hartmann K, Dereser R: Age dependency of laboratory values in dogs and cats. Part II: serum electrolytes, *Tierärztl Prax* 24:169-173, 1996; Kraft W, Hartmann K, Dereser R: Age dependency of laboratory values in dogs and cats. Part III: bilirubin creatinine & proteins in serum, *Tierärztl Prax* 24:610-615, 1996.

* Parameters for which significant age variation has not been found in kittens.

[†]Adult values reached after 1 week of age.

[‡]Adult values reached after 8 weeks of age.

[§]Reference ranges have not been reported for kittens over 6 months of age; 0.8-2.3 mg/dl (adult).

[¶]Adult levels are reached between 6 months and 1 year of age.

[¶]Data from Steiner JM: Diagnosis of pancreatitis, *Vet Clin North Am Small Anim Pract* 33:1181-1195, 2003.



Fluid therapy

Recommended fluid rates



- Pediatric patients have **HIGHER FLUID** requirements than adults due to:
 - Higher percentage of total body water
 - Greater surface area–to–body weight ratio
 - Higher metabolic rate
 - Decreased renal concentrating ability
 - Decreased body fat



Current recommendations of fluid rates in dehydrated pediatric patients



- Fluid bolus of 30 to 40 mL/kg in moderately dehydrated neonates, followed by CRI of warm crystalloids at a rate of 80 to 100 mL/kg/d (*McMichael 2005, McMichael 2011*)
- 1 mL per 30 g of body weight (30–45 mL/kg) by slow i.v. push over 5 to 10 minutes followed by fluid therapy at a rate of 80 to 120 mL/kg/d (*MacIntire, 2008*)
- Maintenance requirements 2-3x higher than for adult animals (120–180 mL/kg/d) (*MacIntire, 2008*)
- Severely dehydrated or hypovolemic patients bolus of 40 – 45 ml/kg (puppies) or 25 – 30 ml/kg (kittens) followed by CRI of warm crystalloids at a rate of 80 to 100 mL/kg/d (*Silverstein*)
- 13 to 22 ml/100 g/ day requirement; maintenance fluid rate 3-6 ml/kg/hour (*von Heimndahl ppt.presentation- <http://www.bvna.org.uk>*)

Always recalculate maintenance plus replacement of losses
(hint -> 2 tbsp of diarrhea = 30 ml of fluids)

Current recommendations of types of fluids used in pediatric patients



- Ideally fluids used should be warmed!
- Delivered intravenously or intraosseus in emergency patients
- **Crystalloids as a first choice:**
 - Lactated Ringer's solution -> lactate also a preferred fuel in neonates in time of hypoglycemia
 - Hartmann's solution (similar though not identical to LRS)

Not suitable in emergency cases but still good to know



Intraperitoneal

- Colostrum, whole blood, or crystalloid fluids can be administered intraperitoneally
- Blood given intraperitoneally is not absorbed for 48 to 72 hours
- Instillation of warm fluids into the peritoneal cavity can be a useful for treating hypothermia and increasing core body temperature – warm fluids max. 2°C higher as core body temperature

Not suitable in emergency cases but still good to know



Subcutaneous fluids

- Only suitable for treatment of mild to moderate dehydration where normal perfusion is maintained
- Dextrose should not be added to isotonic fluids
- If dextrose supplementation is desired 0.45% NaCl with 2.5% dextrose can be administered



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Not suitable in emergency cases but still good to know



Oral fluids

- Only suitable for patients that are not hypothermic, hypoglycemic, or dehydrated
- Effective method of providing hydration and nutrition to neonates that cannot suckle from the dam
- 5- to 8-Fr feeding tube is used
- Tube is passed down the left side of the mouth to the stomach
- The stomach capacity of the neonate is approximately 50 mL/kg



MacIntire, 2008



Glycemic control

Resolving hypoglycemia in pediatric patients



- Clinical signs of hypoglycemia usually not seen!
- Any dextrose bolus should be followed by a CRI that is supplemented with glucose due to risk of rebound hypoglycemia



Control of the body temperature

Resolving hypothermia



- Symptoms associated with hypothermia include :
 - cardiovascular alterations (bradycardia, hypotension, decreased cardiac output, and arrhythmias),
 - prolonged recovery times and drug metabolism
 - increased infection rate
 - decreased wound healing
- Use of techniques that minimize the heat loss
- Active rewarming should be used
 - water blankets, warm air, warming lamps, warm fluids etc.
- Heat sources must be safe, effective, and easily monitored
- Ideally incubators





Pharmacokinetic alterations and pharmacology

Pharmacokinetic Alterations in Neonates



- Primary pharmacokinetic parameters: absorption, distribution, biotransformation (metabolism) and elimination
- Handling of drugs from week to week may be significantly different
- Differences depend on the condition treated and/or the therapeutic index of the drug

Drugs used for resuscitation



- **Atropine** - generally not recommended because bradycardia in newborns likely secondary to direct myocardial depression, not vagally mediated.
- **Doxapram** - for respiratory stimulation may increase ventilatory efforts of the newborn after they have started, but its duration of effect is very short
- **Epinephrine** - for cardiac arrest; adult dosages (0.2 mg/kg) may yield the best results, but increase the risk of significant hypertension. Intravenous or intraosseous administration, if available, generally preferred.

Current recommendation in use of inotropes in pediatric patients



- Contractile elements make up a smaller portion of the fetal myocardium (30%) compared to the adult myocardium (60%)
- Maturation of the autonomic nervous system does not occur until after 8 weeks of age in puppies
- Immaturity of the muscular component of the arterial wall
- Neonatal kidneys unable of autoregulation

Current recommendation in use of inotropes in pediatric patients



- Heart rate elevation and response to dopamine, dobutamine, norepinephrine cannot be predicted until 9-10 weeks of age!
- No clear recommendation of which positive inotrope preferred as oppose to other!
- Individual approach advised!

Antibiotics



- Every antibiotic carries some risk in this patients
- No antibiotic is absolutely contraindicated
- If the only antibiotic that shows activity is one to “avoid” be preapred to use it in life threatening situations
- Beta-lactam antibiotic considered the safest (penicillins, cefalosporins)
- In G- infections broad-spectral coverage required
- Avoid PO and IM dosing in seriously ill neonates

Summary



- One should understandt pediatric patient's unique physiologic system
- One should understand the key differences in areas of diagnosis, monitoring, and treatment
- One should understand that hemodynamic parameters, drug dosages, laboratory data, and diagnostic imaging differ significantly compared with those of adults of the same species

Questions & suggestions

