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WVC ANNUAL CONFERENCE
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An en-lyte-ening guide to electrolyte interpretation

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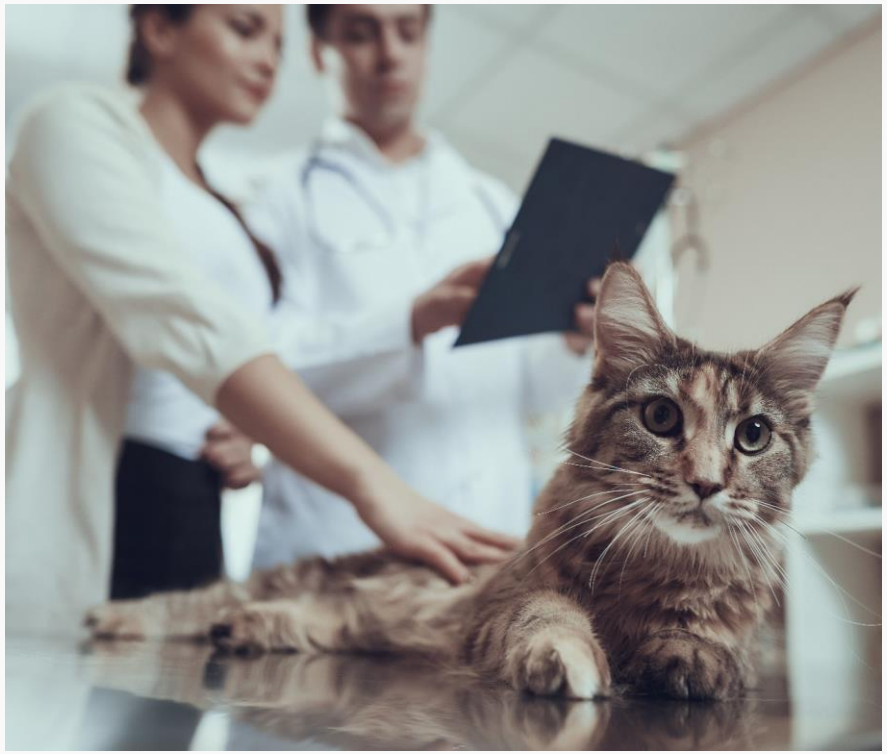
Financial Disclosure

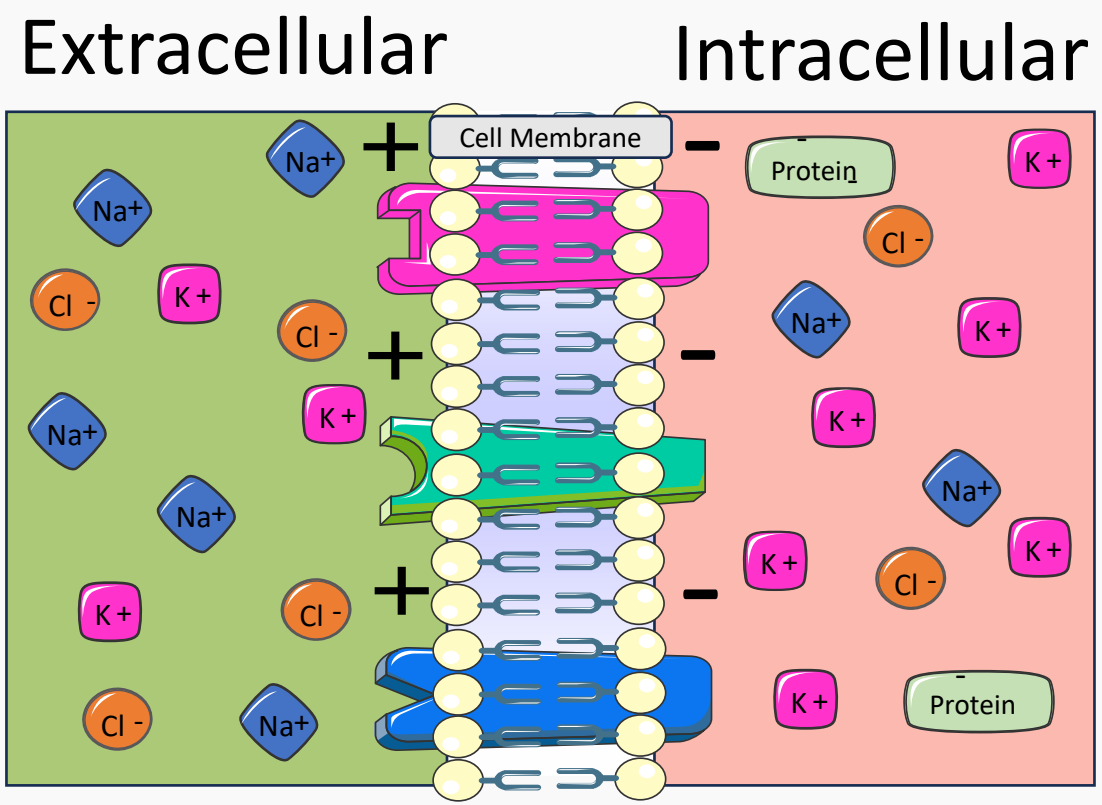
I have a direct or indirect relationship with IDEXX Laboratories. Because of the nature of the relationship, it **will not** influence my presentation.

Learning Objectives

- Recall the importance of electrolytes as part of a complete chemistry panel
- Interpret electrolytes through case examples
- Establish primary diagnostic tools for confirmation of disease
- Design appropriate management strategies



Why are electrolytes important?

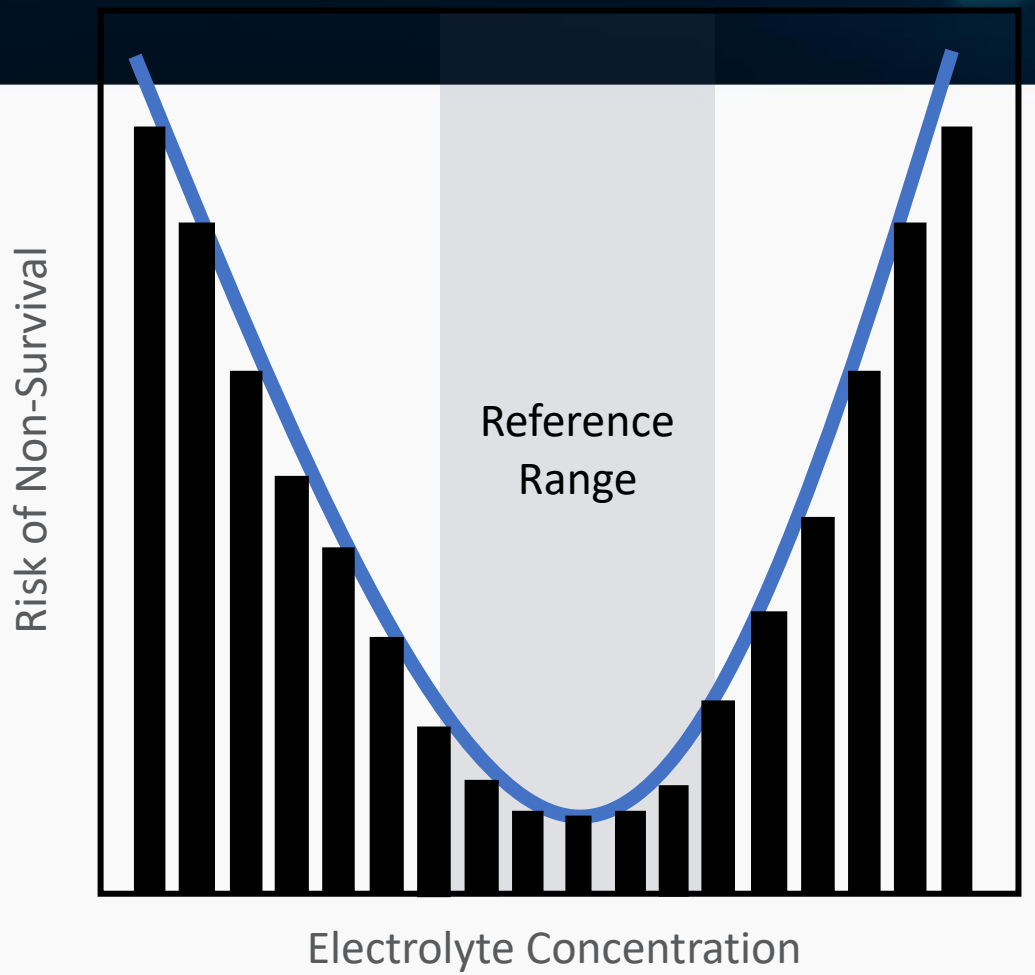


- Electrolytes are minerals found blood and other body fluids
- Essential for:
  - Function of most body systems
  - Maintaining hydration
  - Maintaining acid/base balance
- Electrolyte imbalance is often an indicator of a disease process

Electrolytes in biochemical profile? YES!

- Normal values essential for health
- Abnormal = poor outcome
  - More abnormal = worse outcome
- Dehydration, GI, renal, endocrine disease
- Aid in diagnosis
- Important monitoring tool

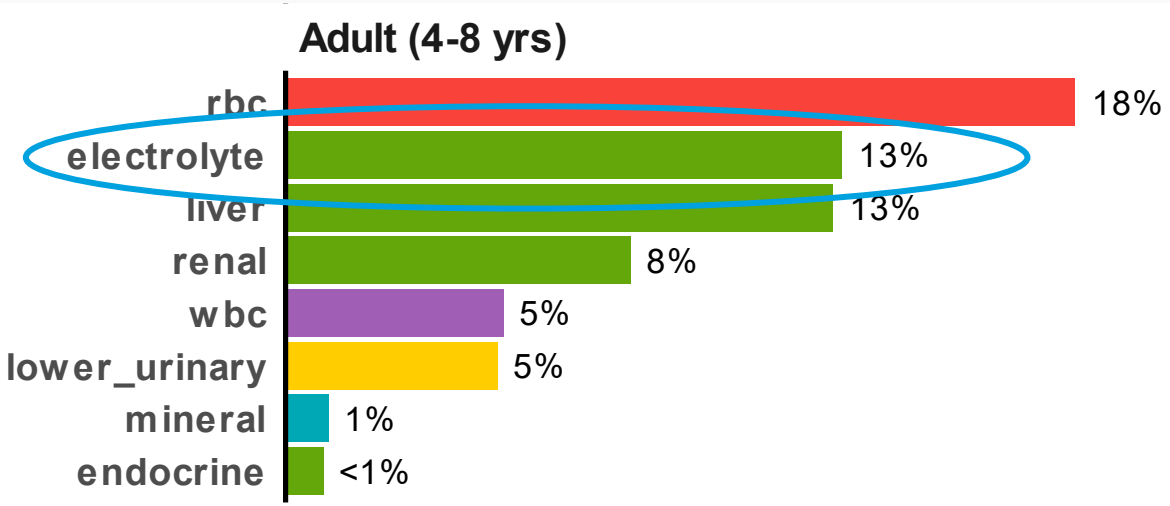
- Can be abnormal in nonclinical pets



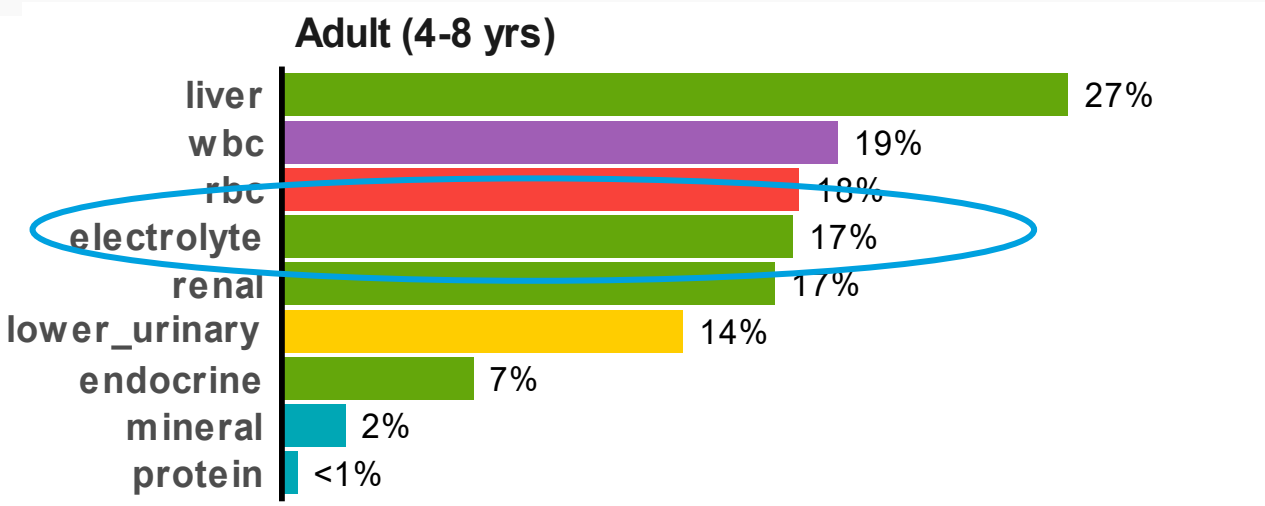
Goggs, Robert, Sage De Rosa, and Daniel J. Fletcher. "electrolyte Disturbances are associated with non-survival in Dogs—a Multivariable analysis." Frontiers in veterinary science 4 (2017): 135.

Prevalence of electrolyte abnormalities in pets

Wellness Testing[1]



All Cause Testing[2]



CBC Chem/CBC Chem Chem/UA UA

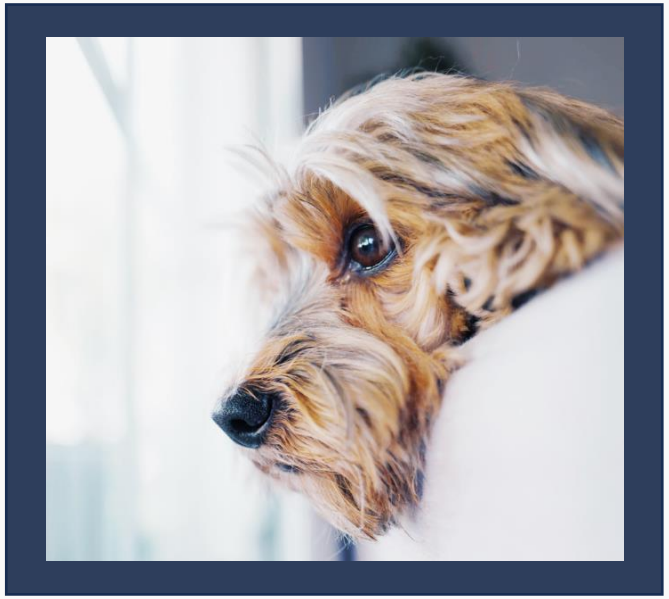
1. Data based on analyses of 167,593 canine wellness profiles (a complete chemistry profile [including the IDEXX SDMA® Test and electrolytes], IDEXX CBC®, urinalysis) and 54,211 feline wellness profiles (a complete chemistry profile [including the IDEXX SDMA® Test and electrolytes], IDEXX CBC®, urinalysis, total T_4 [≥ 7 years of age]) associated with wellness visits; testing performed at IDEXX Reference Laboratories in North America on January 1, 2021–June 1, 2022. Data on file at IDEXX Laboratories, Inc. Westbrook, Maine USA: Study #014_Preventive-Care-Findings_220908090729.
2. Data based on analyses of 47,030 canine in-house profiles (a complete chemistry profile [including the IDEXX SDMA® Test and electrolytes], IDEXX CBC®, urinalysis) and 45,864 feline in-house profiles (a complete chemistry profile [including the IDEXX SDMA® Test and electrolytes], IDEXX CBC®, urinalysis, total T_4 [≥ 7 years of age]); testing performed at on IDEXX VetLab analyzers

WHEN to obtain electrolytes?

- Baseline in healthy patients
- Preanesthetic evaluation
- *Every* sick patient
- *Every* animal on fluids
- Monitoring

How often?

CKD w/ acute exacerbation



Stable on maintenance fluids

Blocked Tom

The big three

Sampling considerations

Electrolytes change **quickly** *in vitro*

Sensitive to **hemolysis**

Sample **quality** critical!

Do not sample from IV catheter after fluids

Do not use EDTA plasma

Do not freeze

Sources:

1. Wenneke, Gitte. " Useful tips to avoid preanalytical errors in blood gas testing: electrolytes" Oct 2003. Accessed 20 Jul 2021 https://acutecaretesting.org/en/articles/useful-tips-to-avoid-preanalytical-errors-in-blood-gas-testing-electrolytes
2. Baruah A, Goyal P, Sinha S, Ramesh KL, Datta R. Delay in specimen processing-major source of preanalytical variation in serum electrolytes. *J Clin Diagn Res*. 2014;8(12):CC01-CC3. doi:10.7860/JCDR/2014/10150.5285

Meet Whitney

- 2-year-old, FS, Labrador
- Vomiting and collapse
- History
  - Waxing and waning history of lethargy
  - Polyphagic
  - Polydipsic

Physical exam

QUIET, ALERT, RESPONSIVE

10%+ DEHYDRATED

T – 100.4^{O}F, P – 84 BPM, R – 16 BPM

Chemistry

TEST	RESULT	REFERENCE VALUE	
Glucose	112	74 - 143 mg/dL	
Creatinine	1.1	0.5 - 1.8 mg/dL	
BUN	25	7 - 27 mg/dL	
BUN: Creatinine Ratio	22		
Phosphorus	5.0	2.5 - 6.8 mg/dL	
Calcium	10.0	7.9 - 12.0 mg/dL	
Sodium	**133**	**144 - 160 mmol/L**	L
Potassium	**5.9**	**3.5 - 5.8 mmol/L**	H
Na: K Ratio	22		
Chloride	**97**	**109 - 122 mmol/L**	L
Total Protein	8.0	5.2 - 8.2 g/dL	
Albumin	3.5	2.3 - 4.0 g/dL	
Globulin	4.5	2.5 - 4.5 g/dL	
Albumin: Globulin Ratio	0.8		
ALT	120	10 - 125 U/L	
ALP	149	23 - 212 U/L	
GGT	**21**	**0 - 11 U/L**	H
Bilirubin - Total	0.5	0.0 - 0.9 mg/dL	
Cholesterol	183	110 - 320 mg/dL	
Amylase	**338**	**500 - 1,500 U/L**	L
Lipase	591	200 - 1,800 U/L	
Osmolality	273	mmol/kg	

Electrolytes

Sodium	133	144 - 160 mmol/L	L
Potassium	5.9	3.5 - 5.8 mmol/L	H
Na: K Ratio	22		
Chloride	97	109 - 122 mmol/L	L

Hematology

TEST	RESULT	REFERENCE VALUE	
RBC	**9.44**	**5.65 - 8.87 M/µL**	H
Hematocrit	59.2	37.3 - 61.7 %	
Hemoglobin	**21.7**	**13.1 - 20.5 g/dL**	H
MCV	62.7	61.6 - 73.5 fL	
MCH	23.0	21.2 - 25.9 pg	
MCHC	36.7	32.0 - 37.9 g/dL	
RDW	19.2	13.6 - 21.7 %	
% Reticulocytes	0.3	%	
Reticulocytes	31.2	10.0 - 110.0 K/µL	
Reticulocyte Hemoglobin	**20.9**	**22.3 - 29.6 pg**	L
WBC	9.14	5.05 - 16.76 K/µL	
% Neutrophils	46.5	%	
% Lymphocytes	36.4	%	
% Monocytes	5.0	%	
% Eosinophils	11.4	%	
% Basophils	0.7	%	
Neutrophils	4.25	2.95 - 11.64 K/µL	
Lymphocytes	3.33	1.05 - 5.10 K/µL	
Monocytes	0.46	0.16 - 1.12 K/µL	
Eosinophils	1.04	0.06 - 1.23 K/µL	
Basophils	0.06	0.00 - 0.10 K/µL	
Platelets	* 228	148 - 484 K/µL	
PDW	- --.--	9.1 - 19.4 fL	
MPV	**15.8**	**8.7 - 13.2 fL**	H
Plateletcrit	0.36	0.14 - 0.46 %	

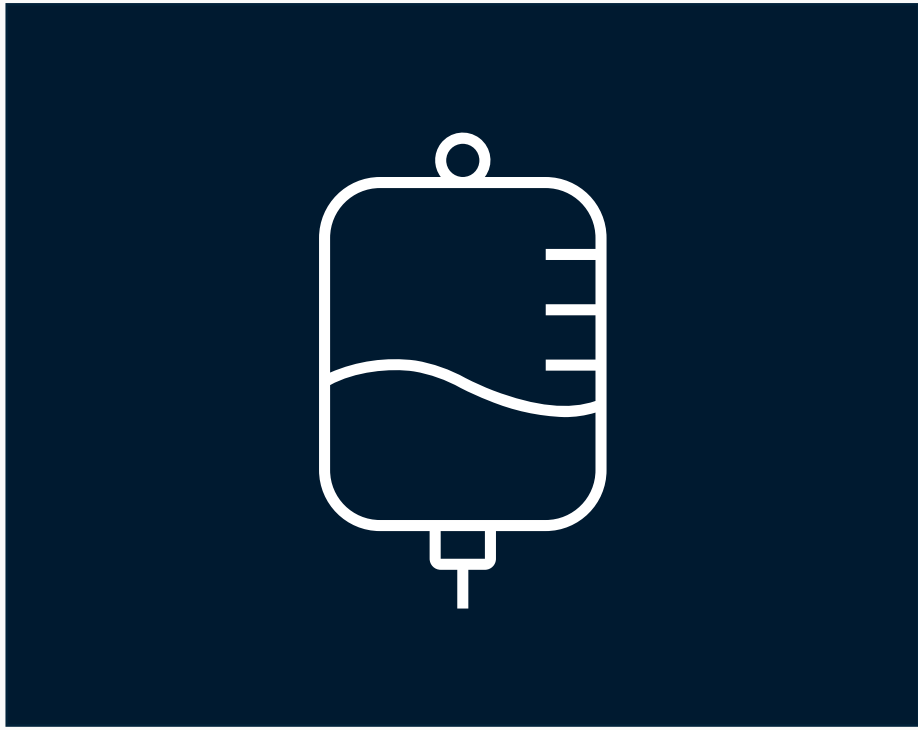
ACTH Stimulation Test

Endocrinology		3/5/24 3:15 AM	
Cortisol - Pre ACTH		<0.2	µg/dL
Cortisol - Post ACTH		<0.2	µg/dL
Cortisol - Post ACTH #2	a	<0.2	µg/dL

Addison's Disease

Treatment

- IV fluids
  - Replacement
  - Maintenance
- Corticosteroids
- Deoxycorticosterone pivalate (DOCP)



Addison's disease

The Great Pretender

- Decreased adrenal production:
  - Glucocorticoids (stress hormones)
  - +/- Mineralocorticoids (electrolytes)
- Low prevalence disease

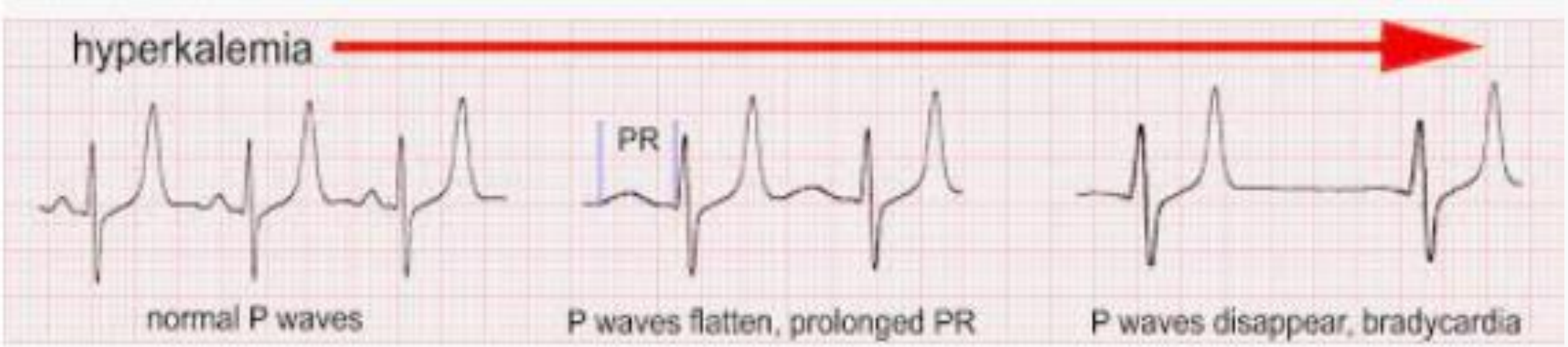
- Early: intermittent nonspecific signs
- Late: acute collapse, coma, death

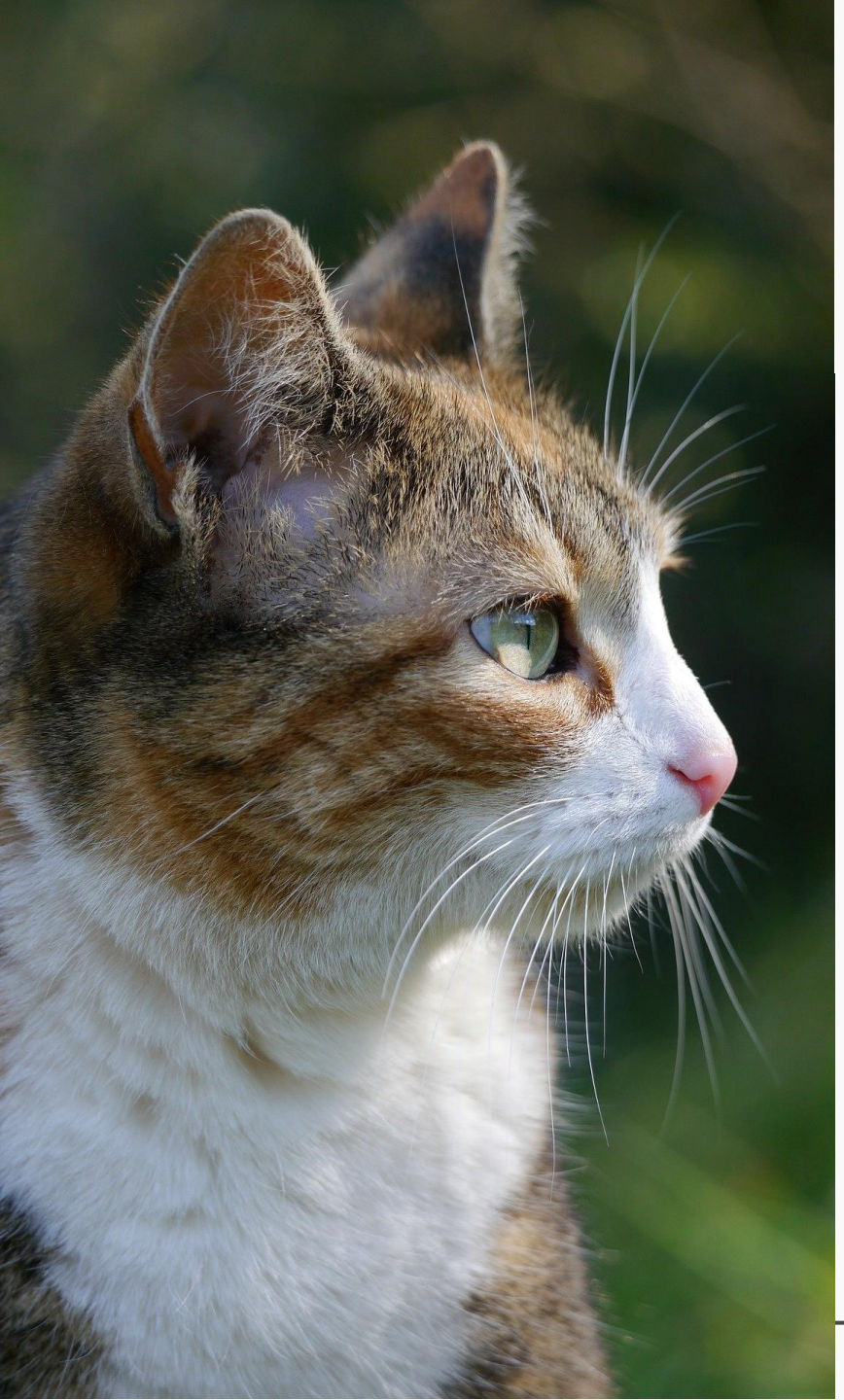
Challenge

- Commonly missed:
  - Addison's often not on differential list until in crisis
- Diagnosis and management of "atypical" Addison's
- Understanding of impact of prior medications

Why it Matters

- Prevention of months of recurring illness, repeat visits and testing for other diseases
- Stressful event can trigger potentially fatal crisis


hyperkalemia
PR
normal P waves
P waves flatten, prolonged PR
P waves disappear, bradycardia



Meet Manny

- 11-year-old, MN, DSH
- Vomiting and collapse
- History
  - Polyuric/polydipsic
  - Progressive weakness

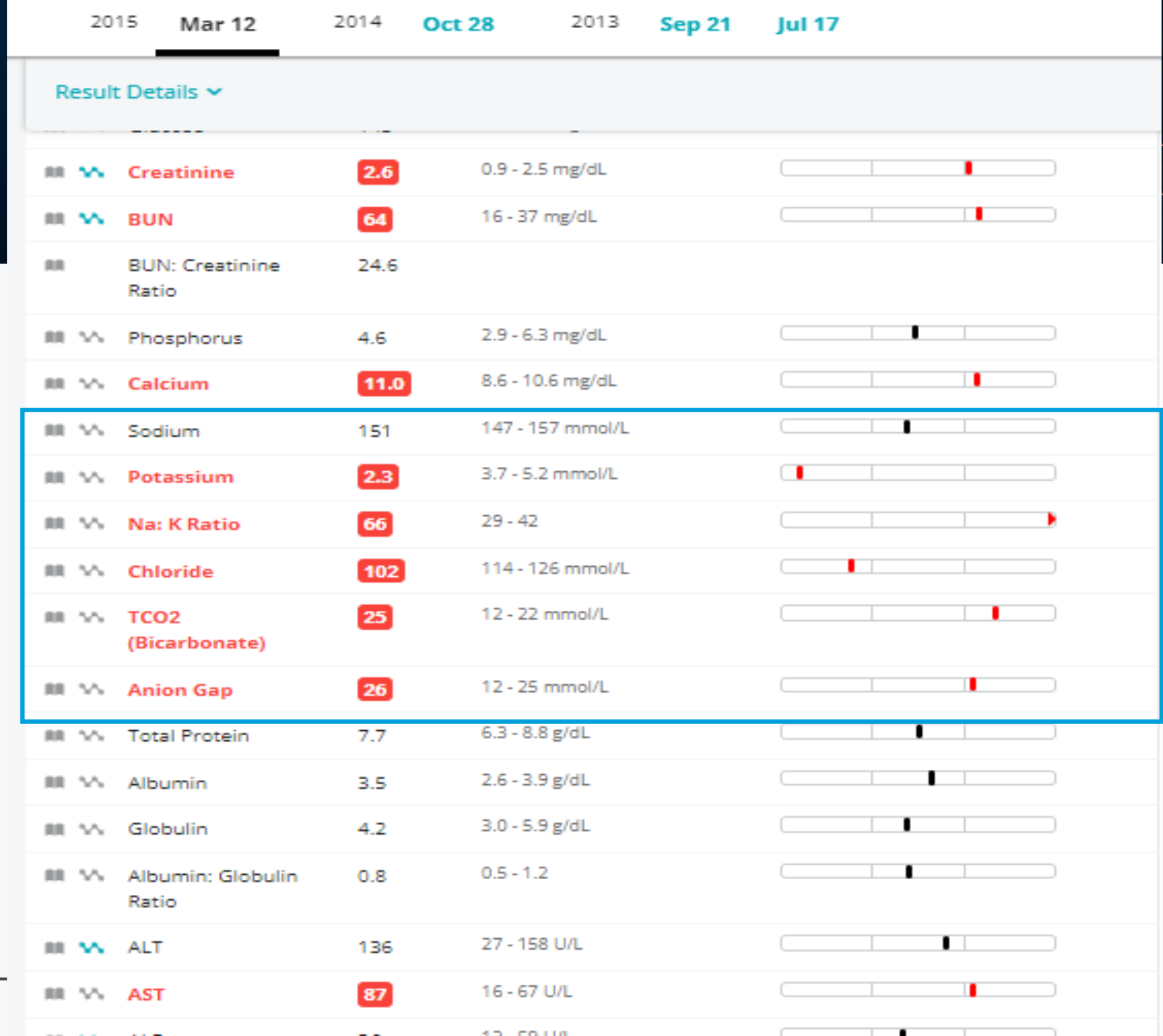
Physical exam

WEAK, HEAD AND NECK VENTROFLEXION

10%+ DEHYDRATED

T – 101.2^{O}F, P – 240 BPM, R – RAPID

Chemistry



2015 Mar 12 | 2014 Oct 28 | 2013 Sep 21 | Jul 17

Result Details

Creatinine	2.6	0.9 - 2.5 mg/dL	
BUN	64	16 - 37 mg/dL	
BUN: Creatinine Ratio	24.6		
Phosphorus	4.6	2.9 - 6.3 mg/dL	
Calcium	11.0	8.6 - 10.6 mg/dL	
Sodium	151	147 - 157 mmol/L	
Potassium	2.3	3.7 - 5.2 mmol/L	
Na: K Ratio	66	29 - 42	
Chloride	102	114 - 126 mmol/L	
TCO2 (Bicarbonate)	25	12 - 22 mmol/L	
Anion Gap	26	12 - 25 mmol/L	
Total Protein	7.7	6.3 - 8.8 g/dL	
Albumin	3.5	2.6 - 3.9 g/dL	
Globulin	4.2	3.0 - 5.9 g/dL	
Albumin: Globulin Ratio	0.8	0.5 - 1.2	
ALT	136	27 - 158 U/L	
AST	87	16 - 67 U/L	

Electrolytes

Sodium	151	147 - 157 mmol/L		152	153	155
Potassium	2.3	3.7 - 5.2 mmol/L		3.2	3.1	3.2
Na: K Ratio	66	29 - 42		48	49	48
Chloride	102	114 - 126 mmol/L		109	114	119
TCO2 (Bicarbonate)	25	12 - 22 mmol/L		23	18	19

Aldosterone Concentration

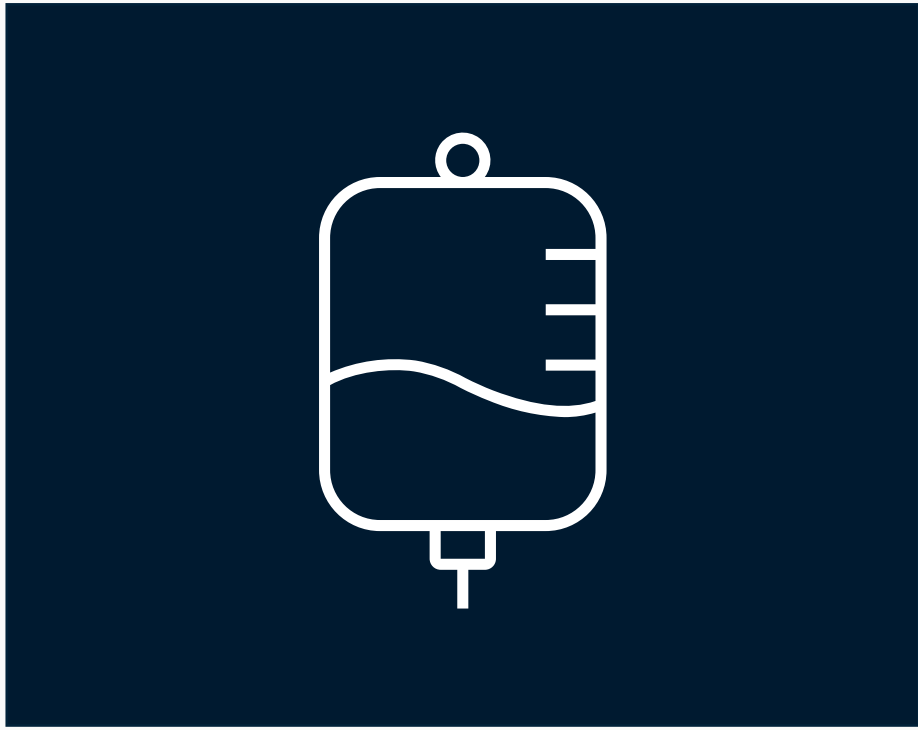
Aldosterone	a. >5,215	pmol/L	

a. Reference Ranges:		Canine	Feline	
	Pre:	14-957	194-388	pmol/L
	Post:	197-2103	277-721	pmol/L

Feline Primary Hyperaldosteronism

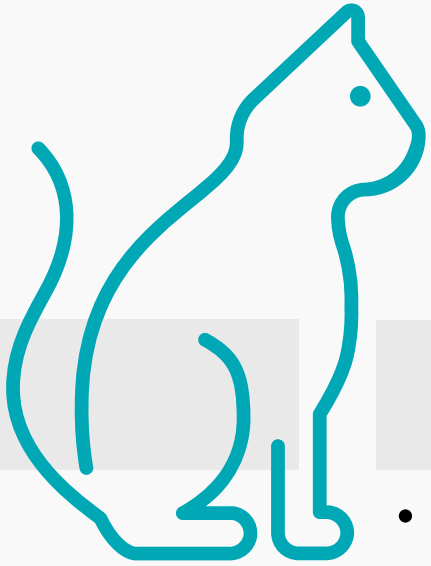
Treatment

- IV fluids
  - Replacement
  - Maintenance
- Manage complications
- Surgical Management
- Medical Management



Primary Hyperaldosteronism

- Increased adrenal production:
  - Aldosterone
- More common than you would think



- Classic clinical signs: ventroflexion, visual impairment, plantigrade stance
- Common diagnostic abnormalities

Challenge

- Commonly missed:
  - Looks like many other feline diseases
- Consider in cats with unexplained hypokalemia and/or hypertension

Why it Matters

- Can have fair to good prognosis with treatment

Meet Luna

- 9-week-old, FI Chihuahua

- History
  - Picked up from breeder 4 days ago
  - Vomiting
  - Not eating well for 3 days
  - Lethargic

Physical exam

DULL, ALERT, RESPONSIVE

10% DEHYDRATED

TPR - NORMAL

Hematology

Hematology

1/30/24 **7:45 PM**

TEST	RESULT	REFERENCE VALUE	
RBC	6.39	5.65 – 8.87 M/µL	
Hematocrit	40.6	37.3 – 61.7 %	
Hemoglobin	13.6	13.1 – 20.5 g/dL	
MCV	63.5	61.6 – 73.5 fL	
MCH	21.3	21.2 – 25.9 pg	
MCHC	33.5	32.0 – 37.9 g/dL	
RDW	18.0	13.6 – 21.7 %	
% Reticulocytes	1.2	%	
Reticulocytes	75.4	10.0 – 110.0 K/µL	
Reticulocyte Hemoglobin	24.2	22.3 – 29.6 pg	
WBC	10.73	5.05 – 16.76 K/µL	
% Neutrophils	*70.0	%	
% Lymphocytes	14.2	%	
% Monocytes	7.1	%	
% Eosinophils	*8.5	%	
% Basophils	0.2	%	
Neutrophils	*7.52	2.95 – 11.64 K/µL	
Lymphocytes	1.52	1.05 – 5.10 K/µL	
Monocytes	0.76	0.16 – 1.12 K/µL	
Eosinophils	*0.91	0.06 – 1.23 K/µL	
Basophils	0.02	0.00 – 0.10 K/µL	
Platelets	467	148 - 484 K/µL	
PDW	14.7	9.1 – 19.4 fL	
MPV	13.0	8.7 – 13.2 fL	
Plateletcrit	**0.61**	**0.14 – 0.46 %**	H

Chemistry

Chemistry

1/30/24 **7:54 PM**

TEST	RESULT	REFERENCE VALUE	
Glucose	**418**	**77 - 150 mg/dL**	H
Creatinine	0.6	0.3 – 1.2 mg/dL	
BUN	**69**	**7 - 29 mg/dL**	H
BUN: Creatinine Ratio	116		
Phosphorus	6.6	5.1 – 10.4 mg/dL	
Calcium	8.0	7.8 – 12.6 mg/dL	
Sodium	157	144 - 160 mmol/L	
Potassium	4.6	3.5 - 5.8 mmol/L	
Chloride	**108**	109 - 122 mmol/L	
Total Protein	5.7	4.8 – 7.2 g/dL	
Albumin	**3.9**	**2.1 - 3.6 g/dL**	H
Globulin	**1.9**	**2.3 - 3.8 g/dL**	L
ALT	62	8 – 75 U/L	
ALP	167	46 – 337 U/L	

Electrolytes

Sodium	157	144 - 160 mmol/L
Potassium	4,6	3,5 - 5,8 mmol/L
Chloride	**108**	109 - 122 mmol/L

Urinalysis

Urinalysis

1/30/24 **10:27 PM**

TEST	RESULT	REFERENCE VALUE
Collection	Table top	
Color	Pale Yellow	
Clarity	Very Cloudy	
Specific Gravity	1,038	
pH	6.0	
Urine Protein	TR	
Glucose	**1,000**	**mg/dL**
Ketones	**15**	**mg/dL**
Blood / Hemoglobin	**250**	**Ery/µL**
Bilirubin	neg	
Urobilinogen	norm	
Leukocyte Esterase	neg	

What does it mean if sodium and chloride are <u>not</u> moving **together**?

Sodium	157	144 - 160 mmol/L
Potassium	4,6	3,5 - 5,8 mmol/L
Chloride	**108**	109 - 122 mmol/L

Sodium	**167**	150 - 165 mmol/L
Potassium	4,1	3,5 - 5,8 mmol/L
Chloride	122	112 - 129 mmol/L

Sodium	152	144 - 160 mmol/L
Potassium	3,9	3,5 - 5,8 mmol/L
Na: K Ratio	39	
Chloride	121	109 - 122 mmol/L

Chloride concentration is affected by acid-base disturbances, *but sodium concentration is <u>not</u> affected by acid-base status*

Hypochloremia: due to hydration or acid-base abnormality?

- Na 144-119 = 25 below normal
- Cl 109-69 = 40 below normal

- Hypochloremic metabolic alkalosis

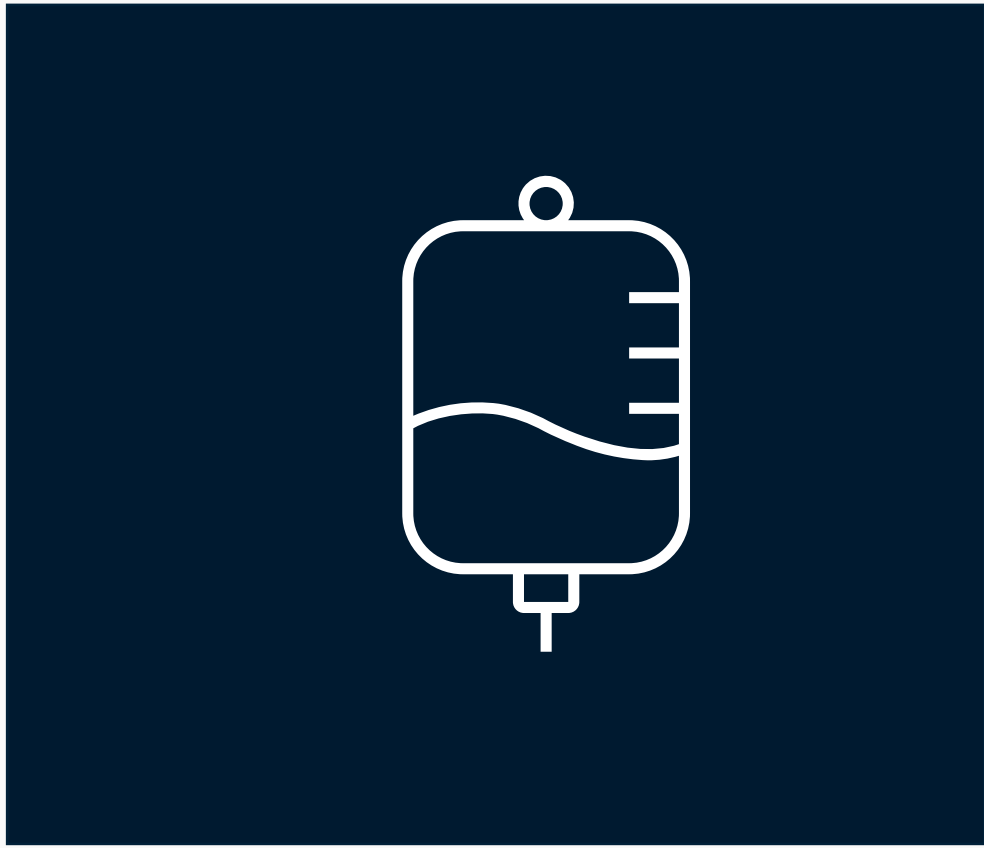
pH	7.5 ↑	
HCO_3	31 ↓	
pCO_2	39	
Na	119 mmol/L	(144 – 160)
K	2.7 mmol/L	(3.5 – 5.8)
Cl	69 mmol/L	(109 – 122)
AG	22	(12 – 24)

- Don’t miss this in vomiting patients… what does it indicate?

GI Obstruction??

Treatment

- **IV fluids**
  - Replacement
  - Maintenance
- **Underlying illness**
- **TLC**



GI Obstruction

- More common than you would think
- Doesn't have to be a foreign body

- Hypochloremia may be your only abnormality on chemistry panel

Challenge

- Commonly missed:
  - Radio-opaque FB
  - Partial obstruction
  - Mass effect – tumor, granuloma

Why it Matters

- Prognosis depends on cause but very good in young animals with foreign body
- Can potentially be fatal

Meet Zephyr

- 14-year-old, male neutered poodle

- History
  - 2 Lbs. weight loss over last 6 months
  - PU/PD
  - Polyphagic

Physical exam

QUIET, ALERT, RESPONSIVE

10% DEHYDRATED

TPR - NORMAL

Hematology

Hematology

3/26/24 (Order Received)
3/27/24 5:12 AM (Last Updated)

TEST		RESULT	REFERENCE VALUE	
RBC		5.51	5.39 - 8.70 M/µL	
Hematocrit		39.2	38.3 - 56.5 %	
Hemoglobin		**12.7**	**13.4 - 20.7 g/dL**	L
MCV		71	59 - 76 fL	
MCH		23.0	21.9 - 26.1 pg	
MCHC		**32.4**	**32.6 - 39.2 g/dL**	L
% Reticulocytes		1.1	%	
Reticulocytes		61	10 - 110 K/µL	
Reticulocyte Hemoglobin		25.4	24.5 - 31.8 pg	
WBC		10.1	4.9 - 17.6 K/µL	
% Neutrophils		64.4	%	
% Lymphocytes		19.4	%	
% Monocytes		12.5	%	
% Eosinophils		3.6	%	
% Basophils		0.1	%	
Neutrophils		6.504	2.94 - 12.67 K/µL	
Lymphocytes		1.959	1.06 - 4.95 K/µL	
Monocytes		**1.263**	**0.13 - 1.15 K/µL**	H
Eosinophils		0.364	0.07 - 1.49 K/µL	
Basophils	[a]	0.01	0 - 0.1 K/µL	
Platelets		**712**	**143 - 448 K/µL**	H

[a] AUTOMATED CBC

Chemistry

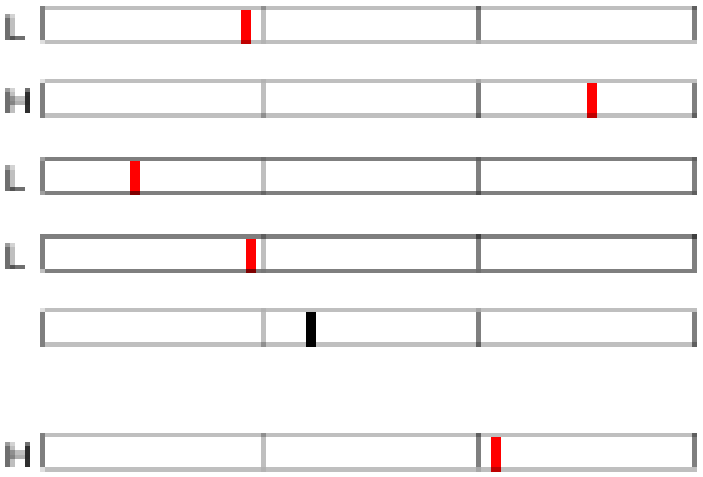
Chemistry

3/26/24 (Order Received)
3/27/24 5:12 AM (Last Updated)

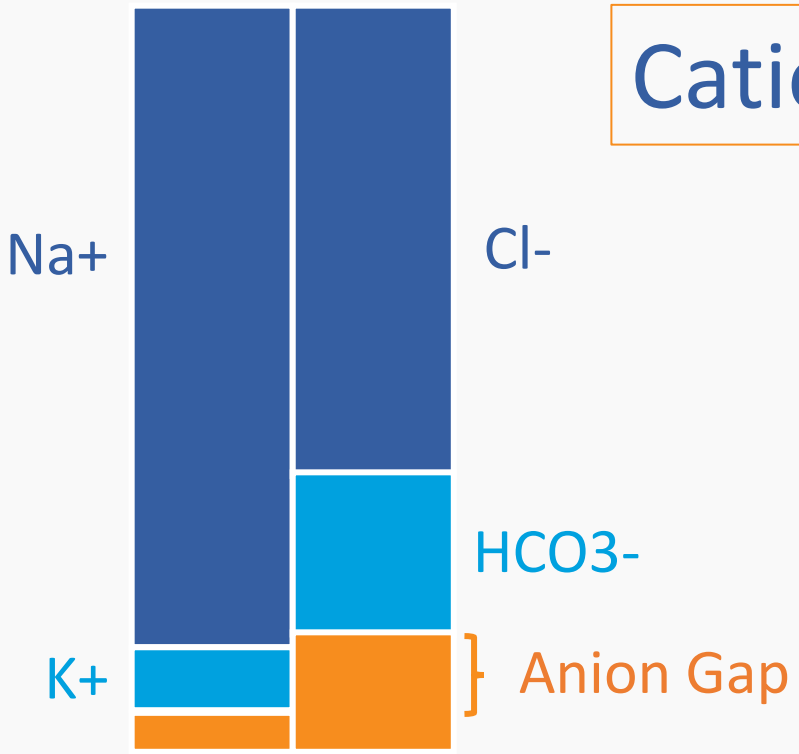
TEST		RESULT	REFERENCE VALUE	
Glucose	a	**484**	**63 - 114 mg/dL**	H
IDEXX SDMA	b	10	0 - 14 µg/dL	
Creatinine		0.8	0.5 - 1.5 mg/dL	
BUN		26	9 - 31 mg/dL	
BUN: Creatinine Ratio		32.5		
Phosphorus		5.1	2.5 - 6.1 mg/dL	
Calcium		8.6	8.4 - 11.8 mg/dL	
Sodium		**140**	**142 - 152 mmol/L**	L
Potassium		**6.5**	**4.0 - 5.4 mmol/L**	H
Na: K Ratio		**22**	**28 - 37**	L
Chloride		**104**	**108 - 119 mmol/L**	L
TCO2 (Bicarbonate)		16	13 - 27 mmol/L	
Anion Gap		**27**	**11 - 26 mmol/L**	H
Total Protein		6.0	5.5 - 7.5 g/dL	
Albumin		3.2	2.7 - 3.9 g/dL	
Globulin		2.8	2.4 - 4.0 g/dL	
Albumin: Globulin Ratio		1.1	0.7 - 1.5	
ALT		**187**	**18 - 121 U/L**	H
AST		**62**	**16 - 55 U/L**	H
ALP		**678**	**5 - 160 U/L**	H
GGT		9	0 - 13 U/L	
Bilirubin - Total		0.1	0.0 - 0.3 mg/dL	

Electrolytes

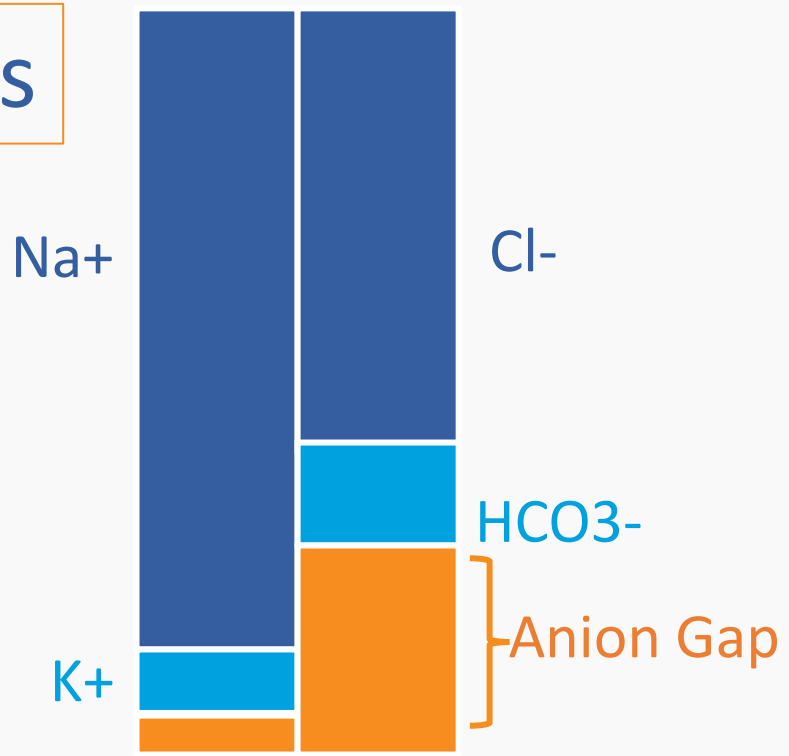
Sodium	140	142 - 152 mmol/L	L
Potassium	6.5	4.0 - 5.4 mmol/L	H
Na: K Ratio	22	28 - 37	L
Chloride	104	108 - 119 mmol/L	L
TCO2 (Bicarbonate)	16	13 - 27 mmol/L	
Anion Gap	27	11 - 26 mmol/L	H



Anion Gap



Cations = Anions



DiBartola, Stephan. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier, 2006.

Urinalysis

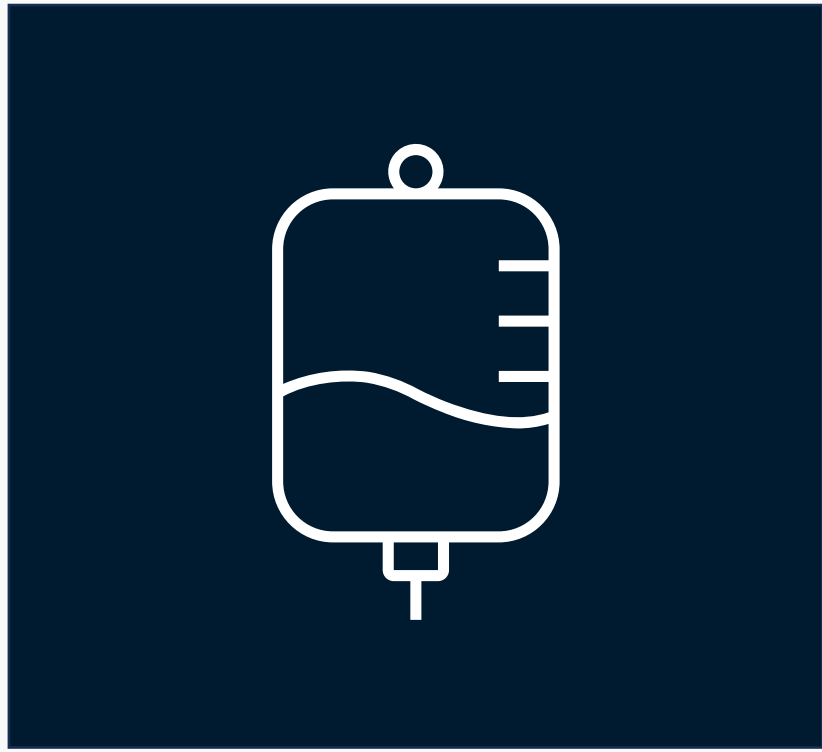
Urinalysis

3/26/24 (Order Received)
3/27/24 5:12 AM (Last Updated)

TEST	RESULT	REFERENCE VALUE	
Collection	CATHETERIZED		
Color	Yellow		
Clarity	CLOUDY		
Specific Gravity	1.044	>= 1.030	
pH	5.5	6.0 - 7.5	L
Urine Protein	1+		
Glucose [a]	3+ (1000 mg/dL)		
Ketones [b]	3+		
Blood / Hemoglobin	NEGATIVE		
Bilirubin	NEGATIVE		
Urobilinogen	NORMAL		
White Blood Cells	0-2	HPF	
Red Blood Cells	0-2	HPF	
Bacteria	NONE SEEN		

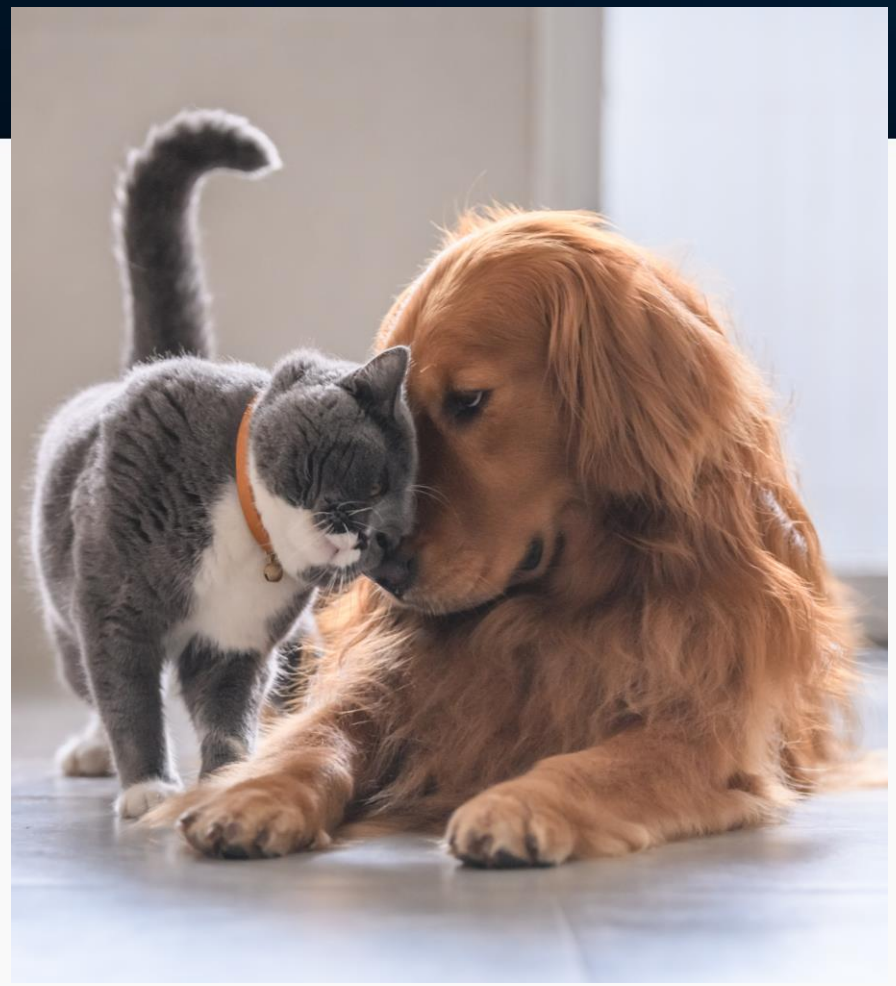
Treatment

- IV fluids
  - Replacement
  - Maintenance
- Insulin
- Underlying illness



Key takeaways

- Electrolytes are important!
- Include electrolytes on biochemical profiles
- Essential in critical patients and patients on fluid therapy
- Serial assessment important to detect new problems and monitor treatment



Questions

Hyperkalemia

- Urinary tract obstruction/rupture
- Acute kidney injury / oliguric renal failure
- Addison's disease (hypoadrenocorticism)
- Body cavity effusion
- Whipworms, *Salmonella*
- Acute tumor lysis syndrome
- Reperfusion after aortic thromboembolism
- Pseudohyperkalemia
  - Thrombocytosis
  - Japanese breeds
  - EDTA contamination

Source: Stephen DiBartola. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier; 2006.

Hypokalemia

- Administration of potassium-free fluids
- Alkalemia
- Vomiting/diarrhea
- Renal disease
- Primary hyperaldosteronism
- Diuretics

Source: Stephen DiBartola. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier; 2006.

Hypernatremia

- Pure water deficit
  - Primary hypodipsia
  - Diabetes insipidus
  - Fever/increased environmental temperature
  - Decreased access to water
- Hypotonic fluid loss
  - Gastrointestinal
  - Third-space loss
  - Cutaneous loss
  - Renal/urinary disease
- Solute gain
  - Salt poisoning
  - Hypertonic fluid administration
  - Hyperaldosteronism
  - Hyperadrenocorticism

Source: Stephen DiBartola. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier; 2006.

Hyponatremia

- Low Plasma Osmolality
  - Congestive heart failure
  - Severe liver disease
  - Nephrotic syndrome
  - Psychogenic polydipsia
  - Renal disease
  - Addison's disease
  - Vomiting and diarrhea
  - Excess diuretic

- High Plasma Osmolality
  - Hyperglycemia
  - Mannitol administration

- Normal osmolality
  - Marked lipemia
  - Possibly marked hyperproteinemia

Source: Stephen DiBartola. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier; 2006.

Hyperchloremia

- Diarrhea
- Salt poisoning
- Renal disease
- Chronic respiratory alkalosis
- Artifact – Lipemia, bromide therapy

Source: Stephen DiBartola. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier; 2006.

Hypochloremia

- Vomiting gastric (upper GI) contents
- Diuretics
- Chronic respiratory acidosis
- Hypoadrenocorticism
- Artifact - lipemia

Source: Stephen DiBartola. *Fluid, Electrolyte and Acid-Base Disorders in Small Animal Practice*. 3rd ed. Saunders Elsevier; 2006.