Lytes, camera, action!
Management of Common Electrolyte Emergencies

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Introduction

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Introduction

Marie Holowaychuk, DVM, DACVECC
www.criticalcarevet.ca
Electrolyte Disturbances
- Occur commonly in the ER
- Can cause profound clinical signs
  - Heart
  - Skeletal muscle
  - GI tract
  - Nervous system
- Require immediate intervention if life-threatening
- Inappropriate management can lead to severe consequences

Measurement of Electrolytes
- In-house electrolyte monitoring is essential in emergency practice
- Bench-top chemistry analyzers
  - IDEXX®
  - VetScan®
- Hand-held devices
  - iSTAT®

Common in Certain Disorders
Endocrine Disease
- Diabetic ketoacidosis
- Addison’s Disease
### Common in Certain Disorders

<table>
<thead>
<tr>
<th>Urinary Tract Disease</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute kidney failure</td>
<td>Uroabdomen</td>
</tr>
</tbody>
</table>

### Common in Certain Disorders

<table>
<thead>
<tr>
<th>Gastrointestinal Disease</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GI foreign body</td>
<td>HGE</td>
</tr>
</tbody>
</table>

### Life-Threatening

- Potassium
- Sodium
- Calcium
Other

• Chloride
• Phosphorus
• Magnesium

“Sammie”
8 yr. old MN Siamese
Straining to urinate

• Temp = 97.2°F (36.2°C)
• HR = 120 bpm
• RR = 40 breaths/min
• BP = 80 mmHg (Doppler)

• Na = 145 mmol/L
• K = 8.4 mmol/L
• Cl = 115 mmol/L
• iCa = 1.03 mmol/L

Conditions Associated With Hyperkalemia

• Oliguric/anuric kidney failure
• Urinary tract obstruction
• Urinary tract rupture
• Hypoadrenocorticism
• Over-supplementation of potassium chloride
• Marked metabolic acidosis
• Drugs (e.g., ACE-inhibitors)
Retrospective study of 223 male cats with UO
• 12% of cats had severe hyperkalemia (> 8.0 mmol/L)
  • 79% of those cats had a pH < 7.2
• K inversely correlated with pH and HCO₃ and positively correlated with BUN and creatinine
• Most of the time, hyperkalemia did not occur in isolation (always with other metabolic derangements)

Hyperkalemia
Clinical Consequences
• Cardiac arrhythmias
• Bradycardia
• Muscle weakness
• Paralysis
• Paresthesia

Hyperkalemia – ECG Changes
• Sometimes none – depends on other concurrent abnormalities (Ca++, Mg++, Na+, acidosis)
• Progressive bradycardia
• Increased T-wave amplitude (narrow/spiked)
• Progressive decreased amplitude R-wave
• Progressive decreased amplitude P-wave
• Disappearance of the P-wave (atrial standstill)
• Ventricular fibrillation or asystole
Historical and physical parameters as predictors of severe hyperkalemia in male cats with urethral obstruction

**Historical Parameters**
- First time obstruction
- Outdoor status
- Anorexia
- Vomiting

**Physical Parameters**
- Rectal temp < 95-96.6°F (35-35.9°C)
- Heart rate < 120 bpm
- Low respiratory rate
- Weak pulses
- Presence of arrhythmia

Concurrent hypothermia and bradycardia predict hyperkalemia 98-100% of the time!

---

**“Sammie”**
8 yr. old MN Siamese
Urethral Obstruction

**Emergency Treatments:**
- Re-warming
- IV catheter placement
- LRS 15 mL/kg IV bolus over 15 minutes
- Analgesia: buprenorphine 0.02 mg/kg IV

---

The influence of crystalloid type on acid–base and electrolyte status of cats with urethral obstruction

- Randomized prospective clinical trial
- 68 male cats with UO: Normosol-R (39 cats) vs. 0.9% NaCl (29 cats)
- Faster increase in HCO₃ and pH in Norm-R cats
- Higher increase in CI in 0.9% NaCl cats
- No difference in rate of decline of potassium
- Use of balanced isotonic crystalloids enables faster normalization of blood gas values and does not slow normalization of potassium
“Sammie”
8 yr. old MN Siamese
Urethral Obstruction

Other Tests:
- ECG
- VBG
- Kidney profile
  (creatinine, BUN)

- BG = 504 mg/dL (28 mmol/L)
- pH = 6.972
- PCO₂ = 34.8 mmHg
- HCO₃ = 7.6 mmol/L
- Lactate = 5.5 mmol/L
- Azostick = 50-80 mg/dL

Observational clinical study
- 15 dogs and 22 cats with K⁺ > 5.5 mmol/L
- 59% of ECG tracings were normal
- K⁺ and HR were poorly or weakly correlated
- Majority of ECG tracings are normal in hyperkalemic patients
- Severity of hyperkalemia does not predict abnormalities/arrhythmias
Reliability of using reagent test strips to estimate blood urea nitrogen concentration in dogs and cats

- Prospective clinical study
- 116 dogs and 58 cats
- Compared Azostick® BUN with laboratory value for detecting azotemia
- Semi-quantitative: 5-15, 15-26, 30-40, 50-80 mg/dL
- Dogs: 95% sensitive and 99% specific (≥ 30-40)
- Cats: 87% sensitive and 100% specific (≥ 50-80)
- Cats with Azostick® ≤ 15-26 are unlikely to be azotemic

Hyperkalemia Emergency Management

- Treat the underlying cause
- Calcium gluconate
  0.5 mL/kg IV slowly
  (cardioprotective)
- Sodium bicarbonate
  1 mL/kg IV bolus
  (avoid giving with calcium gluconate)
- 50% dextrose 1 mL/kg IV bolus (diluted 1:4)
- Regular insulin 0.5 U/kg IV (with 4 mL 50% dextrose per U insulin)

“Sammie”
8 yr. old MN Siamese
Urethral Obstruction

- Calcium gluconate
  0.5 mL/kg IV slowly
- 50% dextrose 1 mL/kg IV bolus diluted 1:4 in LRS
- NaHCO₃ 1 mL/kg IV
- Sedation (ketamine/valem) and urethral unblocking procedure
“Sammie”
8 yr. old MN Siamese
Urethral Obstruction

Outcome:
• K < 5.5 mmol/L within 2 hours
• Normalization of azotemia within 24 hours
• Indwelling urinary catheter for 48 hours
• Discharged after 72 hours in the hospital

“Callie”
3 yr. old FS Shepherd X
Acute collapse

- Temp = 98.9°F (37.2°C)
- HR = 120 bpm
- RR = 40 breaths/min
- BP = 98/66 (74) mmHg (Cardell)
- Na = 136 mmol/L
- K = 8.2 mmol/L
- Cl = 104 mmol/L
- iCa = 1.43 mmol/L
- BG = 42 mg/dL (2.3 mmol/L)

“Callie”
3 yr. old FS Shepherd X
Acute collapse

Emergency Treatments:
• External warming
• PLA 20 mL/kg IV fluid bolus over 15 min (repeated until resolution of shock)
• Calcium gluconate 1 mL/kg IV slow
• 50% dextrose 1 mL/kg IV (diluted 1:4 in PLA)
So if it’s the “great pretender”, how do we diagnose hypoadrenocorticism?

• History
• PE findings
• Labwork including electrolytes (+/- Na:K ratio)
• Adrenal testing
• +/- Abdominal ultrasound

Hypoadrenocorticism
Presenting Signs

History
• Variable!
• Not always acute
• Waxing and waning…
• Weight loss
• Inappetence
• Vomiting
• Diarrhea
• Lethargy
• Weakness
• Collapse

Clinical Signs
• Hypovolemia
• Weak pulses
• Prolonged CRT
• Hypotension
• Dehydration
• (Relative) bradycardia
• Hypothermia
• Poor body condition
• Abdominal pain
• Melena

Hypoadrenocorticism – Labwork

<table>
<thead>
<tr>
<th>Lab Abnormality</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperkalemia</td>
<td>92%</td>
</tr>
<tr>
<td>Sodium:potassium ratio &lt; 27</td>
<td>75-90%</td>
</tr>
<tr>
<td>Increased BUN</td>
<td>90%</td>
</tr>
<tr>
<td>USG &lt; 1.030</td>
<td>88%</td>
</tr>
<tr>
<td>Hyponatremia</td>
<td>84%</td>
</tr>
<tr>
<td>Increased creatinine</td>
<td>61%</td>
</tr>
<tr>
<td>Anemia</td>
<td>34%</td>
</tr>
<tr>
<td>Hypercalcemia</td>
<td>29%</td>
</tr>
<tr>
<td>Hypoglycemia</td>
<td>23%</td>
</tr>
<tr>
<td>Hypoproteinemia</td>
<td>14%</td>
</tr>
<tr>
<td>Lymphocytosis (absolute)</td>
<td>13%</td>
</tr>
<tr>
<td>Eosinophilia (absolute)</td>
<td>10%</td>
</tr>
</tbody>
</table>
Pseudo-Addison’s Disease

- Acute kidney injury
- Kidney disease/failure
- Urinary obstruction
- Uroabdomen
- Trichuris infection
- Gastrointestinal disease
- Third spacing of fluid

Retrospective case-control study
- 53 dogs with confirmed HA and 100 sick dogs without HA

Combining lymphocyte count and Na:K ratio is better than either variable alone to screen for HA

Basal cortisol vs. ACTH stimulation test…the great debate!

- “Gold standard”: post-ACTH cortisol < 2 µg/dL diagnoses HA
- Cost of synthetic ACTH has increased dramatically in the USA over the last decade ($60-100 per vial)
- ACTH availability has also sporadically become an issue
- JAVMA 2007 study suggested using basal cortisol ≥ 2 µg/dL (≥ 55 nmol/L) as a cut-off to rule out HA in dogs with a suspicion of Addison’s
• Retrospective case-control study
• 450 dogs with non-adrenal illness
• 14 dogs with hypoadrenocorticism

• Investigate the accuracy of basal cortisol cut-offs 1 µg/dL (28 nmol/L) and 2 µg/dL (55 nmol/L) to diagnose Addison’s disease

Basal cortisol > 2 µg/dL (> 55 nmol/L) rules out HA, but dogs with < 2 µg/dL (< 55 nmol/L) basal cortisol must have an ACTH stim performed!

Other tidbits about ACTH stim tests...
• Prednisone, prednisolone, or hydrocortisone will cross-react with cortisol assays
• Cosyntropin (liquid) [IV only] is equivalent to Cortrosyn (lyophilized powder) [IM or IV]
• Low-dose ACTH stim tests (5 µg/kg IV) are accurate to diagnose HA
• ACTH can be stored in plastic syringes and frozen (-20°C) for up to 6 months to conserve costs
Use of the Cortisol-to-ACTH Ratio for Diagnosis of Primary Hypoadrenocorticism in Dogs
P. Luthin, J.C. Scott-Moncrieff, and R.W. Wilh

- Retrospective case-control study
- Ratio of basal cortisol to endogenous ACTH is superior to either test alone for diagnosing HA
- **Advantages:** single blood draw and lower cost (no ACTH stim required)
- **Disadvantages:** shipment to outside lab and finicky sample handling (EDTA immediately spun/frozen for shipment)

Prospective observational study
- 30 dogs with confirmed HA and 14 healthy dogs without HA
- **BW correlated with adrenal glad length not thickness**
- **Left adrenal gland thickness < 2.8 mm** was 90% sensitive and 100% specific for diagnosing HA

**“Callie”**
3 yr. old FS Shepherd X
Acute collapse

**Diagnostic Tests:**
- Basal cortisol < 28 nmol/L (< 1µg/dL)

**Added treatments:**
- Dexamethasone 0.1 mg/kg IV
- DOCP 2.2 mg/kg IM

**Outcome:**
- Discharged 36 hours later
Mineralocorticoid Supplementation

**Florinef®**
- 0.01-0.02 mg/kg PO q 12 h
- 0.025-0.1 mg incremental changes in dose as needed
- Can require giving a lot of pills!
- Less need for glucocorticoids?
- More expensive?
- Less convenient

**Percorten-V®**
- 2.2 mg/kg IM/SQ initial dose
- 1.65-2.2 mg/kg every 21-30 days thereafter
- Decrease dose 5-10% if adequate electrolytes
- Better suppression of renin
- More cost efficient at lower doses
- More convenient

Retrospective study
- 49 dogs with primary HA receiving DOCP
- Initial doses ranging from 0.4-3.8 mg/kg
- 40% of dogs had doses < 1 mg/kg
- All dogs had adequate control of electrolytes with no adverse clinical signs noted
- Suggests that label doses might exceed what is needed clinically to manage HA in dogs

The “great pretender”...

**Classic**
- Glucocorticoid and mineralocorticoid deficient
- Young dogs (< 5 years)
- Acute GI signs or shock/collapse
- Electrolyte disturbances

**Atypical**
- Glucocorticoid deficient
- Older at diagnosis
- Chronic signs
- Waxing and waning
- Chronic diarrhea and/or weight loss
- No electrolyte disturbances
- Hypoproteinemia, anemia, low cholesterol
- More common
“Happy”
10 yr. old MN Westie
Diabetic ketoacidosis

- Temp = 101.3°F (38.5°C)
- HR = 120 bpm
- RR = 36 breaths/min
- BP = 130 mmHg (Doppler)
- Na = 148 mmol/L
- K = 2.8 mmol/L
- Cl = 108 mmol/L
- iCa = 1.11 mmol/L

Conditions Associated With Hypokalemia

- Excessive administration of fluids not supplemented with K
- Polyuria
- Severe vomiting or diarrhea
- Insulin administration
- Loop diuretic administration
- Hyperaldosteronism (Conn’s syndrome)

Hypokalemia Clinical Consequences

- Muscle weakness
  - Ventral neck flexion (cats)
- Ventricular arrhythmias
- Paralysis
- Paresthesia
- Lethargy
- Dilute urine
- Decreased GI motility
Hyperaldosteronism (Conn’s Syndrome)

Adrenal Mass
- Usually benign unilateral mass
- Mean age = 10 years (range = 6-13 yrs old)
- Most common sign = hypokalemic myopathy
- Hypertension less common
- HypoK >> hyperNa
- Tx = K suppl, amlodipine, spironolactone, adrenalectomy

Adrenal Hyperplasia
- Tend to be older cats
- Age range = 11-18 years
- Most common signs = hypertension, blindness, kidney failure
- Tx = K suppl, amlodipine, spironolactone, +/- beta blockers
- Most succumb to progressive CKD

Worry about the “K” with DKA?


- Retrospective study evaluating 127 dogs with DKA
- 45% are hypokalemic at presentation
- 84% develop hypokalemia during hospitalization
- Median 3.1 mmol/L (range = 2.0-3.6 mmol/L)
- Hypokalemia associated with longer time to initiation of SQ insulin protocol

Calculating KCI Supplementation

- Quick calculation

<table>
<thead>
<tr>
<th>Serum Potassium (mmol/L)</th>
<th>KCI Added to Fluid Bag (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0-5.5</td>
<td>20</td>
</tr>
<tr>
<td>3.5-3.9</td>
<td>40</td>
</tr>
<tr>
<td>3.0-3.4</td>
<td>60</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>80</td>
</tr>
</tbody>
</table>
Calculating KCl Supplementation

- Calculating based on mEq/kg/hr is more accurate

<table>
<thead>
<tr>
<th>Serum Potassium</th>
<th>KCl calculation (mEq/kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.05-0.1</td>
</tr>
<tr>
<td>Mild hypokalemia</td>
<td>0.15-0.2</td>
</tr>
<tr>
<td>Moderate hypokalemia</td>
<td>0.25-0.35</td>
</tr>
<tr>
<td>Severe hypokalemia</td>
<td>0.4-0.5</td>
</tr>
</tbody>
</table>

"Happy" 10 yr. old MN Westie DKA

Potassium Supplementation:
- KCl 0.5 mEq/kg/hr IV for 4 hours
- Recheck K+ and if normal,
  - KCl 0.01 mEq/kg/hr IV and KPhos 0.01 mEq/kg/hr IV
- Recheck K+ every 8-12 hours

"Happy" 10 yr. old MN Westie 11 kg

Potassium Supplementation:
- KCl 0.2 mEq/kg/hr
- IV fluid rate: 40 mL/hr
Calculating KCl Supplementation

- 0.2 mEq/kg/hr supplementation
- 0.2 x 11 kg = 2.2 mEq/hr
- Receiving 40 mL/hr IV fluids
  - 2.2 mEq/hr + 40 mL/hr = 0.055 mEq/mL
  - 0.055 mEq/mL x 1000 mL/L = 55 mEq/L KCl

Potassium Supplementation
Take-Home Points

- Be aggressive!
- Use K-max for 4-6 hours in cases with severe hypokalemia
- Avoid thrombophlebitis!
- Do not exceed 80 mEq/L KCl via a peripheral vein for prolonged periods of time
- Consider magnesium supplementation in patients with persistent hypokalemia

“Frankie”
4 yr. old MN Sheltie
Obtunded Mentation

- Temp = 100.4°F (38.0°C)
- HR = 130 bpm
- RR = 32 breaths/min
- BP = 120 mmHg (Doppler)
- Na = 178 mmol/L
- K = 4.2 mmol/L
- Cl = 132 mmol/L
- iCa = 1.23 mmol/L
Conditions Associated With Hypernatremia

• Water loss
  - Vomiting
  - Diarrhea
  - Polyuria
• Sodium ingestion
  - Salty/cured meats
  - Homemade play-dough
  - Paint balls
  - De-icer (rock salt)
• Decreased Na+ excretion
  - Kidney failure

Hypernatremia Clinical Consequences

• Brain dehydration!
  - Muscle fasciculations
  - Tremors
  - Seizures
  - Altered mentation

Treatment of Hypernatremia
Beware of Idiogenic Osmoles!

• During chronic hypernatremia, the brain forms molecules to balance the osmolality and prevent water movement into the brain from the blood
Treatment of Hypernatremia

**Acute**
- Serum Na+ can be dropped quickly until clinical signs (seizures, mentation) improve
- Use hypotonic fluids (e.g., D5W, 0.45% NaCl)

**Chronic**
- Serum Na+ must be dropped slowly (0.5 – 1 mEq/hour)
- Use fluids matched with the patient’s serum Na+ (e.g., 0.9% NaCl)

---

Treatment of Hypernatremia

- Water deficit:
  \[ \text{H}_2\text{O deficit} = 0.4 \times \text{lean BW (kg)} \times \left(\frac{\text{[Na+]}}{148} - 1\right) \]
- Administered PO (as water) or IV (as D5W)
- Be cautious with the amount of deficit corrected over a 24-hour period in chronic cases

---

Treatment of Frankie

- Water deficit:
  \[ \text{H}_2\text{O deficit} = 0.4 \times \text{lean BW (kg)} \times \left(\frac{\text{[Na+]}}{148} - 1\right) \]
- Total water deficit:
  \[ = 0.4 \times 16 \text{ kg} \times \left(\frac{184}{148} - 1\right) = 1.56 \text{ L (1560 mL)} \]
- Rate based on hydration deficit/volume status
  - 1560 mL/24 h = 65 mL/h (~1.5 X maintenance)
Options for Frankie if Chronic Hypernatremia

**Option 1**
- Give 500 mL of D5W to rapidly reduce Na+ by ~12 mEq/L
- Over 6 hours = 83 mL/hr (~2X maint.)
- Recheck serum Na+
- Then switch to 0.9% NaCl to restore hydration but not decrease Na+ further

**Option 2**
- Give 0.45% NaCl or LRS to restore hydration over 24 hours but not decrease Na+ too quickly
- Recheck Na+ every 6 hours to ensure no rapid changes

“Frankie”
4 yr. old MN Sheltie

Underlying cause = ingestion of pepperoni

Case Progression:
- Mentation improved after 12 hours of D5W
- Na+ within 24 hours
- Discharged home with no complications

Conditions Associated With Hyponatremia

- Sodium loss
  - Vomiting
  - Diarrhea
  - Effusion
  - Diuretics
  - Hypoadrenocorticism
- Hypovolemia and/or water retention
- Excess hypotonic fluids
- Administration of hypertonic solutions that do not contain Na+
Hyponatremia Clinical Consequences

- Signs related to the underlying disease
- Shock
- Edema/ascites
- Cerebral edema
  - Mental dullness
  - Coma
  - Seizures

Treatment of Hyponatremia

- In normovolemic or edematous patients, water restriction might be the treatment needed
- In hypovolemic patients, NaCl is given to correct the Na⁺ deficit

- Na deficit (mEq):
  \[ = 0.5 \times \text{lean BW (kg)} \times (\text{desired } \text{Na}^+ - [\text{Na}^+]) \]
- Rate of infusion (mL/hr):
  \[ = (\text{Na}^+ \text{ deficit} \times 1000 \text{ mL}) + (\text{fluid } \text{Na}^+(\text{mEq/L}) \times \text{hrs}) \]

Treatment of Hyponatremia

- Ideally increase the serum Na⁺ concentration slowly (0.5 – 1 mEq/hour)
Management of Sodium Disturbances

<table>
<thead>
<tr>
<th>Intravenous Fluid</th>
<th>Sodium (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>0</td>
</tr>
<tr>
<td>0.45% NaCl</td>
<td>77</td>
</tr>
<tr>
<td>LRS</td>
<td>130</td>
</tr>
<tr>
<td>Plasmalyte-A, Normosol-R</td>
<td>140</td>
</tr>
<tr>
<td>0.9% NaCl</td>
<td>154</td>
</tr>
</tbody>
</table>

Play it safe!! If you do not have time to calculate, choose a fluid with the Na+ concentration close to the patient's serum Na+

“Chelsea”
3 yr. old F Chihuahua
Tremors post-whelping
- Temp = 101.2°F (38.4°C)
- HR = 140 bpm
- RR = 42 breaths/min
- BP = 110 mmHg (Doppler)
- Na = 142 mmol/L
- K = 3.8 mmol/L
- Cl = 108 mmol/L
- iCa = 0.83 mmol/L (N: 1.2-1.4 mmol/L)
Conditions Associated With Hypocalcemia

- Hypoparathyroidism
- Eclampsia
- Feline urethral obstruction
- Massive blood transfusion
- Ethylene glycol toxicity
- Severe trauma
- Sepsis
- Protein losing enteropathy
- Pancreatitis
- Malabsorption
- Kidney disease
- Hemodialysis

Conditions Typically Needing Emergency Calcium Supplementation

- Hypoparathyroidism
- Eclampsia
- Feline urethral obstruction
- Massive blood transfusion
- Ethylene glycol toxicity
- Severe trauma
- Septic shock
- Protein losing enteropathy
- Severe pancreatitis
- Malabsorption
- Kidney disease/dialysis

Hypocalcemia Clinical Consequences

- Muscle tremors
- Fasciculations
- Paresthesia (i.e., facial rubbing)
- Ventricular arrhythmias
- Decreased cardiac contractility
- Hypotension

CATs go numb! Convulsions, arrhythmias, tetany, paresthesia
Measuring Calcium

**Total Calcium**
- Use serum or heparinized samples
- Avoid EDTA or citrate tubes

**Ionized Calcium**
- Ideally collected anaerobically using pre-filled heparin syringes
- Avoid serum separator tubes
- Heparinized samples and portable analyzers measure lower than serum

Can tCa predict iCa?

**Dogs:**
- tCa and iCa have 27% disagreement
- 36% disagreement in dogs with CKD
- tCa underestimates ionized hypocalcemia

**Cats:**
- tCa and iCa have 40% disagreement
- tCa overestimates ionized hypocalcemia
- Low tCa predicts ionized hypocalcemia 90% of the time

What about adjusted tCa?

**Dogs:**
- Adjusted Ca and iCa have 38% disagreement
- 53% disagreement in dogs with CKD
- Adjusted Ca underestimates ionized hypocalcemia
So what's the bottom line?

- **Dogs:**
  - Do not use tCa or aCa to predict ionized hypocalcemia – especially if critically ill
- **Cats:**
  - If the tCa is normal, iCa will likely also be normal
  - If the tCa is low, iCa should be measured

---

Eclampsia (Puerperal Tetany)

- Occurs during the first 4 weeks of lactation
- Small breed dogs
- Large litter sizes
- Unknown cause
- iCa ranges from 0.4-0.8 mmol/L
- Relapses occur in 10% of dogs despite at-home calcium supplementation

---

Hypocalcemia

Emergency Management

- IV calcium supplementation if iCa < 1.0 mmol/L or clinical signs
- Never give injectable calcium SQ!
- PO calcium supplementation or vitamin D long term
**Hypocalcemia**

**Emergency Management**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Concentration</th>
<th>Dose</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca gluconate</td>
<td>10% solution</td>
<td>0.5 – 1.5 mL/kg IV</td>
<td>Stop if bradycardia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-15 mg/kg/hr</td>
<td></td>
</tr>
<tr>
<td>Ca chloride</td>
<td>10% solution</td>
<td>5 – 15 mg/kg/hr</td>
<td>Stop if bradycardia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Very irritating if given perivascular!</td>
</tr>
</tbody>
</table>

**Hypocalcemia**

**Oral Supplements**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Concentration</th>
<th>Dose</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca carbonate</td>
<td>40% of tablet</td>
<td>25-50 mg/kg/day</td>
<td>Most common</td>
</tr>
<tr>
<td>(Tums®)</td>
<td>(various sizes)</td>
<td>(divided doses)</td>
<td></td>
</tr>
<tr>
<td>Calcitriol</td>
<td>Various</td>
<td>20-30 ng/kg/d</td>
<td>1-4 days until maximum effect reached</td>
</tr>
<tr>
<td></td>
<td>concentrations</td>
<td>for 3-4 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-15 ng/kg/d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>maintenance</td>
<td></td>
</tr>
</tbody>
</table>

**“Chelsea”**

3 yr. old F Chihuahua
Tremors post-whelping

Emergency Treatments:
- IV catheter placement
- Calcium gluconate
  1 mL/kg IV slowly
- LRS IV fluids with Ca gluconate 10 mg/kg/hr
- Oral calcium supplementation
  (Tums® ½ tablet q 12 h) to go home
```
"Boomer"
10 yr. old MN Golden
PU/PD, lethargy
  • Temp = 100.4°F (38.0°C)
  • HR = 90 bpm
  • RR = 30 breaths/min
  • BP = 140 mmHg (Doppler)
  • Na = 144 mmol/L
  • K = 3.7 mmol/L
  • Cl = 110 mmol/L
  • iCa = 1.9 mmol/L
    (N: 1.2-1.4 mmol/L)

Conditions Associated With
Hypercalcemia
  • Granulomatous dz, grapes
  • Osteolytic
  • Spuritus
  • Hyperparathyroidism
  • D vitamin D intoxication
  • Addison's disease
  • Renal disease
  • Neoplasia
  • Idiopathic
  • Temperature (hypothermia)

Ionized Hypercalcemia in Dogs: A Retrospective Study of
J.S. Messinger, W.E. Windham, and C.R. Ward
  • Neoplasia (58%)
    - LSA (78%)
    - Carcinoma (11%)
    - Anal sac AC (6%)
  • Kidney failure (17%)
    - Chronic (89%)
    - Acute (11%)
  • Hyperparathyroidism (13%)
  • Hypoadrenocorticism (5%)
  • Vitamin D toxicity (3%)
```
“Boomer”
10 yr. old MN Golden
Hypercalcemia

Diagnostic Work-up:
• Thorough history
• CBC
• Biochemistry profile
• Urinalysis
• Chest radiographs
• Abdominal radiographs and/or ultrasound
• PTH, PTH-rp, 25-OH vitamin D panel
• +/- aspirates/biopsies
• +/- bone marrow
• +/- cervical ultrasound

PREVALENCE OF INCIDENTAL THYROID NODULES IN ULTRASOUND STUDIES OF DOGS WITH HYPERCALCEMIA (2008-2013)

Retrospective case review
• 91 dogs with hypercalcemia (tCa > 12 mg/dL (> 3.0 mmol/L) and no palpable thyroid mass undergoing cervical ultrasound
• 88% of dogs had at least 1 parathyroid nodule identified
• 15% of dogs had at least 1 thyroid nodule identified
  • 22% of these were malignant
• Cervical ultrasound is warranted in dogs with hypercalcemia and no identifiable cause and nodules should be aspirated and assessed for malignancy

Hypercalcemia
Clinical Consequences
• “Stones” nephrolithiasis
• “Bones” osteoporosis, osteomalacia
• “Abdominal groans” constipation, nausea, vomiting, inappetence
• “Psychiatric moans” lethargy, weakness, ataxia
• “Thrones” PU/PD
Hypercalcemia
Emergency Management

- No “magic number” to dictate treatment
- Depends on clinical signs, rate of development, and concurrent biochemical abnormalities
- Serum tCa 12-14 mg/dL (3.0-3.5 mmol/L) might be well tolerated chronically
- Serum tCa > 14-15 mg/dL (3.5-3.75 mmol/L) usually requires emergency intervention

Hypercalcemia
Emergency Management

- Restore hydration and hypovolemia
- Diuretic therapy (when hydrated)
- Treat the underlying cause
- Consider other medications if severe hypercalcemia refractory to above treatments

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Dose</th>
<th>Onset of Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid therapy (0.9% NaCl)</td>
<td>100-150 mL/kg/day</td>
<td>Hours</td>
</tr>
<tr>
<td>Furosemide</td>
<td>1-2 mg/kg IV, SQ 0.5 mg/kg/hr CRI</td>
<td>Hours</td>
</tr>
<tr>
<td>Prednisone</td>
<td>1 mg/kg IV, PO q 12 h</td>
<td>2-4 days</td>
</tr>
<tr>
<td>Calcitonin</td>
<td>4-6 U/kg SQ, IM q 6-12 h</td>
<td>2-6 hours</td>
</tr>
<tr>
<td>Pamidronate</td>
<td>1.5-2.3 mg/kg IV (dogs) 1.0-1.5 mg/kg IV (cats)</td>
<td>24-48 hours</td>
</tr>
<tr>
<td>Mithramycin</td>
<td>25 mg/kg IV (1-2X/week)</td>
<td>24-48 hours</td>
</tr>
</tbody>
</table>
**“Boomer”**
10 yr. old MN Golden Hypercalcemia

Case Outcome:
- tCa = 15.8 mg/dL (3.95 mmol/L)
- Chest rads = mediastinal mass
- Aspirates = LSA
- 0.9% NaCl 2X maint.
- Furosemide 1 mg/kg IV
- Dexamethasone 0.1 mg/kg IV
- Thoracotomy surgery
- tCa normal within 48 hours

**“Samson”**
2 yr. old MN BMD Acute vomiting

- Temp = 100.8°F (38.2°C)
- HR = 120 bpm
- RR = 36 breaths/min
- BP = 120 mmHg (Doppler)
- Na = 137 mmol/L
- K = 3.6 mmol/L
- Cl = 96 mmol/L
- iCa = 1.23 mmol/L
Conditions Associated With Hypochloremia

- Same conditions associated with hypoNa

- Loss of chloride in excess of sodium:
  - Metabolic alkalosis
  - Vomiting of stomach contents (HCl)
  - Gastric suctioning
  - Thiazide or loop diuretics

Hypochloremia Clinical Consequences

- Usually related to the underlying cause

- Metabolic alkalosis and/or other electrolyte disturbances (e.g., hypokalemia) are common

Acid Base and Electrolyte Abnormalities in Dogs with Gastrointestinal Foreign Bodies

- Retrospective case review
- 138 dogs with GI foreign bodies
- Hypochloremia (51%) was the most common abnormality
- Metabolic alkalosis (45%), hyperlactatemia (41%), hypokalemia (25%), and hyponatremia (21%) also occurred
- Location of FB (upper vs. lower GI) was not associated with any electrolyte or acid-base disturbance
Approach to Hypochloremia

- Chloride can be corrected for the Na+ to confirm an absolute hypochloremia is present

- **Dogs:**
  
  Corrected Cl\(^-\) = Cl\(^-\) \times 146/Na\(^+\)
  
  Normal corrected chloride = 107 – 113 mEq/L

- **Cats:**
  
  Corrected Cl\(^-\) = Cl\(^-\) \times 156/Na\(^+\)
  
  Normal corrected chloride = 117 – 123 mEq/L

### Retrospective case review

- 1,805 dogs and cats included with acid-base results in a 13-month period
- 19% of patients had a metabolic alkalosis (based on increased base excess)
- Hypochloremia (measured) in 27% of dogs and 41% of cats
- Hypochloremia (corrected) in 7% of dogs and 87% of cats
- Free water deficit occurs commonly in cats, which emphasizes the importance of correcting chloride

---

### “Samson”

2 yr. old MN BMD

Acute vomiting

Corrected chloride:

\[ \text{Corrected chloride} = \text{Cl}^- \times \frac{146}{\text{Na}^+} \]

\[ = 96 \times \left( \frac{146}{137} \right) \]

\[ = 102 \text{ mEq/L} \]

### Diagnostic Work-up:

- Abdominal radiographs
- Abdominal ultrasound

### Treatment Plan:

- Rehydration fluid therapy with 0.9% NaCl
- Abdominal exploratory

### Outcome:

- R&A surgery with uneventful recovery
### Conditions Associated With Hyperchloremia

- Same conditions associated with hyperNa
- KBr therapy (pseudohyperchloremia)
- Diarrhea
- Kidney failure
- Renal tubular acidosis
- Chronic respiratory alkalosis
- Diabetes mellitus/DKA
- Hypoadrenocorticism

### Hyperchloremia Clinical Consequences

- Clinical signs usually related to the underlying cause

**Treatments:**
- Management of the underlying cause
- Hypotonic fluid therapy (limit chloride intake)

### Conditions Associated With Hypophosphatemia

- **Maldistribution:**
  - DKA
  - CHO load/insulin therapy
  - Respiratory alkalosis
  - TPN/refeeding syndrome
  - Hypothermia
- **Increased loss:**
  - Hyperparathyroidism
  - Renal tubular acidosis
  - Renal transplantation
  - Eclampsia
- **Decreased intake**
Hypophosphatemia
Clinical Consequences

Clinical Signs
- RBC fragility (hemolysis) \([P < 1.0 \text{ mg/dL (0.3 mmol/L)}]\)
- Impaired \(O_2\) delivery
- Impaired leukocytes
- Impaired clot retraction
- Thrombocytopenia
- Rhabdomyolysis
- GI ileus
- Impaired cardiac contractility

Treatment
- Prevention!
  - Anticipate and supplement (e.g., DKA, TPN)
- Supplement if clinical signs or severe hypophosphatemia \((< 2.0 \text{ mg/dL (0.65 mmol/L)})\)
  - Avoid over-supplementation

Phosphorus Supplementation

<table>
<thead>
<tr>
<th>Drug</th>
<th>Concentration</th>
<th>Dose</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na-phosphate</td>
<td>3 mmol/mL</td>
<td>0.01-0.06 mmol/kg/hr IV Recheck P every 8-12h</td>
<td></td>
</tr>
<tr>
<td>K-phosphate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-phos</td>
<td>125-250 mg</td>
<td>?</td>
<td>Avoid in vomiting or symptomatic patients</td>
</tr>
<tr>
<td>Neutra-phos</td>
<td>tablets/powders</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reasonable to supplement ½ of potassium in DKA/similar patients with K-phos (and other ½ with KCl)

Conditions Associated With Hyperphosphatemia

- Maldistribution:
  - Tumor lysis syndrome
  - Rhabdomyolysis
  - Hemolysis
- Increased intake:
  - Phosphate enemas
  - Vitamin D toxicity
  - Over-supplementation
  - Young/growing animal

- Decreased excretion:
  - Kidney failure
  - Uroabdomen
  - Urethral obstruction
  - Hypoparathyroidism
  - Hyperthyroidism
Hyperphosphatemia
Clinical Consequences

Clinical Signs
• Hypocalcemia (tetany)
• Soft tissue mineralization
• Systemic calciphylaxis
• Acute kidney injury
• Cardiovascular disease

Treatment
• IV fluids (volume expansion, ↑ GFR)
• Low-protein diet
• Dextrose (+/- insulin)
• Phosphate binders (for CKD Stage 2-4 patients if P > 6 mg/dL [1.9 mmol/L])
• Avoid calcium supplementation!

Phosphate Binders

- Usually contain aluminum or calcium and hydroxide, carbonate, or acetate
- 90-100 mg/kg/day divided 2-3 X/day (calcium acetate 50-80 mg/kg/day)
- Constipation can be a side effect
- Best when given immediately before or after a meal (not effect > 2 hours after eating)
- Newer phosphate binders = polymeric resins
  - Bind Phos and release Cl (do not contain Al or Ca)
  - Slow transit time (extended periods of binding)
  - $$ and can bind other substances (e.g., cholesterol, bile acids, vitamins)

<table>
<thead>
<tr>
<th>Drug</th>
<th>Concentration</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-OH (Alternagel®)</td>
<td>600 mg/5 mL</td>
<td>30 mg/kg q 8 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45 mg/kg q 12 h</td>
</tr>
<tr>
<td>Ca carbonate (Tums®)</td>
<td>500 mg (regular)</td>
<td>30 mg/kg q 8 h</td>
</tr>
<tr>
<td></td>
<td>750 mg (extra-strength)</td>
<td>45 mg/kg q 12 h</td>
</tr>
<tr>
<td>Sevelamer-HC (Renagel®)</td>
<td>400 mg tablets</td>
<td>33-54 mg/kg q 8 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50-80 mg/kg q 12 h</td>
</tr>
<tr>
<td>Lanthanum carbonate (Fosrenol®)</td>
<td>500 mg chewable tablets</td>
<td>12.5-25 mg/kg/day (start with ½ dose) (do not swallow tablets whole)</td>
</tr>
</tbody>
</table>
“Zeus”
9 yr. old MN Chihuahua
Ventricular tachycardia
Severe pancreatitis

- Temp = 102.3°F (39.1°C)
- HR = 180 bpm
- RR = 40 breaths/min
- BP = 90 mmHg (Doppler)

- Na = 144 mmol/L
- K = 3.3 mmol/L
- Cl = 109 mmol/L
- iCa = 1.10 mmol/L

“Zeus”
9 yr. old MN Chihuahua
Refractory ventricular tachycardia

- Lidocaine 2 mg/kg IV x 4 boluses
- Lidocaine 75 mg/kg/hr CRI
- KCl 0.5 mEq/kg/hr IV CRI x 4 hours
- Other anti-arrhythmia medication?
- Magnesium??

Conditions Associated With Hypomagnesemia

- Gastrointestinal losses
  - Vomiting/diarrhea
  - Gastric suctioning
- Decreased intake
  - Inappetence
  - Malabsorption
  - Short bowel syndrome
- Renal losses
  - Polyuria/oluresis
  - Dialysis
- Endocrine diseases
  - Hyperparathyroidism
- Drugs:
  - Diuretics
  - Cytotoxic drugs
  - Aminoglycosides
  - Cyclosporine
  - Pamidronate
  - Amphotericin B
  - Beta-agonists
  - Citrate (blood products)
  - ACE-inhibitors
  - Mannitol
  - Digoxin
Hypomagnesemia
Clinical Consequences
- Ventricular arrhythmias
- Supraventricular tachycardia
- Gastrointestinal dysmotility
- Hypertension/vasospasm
- Bronchoconstriction
- Electrolyte deficiencies
  - Hypocalcemia
  - Hypokalemia
- Tetany/muscle spasms
- Seizures

“Zeus”
9 yr. old MN Chihuahua
Refractory ventricular tachycardia
- Total Mg = 1.2 mEq/L (0.6 mmol/L)
- Ref. range = 1.4 – 2.6 mEq/L (0.7 – 1.3 mmol/L)
- iMg measurement not available
- If clinical signs, treat regardless of Mg measurement!

Treatment of Hypomagnesemia
Emergency Treatment:
- MgSO₄ 0.3 mEq/kg IV bolus over 20-30 min
- Diluted 1:10 in 0.9% NaCl or D5W

Maintenance Therapy
- MgSO₄ 0.02 – 0.04 mEq/kg/hour IV CRI (0.5-1 mEq/kg/day)
What other patients might need Mg supplementation?

- PLE
- Asthma

- DKA
- Tetanus

- Massive transfusion
- Ileus
Retrospective case review and prospective study

4% of Boxers and 15% of Bulldogs exhibited total hypomagnesemia

Bulldogs evaluated prospectively had tMg, iMg, and parenteral Mg tolerance testing at the low end or outside the reference range

Mg deficiency appears common in Bulldogs and might be related to hypertension and obstructive sleep apnea in the breed

Beware of hypermagnesemia!

Usually due to over-supplementation of Mg
- Miscalculation of CRI
- Oral Mg-containing phosphate binders

Patients with kidney failure are more susceptible

Hypermagnesemia Clinical Consequences

- Hypotension
- Bradycardia
- Prolonged PR interval
- Cardiac arrest
- Lethargy
- Weakness
- Flaccid paralysis
- Respiratory failure
- Decreased deep tendon reflexes
Hypermagnesemia Emergency Treatment

- Discontinue Mg supplementation
- IV fluid therapy (0.9% NaCl)
- Diuretic (furosemide) administration
- 10% calcium gluconate 1 mL/kg IV slowly

Conclusions

- Electrolytes should be part of the initial lab work for any emergent/critical patient
- Electrolyte disturbances can give clues as to the patient’s underlying condition
- Appropriate treatment of electrolyte emergencies can be life-saving

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Dr. Garret Pachtinger
- CVC Washington D.C, April 2015
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Questions?
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