STAT Databases: Harnessing the Power of Point of Care Diagnostics

Amanda A Cavanagh, DVM, DACVECC

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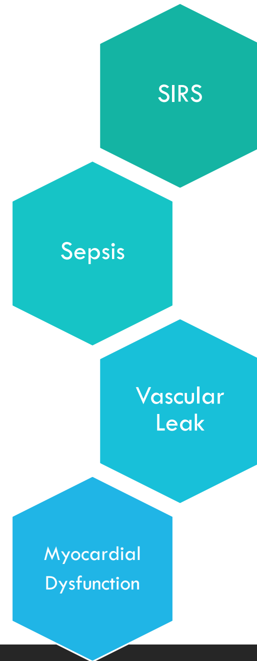
Why do fluids fail?



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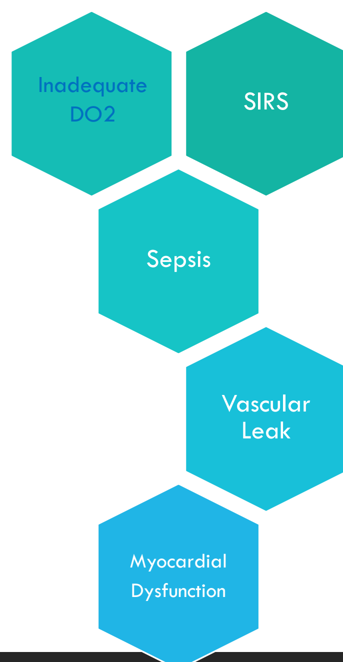

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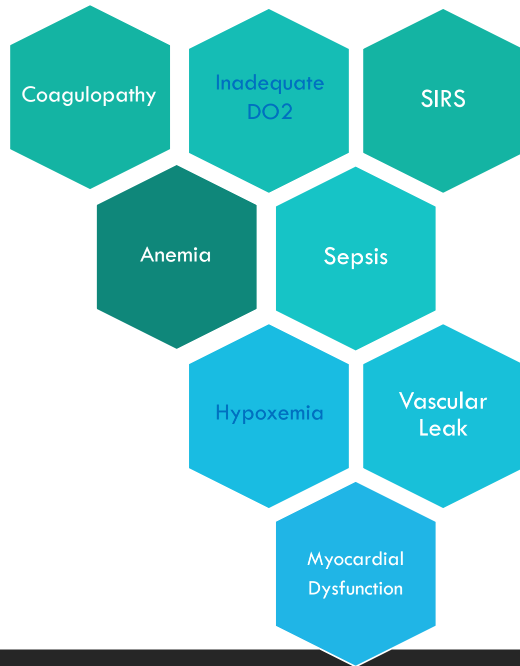

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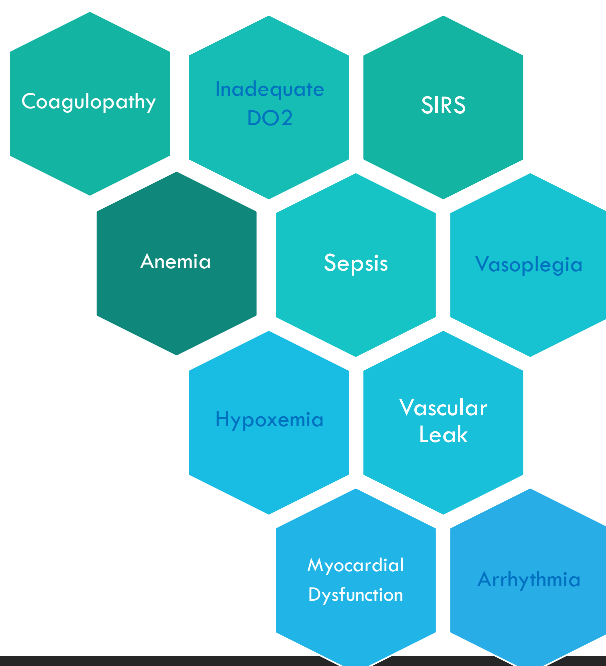

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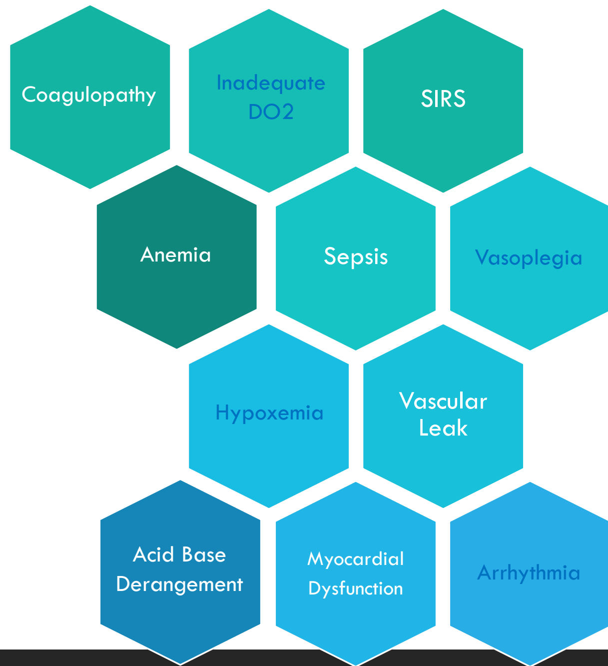
Why do fluids fail?



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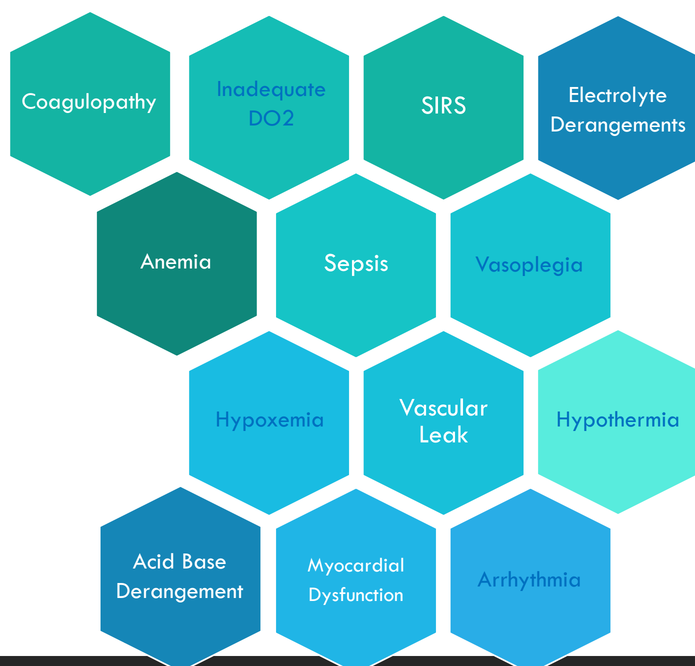
Why do fluids fail?



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Why do fluids fail?

- Coagulopathy
- Inadequate DO2
- SIRS
- Electrolyte Derangements
- Anemia
- Sepsis
- Vasoplegia
- Hypoxemia
- Vascular Leak
- Hypothermia
- Acid Base Derangement
- Myocardial Dysfunction
- Arrhythmia

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Instrumentation

- IV Catheter
- Central venous catheter
- EKG
- SpO2
- Temperature probe
- Blood Pressure

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What is a STAT ER Database?

- Venous Blood Gas
- PCV/Total Solids

Sample Type	Venous			
Blood Gas Temp.	98.6			Deg F
Fraction Inspired O2	21.0			%
Hemoglobin Conc.	23.3			g/dL
Barometric Pressure	637			mmHG
Blood pH	7.189	P	7.33 - 7.45	
Blood pCO2	30.0		24 - 39	mmHG
Blood pO2	40.5	L	67 - 92	mmHG
Blood HCO3- (calculated)	11.0	L	17 - 27	mEQ/L
Actual Base Excess	-17.1			mmol/L
Oxygen Saturation	53.4			%
Temp. corrected Blood pH	7.189			
Temp corrected pCO2	30.0			mmHG
Temp corrected pO2	40.5			mmHG
Calc Total O2	16.5			Vol%
Blood Sodium	154		145 - 156	mEQ/L
Blood Potassium	5.2		4.1 - 5.6	mEQ/L
Blood Chloride	123	H	104 - 113	mEQ/L
Blood Anion Gap	25.5	H	13 - 24	mEQ/L
Ionized Calcium	1.19			mmol/L
Ionized Calcium Corrected	.		1.12 - 1.40	mmol/L
Not available.				
Blood Glucose	48	L	67 - 114	mg/dL
Blood Lactate	4.5	H	0.20 - 1.44	mmol/L
Blood Creatinine	2.85	H	0.7 - 1.9	mg/dL

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What is a STAT ER Database?

- PCV/TS
- Blood Glucose
- Blood Lactate
- Electrolytes

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Hypothermia

Hypothermia
- Decreased catecholamines
- Decreased α_1 response
- Bradycardia

Shivering with Fever
- O2 consumption

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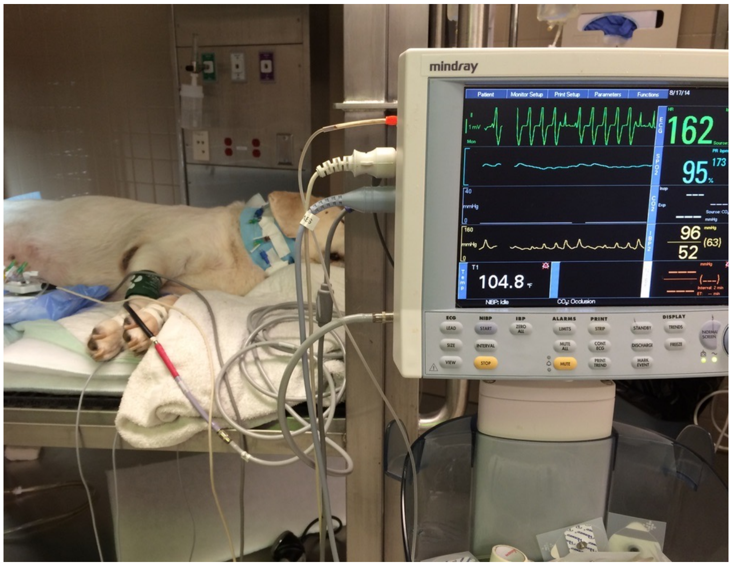
Arrhythmia



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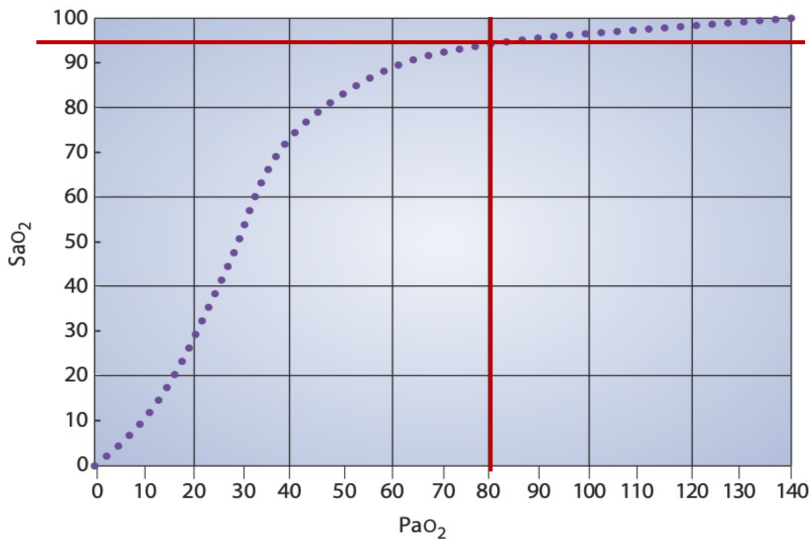
Hypoxemia



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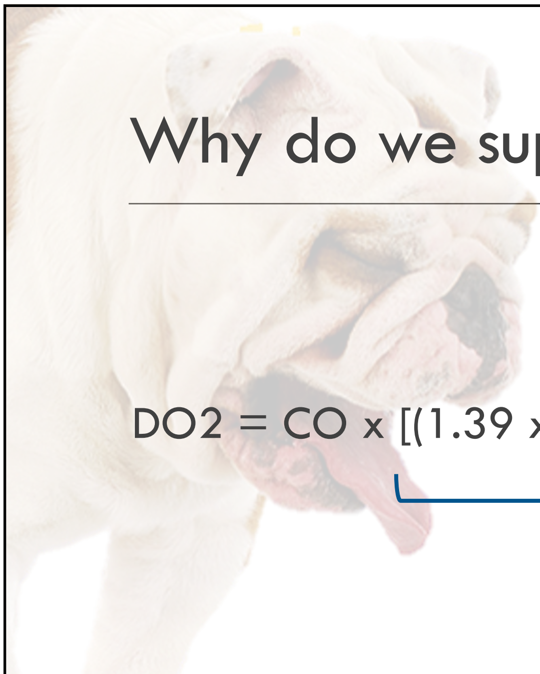

Why do we supplement O2?

$$DO_2 = CO \times \underbrace{[(1.39 \times Hgb \times SaO_2) + (PaO_2 \times 0.003)]}_{CaO_2}$$

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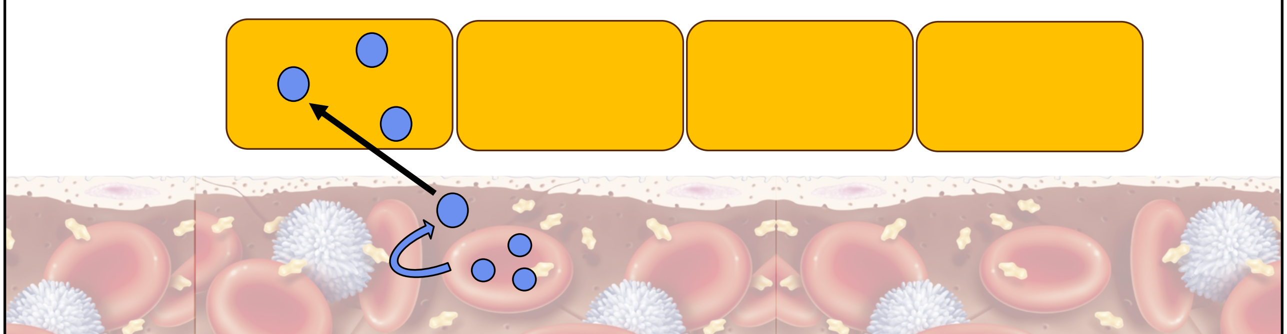
Why do we supplement O2?



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Hypoxemia

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TABLE 1 Modes of oxygen supplementation in veterinary patients.

	FiO_2 (%)	Flow rate	Advantages	Limitations	Indications
Low flow					
Flow by	25–45	6–8 L/min	• Utilizes readily available equipment	• Not appropriate for prolonged therapy • Wasteful	• Triage and procedures • Initial stabilization
Oxygen cage	21–60		• Well tolerated • Allows eating and drinking	• Reduced access to patients • FiO_2 rapidly decreases when doors opened • Larger patients	• Patients that will not tolerate nasal oxygen or in which nasal oxygen is contraindicated
Face mask	35–55	1–6 L/min	• Utilizes readily available equipment • Rebreathing at low rates	• Not appropriate for prolonged therapy • FiO_2 depends on fit of mask	• Triage and procedures • Initial stabilization • Risk of rebreathing
Nasal prongs		50–150 ml/kg/min	• Easy to place • Well tolerated	• Poor patient tolerance at high flow rates • Not suitable for some facial conformations	• Ongoing oxygen support in hospital
Nasal catheter	30–60	50–150 ml/kg/min	• Well tolerated	• Poor patient tolerance at high flow rates • Harder to place	• Ongoing oxygen support in hospital
High flow					
CPAP	21–100		• Reliable FiO_2 • Delivers PEEP • Humidifies inhaled gases	• Often requires heavy sedation • Specific equipment	• Hypoxaemia despite oxygen support • Upper airway obstruction
HFNOT	21–100	10–60 L/min	• Reliable FiO_2 • Delivers PEEP • Humidifies inhaled gases	• Specific equipment	• Hypoxaemia despite conventional oxygen therapy • Increased work of breathing
Mechanical ventilation	21–100		• Reliable FiO_2 • Delivers PEEP • Humidifies inhaled gases	• Specific equipment • High complication rate • High cost	• Hypoventilation • Hypoxaemia despite oxygen support • Increased work of breathing (fatigue)

Whitney and Kier. Frontiers. 2023

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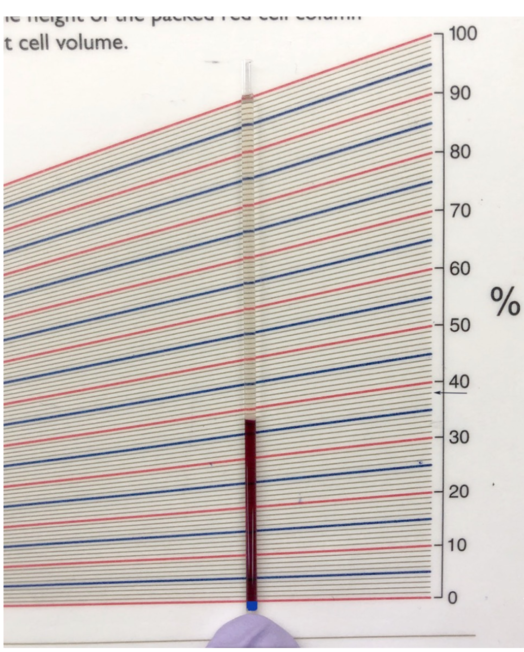
PCV and Total Solids

- PCV
- Total Solids
- Color of Serum
- Buffy Coat



RETROSPECTIVE STUDY

Veterinary Emergency and Critical Care WILEY

Retrospective evaluation of admission total plasma protein as a predictor of red blood cell transfusion requirement in dogs diagnosed with traumatic and nontraumatic hemoabdomen: 90 dogs (2009–2019)

Miranda Buseman DVM[1] | April E. Blong DVM, DACVECC[1] | Lingnan Yuan[1] | Jonathan P. Mochel DVM, MSc, PhD, DECVPT[1] | Rebecca A. L. Walton DVM, DACVECC[1,2]

- 90 Dogs with hemoabdomen
  - Traumatic hemoabdomen
  - Non-traumatic hemoabdomen
- How do I know who needs a transfusion?

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- 90 Dogs with hemoabdomen
  - Traumatic hemoabdomen
  - Non-traumatic hemoabdomen
- How do I know who needs a transfusion?
  - Does PCV predict transfusion needs?
  - Does total plasma protein predict transfusion needs?

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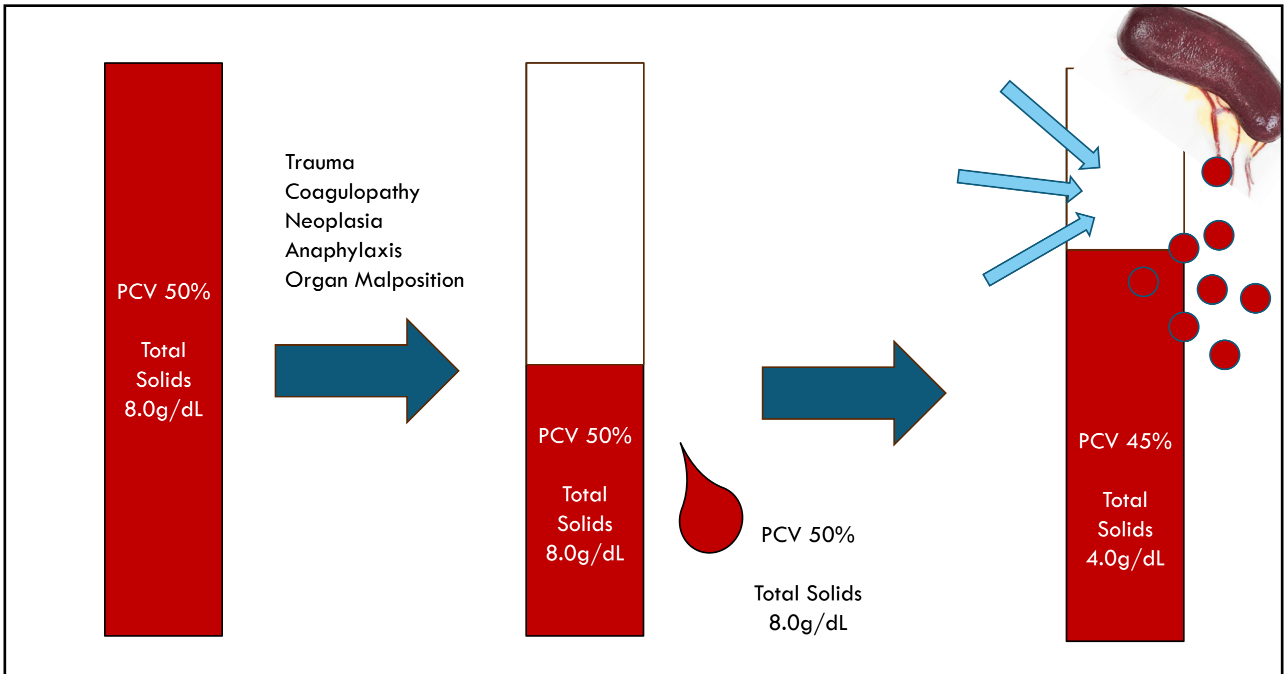

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Low admission Total Protein = increased risk of transfusion

Every 1 g/dL decrease in TP → 2x risk of needing transfusion

Lower PCV/TS ratio increased risk of needing transfusion

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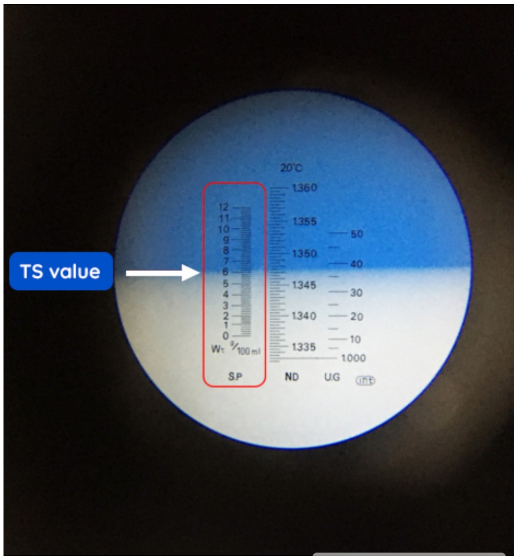

"Total Solids" vs Plasma Proteins

Plasma Proteins

- Chemistry Panel
- Albumin + Globulins

"Total Solids"

- Point of Care Refractometer
- Refractive Index
- Albumin + Globulins + Fibrinogen

wvs.academy.

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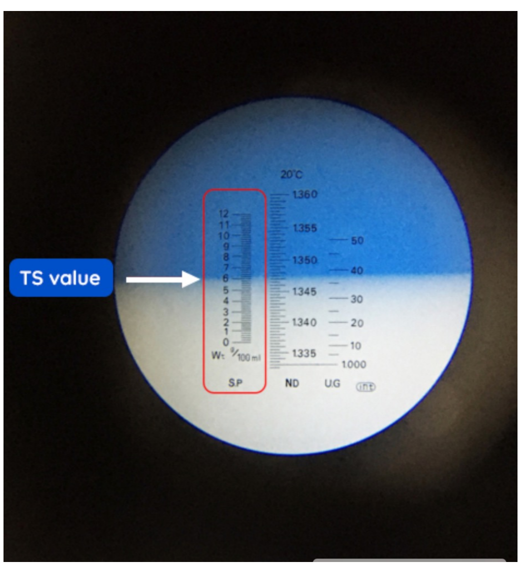

"Total Solids"

- Point of Care Refractometer
- Refractive Index
- Albumin + Globulins + Fibrinogen
- Triglycerides and Cholesterol
- Hemolysis
- Glucose
- Urea

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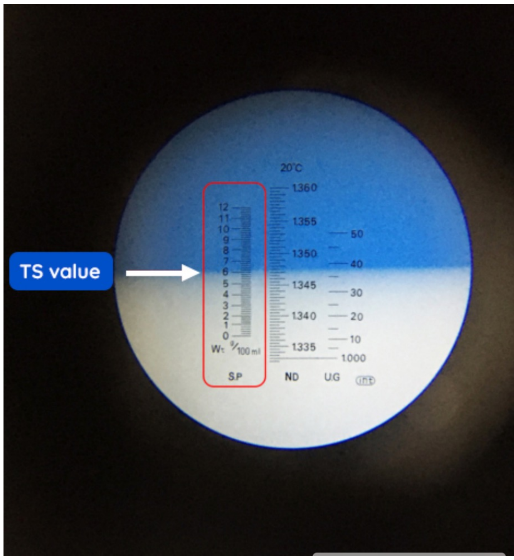

Elevated “Total Solids”

- Concentrated Albumin
- Hyperglobulinemia
- Elevated Fibrinogen
- Triglycerides and Cholesterol
- Hemolysis
- Glucose
- Urea, Creatinine
- Sodium and Chloride

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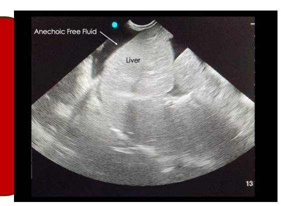
Anemia with Low Total Solids → Blood Loss

Blood Loss → POCUS for Cavitary Hemorrhage

Blood Loss → GI Hemorrhage

Blood Loss → External Hemorrhage



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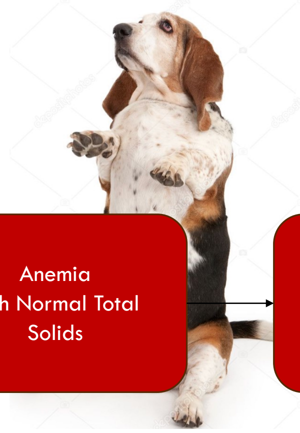
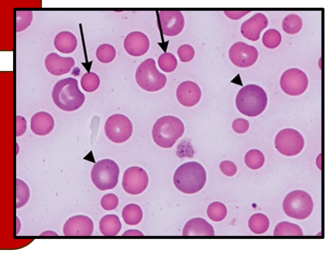


Anemia
with Normal Total
Solids

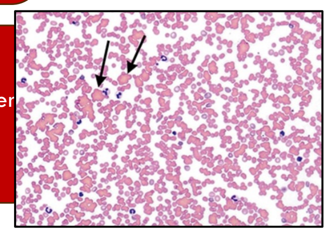
→ Red Cell Destruction
or
Lack of Production

→ Slide Agglutination

→ Blood Smear for
Spherocytes



→ Blood Smear for other
WBC and Platelets



https://todaysveterinarypractice.com/hematology/in-clinic-hematology-the-blood-film-review/

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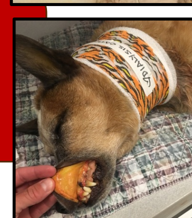
Normal PCV
Low Total Solids

→ Protein Losing
Nephropathy → UA, UPC
and POCUS

→ Protein Losing
Enteropathy → Globulins
and POCUS

→ Hepatic Dysfunction → Chemistry



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PCV and Total Solids

- PCV
- Total Solids
- Color of Serum
- Buffy Coat

Bilirubin

Hemolysis

Lipemia

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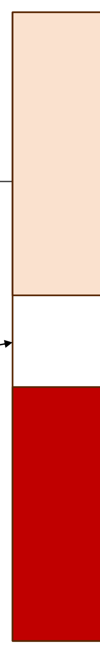
PCV and Total Solids

- PCV
- Total Solids
- Color of Serum
- Buffy Coat



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PCV and Total Solids

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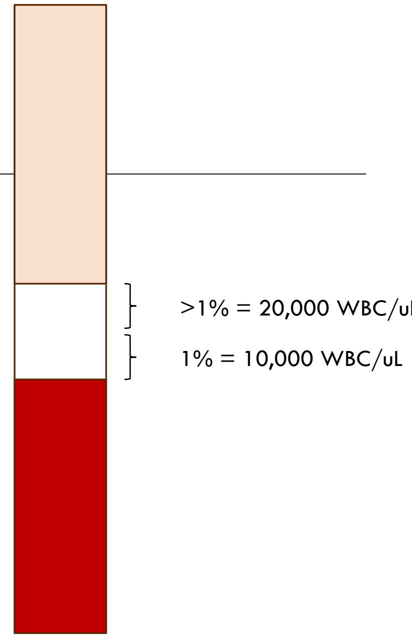

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PCV and Total Solids

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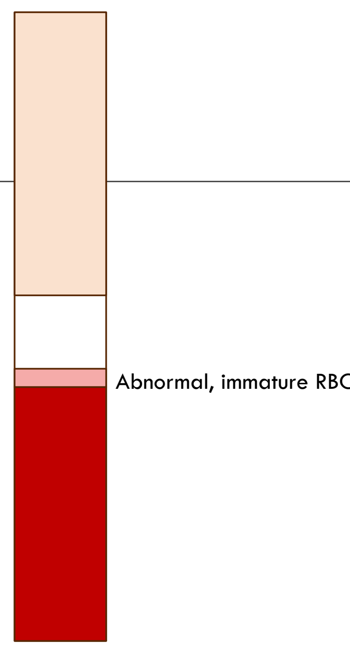

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Blood Gas Analysis

pH Derangements

Respiratory

A_{TOT}

Strong Ion Difference

Unmeasured Anions

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Blood Gas Analysis

pH Derangements

Respiratory

A_{TOT}

Strong Ion Difference

Unmeasured Anions

Cardiovascular Effects

↓ Adrenergic Receptor Activity

Decreased SVR

Negative Inotropy

↑ Parasympathetic Tone

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Blood Gas Analysis

pH Derangements

- Respiratory → Normal $PvCO_2$ = 40mmHg
- A_{TOT}
- Strong Ion Difference
- Unmeasured Anions

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Blood Gas Analysis

pH Derangements

- Respiratory
- A_{TOT}
- Strong Ion Difference
- Unmeasured Anions

Acidosis
Reverse Sedatives
Evacuate Pleural Space
Ventilate

Alkalosis
Analgesia
Anxiolytics

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Blood Gas Analysis

pH Derangements

- Respiratory
- A_{TOT}
- Strong Ion Difference
- Unmeasured Anions

Acidosis (↑ alb, phos)
Free Water Loss
AKI/CKD
Renal Hypoperfusion

Alkalosis (↓alb, phos)
PLE/PLN
Hypophosphatemia

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Blood Gas Analysis

pH Derangements

- Respiratory
- A_{TOT}
- Strong Ion Difference
- Unmeasured Anions

Acidosis
Hyponatremia
Hyperchloremia

Alkalosis
Hypernatremia
Hypochloremia

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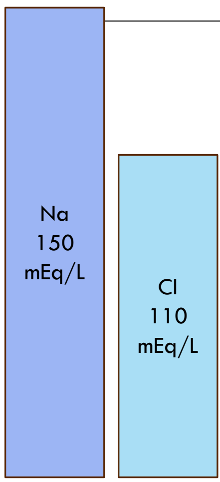
Strong Ion Difference



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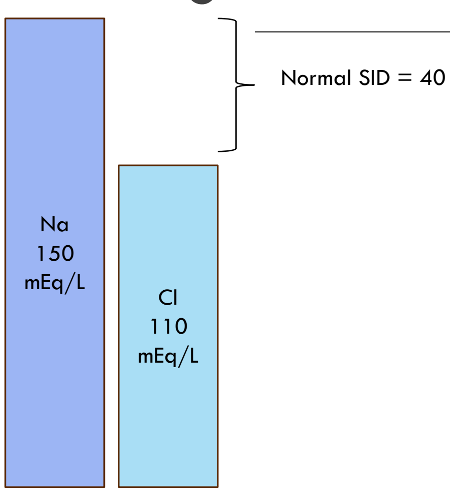
Strong Ion Difference



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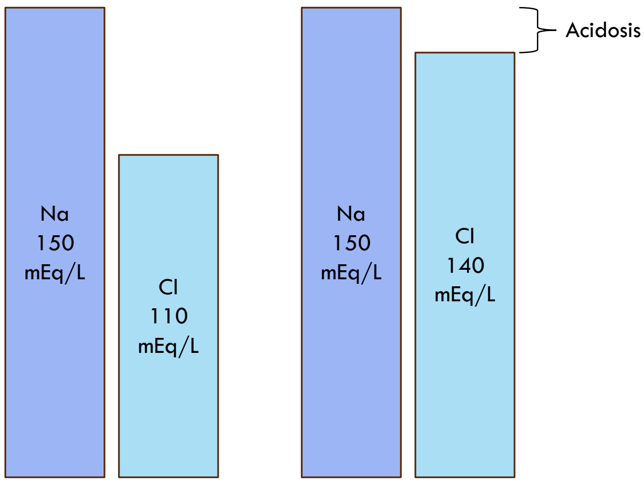
Strong Ion Difference



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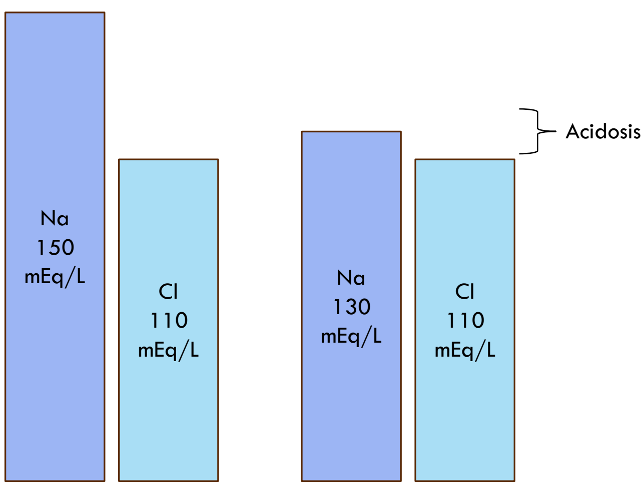
Strong Ion Difference



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Strong Ion Difference

Na
150
mEq/L

Cl
110
mEq/L

Na
154
mEq/L

Cl
154
mEq/L

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Strong Ion Difference

Resuscitate with Balanced Crystalloids

Dilute drugs and electrolytes with D5W

- 0.9% NaCl is acidifying (SID = 0)
- Avoid excess Na

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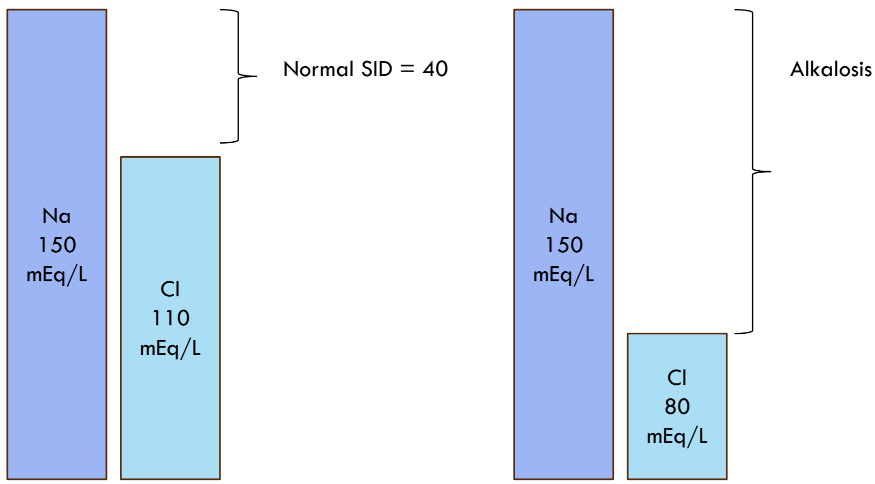
Strong Ion Difference



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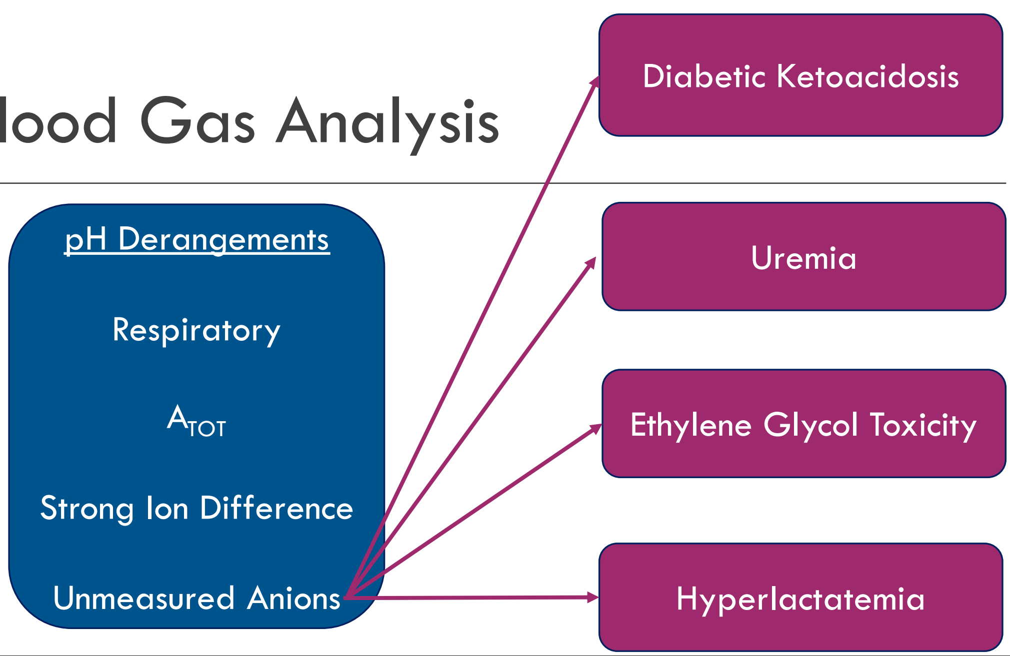
Blood Gas Analysis



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Lactate

Normal Lactate < 2mmol/L

Butler et al., Am J Pathology. 2020

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Lactate

Poor Perfusion: Hypovolemia

- Tachycardia
- Weak, thready pulses
- Pale MM, long CRT
- Cold extremities
- Weakness, collapse
- Dull mentation

Butler et al., Am J Pathology. 2020

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Lactate

Poor Perfusion: Hypovolemia
- Tachycardia
- Weak, thready pulses
- Pale MM, long CRT
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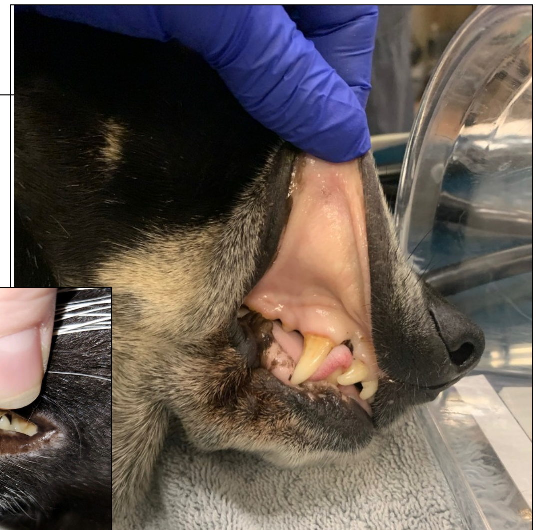
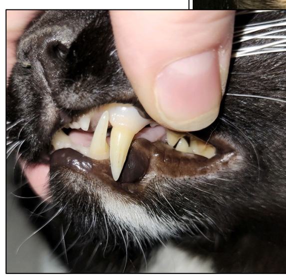

Butler et al., Am J Pathology. 2020

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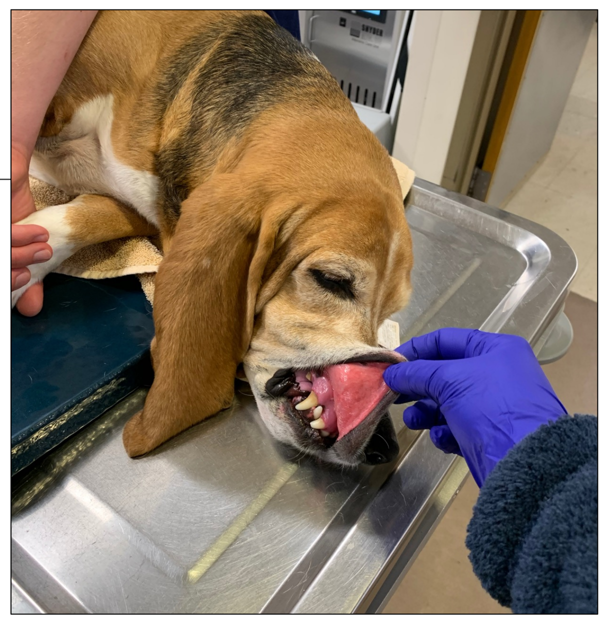
Lactate

Non-Volume Poor Perfusion
- Tacky or brady arrhythmias
- Poor heart contractility
- Dilated vessels
- Clots and tissue death
- GI or splenic torsion and tissue death



Butler et al., Am J Pathology. 2020

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Lactate

Normal Perfusion

Increased O2 Demand
- Shivering with fever
- Seizures

Catecholamines
- Endogenous (SIRS, sepsis)
- Exogenous (vasopressors)

Butler et al., Am J Pathology. 2020

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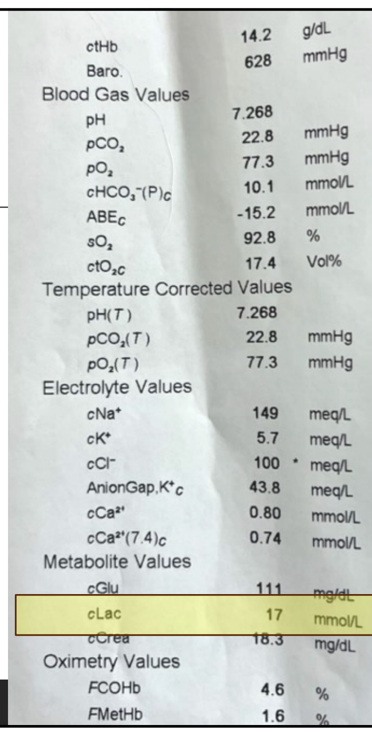
Erroneous Lactate



ctHb	14.2	g/dL
Baro.	628	mmHg
Blood Gas Values		
pH	7.268	
pCO_2	22.8	mmHg
pO_2	77.3	mmHg
$cHCO_3^-(P)_c$	10.1	mmol/L
ABE_c	-15.2	mmol/L
sO_2	92.8	%
ctO_{2c}	17.4	Vol%
Temperature Corrected Values		
pH(T)	7.268	
$pCO_2(T)$	22.8	mmHg
$pO_2(T)$	77.3	mmHg
Electrolyte Values		
cNa^+	149	meq/L
cK^+	5.7	meq/L
cCl^-	100 *	meq/L
$AnionGap,K^+_c$	43.8	meq/L
cCa^{2+}	0.80	mmol/L
$cCa^{2+}(7.4)_c$	0.74	mmol/L
Metabolite Values		
cGlu	111	mg/dL
cLac	17	mmol/L
cCrea	18.3	mg/dL
Oximetry Values		
FCOHb	4.6	%
FMetHb	1.6	%

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Blood Glucose

Hypoglycemia

Sepsis
Hepatic Dysfunction
Paraneoplastic
Addison's Disease
Refeeding Syndrome
Neonates

57

Blood Glucose

Hypoglycemia

Sepsis
Hepatic Dysfunction
Paraneoplastic
Addison's Disease
Refeeding Syndrome
Neonates

Neurologic Effects

Depressed LOC
Seizures
Ataxia
Blindness

Systemic Effects

Muscle Weakness
Sympathetic Activation
Arrhythmia
Circulatory Collapse

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Point of Care Glucometers

Hemoconcentration

◦ Less plasma interfacing with the reagent = falsely LOW blood glucose

Anemia

◦ More plasma interfacing with reagent = falsely HIGH blood glucose

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Point of Care Glucometers

$$\text{Corrected POC Glucose} = POC_{glu} + ([1.6 \times PCV]-81.3)$$

Lane SL, et al., J Am Vet Med Assoc. 2015 Feb 1;246(3):307-12.

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Blood Glucose

2775 mOsm/L undiluted

Peripheral Catheters: dilute to <600mOsm/L in D5W

For
Address Date

℞

Dextrose 50%

Bolus: 1ml/kg diluted 1:4 given over 5 min
CRI: 1.25% - 12.5% in crystalloid fluid

Goal: blood glucose 100-180 mg/dL

REFILL TIMES , M.D.
DEA NO. Address

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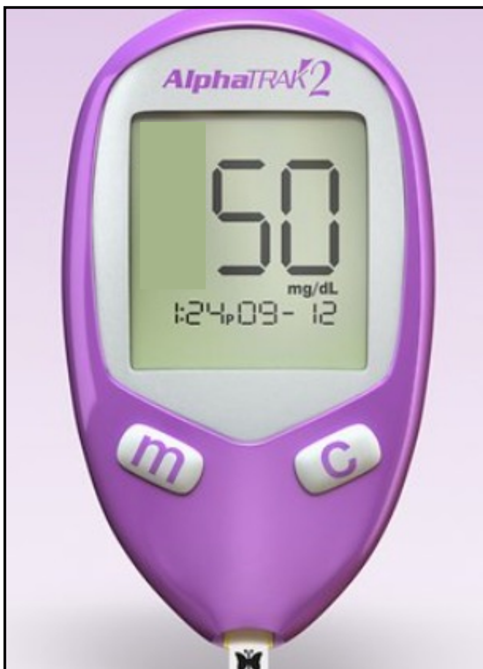

Blood Glucose

For
Address Date

℞

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REFILL TIMES , M.D.
DEA NO. Address

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Blood Glucose

For

Address Date

℞ Dextrose 50%

Central Catheter: 0.1 – 0.5 g/kg/hour

REFILL TIMES , M.D.

DEA NO. Address

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Ionized Hypocalcemia

Cause

Sepsis
Abnormal PTH Levels
Vitamin D Deficiency
Abnormal Mg
Renal Injury or Loss
Pancreatitis
CPDA in transfusion

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Ionized Hypocalcemia

Cause

Sepsis
Abnormal PTH Levels
Vitamin D Deficiency
Abnormal Mg
Renal Injury or Loss
Pancreatitis
CPDA in transfusion

→

Effects

Myocardial Dysfunction
Impaired Smooth Muscle Tone
Coagulopathy

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Ionized Hypocalcemia

Indications

- iCa < 1.0 mmol/L
- Refractory hypotension
- Inotropic support
- 2 units blood products

For
Address Date

℞ Calcium gluconate 10%

1ml/kg diluted 1:4 given over 20 minutes

Continuous EKG

Recheck ionized calcium

REFILL TIMES , M.D.
DEA NO. Address

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Ionized Hypocalcemia

680 mOsm/L undiluted
100mg calcium gluconate / mL

Peripheral Catheters: dilute to 10-50mg/mL in D5W

For
Address Date
℞

Calcium gluconate 10%

1ml/kg diluted 1:2 - 1:10
Give over 20 minutes

Continuous EKG

REFILL TIMES , M.D.
DEA NO. Address

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Ionized Hypocalcemia

6782 mOsm/L undiluted
230mg calcium gluconate/mL

Peripheral Catheters: dilute to <600mOsm/L (1:10) in D5W

For
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Calcium gluconate 23%

0.5 ml/kg diluted 1:10 given over 20 min

Continuous EKG

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Hypokalemia

Cause

Decreased Intake
GI and Renal Loss
Drugs
Transcellular Shifts
(catecholamine, insulin, pH)

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Hypokalemia

Cause

Decreased Intake
GI and Renal Loss
Drugs
Transcellular Shifts
(catecholamine, insulin, pH)

Cardiac Effects
Prolonged AP
Refractory to Lidocaine

Renal Effects
Renal Vasoconstriction
Decreased ADH Response

Systemic Effects
Metabolic Acidosis
Glucose Intolerance
Muscle Weakness

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Hypokalemia

Guideline for Potassium Supplementation in Dogs and Cats

Serum Potassium Concentration (mEq/L)	mEq KCl to Add to 1 L of Maintenance Fluids
< 2.0	80
2.1–2.5	60
2.6–3.0	40
3.1–3.5	25–30
3.6–5.0	20
>5.0	none

Merck Veterinary Manual

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Hypokalemia

Maintenance K+ = 0.05-0.1mEq/kg/hr in the fluid bag

0.15-0.4 mEq/kg/hr in the fluid bag

Max K+ (K max) = 0.5 mEq/kg/hr CRI **not in the bag**!

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Hypokalemia

10kg Dog needing 0.3mEq/kg/hour KCl at a fluid rate of 55ml/hr

(10kg) x (0.3mEq/kg/hr) = 3 mEq/hr of KCl

[3 mEq/hr of KCl] / [55 ml/hr] = 0.05 mEq/ ml x 1000 = **54 mEq/L KCl**

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Hypokalemia: Kmax

4000 mOsm/L undiluted

Peripheral Catheters: dilute to <600mOsm/L (1:6) in D5W

Central Catheters: can deliver undiluted, but caution!

For

Address Date

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Potassium Chloride (KCl 2mEq/mL)

0.5mEq/kg/hour CRI diluted*

Administer CRI for 2-4 hours; recheck K+

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Ionized Hypomagnesemia

<u>Cause</u>

Decreased Intake
GI Loss
Renal Loss

<u>Effects</u>

Potassium Wasting
Hypocalcemia
Ventricular Arrhythmias
Increased SVR

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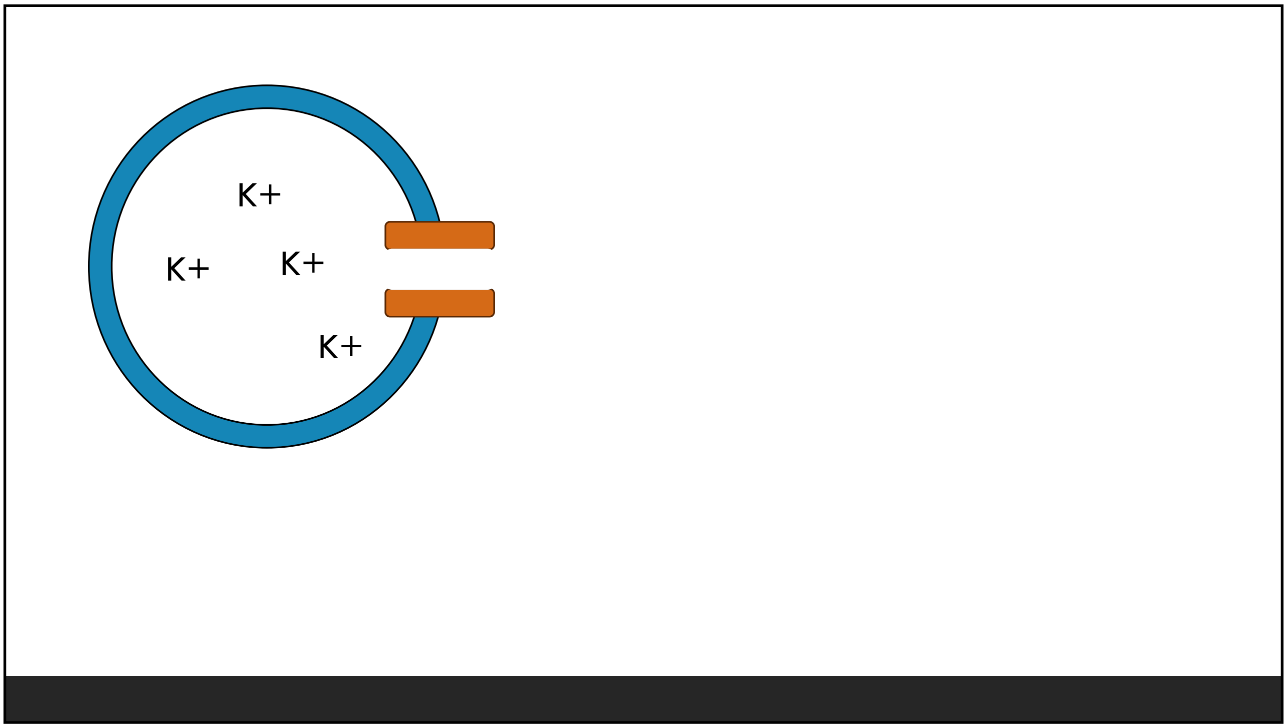

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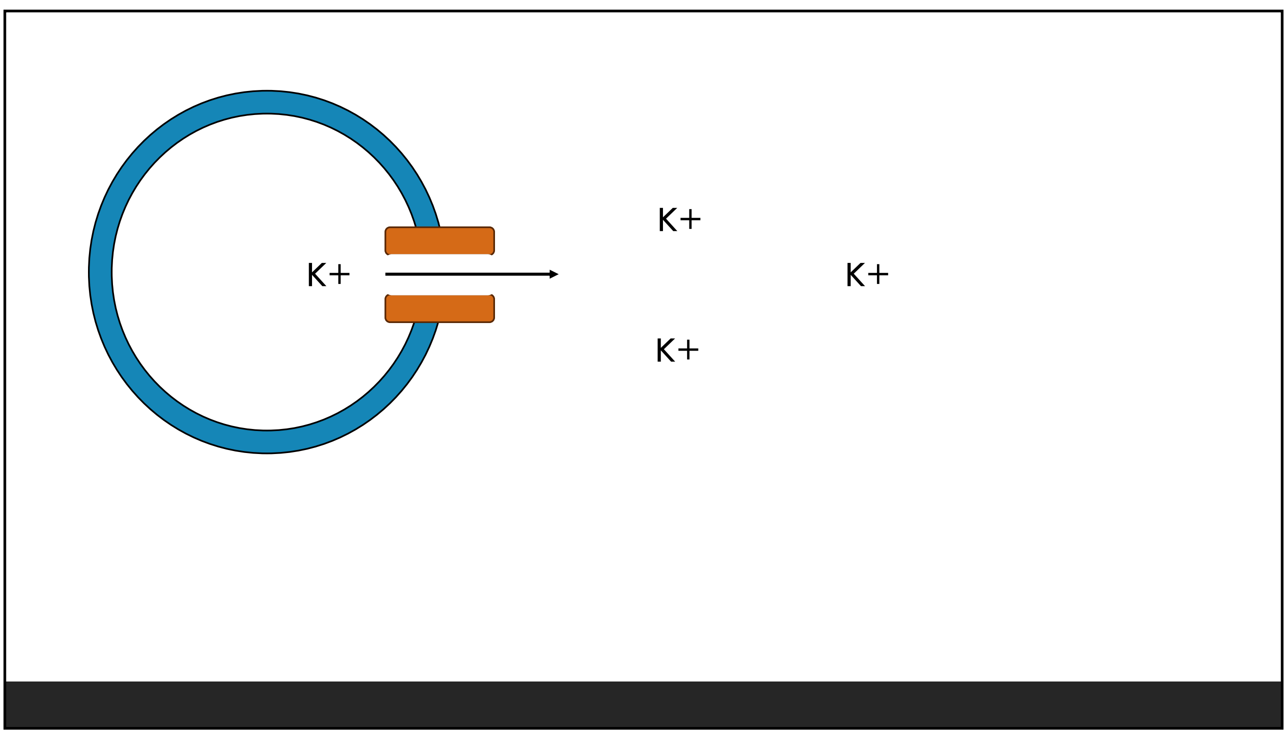

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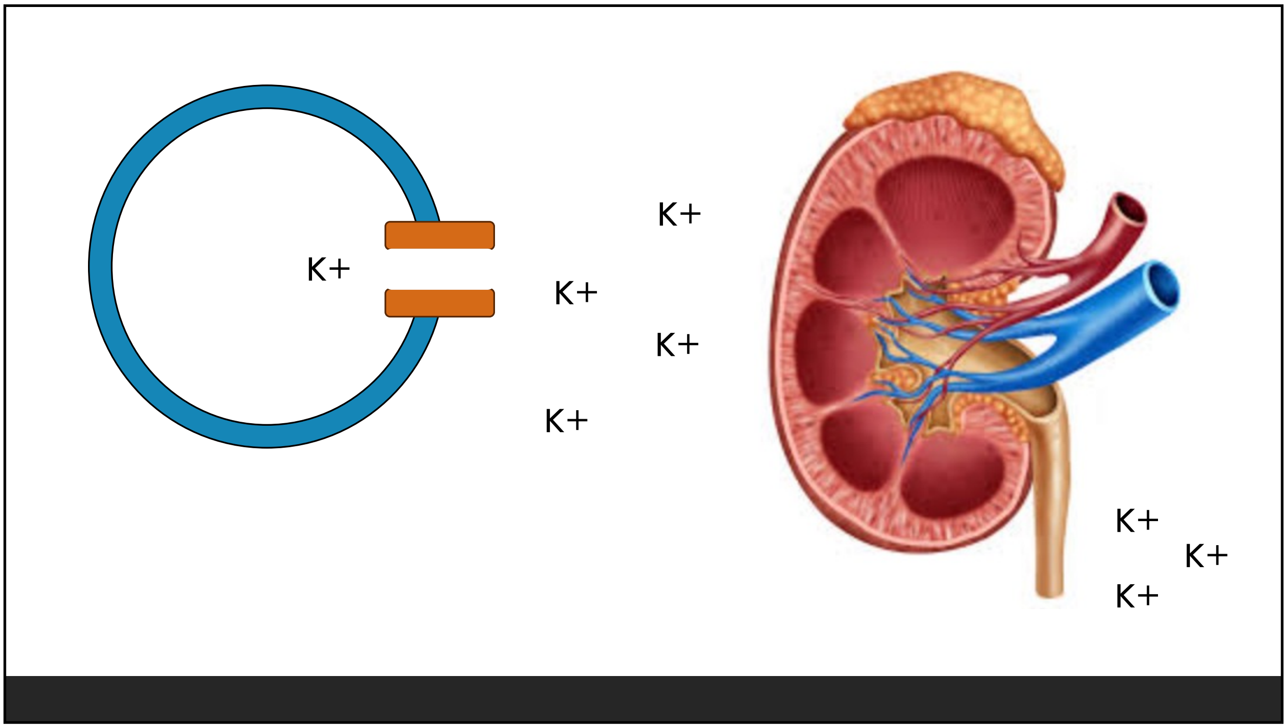

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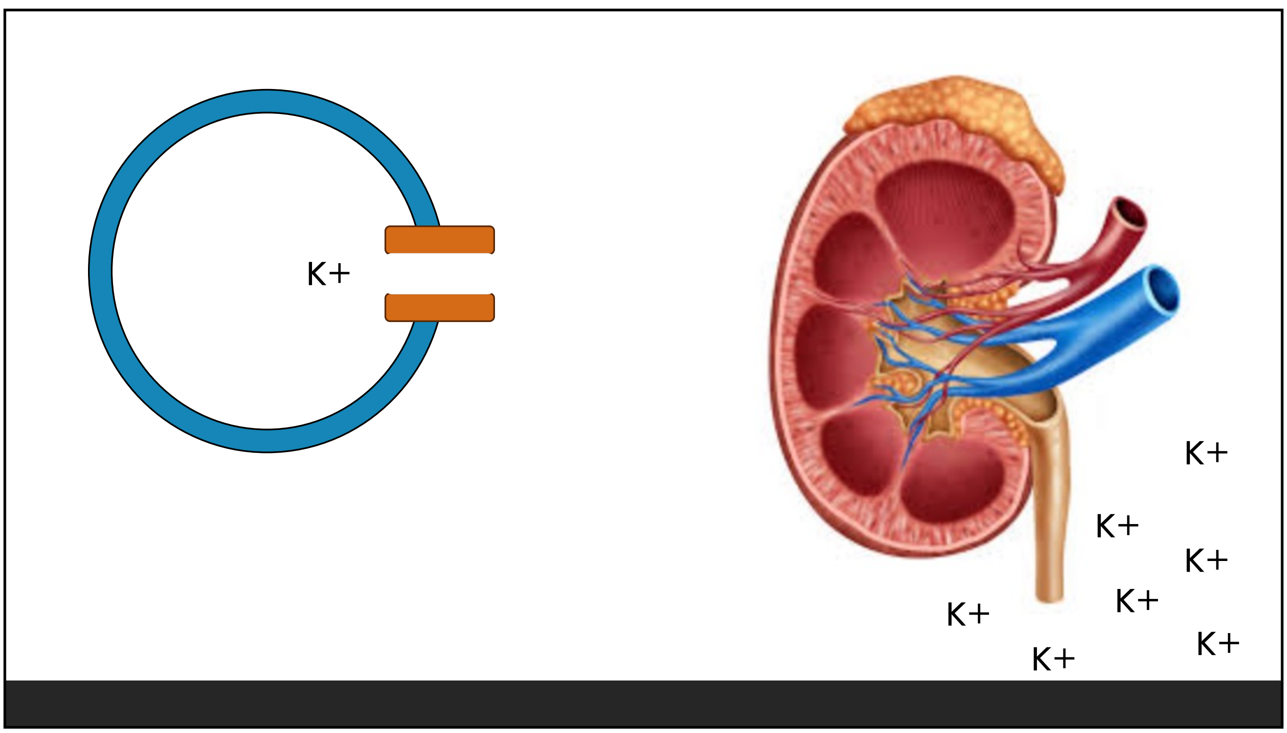

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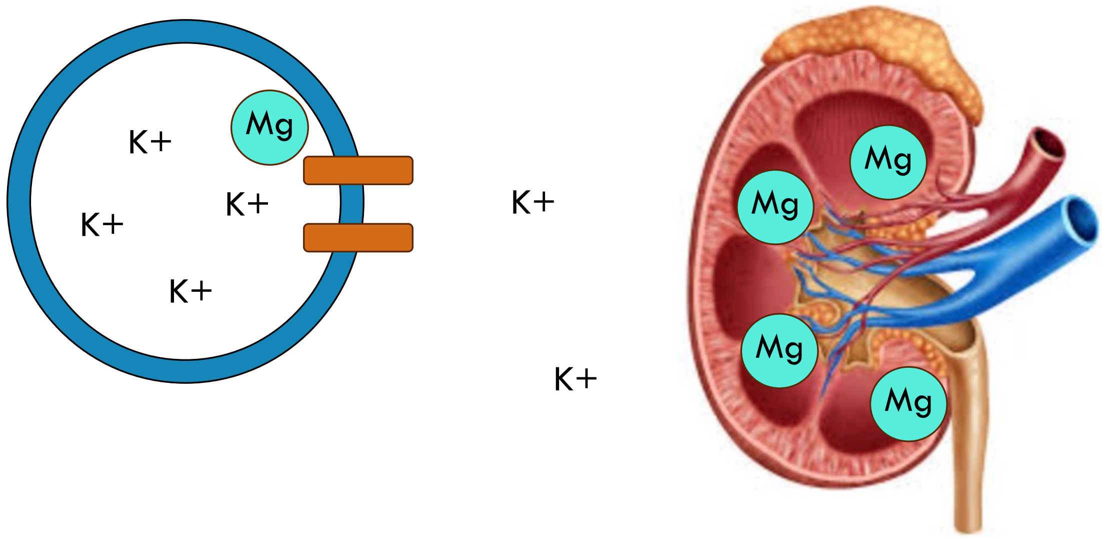

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Hypomagnesemia

Cannot measure iMg

Indications:

- Hypokalemia
- Arrhythmia
- Suspected Mg wasting

For__________
Address__________ Date __________

℞

Magnesium Chloride 20% (1.97mEq/ml)

Bolus 0.3mEq/kg diluted 1:4 in D5W over 20 minutes with EKG

0.75 mEq/kg/day CRI in fluids

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Hypomagnesemia

2951 mOsm/L undiluted

Peripheral Catheters: dilute to <600mOsm/L (1:4) in D5W

For

Address Date

℞

Magnesium Chloride 20% (1.97mEq/ml)

Bolus 0.3mEq/kg diluted 1:4 in D5W over 20 minutes with EKG

0.75 mEq/kg/day CRI in fluids

REFILL TIMES , M.D.

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Summary

Point of Care Diagnostics

- Repeatable!
- Inexpensive!
- Impactful to fully resuscitate pet

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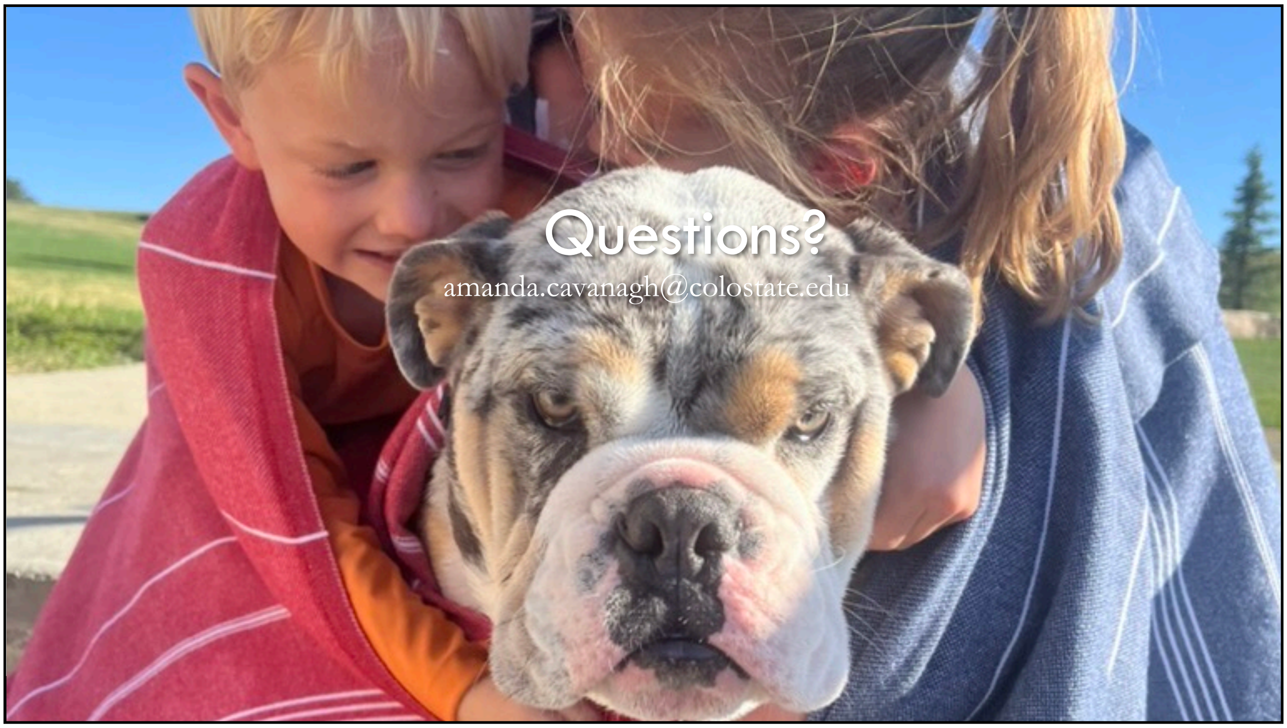

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