CREATING CLARITY

“Test something, no, test EVERYTHING….STAT!’

Choosing and interpreting useful diagnostics in emergency patients.

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IDEXX Medical Education Specialist

Before we talk about which tests let’s talk about when…

Never delay necessary treatment to run diagnostics

- Stabilize respiratory status
  - Patent airway
  - Oxygen by least stressful method
  - Chest tap
- Support cardiovascular system
  - IV or IO fluids, medications
  - Stop bleeding
  - Blood products
- Cover pain, anxiety, stress
  - Narcotic analgesics
  - Acepromazine (cautious)

A

B

C

Point-of-care ultrasound (POCUS)

- Extension of physical exam
- Simultaneous with stabilization
- Cullen’s sign – bruise around umbilicus with hemoabdomen
- POCUS for perfusion impairment – CVC as crosses diaphragm – collapse w resp cycle = hypovolemia
- T-FAST
- A-FAST

Thoracocentesis can be life saving (and diagnostic)

- Sternal recumbency with minimal restraint
- Butorphanol 0.2-0.4 mg/kg IV, IM
- Topical lidocaine cream
- 18 g IV cath for dogs, 21 g ¾ inch butterfly for cats or small dogs
- 7-9th intercostal space
- Slightly below costochondral junction (avoid internal thoracic artery)
- Direct needle ventrally
- Avoid intercostal artery (runs along caudal edge of rib)

It all boils down to DO2

DO2 = CO (cardiac output) x CaO (arterial oxygen content)

Stroke volume x Heart rate

- Contractility
- Preload
- Afterload

Bound to Hb + Dissolved in blood

Hb x 1.34 x SaO2 → 19.7 ml O2/100 ml (98.5%)

PaO2 x 0.003 → 0.3 ml O2/100ml (1.5%)

Perfusion parameters and blood pressure

Perfusion markers – aim for normal.

- Mentation
- HR, pulse quality
- Mucous membrane color, CRT <2 sec
- Lactate <2.5 mmol/L or serial improvement
- Base excess >4 mmol/L
- Urine output 0.5-1.0 ml/kg/h

Normal blood pressure ≠ adequate perfusion

$$BP = CO \times SVR$$

Palpable femoral pulse ≠ normal BP

- Femoral pulse = systolic BP >50-60 mm Hg
- **Dorsal pedal/metatarsal pulse = systolic BP >80-90 mm Hg**
- Pulsus deficits → arrhythmia
- Pulsus paradoxus (pulse weak during inspiration) → pericardial effusion
- Don’t delay CPR

Which lab tests and when?

- PCV/TS
- BG
- Lactate

} Immediately

- Electrolytes
- Venous blood gas
- C-reactive protein

} ASAP

- CBC, biochemical panel, urinalysis
- Coagulation tests (as needed)
- Store samples for add-on testing

} ASAP

Is this trauma dog bleeding internally?

Time	T	P	R	PCV	TS	DEXT	AZO	Na	K	Lact	BP	UOP
10 am	100	160	Pant	45	5.0	160	5–15	147	4.4	4.4	100	

2 hours after aggressive rapid large volume IV fluids…

Time	T	P	R	PCV	TS	DEXT	AZO	Na	K	Lact	BP	UOP
10 am	100	160	Pant	45	5.0	160	5–15	147	4.4	4.4	100	
Noon	98	**280**	Pant	**24**	**1.2**	142	**30-40**	144	4.0	**6.5**	78	80
2 pm												
4 pm												
6 pm												

What PCV *with* TS can tell you about your patient…

PCV	**TS**	
N	N	normal or acute haemorrhage
↓	↓	haemorrhage
↓	N	haemolysis
↑	↑	dehydration
↑	N	polycythaemia

Repeat every 20-30 minutes until stable, then q8-12h

3 main causes of anaemia

Chronic disease/inflammation

Haemorrhage

Haemolysis

Best indicator of regeneration?

MCV

MCHC

Reticulocyte percent

Absolute reticulocyte count

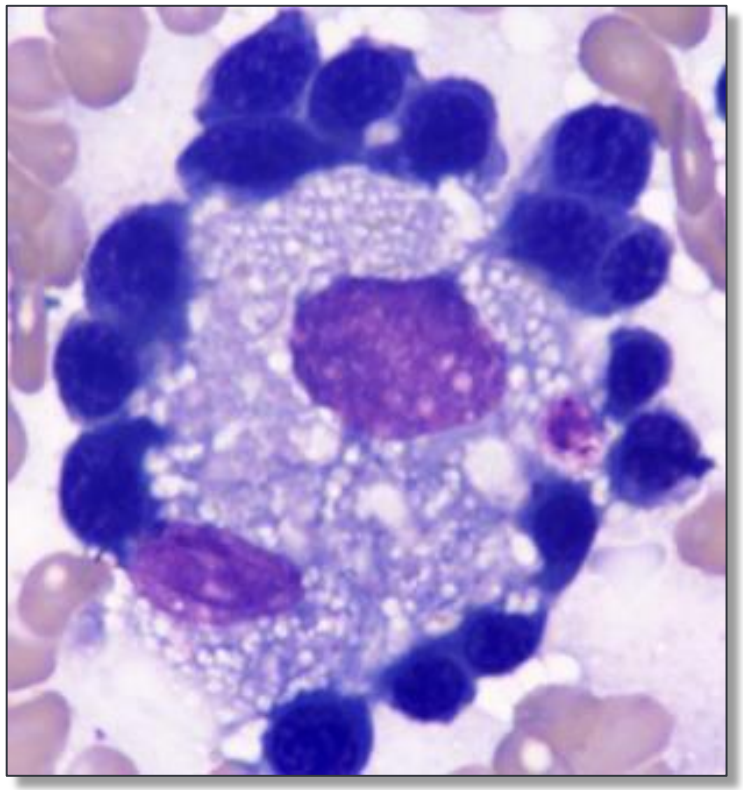
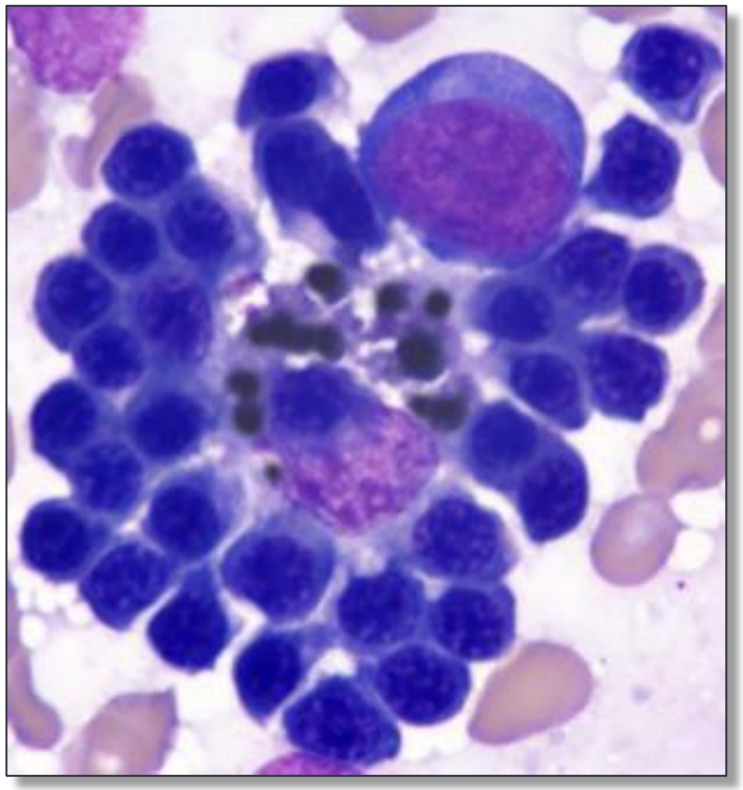
Earliest indicator of iron deficiency?

MCV

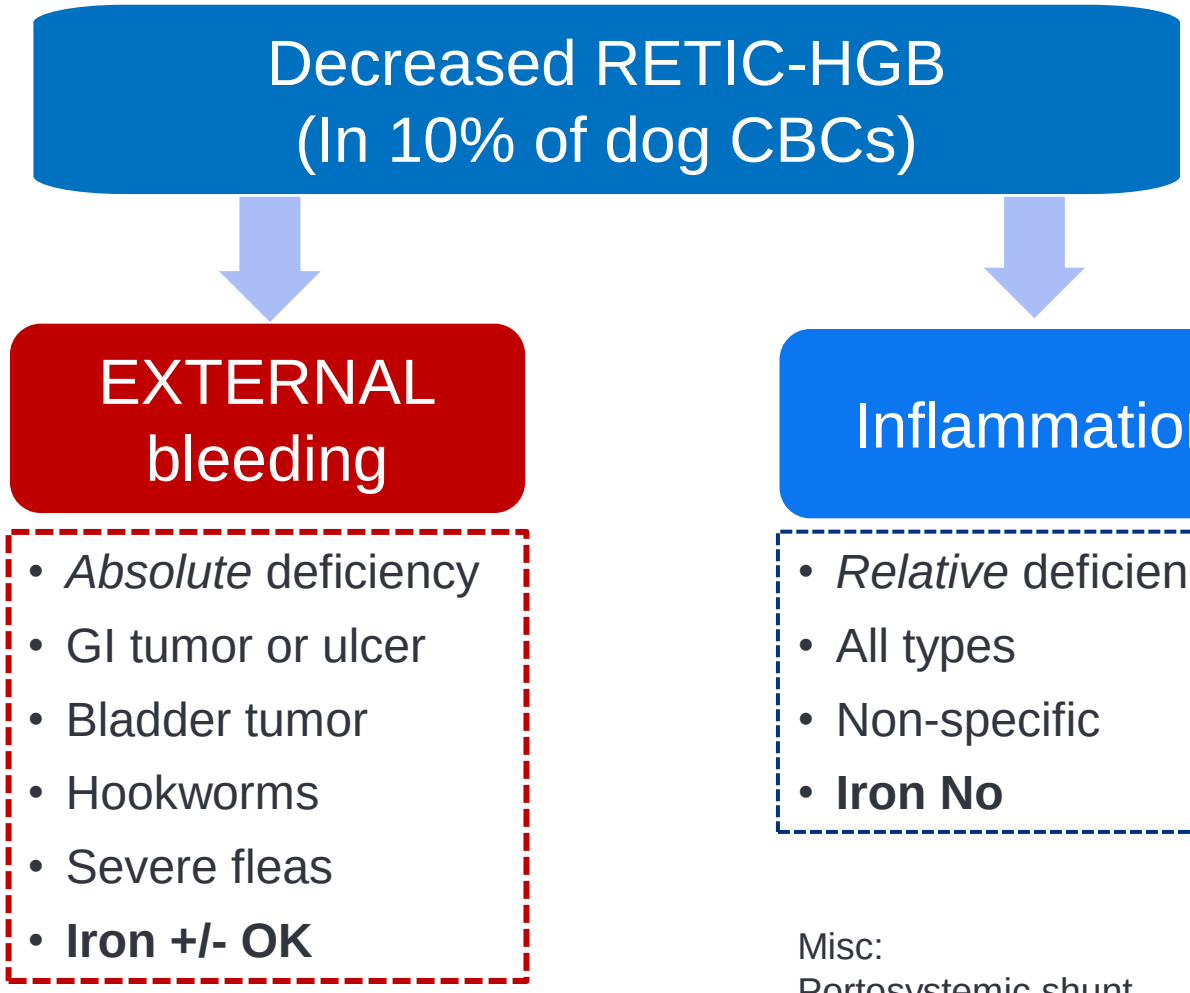
MCHC

Reticulocyte haemoglobin concentration

RETIC-HGB indicates iron availability in bone marrow: *decreases* with…

External bleeding (true iron deficiency)	Inflammation (relative iron deficiency)
	

Detect decreased iron availability in **days** (not months).



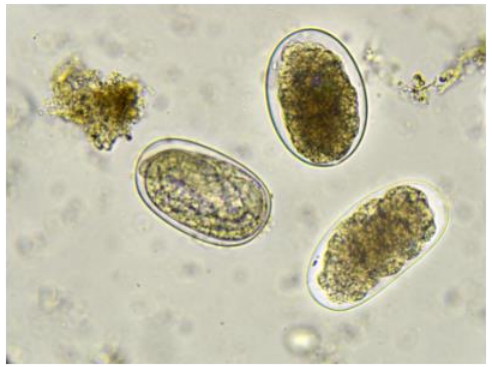
>90% of the time

Misc:
Portosystemic shunt
Asian breeds (normal variation)

Normal PCV does not rule out haemorrhage or haemolysis.

Reticulocytosis without anaemia

(≈10% of dogs & cats worldwide. Higher mortality.)

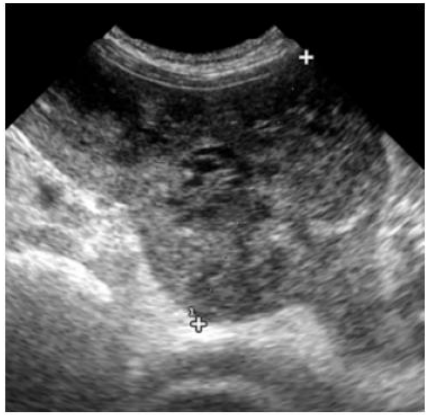


Healthy excited pet

- Splenic contraction
- *Mild* bleeding/haemolysis
- Hookworms

‘ADR’ or older pet

>135,000/uL



- Neoplasia
- *Occult* bleeding/haemolysis
- Infection
- Cardiac, respiratory
- Other…

Blood glucose

- <3 mmol/L
  - 50% dextrose 0.5-1.0 ml/kg (0.25-0.5 gm/kg) over 5 min, dilute 1:4 if peripheral catheter
  - Feed if asymptomatic insulinoma suspect
  - Insulin:glucose panel (can’t interpret if BG>3 mmol/L)

- >16 mmol/L
  - Stress?
  - Ketones?
  - Rehydrate, restore volume to determine true severity

Lactate: indicator of oxygen delivery (perfusion)

- Poor perfusion (↓ DO2) most common cause of increased lactate
- Increase proportional to perfusion deficit
- Initial value *may* be prognostic, e.g., GDV, trauma, IMHA…
- Change in lactate more important, if not improving change something
- Daily in hospitalized patients to detect occult/early perfusion deficits
  - May increase before PE signs of poor perfusion
  - Acute increase in stable patient
    - Occult hypovolemia (3rd space)
    - Ischemia (torsion)
    - Increased metabolism (shiver, seizure…)

Serial lactate for prognosis: some guidelines…

- **Trauma** >4.0 predicted non-survival
- **IMHA** >4.4 worse survival, <2 within 6 hr of admission all survived
- **Septic peritonitis** persistent increase ≥6 hr non-survival
- **Post-op** increasing lactate non-survival
- **GDV** decrease of >4 or 42% from pre- and post-resuscitation before surgery
  good prognosis

- **BUT** – some animals with high initial lactates that don't decrease survive – so try!

Lactate bottom line:

- Measure in all critical patients (consider in all hospitalized patients)
- If increased aggressive treatment to restore DO2 (blood products if necessary)
- Should see rapid normalization
  - Should decrease by 50% every 1-2 h
  - If not investigate further and adjust treatment
- Rough guidelines for degree of decreased perfusion (normal <2.5 mmol/L)
  - Mild 3-5 mmol/L
  - Moderate 5-7 mmol/L
  - Severe >7 mmol/L

The good news about blood gas:

- Base excess on venous blood gas best perfusion indicator
  - More specific for ↓ DO_2 than lactate
- **Can** assess ventilation – $PvCO_2 \approx PaO_2$
- **Cannot** assess lung oxygenating ability – ignore PvO_2

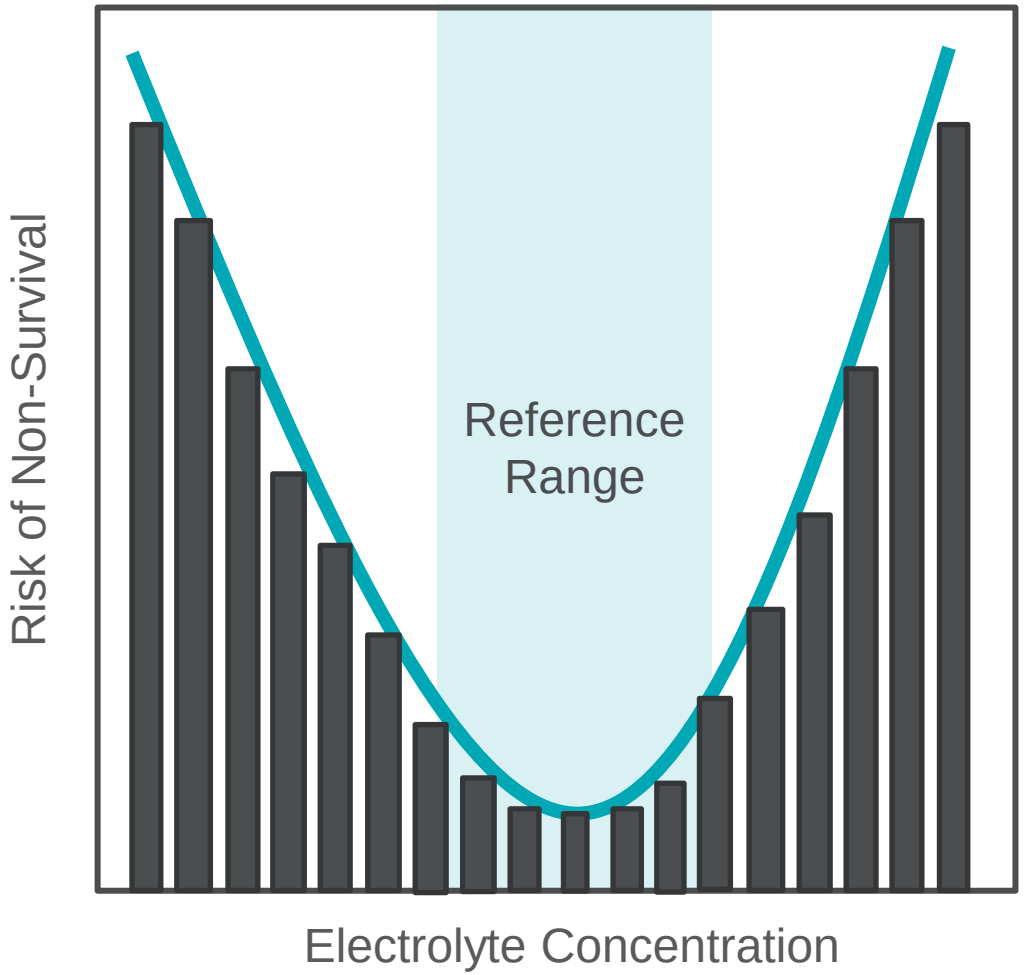
Therefore:

- Arterial only with severe respiratory disease

Rule of 4:	
pH	7.4
PCO_2	40
HCO_3^-	24
BE	-4

Electrolytes essential for cell function

- Abnormal = poor outcome
  - More abnormal = worse outcome
- Determine degree of illness
- Guide emergency treatment
- Monitor response to treatment
- Abnormalities may develop during treatment
  - Fluid therapy
  - Diuretics



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Goggs R, De Rosa S, Fletcher DJ. Multivariable analysis of the association between electrolyte disturbances and mortality in cats. J Feline Med Surg. 2018 Dec;20(12):1072-1081.

Hyperkalemia

- Absolute K value not predictive of arrhythmia
- Rate and magnitude of increase important
- Ca, Na, Mg, acid-base involved

- Bradycardia (rarely tachycardia) and hypothermia specific for K>8

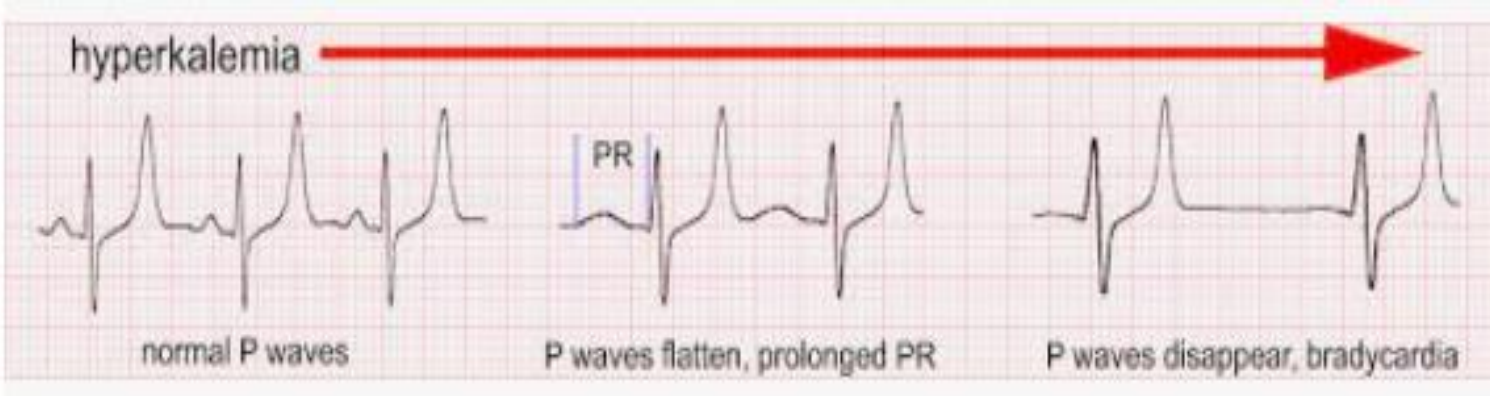
- **Sino**ventricular rhythm
  - SA node fires, impulses transmitted to AV node and ventricles by internodal pathways
  - P waves absent because atrial myocytes not activated

Rule out pseudohyperkalemia

- Thrombocytosis

- Haemolysis in Japanese breed
  - High potassium mutation first in Korean dogs, in 10/13 Japanese breeds
  - Intracellular K concentration 35x higher

- EDTA contamination of serum sample
  - Hyperkalemia with hypocalcemia


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

Treat life-threatening hyperkalemia

- IV isotonic crystalloid (ok if contains K)
- 10% calcium gluconate
  - Cardioprotective, 20 minute duration
  - 0.5-1.5 ml/kg (dilute to 3.33%) over 10-15 minutes
- Regular insulin and 50% dextrose
  - ¼ U/kg with 2 gm 50% dextrose/U of insulin
- HCO3 rarely necessary
  - Consider if pH<7.1, HCO3<12 mmol/L
  - BW (kg) x 0.3 x (24 – HCO3) = mEq HCO3 deficit
  - Give ½ deficit IV over 30 minutes
  - If pH not >7.2 remainder in IV fluids over 2-4 hr

You find hypokalemia and hypertension in a cat…

Primary hyperaldosteronism

- Most common adrenal disease in cats
- Hypokalemia, hypertension
- Progressive renal / cardiac damage due to aldosterone AT1 receptor effects
- Unilateral adrenal carcinoma or adenoma most common
- Diagnosis → adrenal mass, ↑ basal aldosterone + hypokalemia usually sufficient
- Treatment
  - Surgery → Adrenalectomy
  - Medical → Spironolactone 2 mg/kg q12h, amlodipine 0.1–0.2 mg/kg q24 h, K gluconate 1–6 mEq/cat q12h

Fluid of choice for adrenal crisis?

Chloride is special

- Like sodium important for osmolality
- Unlike sodium guide to acid-base balance
- Chloride is a weak metabolic acid
  - High chloride = metabolic acidosis
  - Low chloride = metabolic alkalosis
- If chloride ‘moves’ more than sodium there is an acid-base problem
  - Ideally confirm with blood gas pH and bicarbonate

Chloride low: hydration or acid-base abnormality?

- Na 139 mEq/L (142-150 mmol/L)
- Cl 80 mEq/L (105-118 mmol/L)

- Difference from reference interval
  - Na 3 below lower limit
  - Cl 25 below lower limit

- Corrected Cl = (Normal Na/Measured Na) x Measured Cl
  - 146 (142+150/2)/139 x 80 = 84

3-yr-old FS Labrador retriever presents for vomiting

VetStat results: venous

pH	7.5	
HCO_3	32 mmHg	
pCO_2	40 mmHg	
Na	119 mEq/L	(144 – 160)
K	2.7 mEq/L	(3.5 – 5.8)
Cl	69 mEq/L	(109 – 122)
AG	22	(12 – 24)

Rule of 4:
pH 7.4
HCO3 24
CO2 40
BE -4

Tests on effusion:

- Glucose fluid >20 mg/dL lower than blood glucose = septic effusion
- Lactate fluid >2 mmol/L higher than blood = septic effusion
- PCV fluid ≈ PCV of peripheral blood = haemoperitoneum
- Creatine or K of fluid ≥ 2x blood = uroperitoneum
- Bilirubin in fluid ≈ blood = bile peritonitis
- Triglycerides of fluid ≥2x blood = chyloabdomen
- Spec cPL >500 = acute (acute on chronic) pancreatitis

Traditional and newer markers to assess kidneys

Functional markers (serum)

BUN

CREA (70-75% function loss before increase)

SDMA (30-40% function loss before increase)

FGF-23 maybe someday

Often normal w/in 1st 48 h of acute injury

Injury markers (urine)

Granular casts

Renal epithelial cells

Proteinuria

Normoglycemic glucosuria

Cystatin B now

Detect subclinical kidney injury before ↓ GFR

GFR biomarker ideally: (*Function*)	BUN (early 1900s)	Creatinine (1926)	SDMA (2015)
Produced at constant rate			X
Freely filtered at glomerulus	X	X	X
No tubular secretion/reabsorption			X
No nonrenal elimination		X	X
Physiologically inert		X	X

- BUN > creatinine = dehydration, upper GI bleed, high protein diet, glomerular
- ↑ Creatinine only = increased muscle mass, recent high protein meal…
- ↑ SDMA = decreased GFR

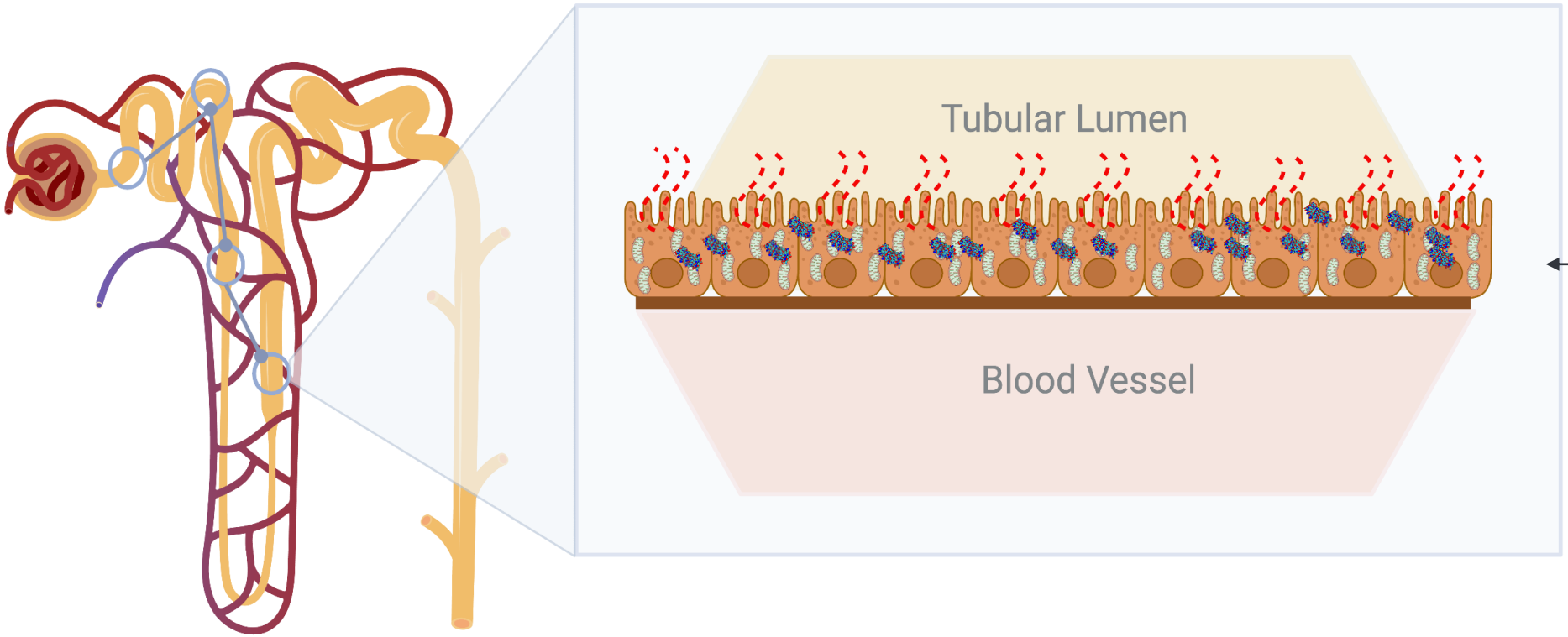
Hot Topic: active ***injury*** biomarkers.

- Released from stressed, damaged, ruptured kidney cells
- Presence in URINE sensitive predictor of **acute or sustained** renal tubular cell injury
- Epithelial damage present in AKI prior to increase in functional markers
- Degree of epithelial damage associated with disease progression and survival

"…IRIS encourages more studies to be initiated and ultimately published in peer-reviewed journals to provide the evidence for their use in clinical practice."

Urine Cystatin B detects *active* kidney tubular damage

(ALT of the kidney)



Harjen HJ, Anfinsen KP, Hultman J, et al. Evaluation of urinary clusterin and cystatin B as biomarkers for renal injury in dogs envenomated by the European adder (Vipera berus). Top Companion Anim Med. 2022;46:100586. doi:10.1016/J.TCAM.2021. 100586

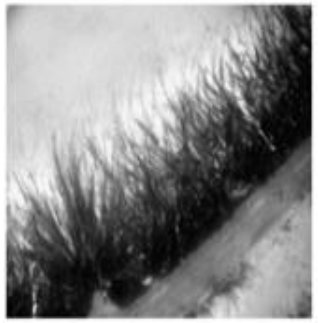
Starybrat D, Jepson R, Bristow P, et al. Prospective evaluation of novel biomarkers of acute kidney injury in dogs following cardiac surgery under cardiopulmonary bypass. J Vet Emerg Crit Care. 2022; 32(6):733-742. doi:10.1111/VEC.13250

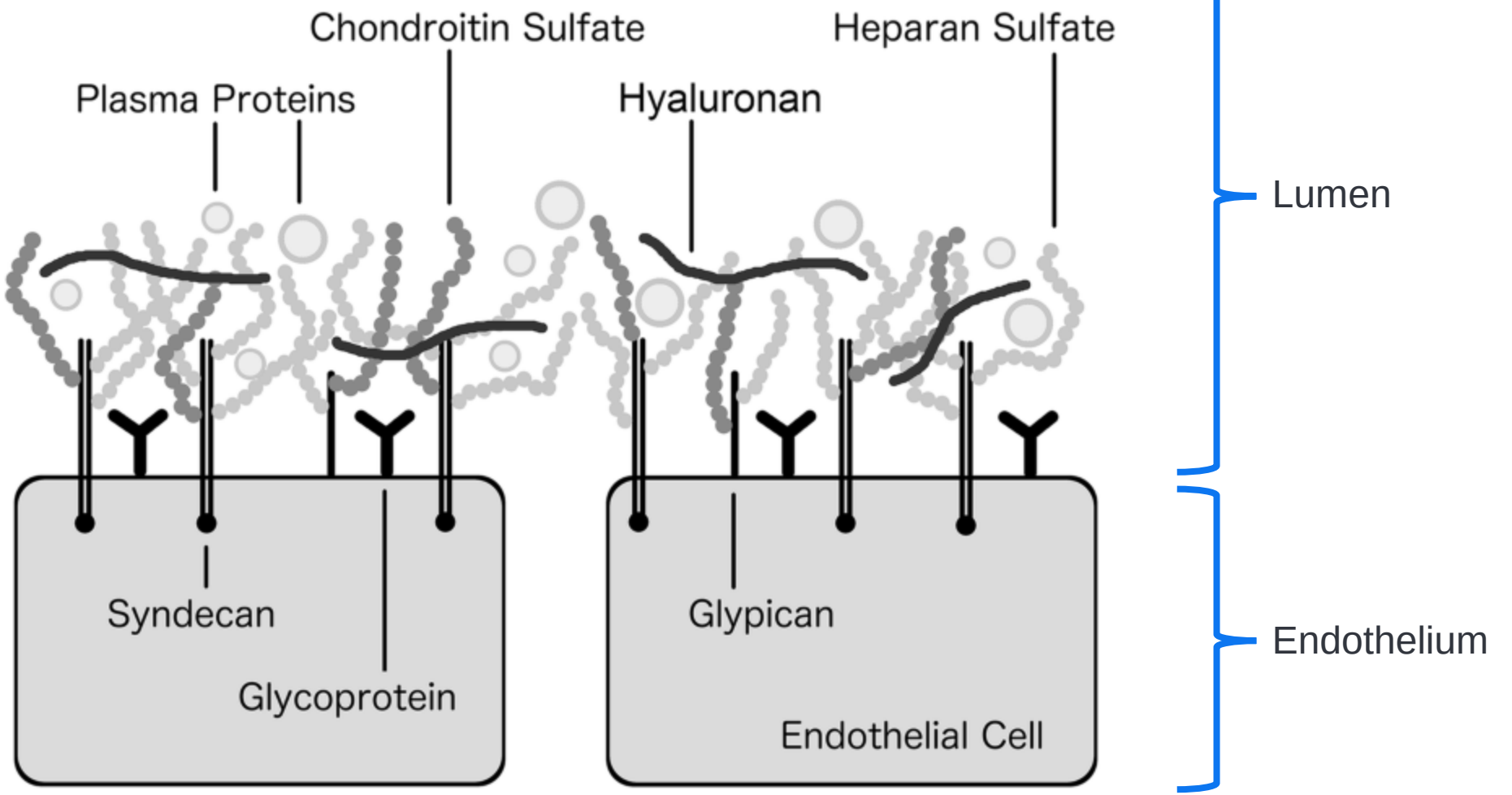
Consider Cystatin B with:

- AKI
  - Confirm active injury following toxin exposure
  - Monitor treatment and recovery from acute injury event
  - Monitor high risk patient on NSAIDs
  - Monitor kidneys during shock, heat stroke, pancreatitis, envenomation…
- CKD
  - Predict progression of Stage 1 CKD in dogs
  - Identify early CKD (?)
- Others…??

Fluid therapy revamp: less may be more.

- Fluids are drugs – avoid overdose
- Restore euvolemia and euhydration
- Resuscitate with calcium-containing isotonic crystalloid (LRs, Hartmann's)
  - Normosol-R, Plasmalyte-148 – no Ca, acetate vasodilatory (?)
- Hypertonic saline if critical especially large dog, traumatic brain injury…
- Switch to maintenance fluid once resuscitated
  - 0.45% NaCl in 2.5% dextrose, 1:1 dilution LRs with D5W, K supplementation prn
- 0.9% NaCl – acidifying, chloride affect on renal vasculature (vasoconstriction)
- Use natural colloid, i.e., plasma, canine-specific albumin
- Avoid synthetic colloids unless no other options




Chondroitin Sulfate
Heparan Sulfate
Plasma Proteins
Hyaluronan
Syndecan
Glycoprotein
Glypican
Endothelial Cell
Lumen
Endothelium
Interstitium

EG damaged by:

- Sepsis/SIRS, e.g., acute pancreatitis
- Trauma
- Ischemia-reperfusion (e.g., feline aortic thromboembolism)
- Fluid resuscitation with larger volume crystalloids

- Results in:
- Microcirculatory collapse (vasodilatory shock)
- Tissue edema
- Proinflammatory state
- Hypercoagulability, thrombosis

Resuscitation: low and slow

Isotonic crystalloid 10-15 ml/kg dog, 5-10 ml/kg cat x 2-3

Hypertonic saline 7.2% 4 ml/kg once if critical

Then fresh frozen plasma, canine specific albumin

- FFP 10-20 ml/kg
- Canine-specific albumin 16%, 1 g/kg

IV fluids after nephrotoxin exposure: help or hurt?

- NSAIDs, lily (cat), grapes (dog)
- Fluids at 2-3x maintenance 2-3 d to induce diuresis standard recommendation
  - No evidence for increased toxin excretion or prevention of tubular damage
  - Increases ANP which can degrade EG
  - Kidney interstitial edema → ↑ intraparenchymal pressure (rigid capsule) – ↓ perfusion, ↓GFR
- Excessive fluid may *contribute* to AKI rather than prevent it.
- No mandatory hospitalization for IV fluids
- Use basic principles
  - Correct dehydration/hypovolemia, replace losses from V/D, maintenance if inappetence
  - Discharge when eating and drinking normally w/o excessive losses

If azotemia worsens on IV fluids consider *decreasing* fluid rate.

Especially if total daily volume exceeds maintenance or if weight gain.

STOP fluids, +/- Lasix 1-4 mg/kg IV

In an emergency the first pulse to take is your own.

Thank you!