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VMX
VETERINARY MEETING & EXPO

DIAGNOSIS AND MANAGEMENT OF COMMON CARDIAC COMORBIDITIES.

BILL SAXON, DVM, DACVIM, DACVECC

(NOT BOARD-CERTIFIED CARDIOLOGIST)

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CONFLICT OF INTEREST DISCLOSURE:

I have financial interest, arrangement or affiliation with:

- IDEXX, full-time employee.

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VETERINARY MEETING & EXPO

Cardiac patients and:

Kidney disease
Hypertension
Endocrine disease
Anesthesia
Corticosteroids

Oxygen delivery (DO2) =

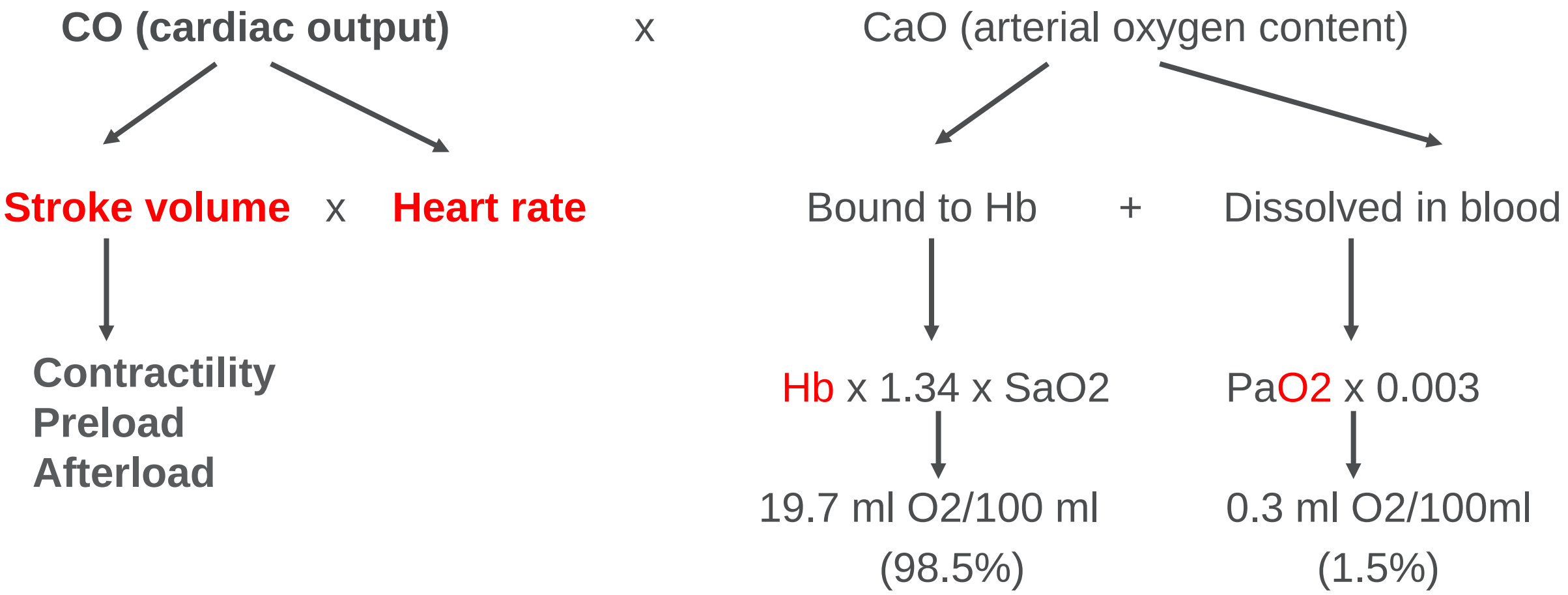


Image courtesy Cardiac Education Group
www.cardiaceducationgroup.org

BSAVA BRITISH SMALL ANIMAL VETERINARY ASSOCIATION

PAPER

Cardiovascular–renal axis disorders in the domestic dog and cat: a veterinary consensus statement

J. L. Pouchelon*, C. E. Atkins†, C. Bussadori‡, M. A. Oyama§, S. L. Vaden†, J. D. Bonagura¶, V. Chetboul*, L. D. Cowgill||, J. Elliot**, T. Francey††, G. F. Grauer‡‡, V. Luis Fuentes§§, N. Sydney Moise¶¶, D. J. Polzin||||, A. M. Van Dongen*** and N. Van Israël†††

Journal of Small Animal Practice (2015) 56, 537–552 DOI: 10.1111/jsap.12387

IDEXX

How does heart disease affect kidneys? $CvRD_H$

Traditional

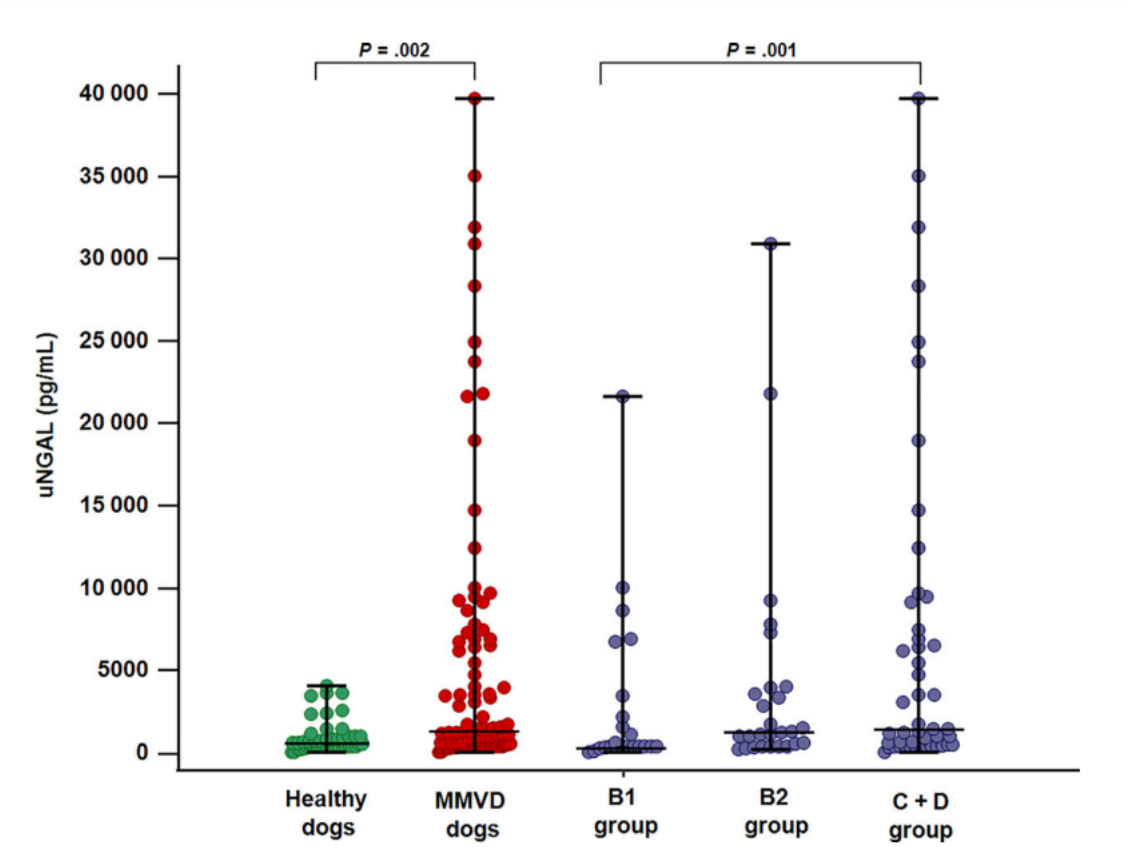
- Decreased cardiac output
- Decreased renal perfusion
- Decreased GFR
- Increased functional markers (blood)
  - BUN, creat, SDMA

Revised

- Renal congestion
- Inflammation
- Tubular damage
- Increased injury markers (urine)
  - Cystatin B, granular casts

Blood *and* urine needed to assess heart disease affect on kidneys.

Subclinical *tubular* damage in all MMVD stages



Troia et al. JVIM 2022

Azotemia and kidney injury in cats with CHF

- Azotemia present in 44% at diagnosis, up to 75% during treatment
- “Kidney injury” (creat increase ≥0.03 mg/dL over any time frame) in 66%
  - Injury markers not evaluated
- KI risk highest during initial treatment in hospital
- ACEi - fewer life-time KI events, smaller increase in creatinine
  - At least safe if not renoprotective
- Azotemia and KI did not influence survival
  - Relieving renal congestion more important?
- Only age correlated with outcome

Rogg S, et al. JVIM. 2025;39(1):e17254. doi:10.1111/jvim.17254

Your cardiac patient is azotemic. Fluids? Furosemide? Both?

- Fluids
  - LRs (lowest Na of replacement fluids) IV for hypovolemia
  - LRs or 0.45% NaCl in 2.5% dextrose IV or SC for dehydration
  - **Water via feeding tube for mild dehydration**

- Furosemide
  - If normal volume and hydration
  - IV route preferred

- Probably not both
  - Withhold furosemide until volume / hydration restored and signs of overload
  - Mild hypovolemia (even azotemia) better tolerated than persistent volume overload

Hypovolemia vs dehydration

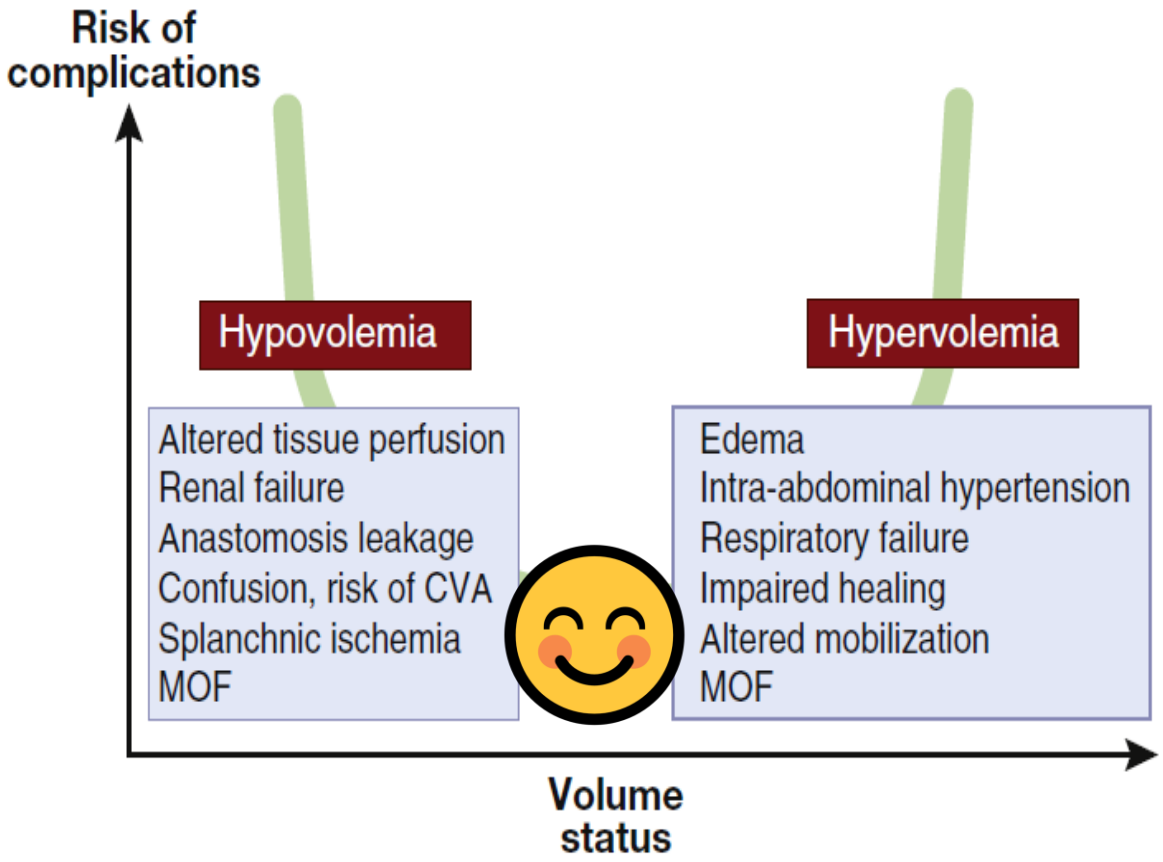
Hypovolemia (rapid)

- Loss from vascular space
- Impaired tissue perfusion
- Parameters
- Balanced crystalloid IV, IO
  - No additives
- Correct 1-2 hr

Dehydration (gradual)

- Loss from interstitial space
- Volume normal unless severe (10-12%)
- Parameters
- Balanced crystalloid IV, SC
  - Additives (e.g., KCl prn)
- Correct 4=24 hr

Get started and monitor, monitor, monitor…



Fluid therapy with cardiac disease

- Stable heart patient needs fluids (e.g., general anesthesia)
  - LRs at 2-5 ml/kg/hr
  - 0.45% NaCl in 2.5% dextrose with KCl if more severe heart disease or you're worried
- CHF patient is hypovolemic (e.g, vomiting)
  - LRs to restore volume
  - 0.45% NaCl in 2.5% dextrose with KCl for ongoing fluids
- CHF patient is dehydrated (e.g., cat on furosemide)
  - Water via NE or NG tube
  - SC fluids
  - LRs or low sodium fluid

  } Mild, 5-7%
- Pericardial effusion with hypotension
  - LRs to increase volume to overcome increased filling pressure

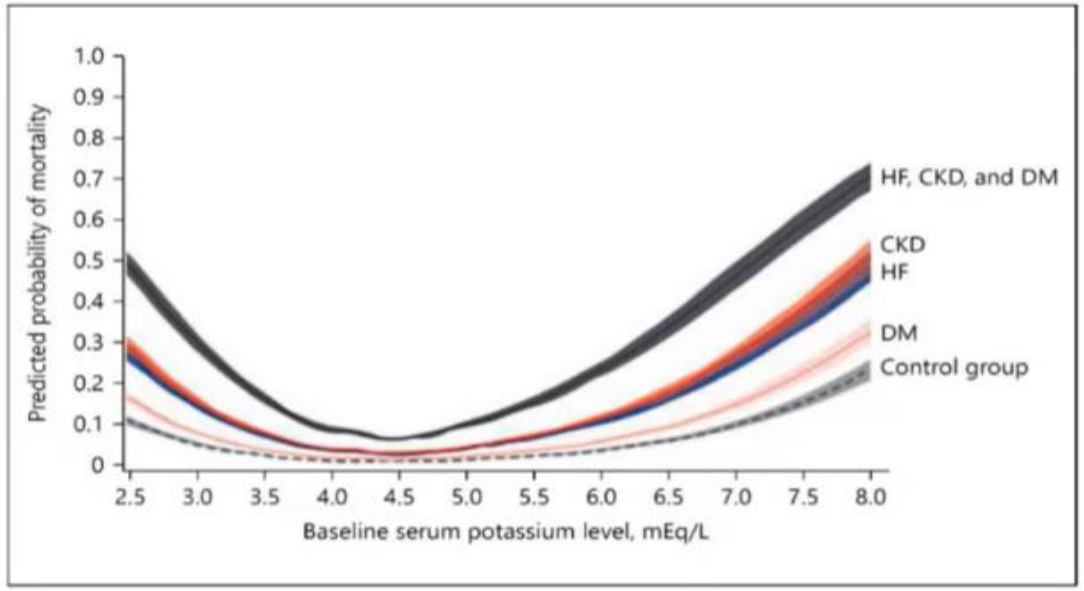
VETERINARY PRACTICE GUIDELINES

2024 AAHA Fluid Therapy Guidelines for Dogs and Cats

Mariana Pardo, BVSc, MV, DACVECC†, Erin Spencer, MEd, CVT, VTS (ECC)†,
Adesola Odunayo, DVM, MS, DACVECC, Mary L. Ramirez, DVM, DABVP (Canine and Feline),
Elke Rudloff, DVM, DACVECC, cVMA, Heidi Shafford, DVM, PhD, DACVAA, Ann Weil, DVM, MS, DACVAA,
Ewan Wolff, DVM, PhD, DACVIM (Small Animal Internal Medicine)

Monitor for hypo- not just hyperkalemia

(Mortality increased with every 0.1 mEq/L change <4 mEq/L and >5 mEq/L)



Collins et al Am J Nephrol 2017

Hypokalemia with heart disease: prevent and manage

- K supplementation in 1/3-1/2 cats and 1/3 dogs in heart failure (referral)
- K <4 prior to diuretics → supplement
- K normal prior to diuretics → recheck lytes 7 days
  - ≥4 no supplementation
  - <3.7 supplement
- K at 4 week recheck
  - ≥4.5 on supplementation stop
  - <3.7 start or increase supplement

Potassium gluconate:
Cats 2-6 mEq/d divided q8-12
Dogs 2.2 mEq/10 kg

How does kidney disease affect the heart? $CvRD_K$

- AKI
  - Hypovolemia → ↓ preload
  - Electrolyte, acid-base, electrolyte abnormalities, cytokines → ↓ contractility, arrhythmia
  - Acute decompensation → CHF

- CKD
  - Systemic hypertension → ↑ afterload
  - Electrolyte, acid-base, electrolyte abnormalities, uremia → ↓ contractility
  - Progressive cardiac ‘stress’

Detect *pre-azotemic* kidney disease to protect heart

- AKI
  - **Injury markers in urine up to 48 h before increased functional (GFR) markers in blood**
  - Complete urinalysis (cysto not necessary) evaluate for:
    - Granular casts, euglycemic glucosuria, proteinuria
    - Cystatin B

- CKD
  - Creatine, SDMA trending up but within reference interval
  - USG decreasing over time
  - Body weight decreases early with CKD in cats (up to 3 years before diagnosis)
  - Persistent renal proteinuria = proteinuric CKD (no azotemia in Stage 1)

CONSENSUS STATEMENT | Open Access

ACVIM consensus statement: Guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats

Mark J. Acierno, Scott Brown, Amanda E. Coleman, Rosanne E. Jepson, Mark Papich, Rebecca L. Stepien, Harriet M. Syme

First published: 24 October 2018 | https://doi.org/10.1111/jvim.15331

Normotensive (minimal TOD risk)	SBP <140 mm Hg
Prehypertensive (low TOD risk)	SBP 140-159 mm Hg
Hypertensive (moderate TOD risk)	SBP 160-179 mm Hg
Severely hypertensive (high TOD risk)	SBP ≥180 mm Hg

New normal

Assess kidneys, endocrine

Treat here

Target organ damage

Acclimate 5-20 minutes out of carrier, cuff width 30-40% circumference forelimb, tail base.

IDEXX

Hypertension: ≥80% secondary to kidney or endocrine disease

- Cat
  CKD, hyperthyroidism, primary hyperaldosteronism, glomerulopathy, pheochromocytoma

- Dog
  CKD, AKI, Cushing's, diabetes mellitus, glomerulopathy, pheochromocytoma, hypothyroidism (rare)

Cats:
Amlodipine:
<200 mm Hg 0.625 mg SID
≥200 mm Hg 1.25 mg SID

Telmisartan:
2 mg/kg once daily

Dogs:
Benazepril:
0.25-0.5 mg/kg SID

Amlodipine:
0.125-0.25 mg/kg SID

Telmisartan:
1-2 mg/kg SID

Some endocrine comorbidities

Primary hyperaldosteronism (PHA) in cats

- Most common adrenocortical disease in cats
- Hypertension, hypokalemia
- 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

Is it PHA or CKD?

- PHA more likely if:
  - Phosphorous normal or low
  - Metabolic alkalosis
  - Increased CK
  - Hypertension and hypokalemia disproportionate to degree of azotemia
    - Hypokalemia unresponsive to oral potassium supplementation is a clue
  - Adrenal mass vs small irregular kidneys on abdominal ultrasound

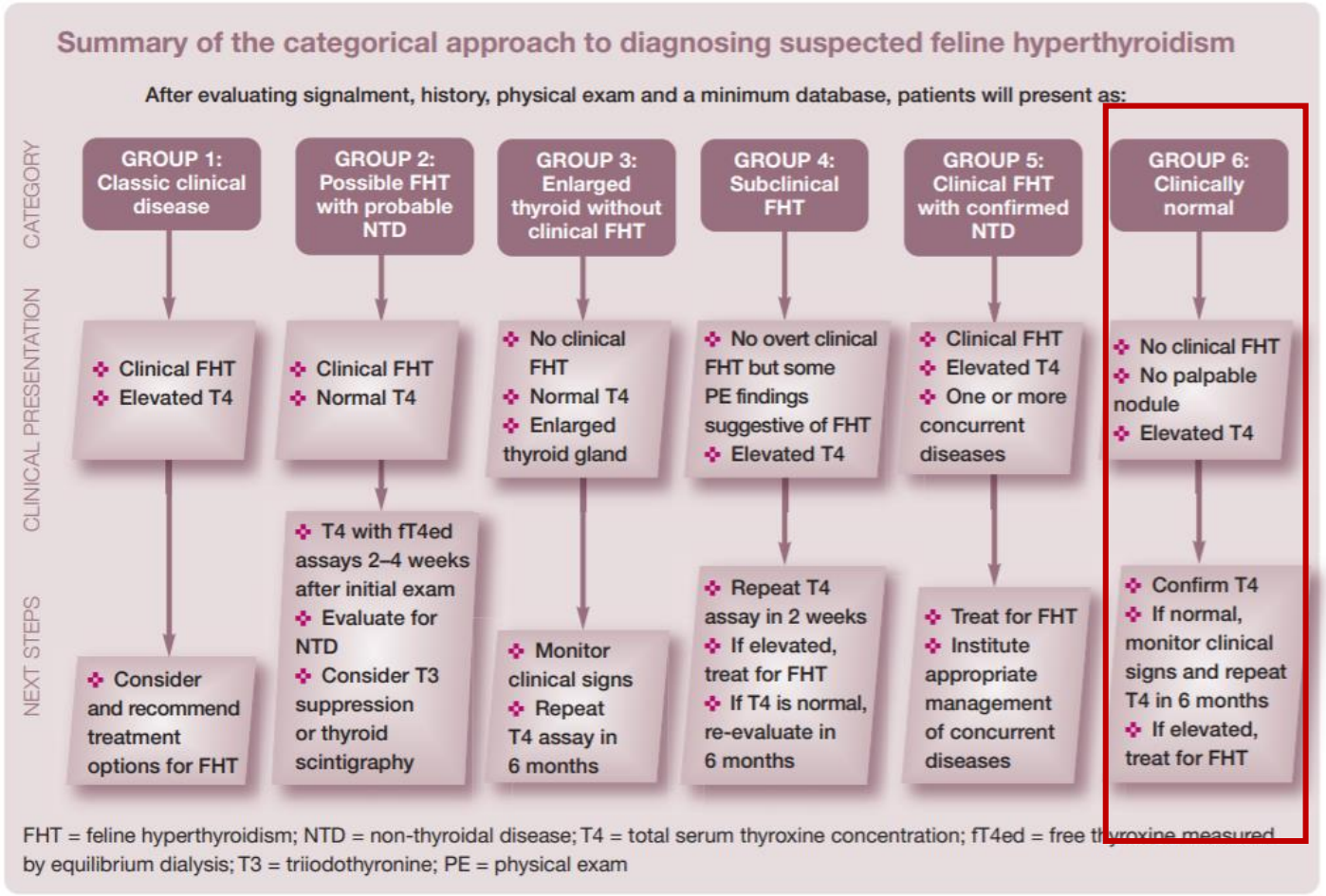
PHA and CKD can co-exist. Maintain awareness.

SPECIAL ARTICLE

Journal of Feline Medicine and Surgery (2016) **18**, 400–416

2016 AAFP Guidelines for the Management of Feline Hyperthyroidism

Treat asymptomatic cats with persistent increased T4



How would **you** confirm hyperthyroidism in a cat with borderline TT4?

Repeat TT4?
Free T4
TSH?

Feline hyperthyroidism → cardiac disease, hypertension

- T4 direct and indirect affects on cardiovascular system
  - Hypertension in ≈ 35%, esp if concurrent renal
  - Direct → inotropy, chronotropy
  - Indirect → adrenergic, volume overload (↑ preload, ↓ afterload), systemic hypertension
    - ↑ CO x ↑ HR = ↑ BP
  - Myocardial hypertrophy from volume and pressure overload
- Hypertension develops median 5.3 mo post treatment in ≈20%
  - Monitor BP minimum 6 mo after starting tx
- Clinically relevant thyrotoxic heart disease rare <6 yr of age, CHF uncommon
- Thyrotoxic heart disease indistinguishable from primary cardiomyopathy
- BNP, cTnI normalize 3 months after euthyroid with thyrotoxic heart disease

Tachyarrhythmias with hyperthyroidism

- Atrial tachycardia
- VPC, multiform
- Ventricular tachycardia

- Atenolol: 6.25-12.5 mg/cat q12h
- Diltiazem (if asthma): 7.5 mg/cat q8h (standard formula), 30-60 mg/cat q12-24h (sustained release)

Canine hypothyroidism

- Cardiac signs uncommon unless prior heart disease
- PE abnormalities +/-
  - Muffled heart sounds, weak apex beat, weak pulse, bradycardia
- Treatment precautions with heart disease
  - Start ¼ standard thyroxine dose
  - Increase by ¼ weekly
  - HypoT4 decreases digoxin clearance
    - 8h post pill digoxin level
    - Target range 0.5-1.0 ng/mL

Cushing’s syndrome in dogs

- Rarely causes heart disease – can exacerbate
- Cortisol
  - ↑ SVR by ↑ catecholamine sensitivity and angiotensin production
  - ↑ volume due to mineralocorticoid activity
- Hypertension in 57-82%
  - Increases regurgitant fraction with valvular disease
- Pulmonary hypertension/thromboembolism
  - Right-sided CHF
  - Acute onset respiratory signs
  - Monitor and treat proteinuria

Your cardiac patient needs anesthesia

- Preoperative
  - Correct dehydration prior to general anesthesia
  - Minimize stress-induced tachycardia (premed, fear free)
  - Preoxygenate
- Intraoperative
  - LRs (lowest Na concentration, 140 mEq/L, of balanced crystalloids)
    - 0.45% NaCl in 2.5% dextrose if severe cardiomegaly
  - Max 5 ml/kg/hr dog, 3 ml/kg/hr cat
    - Furosemide 1-2 mg/kg IV and lower fluid rate if volume overload
  - Use agents that maintain cardiac output (no dexmedetomidine)
  - Inotropes (dobutamine) and lower vaporizer setting for hypotensive episodes
  - No fluids if short procedure with IV anesthetics (patient euvolemic, euhydrated)
- Postoperative
  - No fluids with quick return to eating/drinking
  - 0.45% NaCl in 2.5% dextrose at maintenance prn

Corticosteroid-induced CHF in cats

- Injectable and oral forms
- Increased preload (volume)
  - Up to 50% with IM intermediate/long-acting formulations
  - Mineralocorticoid effects
  - Insulin resistance-mediated hyperglycemia causing osmotic fluid shift
- Increased afterload
- NT-proBNP baseline and during therapy?
  - Prednisolone 2 mg/kg/d x 7 d to cats with no prior signs of heart disease
  - >60% increase from baseline in 60%; from normal to >100 pmol/L in 38%
- Increase >60% while monitoring → alternate drug, budesonide

Block CL, Oyama MA. Echocardiographic and biomarker evidence of plasma volume expansion after short-term steroids administered orally in cats. J Vet Intern Med. 2020;34:29–34.

SNAP proBNP

- Consider with
  - Respiratory signs, murmur/gallop, prean, yearly screening >6 y, before fluids/steroids
- Normal rules out moderate to severe heart disease
- Not sensitive enough to screen at risk breeds…

SNAP Feline proBNP Test	Normal	Abnormal	
	 Sample spot is lighter than reference spot.	 Sample spot is the same color as reference spot.	 Sample spot is darker than reference spot.
Cardiopet proBNP Test	<150 pmol/L	150–200 pmol/L	>200 pmol/L

Ranges: Sensitivity (65%-84%) and Specificity (83%-100%)

Hannas et al, JVIM 2020
Harris et al, JVIM 2017
Machen et al, JVC 2014

Causes of CHF in cats with better potential outcomes

Precipitating event common in cats in CHF.

- Consider baseline and serial NT-proBNP (SNAP or quantitative) with:
- Stress
  - Tachycardia-induced CHF
  - Cat friendly, gabapentin before visit…
- IV fluid therapy
  - Especially large volume, e.g., diabetic ketoacidosis, post urethral obstruction diuresis
  - Body weight using gram scale minimum bid
  - Serial BNP
- General anesthesia
  - Adjust anesthetic protocol, careful fluid administration, +/- postpone procedure
  - Minimize stress in perianesthetic period with multimodal therapy
- Corticosteroid-induced CHF

Luis Fuentes V et al. ACVIM consensus statement guidelines for the classification, diagnosis, and management of cardiomyopathies in cats. J Vet Intern Med. 2020;34:1062–1077

THANK YOU!

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Tubules most vulnerable part of nephron.

Impacted first with decreased perfusion, ischemia, toxin, etc.

Markers of tubular injury found in URINE (not blood).

May detect 2 days before functional markers (creat, SDMA) increase.

Injury markers:
Euglycemic glucosuria
Proteinuria
Granular casts (fresh sediment exam)
Cystatin B

Is it PHA or CKD

How would **you** confirm hyperthyroidism in a cat with borderline TT4?

Repeat TT4, free T4, TSH?

Standard proteinuria treatment – updated IRIS recommendations

- Renal diet
- Telmisartan 1.0 mg/kg/day
- Clopidogrel 1-4 mg/kg/day (dogs), 18.75 mg/cat/day if albumin <20.0 mg/L
- If poor response consider:
  - Increasing telmisartan by 1 mg/kg/d up to 3 mg/kg/d
  - Adding amlodipine if hypertension does not resolve with telmisartan
  - Omega-3 fatty acids, 70-80 mg/kg of sum of EPA and DHA
- Monitor:
  - SDMA/creatinine, K, blood pressure 5-7 d after start and dose change of RAAS inhibitor
  - UPC (pooled), albumin + above 3-4 wk after start and dose change
  - q4-6 mo, CBC, panel, UA, UP/C (pooled), blood pressure

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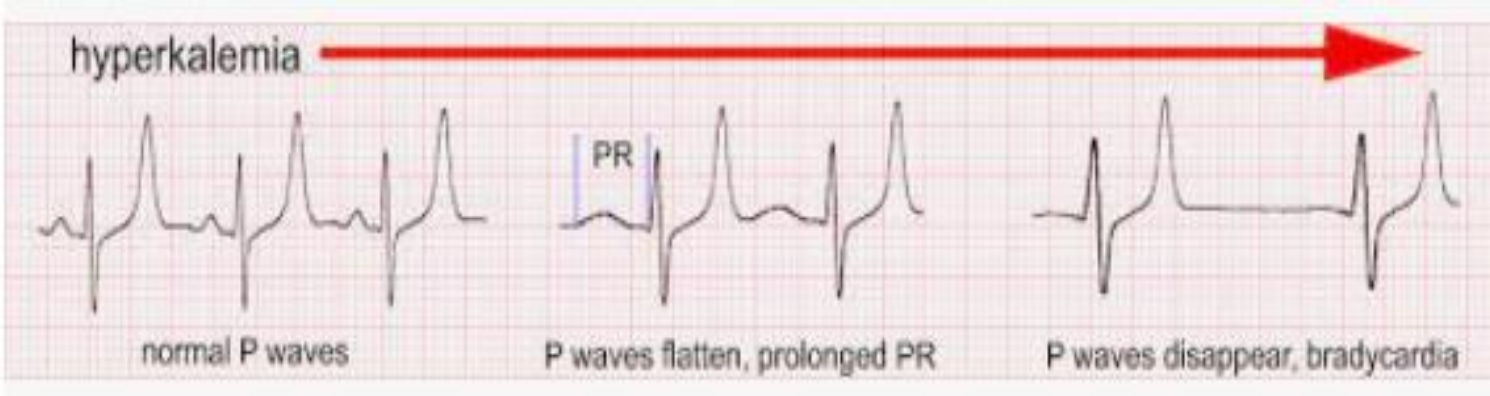
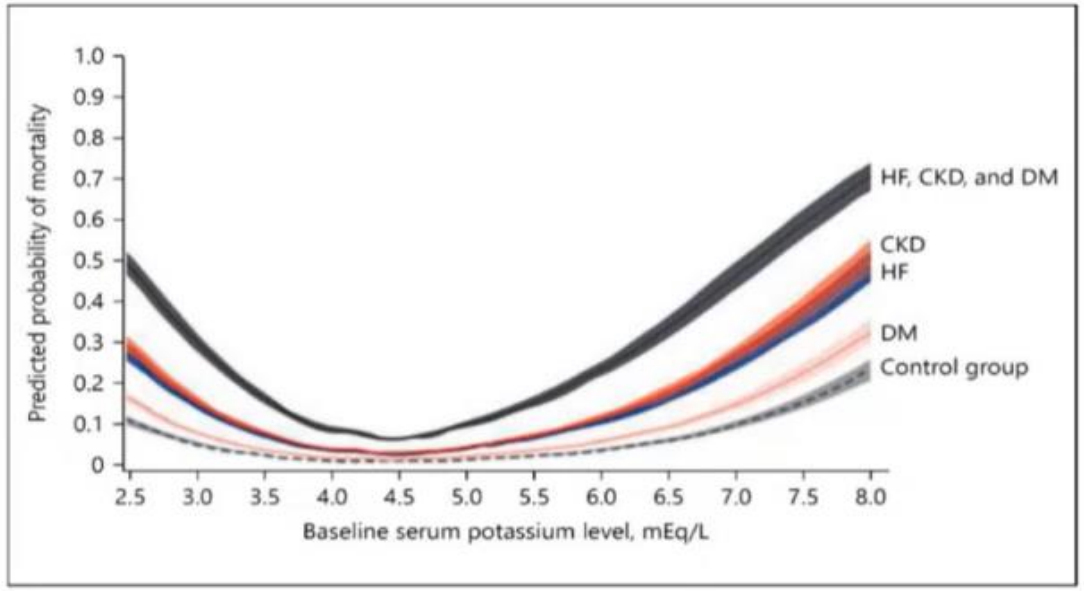
When your cardiac patient has abnormal potassium…


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

Mortality increased with hyper- and HYPOkalemia
(with every 0.1 mEq/L change <4 and ≥5 mEq/L)



Collins et al Am J Nephrol 2017

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

- Sinoventricular 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

- Hemolysis 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

Treat life-threatening hyperkalemia

- IV isotonic crystalloid (ok if contains K)
- 10% calcium gluconate
  - Cardioprotective, buys time
  - 0.5-1.5 ml/kg 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

Hypokalemia causes and exacerbates arrhythmias

- Renal loss
  - Concurrent kidney, thyroid, adrenal (hyperaldosteronism)
- GI loss
  - Vomiting presenting sign in 30% cats in heart failure
- Inappetence
  - Dehydration especially cats on diuretics
  - Mirtazipine early
- Diuretics

When your cardiac patient is in shock…

Fluid therapy revamp: less may be more.

- Fluids are drugs – avoid overdose
- Restore euvolemia and euhydration
- Resuscitate with calcium-containing isotonic crystalloid (LRs, Hartmann)
  - 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
- Use natural colloid, i.e., plasma, canine-specific albumin
- Avoid synthetic colloids unless no other options

Resuscitation: low and slow

Isotonic crystalloid 10-20 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

Assess response, goal normal parameters:

Mentation

HR, pulse quality

Mucous membrane color, CRT <2 sec

Systolic blood pressure 80-90 mm Hg

Lactate <2.5 mmol/L or serial improvement

Urine output 0.5-1.0 ml/kg/h

Clues from pulses

- 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

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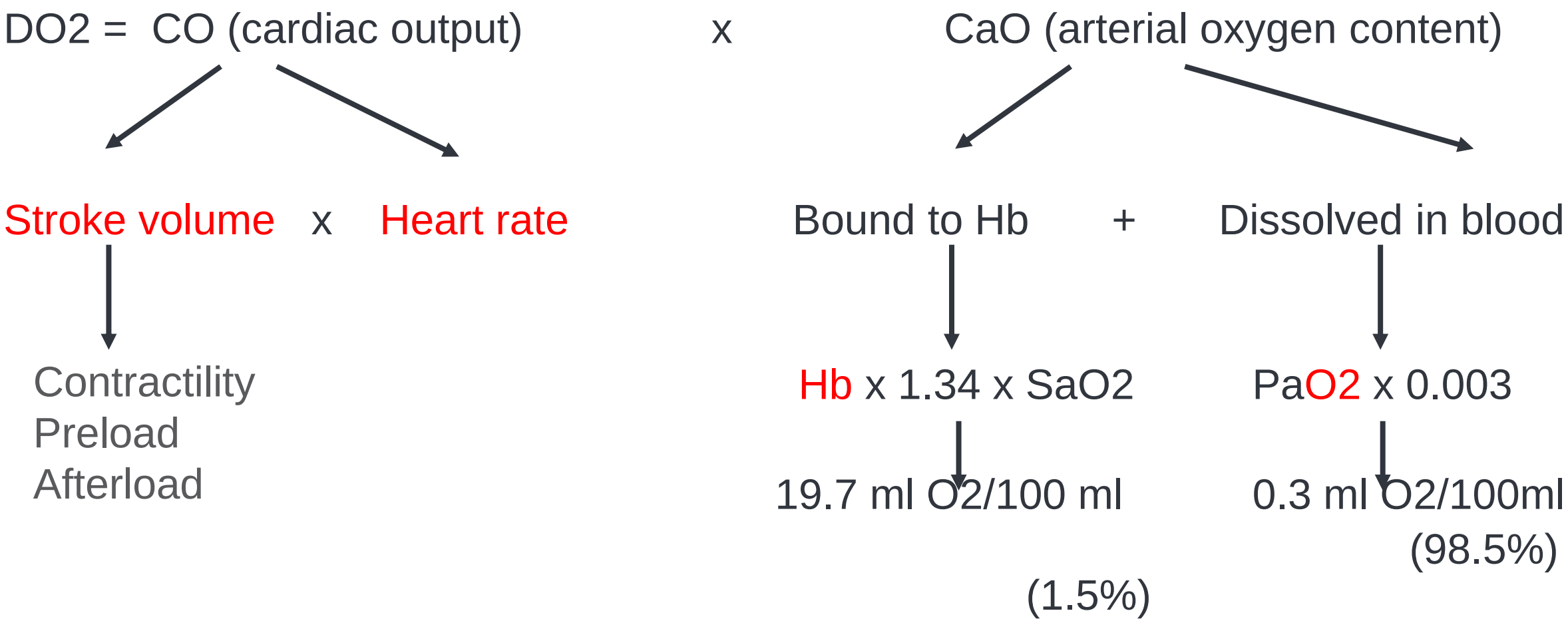
  } Mild, 5-7%
- Pericardial effusion with hypotension
  - LRs to overcome increased filling pressure

Thank you!

It all boils down to DO2



Links between heart, vasculature and kidneys.

- Anatomical
  - Vascular system
  - Kidneys receive 20% cardiac output
- Physiological
  - Cardiac output → renal perfusion
  - Kidney → volume, electrolyte and acid-base homeostasis
- Pathophysiological
  - **Cardiovascular disease ↔ kidney disease**

BSAVA BRITISH SMALL ANIMAL VETERINARY ASSOCIATION

PAPER

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Journal of Small Animal Practice (2015) 56, 537–552 DOI: 10.1111/jsap.12387

IDEXX

Cardiac disease and kidney disease go hand in hand…or better

Cardiovascular disease and kidney disease go hand in hand…

CREATING CLARITY

Diagnosis and management of common cardiac comorbidities..

Bill Saxon, DVM, DACVIM, DACVECC
IDEXX Medical Education Specialist

CONSENSUS STATEMENT | Open Access

ACVIM consensus statement: Guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats

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Assess kidneys, endocrine

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Severely hypertensive (high TOD risk)	SBP ≥180 mm Hg

Treat here

Target organ damage

Acclimate 5-20 minutes out of carrier, cuff width 30-40% circumference forelimb, tail base.

IDEXX

Heart Kidney – IVECCS 2025