Vienna Veterinary 2026

SUMMIT

PRACTICAL KNOWLEDGE IN HISTORICAL PLACES

CONFERENCE PROCEEDINGS

8-10 May 2026

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DECVDI, FTA Radiology, Founder of vetrad.de

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Founder & CEO of sonopath.com

Welcome

to the

Vienna Veterinary

SUMMIT 2026

May 8th to 10th, 2026
Vienna, Austria

Vienna Veterinary 2026 SUMMIT
CURRENT KNOWLEDGE IN HISTORICAL PLACES

DISCLAIMER

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SPEAKERS

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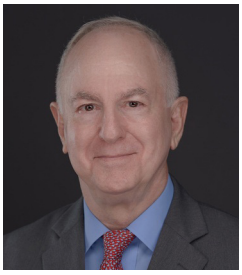

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Thoracic radiography in dogs and cats – capabilities, insights, limitations

Nele Eley, Mareike-Kristin Marx

1

Use of thoracic radiography

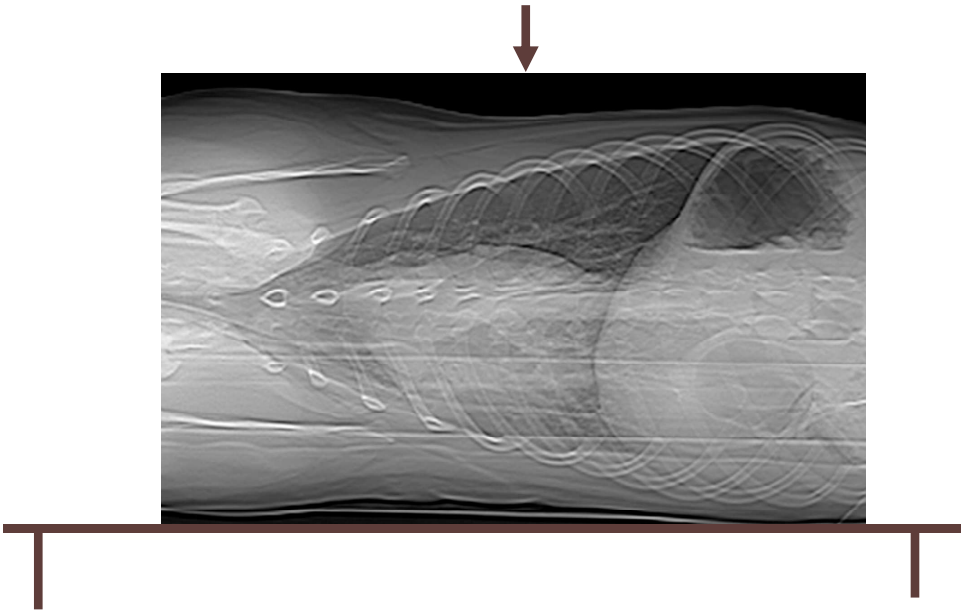
- Heart or lung
- Whats going on in the lung?
- Mediastinum?
- Thoracic wall / Boundaries

2

Use of thoracic radiography

- Anatomy & Projections
- Mediastinal masses
- Lungs
- Cardiovascular
- CASES

3



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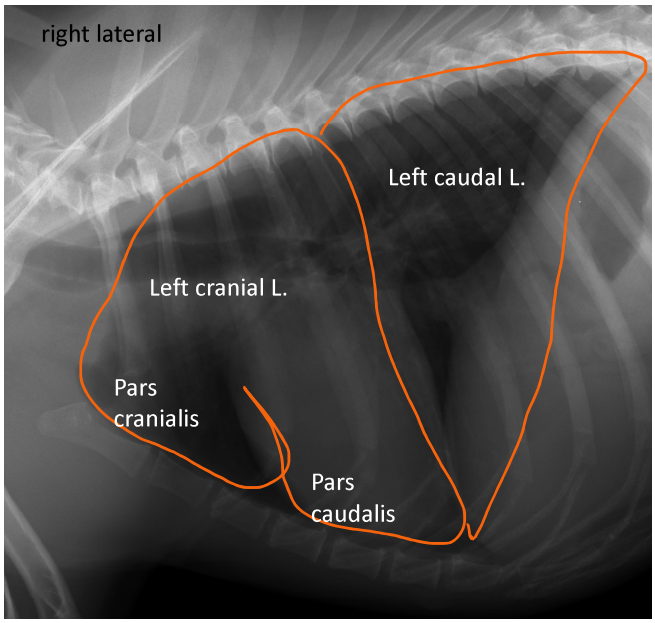
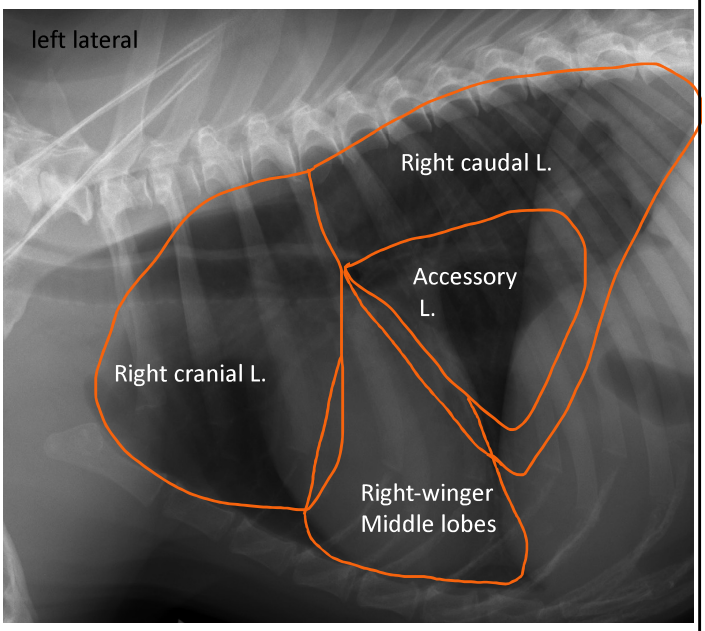
Radiographic anatomy lung

Wien, 2026





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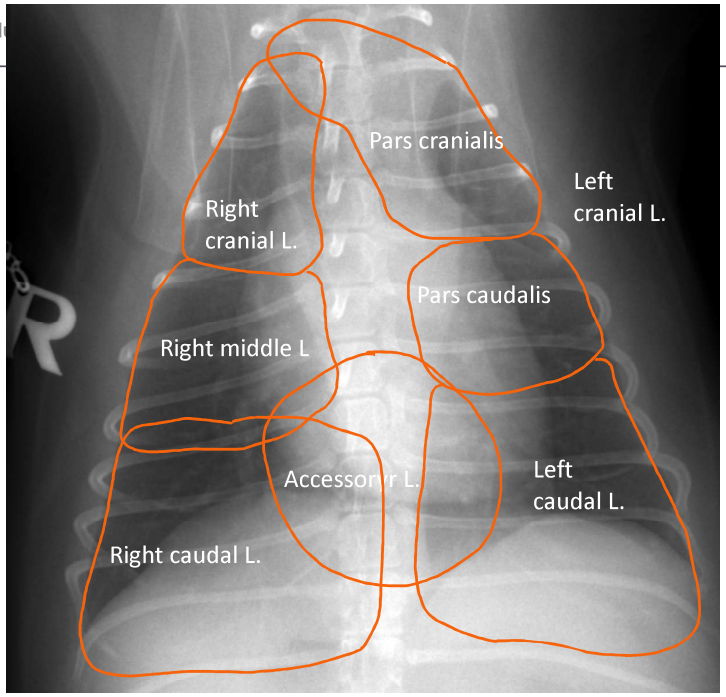
Radiographic anatomy l

Wien, 2026



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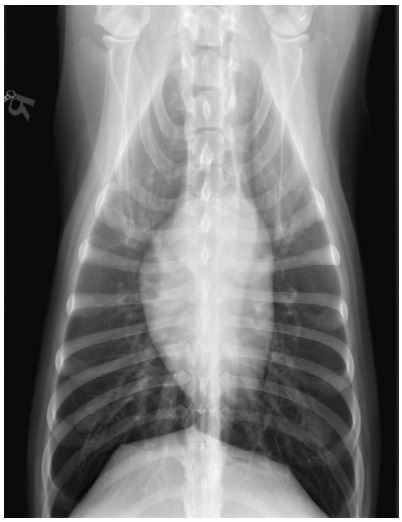
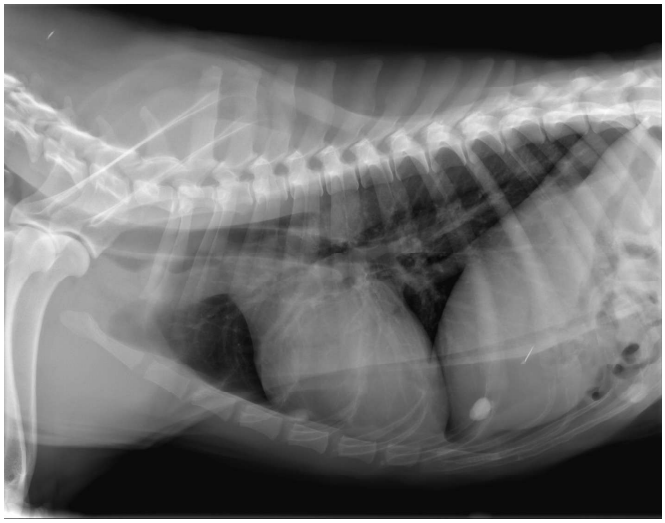
Cave: 3D→ 2D





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Standard Views

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Standard views

Lung	**Right/left lateral** + ventrodorsal
Heart	**Right lateral, DV**
Small amount of **pleural effusion**	**VD** / lateral
Pneumothorax	**Lateral**

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Standardprojektionen

Lunge	➢laterolateral (rechts-/linksanliegend, je nach Befund) + ventrodorsal
Herz	laterolateral rechtsanliegend + dorsoventral
Kleine Menge Pleuraerguss	ventrodorsal (wenn möglich) + laterolateral
Pneumothorax	besser sichtbar in laterolateral, wenn möglich

Teleradiologie für die Veterinärmedizin Schubertstraße 42 35392 Gießen, Deutschland info@vetrad.de www.vetrad.de

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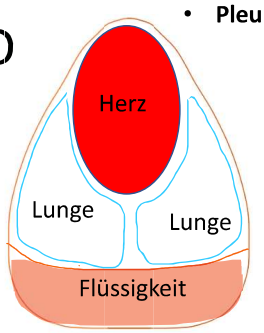
Standard Projections

Wien, 2026

Positioning - Pleural effusion

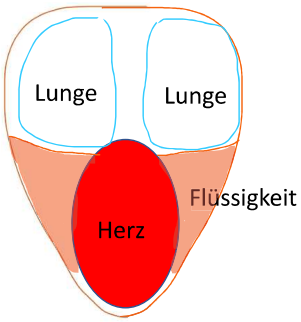
VD

- Risk of dyspnea / decompensation
- Lower fluid level
- **Cardaiac silhouette better seen**
- **Pleural fissures more visible**



DV

- Well tolerated
- Higher fluid levels
- Heart not assessable



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VD

DV

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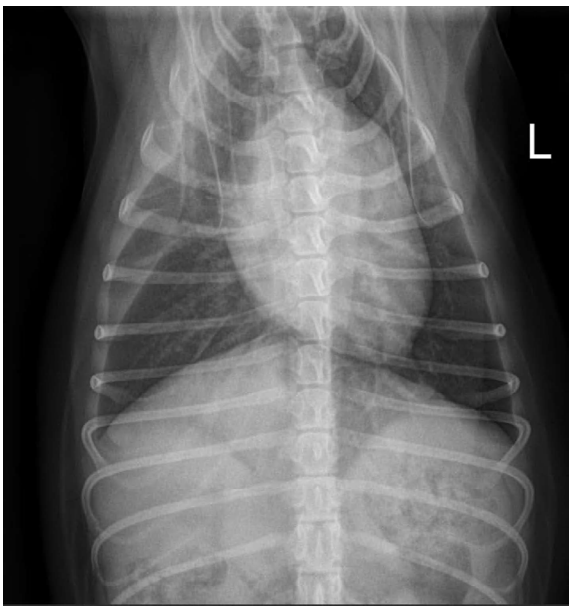

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Wien, 2026

Trauma / Distress views & Staging

Dyspnea	DV
Trauma No patient dies on the x-ray table	Lateral or DV
Tumorstaging	Right / left lateral plus VD

Ober & Barber, *VRUS 2006*

12% diagnostic gain in adding a 3rd view
2 views detect approx. 85-90% of what 3 views detect
Rads have limited Sensitivity

17

Wien, 2026

Thoracic Screening pulmonary metastases

Comparative Study > Vet Radiol Ultrasound. 2006 Oct-Nov;47(6):542-5.
doi: 10.1111/j.1740-8261.2006.00183.x.

Comparison of two- vs. three-view thoracic radiographic studies on conspicuity of structured interstitial patterns in dogs

Christopher P Ober [1], Don Barber

Result changes in 12-15% with 3 instead of 2 views

Comparison of three-view thoracic radiography and computed tomography for detection of pulmonary nodules in dogs with neoplasia

Laura J. Armbrust, DVM, DACVR; David S. Biller, DVM, DACVR; Aubrey Bamford, BS; Ruthanne Chun, DVM, DACVIM; Laura D. Garrett, DVM, DACVIM; Michael W. Sanderson, DVM, MS, DACVMP

Sensitivity X-ray for Mets: 71-95%

Negative Predictive Value: 65-89%

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Wien, 2026

Mediastinal mass effects

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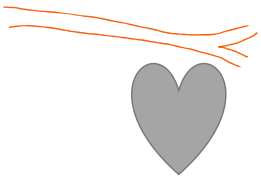
Wien, 2026

Mediastinal mass effect - deviation of trachea



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Diagnosis of mediastinal masses

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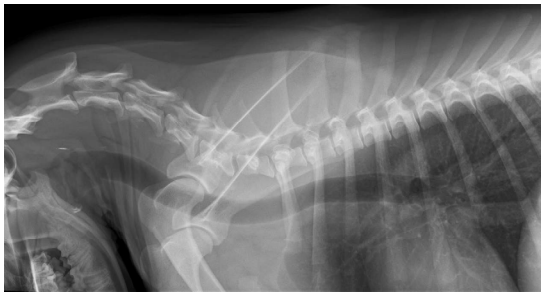
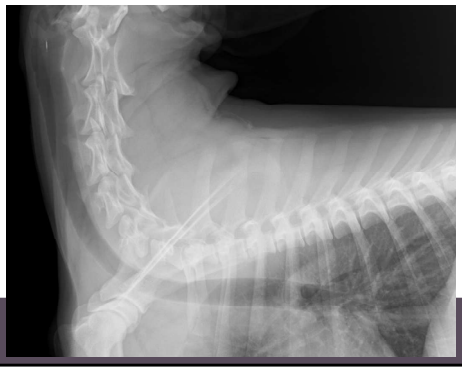
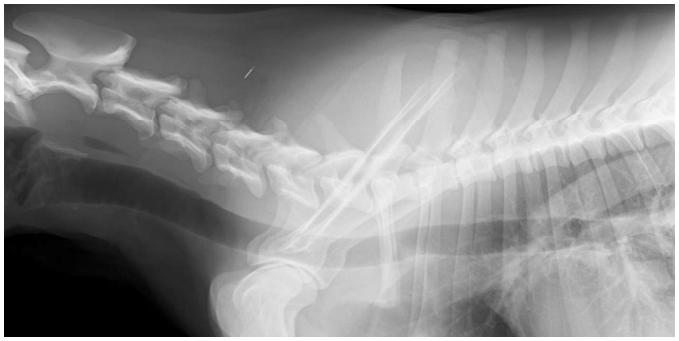




Influence of head and neck position



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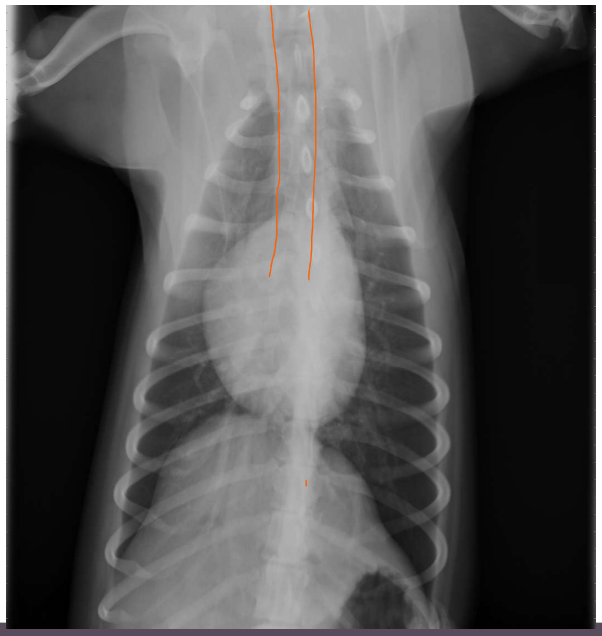
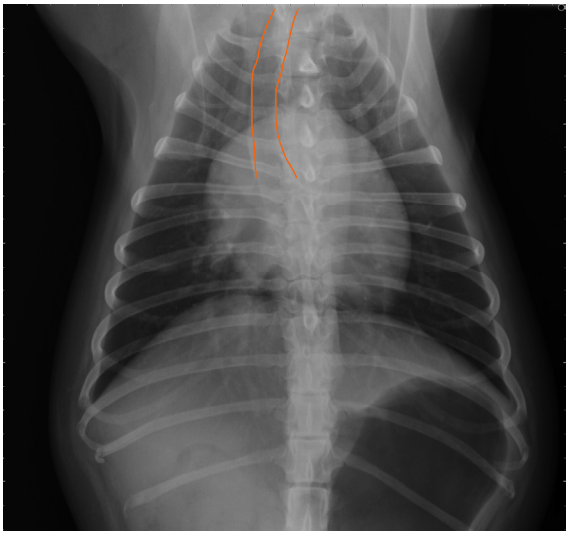
Mediastinal Mass Effects

Wien, 2026



Influence of the breed



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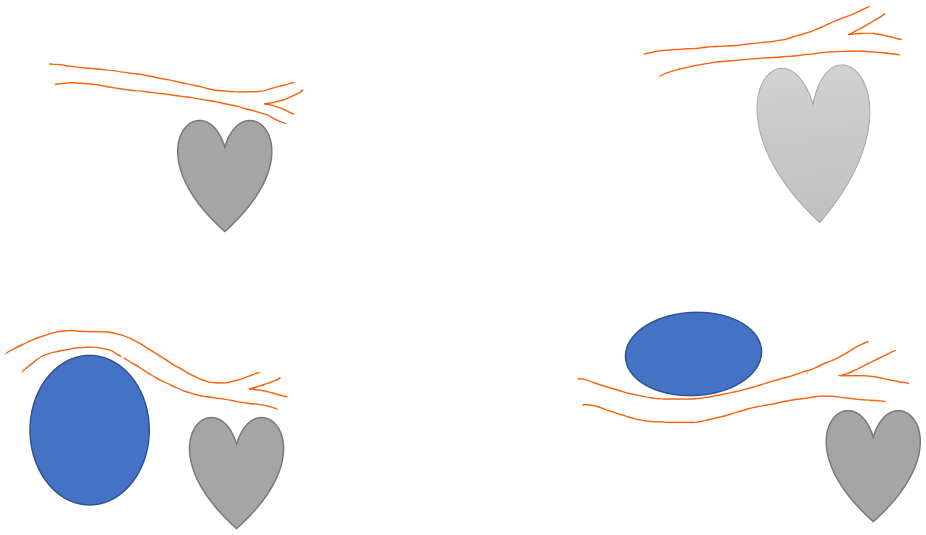
Tracheal displacement in mediastinal mass effects



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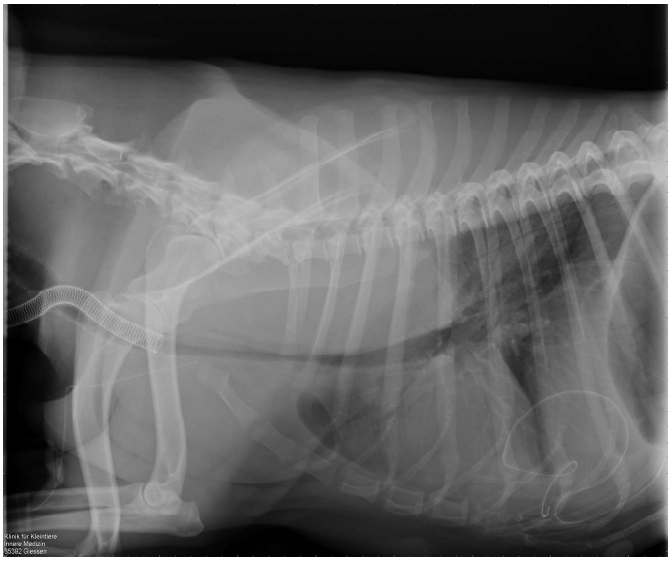
Examples



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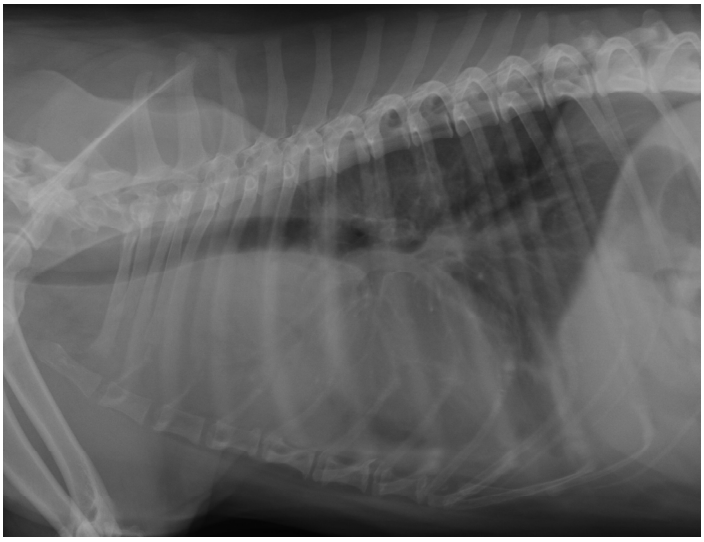
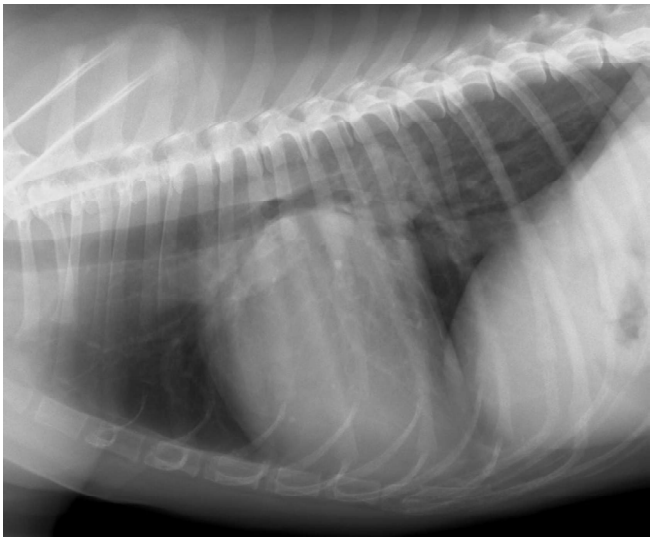
Examples





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Lung

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Assessment of the lungs – Chill…not the pattern yet

1. Pulmonary volume: Increased, preserved, reduced?
2. Pulmonary density: Increased, preserved, reduced?
3. Pattern

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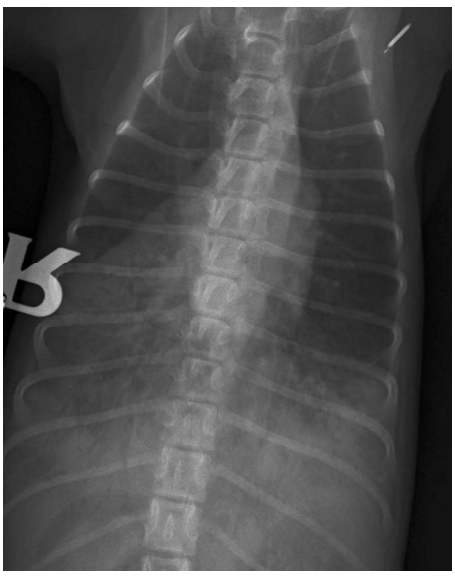
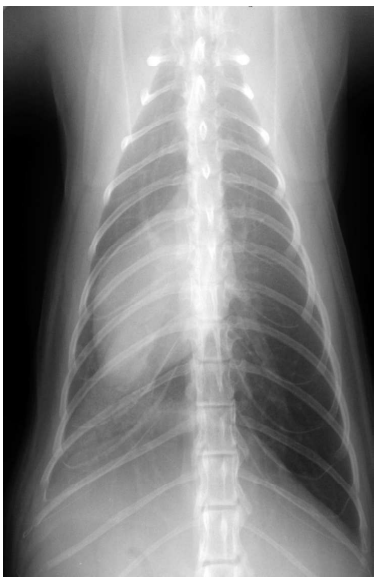
Assessment of the lungs

1. Lung volume

   Ipsilateral vs. contralateral Mediastinal Shift





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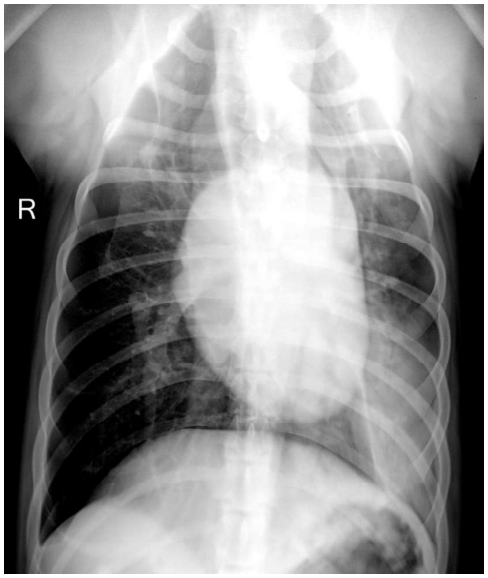
Alveolar pattern

Wien, 2026

Volume of the affected area

- Reduced
  - Ipsilateral midline shift
  - Atelectasis
- Increased or maintained
  - Missing or contralateral midline shift
  - Consolidation cells / fluids....



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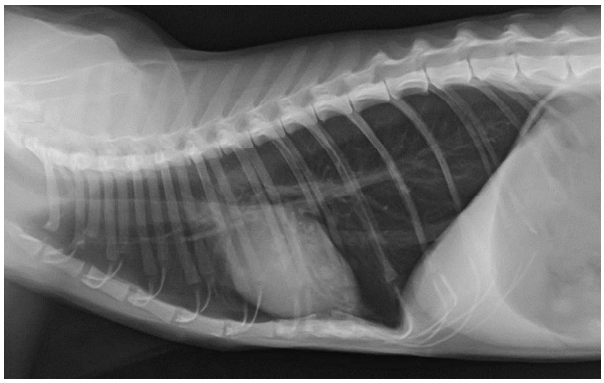
Lungs

Wien, 2026

Assessment of the lungs

- 2. Lung density: Increased, preserved, reduced?



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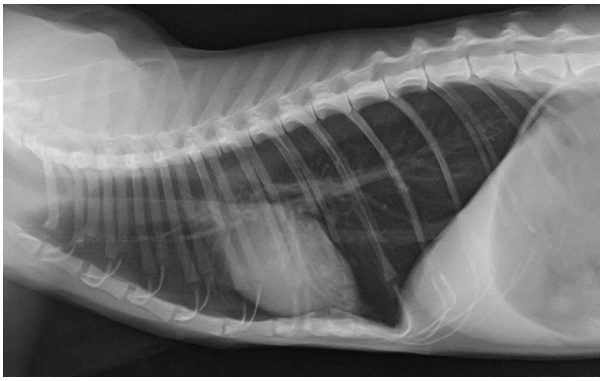
Lung density



Generalized reduced density

- Air trapping / hyperinflation
- Hypoperfusion
- Overexposure
- Cachexia
- CNS stimulation

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Lung density

- Generalized / focally increased density
  - Pathology
  - Artificially
    - Expiration
    - Obesity
    - Motion blur
    - Summations
    - (Underexposure)

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Now we can talk about patterns

- Alveolar
- Interstitial: Unstructured/ Structured
- Bronchial
- Vesicular
- Vascular

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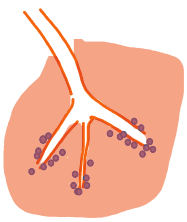
Alveolar

- Alveoli
  - Filled with cells / fluid or collapsed = soft tissue density
  - "White background"
  - Vessels obscured
  - Can be patchy / cloudy / solid
  - (Airbronchograms)



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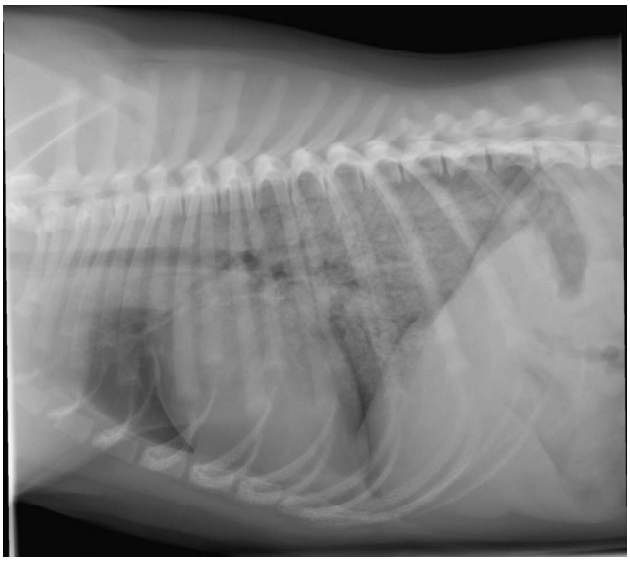
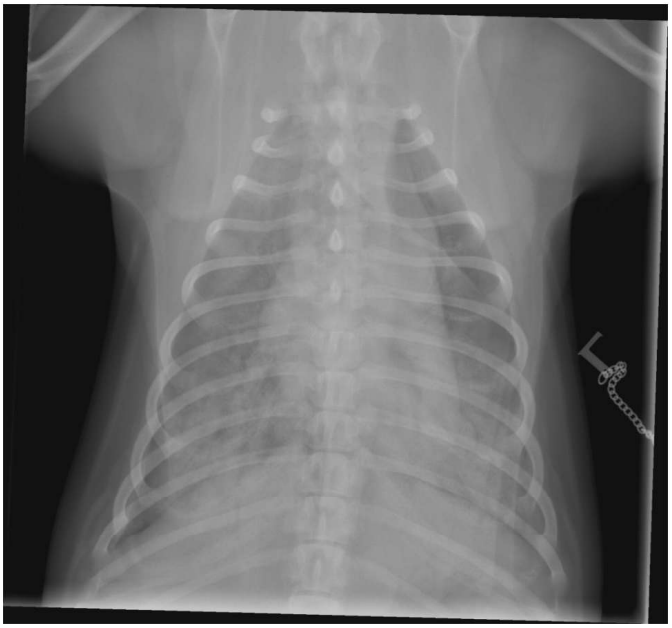
Alveolar pulmonary pattern

Wien, 2026





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Alveolar pulmonary pattern

Wien, 2026

Infectious	Non-infectious
Pneumonia	**Atelectasis**
Bacterial, viral, fungal, Mycoplasma	Hemorrhage
Aspiration → Bacterial	**Neoplasia**
Foreign bodies → Bacterial	Cardiogenic pulmonary **edema**
	Non-cardiogenic pulmonary **edema**
	Allergic lung diseases
	Lung lobe torsion
	Contusion
	Thrombembolism

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Distribution of the alveolar pattern

- **Cranioventral:** Pneumonia!
- **Caudodoral:** inhaled foreign matter, non-cardiogenic edema
- **Perihilar:** cardiogenic edema (dog)??
- **Peripheral**: parasitic pneumonia, infarction
- **Multifocal/random:** hemorrhage, ARDS, cardiogenic edema (cat), neoplasia

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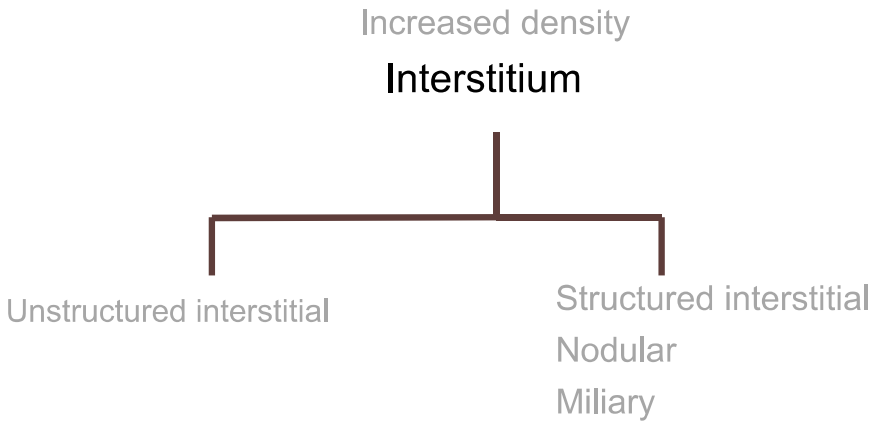

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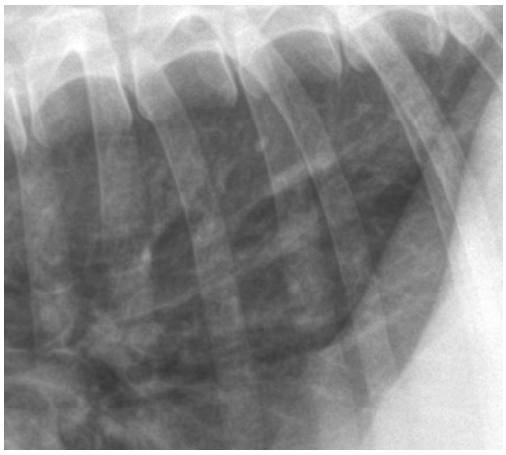
Unstructured interstitial pattern

- Diffuse increase in background density
- Increased visibility of the bronchi
- Reticular, ground glass like
- Vessels still seen
- black background!



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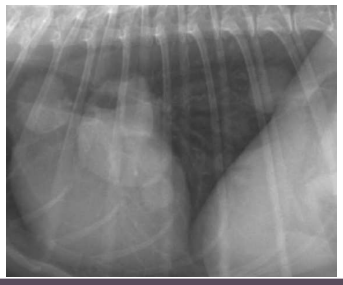
Structured interstitial pattern

Nodular:

- Soft tissue dense nodules / masses
- Black background



Miliary:

- Muplitel mini nodules
- Black Background

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Unstructured interstitial pattern

Infektiös (Pneumonie)	nicht-infektiös
artifiziell	artifiziell
	Dystelektasis
Early pneumonia, viral pneumonia	**Early/mild** contusion or hemorrhage
Leptospirosis (reticulonodulär)	**Early/mild** edema – cardiogeninc and non-cardiogenis
	Thrombembolism
	Pulmonary fibrosis
	Neoplasia (lymphoma)
	Radiation-induced pneumonitis
	Oxygen therapy

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Structured-interstitial pattern

Solitary nodular lesion?
C – H – A – N - G

Nodular	Miliary
Metastases / **N**eoplasia	Metastases
Granuloma incl. FIP	Granulomas
Abscess	Hematogenous bacterial pneumonia
Hematoma	Mycoses
Cyst	
(mucus-filled bronchiectasias)	
(Pulmonary Osteomata)	

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Single mass, multiple pulmonary osteomas

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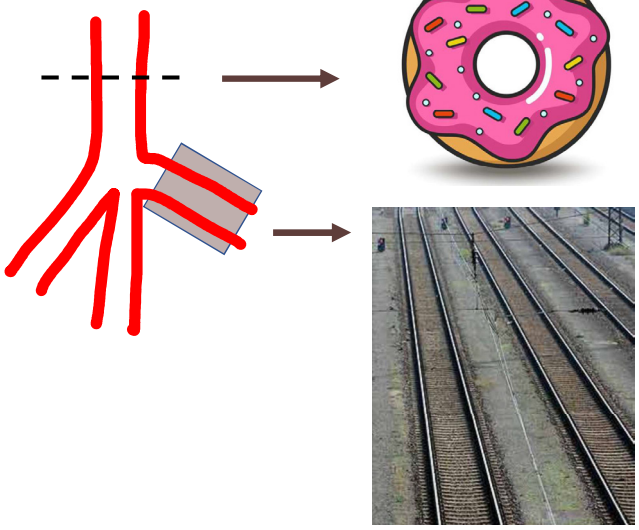
Bronchial pattern

→ Bronchi

- Increased visibility of bronchi
- "Donuts" & "Tramlines"
- Smooth to blurred
- Narrow or dilated (bronchiectasias)
- Can be mineralized
- Black background, vessels visible



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Bronchial pattern

1) Intraluminal Exudate
2) Thickened wall of the bronchi
3) Peribronchial infiltrates

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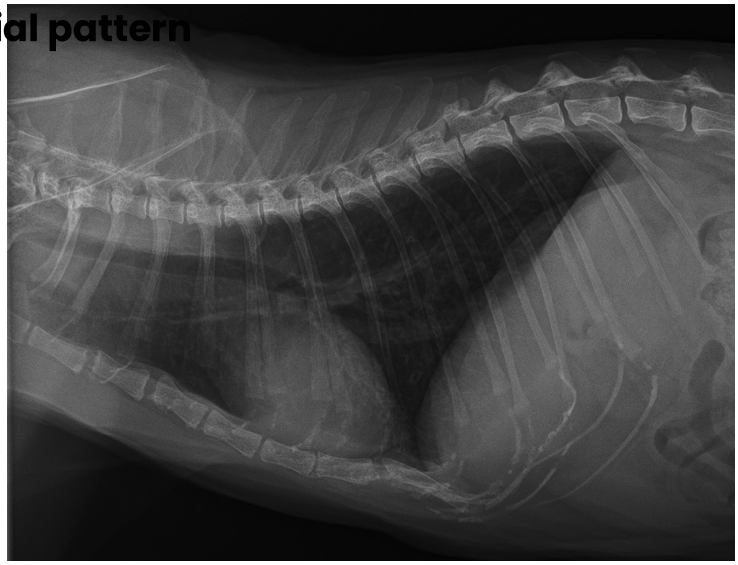
Bronchial pattern



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Bronchial pattern

Inflammatory (chron. bronchitis)	non-flammatory
Allergic (eosinophilic, asthma)	Age-related
Viral	Neoplasia (eg, bronchial cell carcinoma)
Bacterial	Wall edema
Fungal	Hyperadrenocorticism (mineralizations)
Protozoa (toxoplasmosis)	Ciliary dyskinesia
Parasitic	

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Vesicular pattern

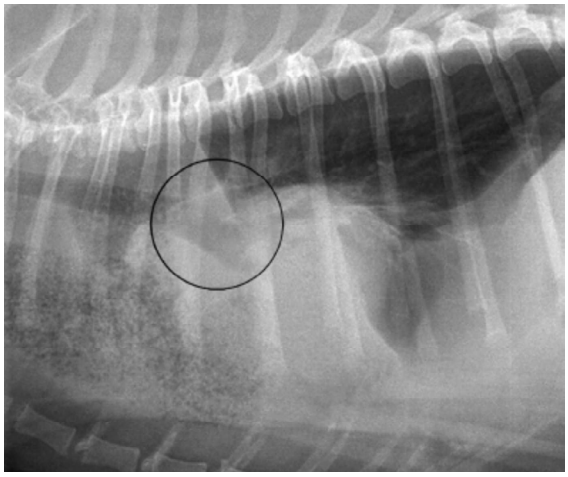
→ Gas vesicles

"Salt & Pepper"

= vesicular emphysema

Bright background

+ Thoracic effusion + abnormal course bronchus = pulmonary lobe torsion



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Assessment of the lungs

1. Volume → Midlineshift?
2. Density?
3. Black or white backgrpund?
   → White: alveolar, (vesicular)
   → Black: interstitial, bronchial
4. Alveolar vs. Interstitial: Are Pulmonary Vessels Visible or Not?
   → No → alveolar
   → Yes → interstitial
5. Is a structure recognizable? Nodular?
6. Distribution

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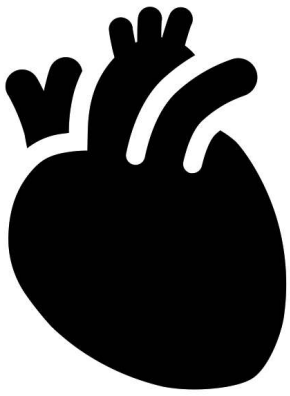
Cardiovascular structures



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Fälle²

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Fall 1

- Mischling, 1,5 Jahre, wk, aus Rumänien
- Leistungsintolerant, Tachypnoe in Ruhe

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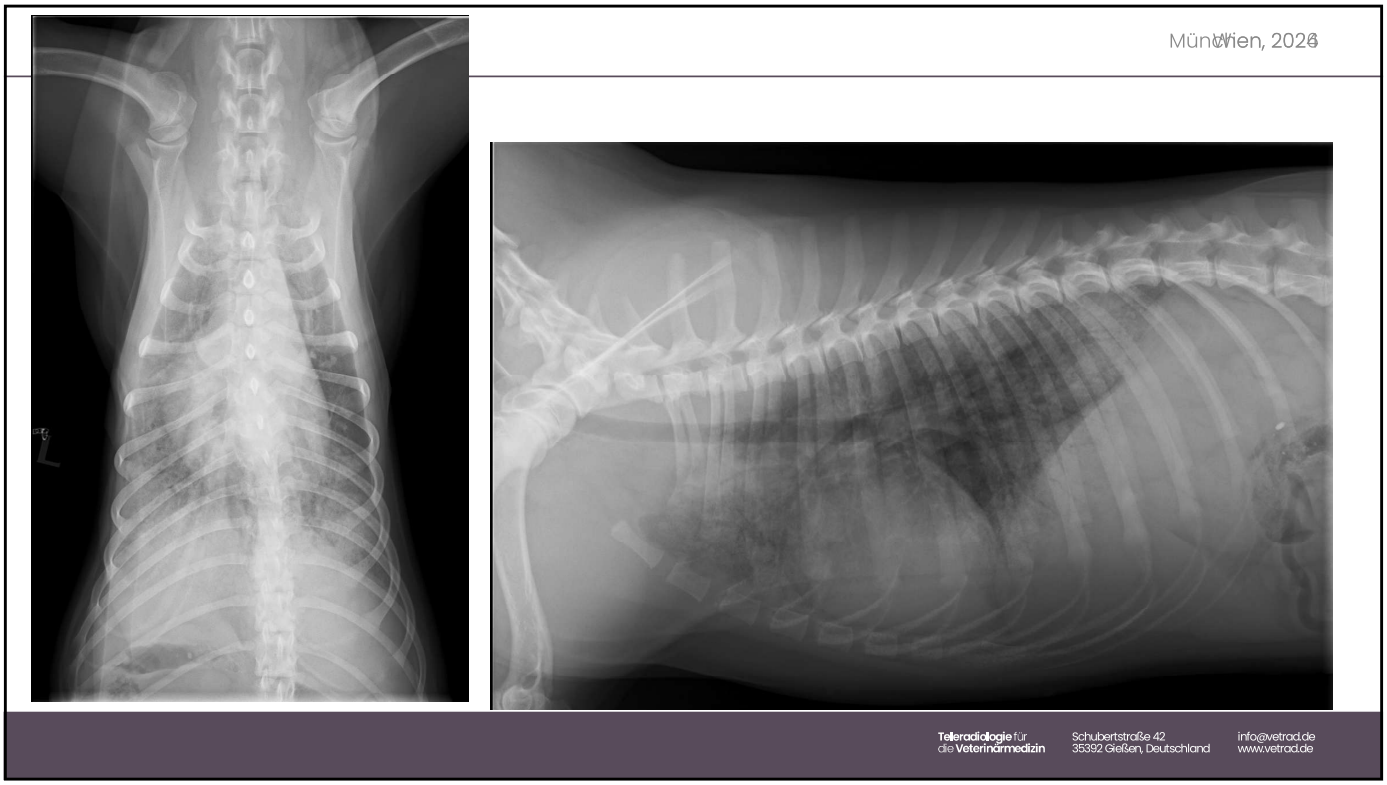
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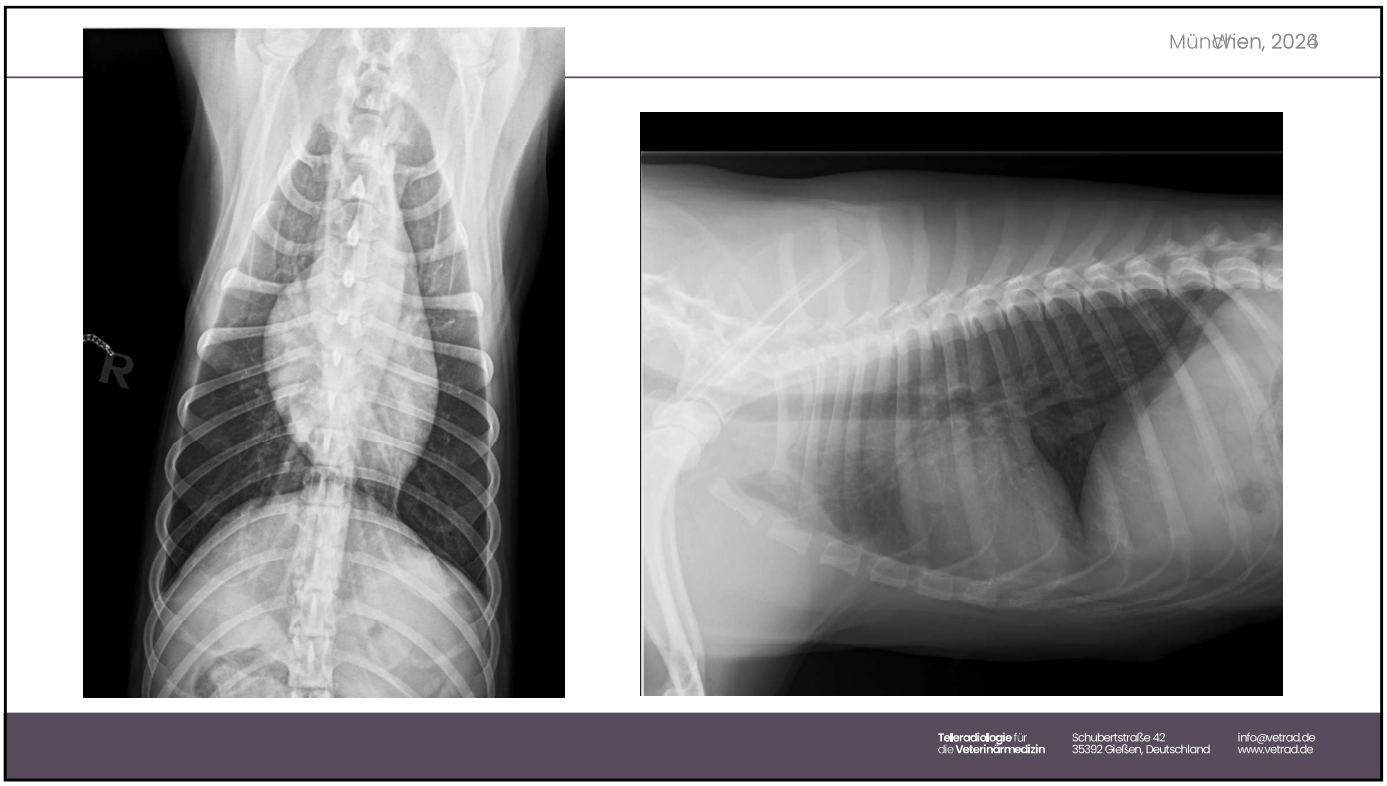
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Retrospective evaluation of thoracic computed tomography findings in dogs naturally infected by *Angiostrongylus vasorum*

Mark E. Coia, Gawain Hammond, Daniel Chan, Randi Drees, David Walker, Kevin Murtagh, Janine Stone, Nicholas Bexfield, Lizzie Reeve, Jenny Helm

First published: 20 April 2017 | https://doi.org/10.1111/vru.12505 | Citations: 7

Pathogens. 2023 Feb; 12(2): 273. PMCID: PMC9965210
Published online 2023 Feb 7. doi: 10.3390/pathogens12020273 PMID: 36839545

Clinical, Radiological, and Echocardiographic Findings in Cats Infected by *Aelurostrongylus abstrusus*

Ettore Napoli,[1,†] Michela Pugliese,[1,†] Angelo Basile,[2] Annamaria Passantino,[1,*] and Emanuele Brianti[1]

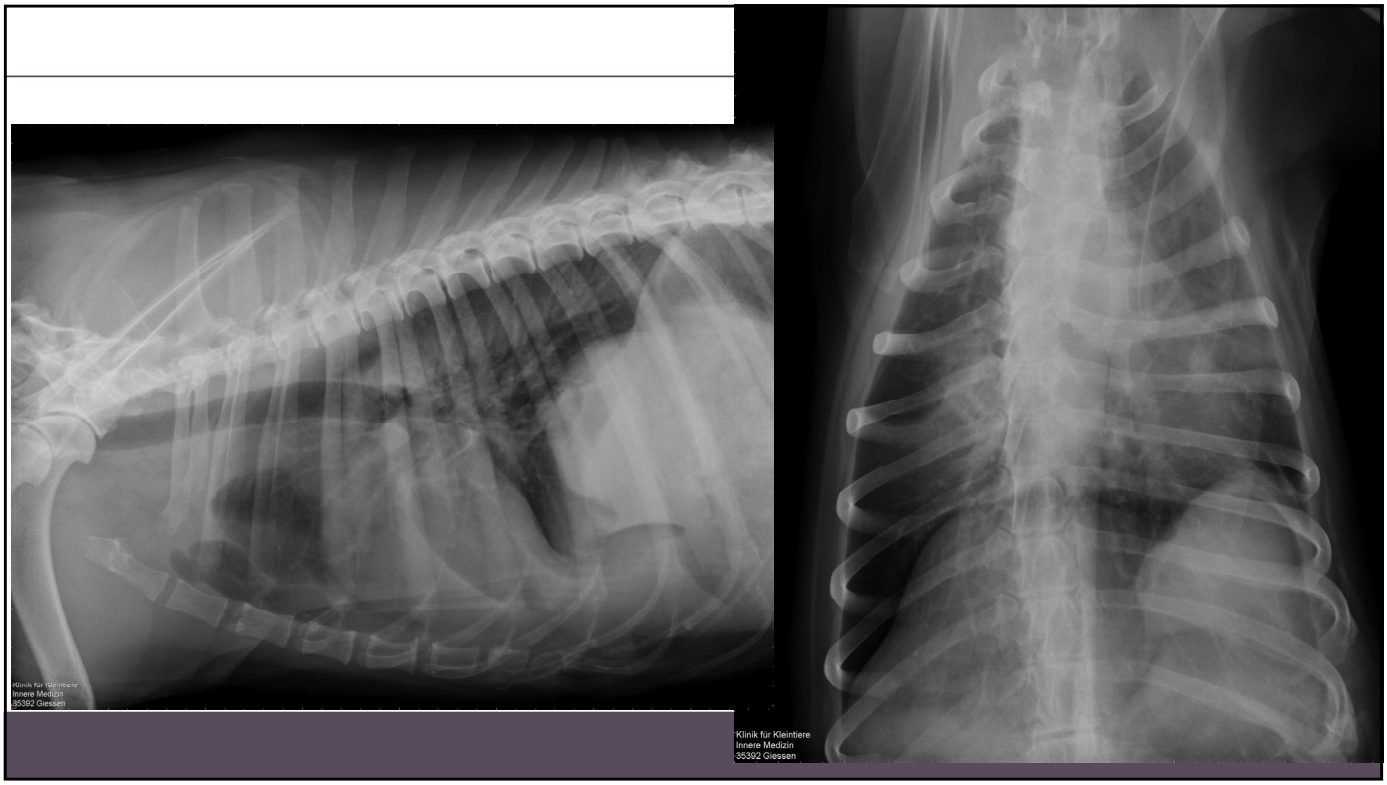
Maria Pereira, Academic Editor and Teresa Letra Mateus, Academic Editor

55

Fall 2

- Deutsch Drahthaar, wk, 11 Jahre
- Fieber, Apathie, seit 1 Woche
- Keine Besserung unter Schmerzmittel und Antibiose

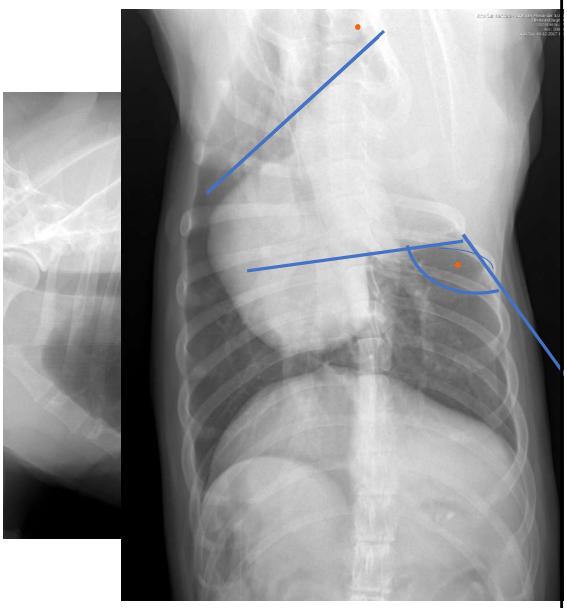
56



57

Extrapleuralzeichen

- Massen der Thoraxwand, die tangential getroffen werden
- Stumpfer Winkel zw. Läsion und Brustwand
- Masseneffekt auf intrathorakale Strukturen
- Rippen?



orthogonal

tangential

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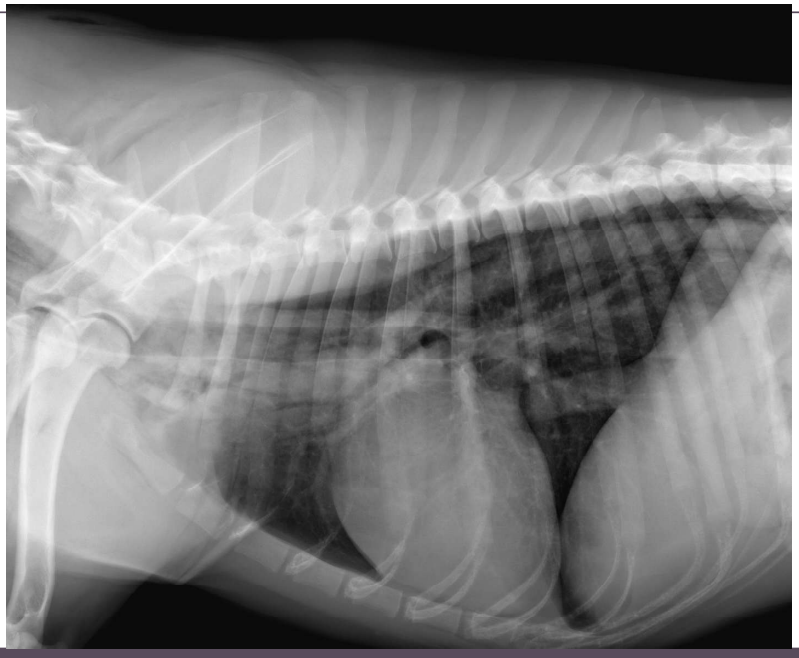
Fall 3

- Labrador, 5 Jahre, m
- Blutung aus der Maulhöhle nach Stöckchenspiel

59



60

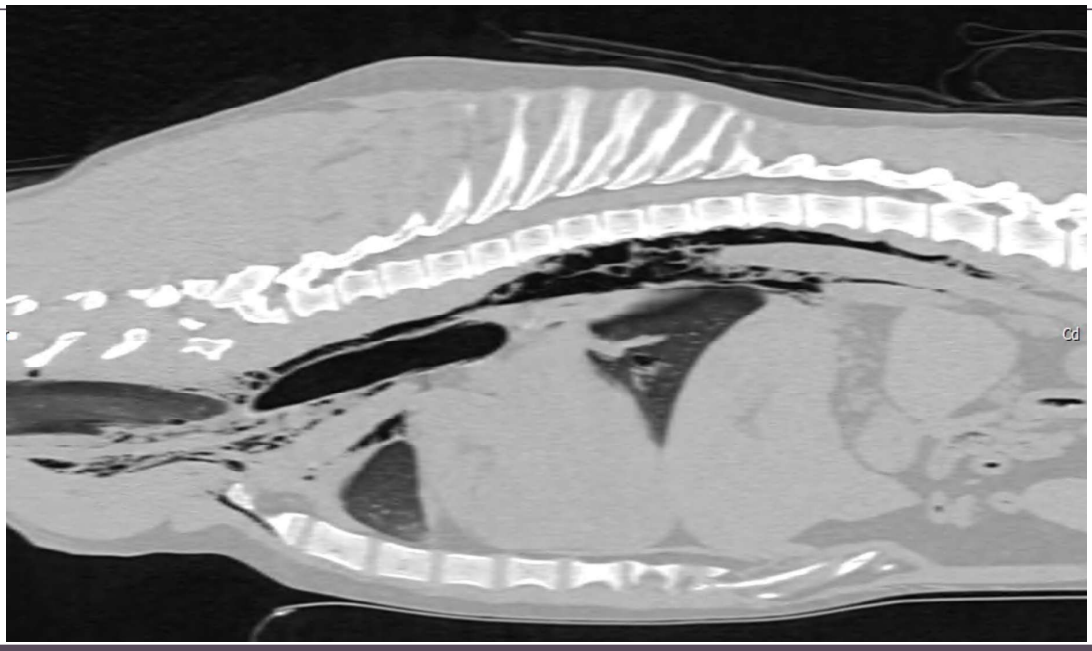
Pneumomediastinum

- Mediastinale Organe werden kontrastiert & sichtbar

→ Gas → Kontrast

- Ursachen:
  - Zervikale Wunde
  - Ösophagusperforation
  - Tracheaperforation
  - Nicht sekundär zu Pneumothorax!
- Fortleitung in Retroperitoneum möglich

61



62

> Vet Radiol Ultrasound. 2017 Mar;58(2):144-150. doi: 10.1111/vru.12457. Epub 2016 Dec 1.

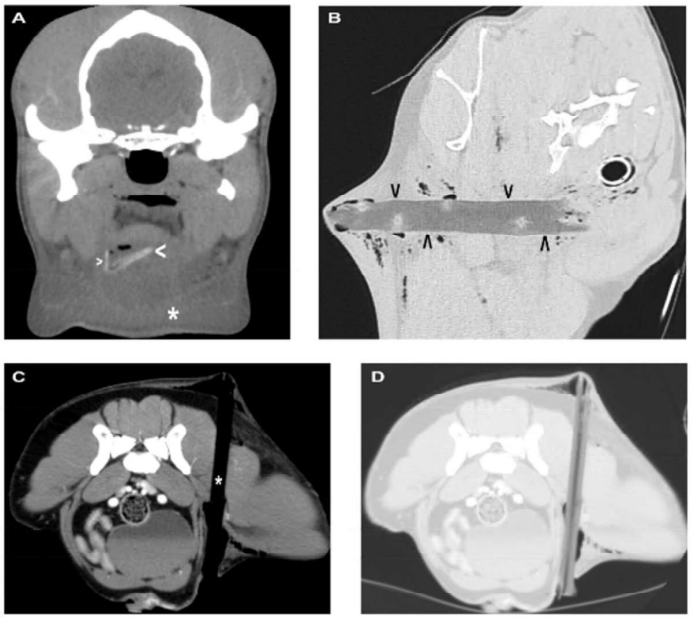
RESULTS OF COMPUTED TOMOGRAPHY IN DOGS WITH SUSPECTED WOODEN FOREIGN BODIES

Christopher R Lamb [1], Elizabeth H W Pope [1], Karla C L Lee [1]

Affiliations + expand

PMID: 27910171 DOI: 10.1111/vru.12457

- Sensitivität CT 79%

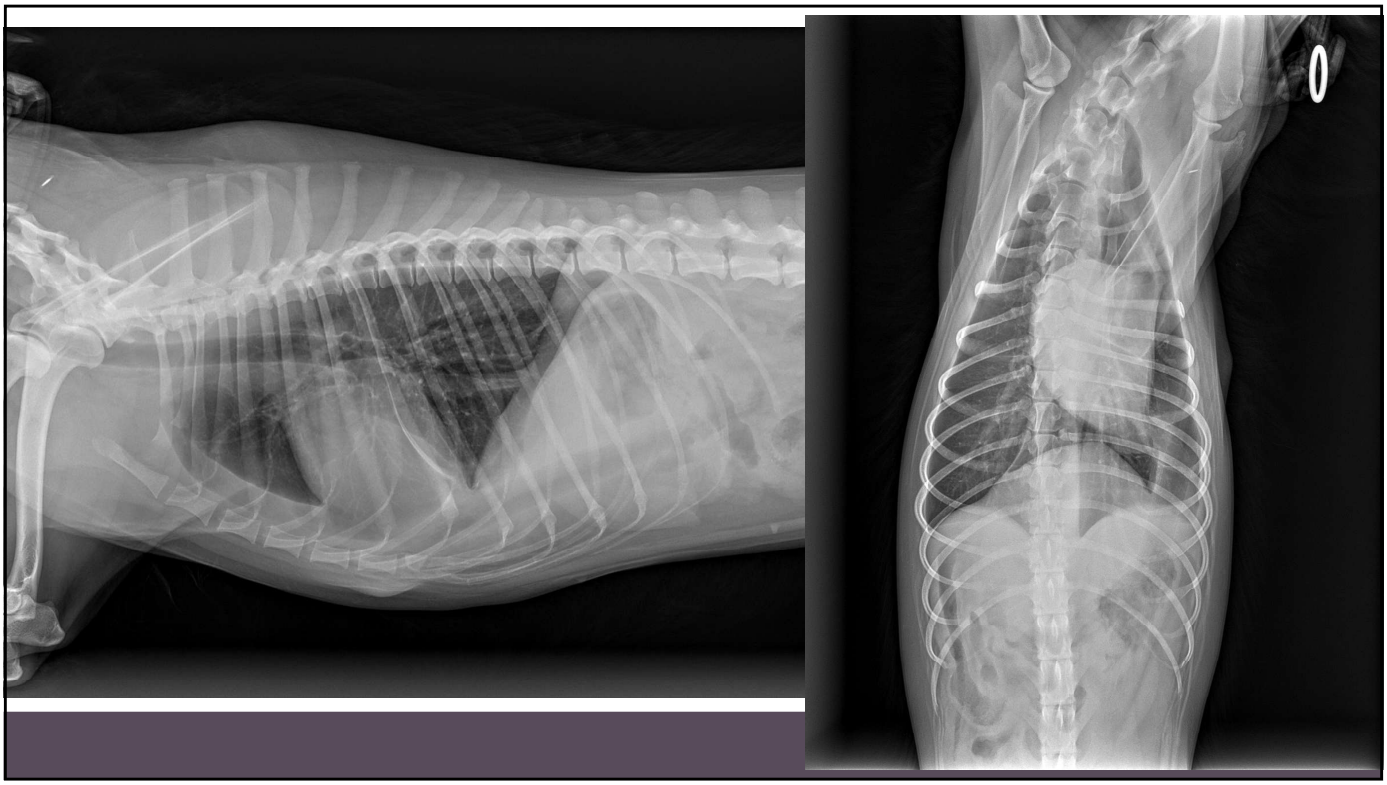


63

Fall 4

- Border Collie, 4 Jahre, wk
- Vor 1 Woche weggelaufen, kam mit Verletzung an der Thoraxwand und Schwellung zurück
- Fieber
- Schmerzhaft beim Ablegen

64



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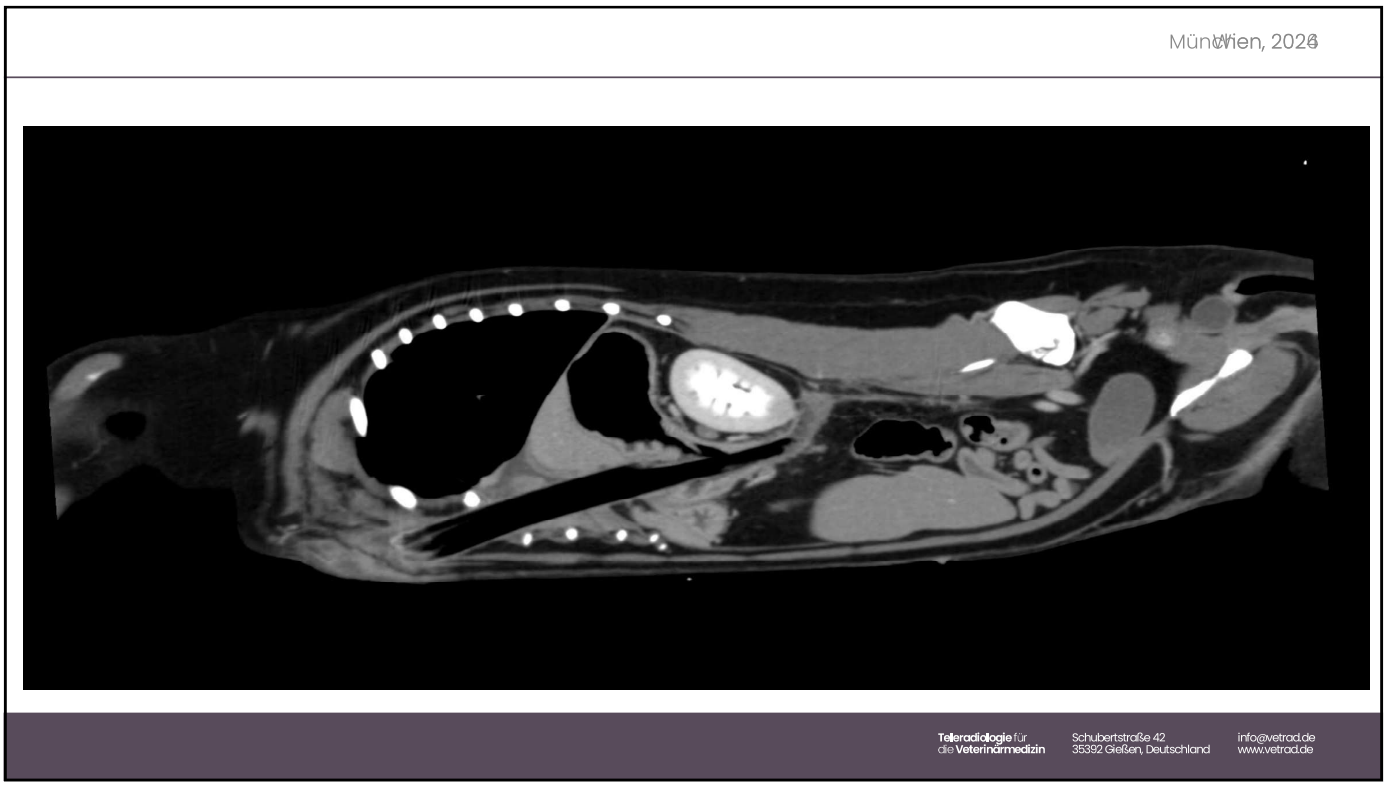
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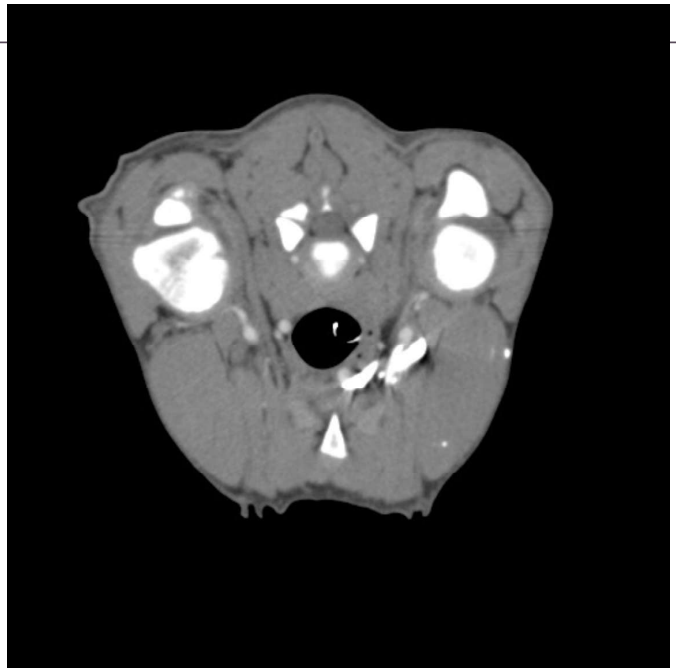


67

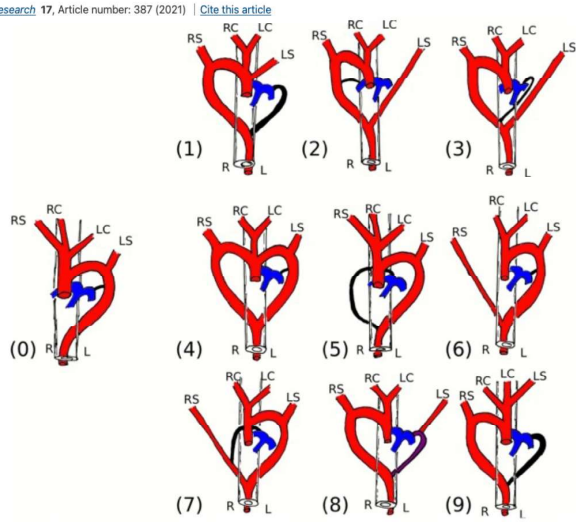
Vaskuläre Ringanomalien

- Häufig: Persistierender 4. Aortenbogen rechts + linkes Lig arteriosum (Typ 3)
- Gefäßring um Trachea und Ösophagus möglich
- → Divertikelbildung des Ösophagus
  - selten bei Typ 2 und 6

Anomalies of the aortic arch in dogs: evaluation with the use of multidetector computed tomography angiography and proposal of an extended classification scheme

Christiane Schorn, Nicolai Hildebrandt, Matthias Schneider & Sebastian Schaub

BMC Veterinary Research 17, Article number: 387 (2021) | Cite this article

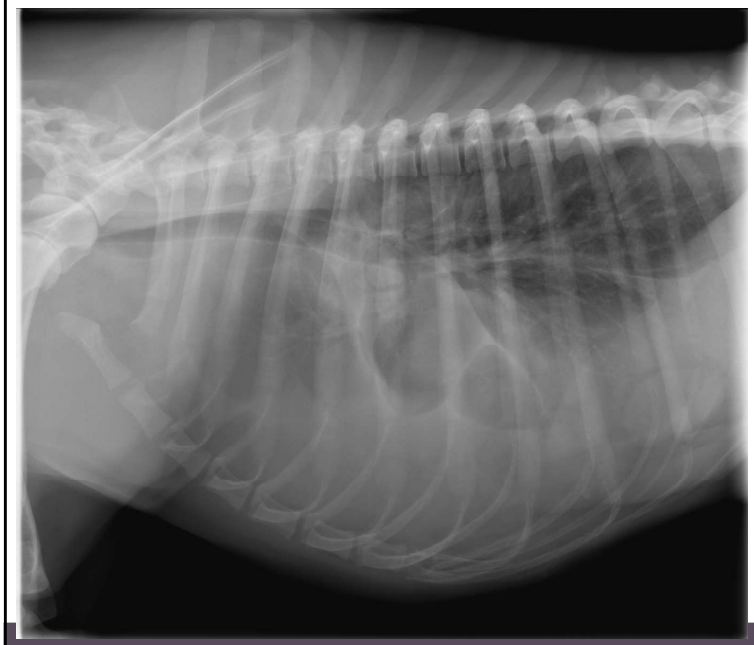


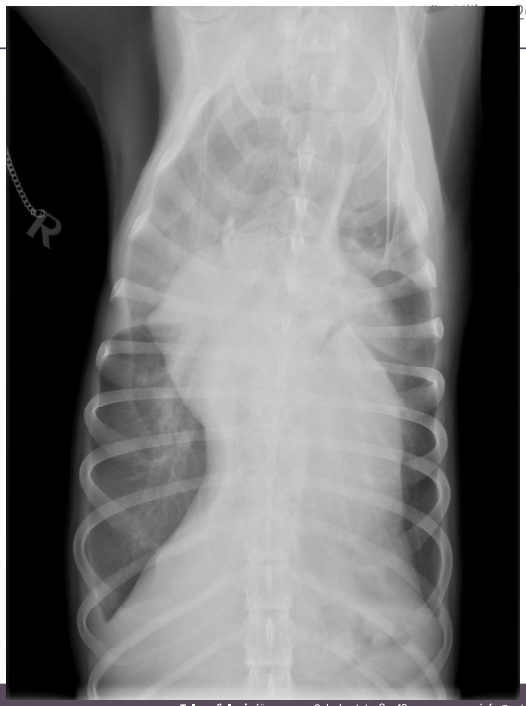
68

Fall 8

- Weimaraner
- 3 Jahre
- M
- 10 Tage nach Autounfall: Tachypnoe

69



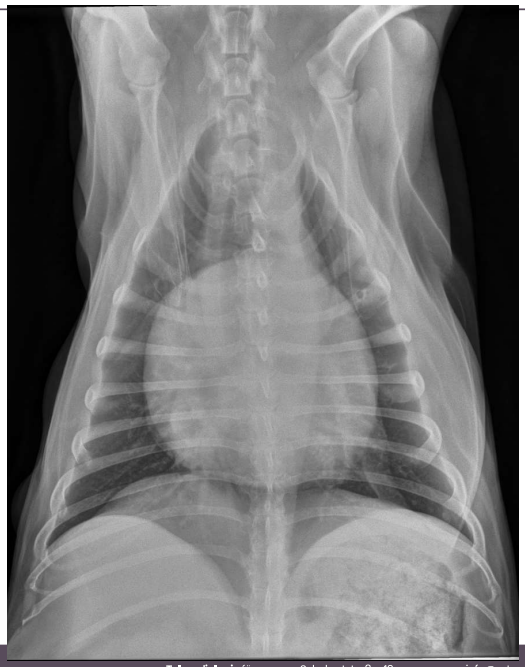


70

Fall 9

- Mix
- 6J
- Mk
- Unruhig bis lethargisch, angespanntes Abdomen

71

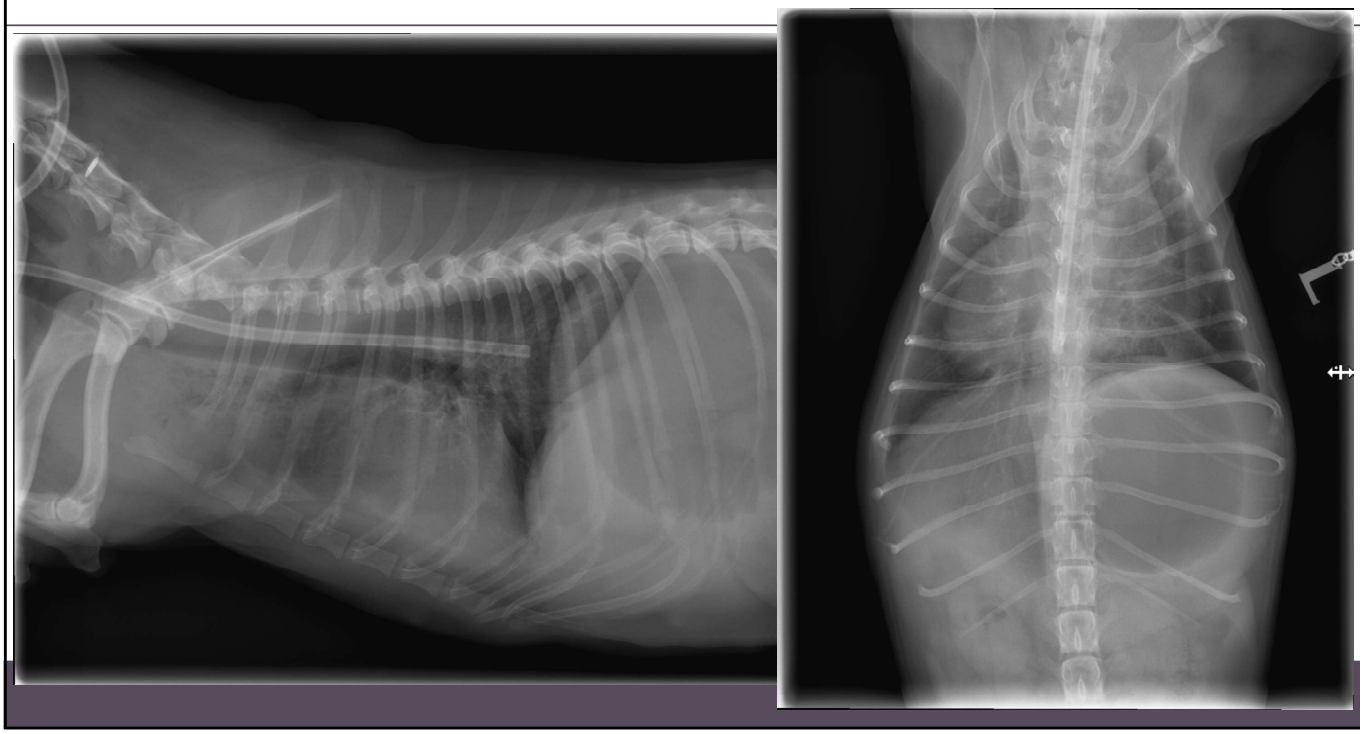


72

Fall 11

- Havaneser
- Wk
- 11J
- Ösophagussonde erhalten aufgrund Kieferfrakturen
- Plötzlich auf Station aufgefallen mit Dyspnoe
- Reduziertes Allgemeinbefinden, Hypothermie

78



79

Fall 12

- Yorkshire Terrier
- 8J
- Wk
- Angespanntes Abdomen
- Klin. Untersuchung: verschärfte Atmung, Herzgeräusch 3/6
- Undulierendes, angespanntes Abdomen

80

81

82

Vet Parasitol. 2020 Jul:283:109156. doi: 10.1016/j.vetpar.2020.109156. Epub 2020 May 30.

Clinical and diagnostic imaging findings in 37 rescued dogs with heartworm disease in Germany

Imke Maerz [1]

Affiliations + expand

PMID: 32526608 DOI: 10.1016/j.vetpar.2020.109156

- Lungenparenchymveränderungen
- MPA vergrößert
- Vergrößerte Lungenarterien (vor allem kaudal, peripher)
- (Rechtsherzvergrößerung)

83

Lungengefäße

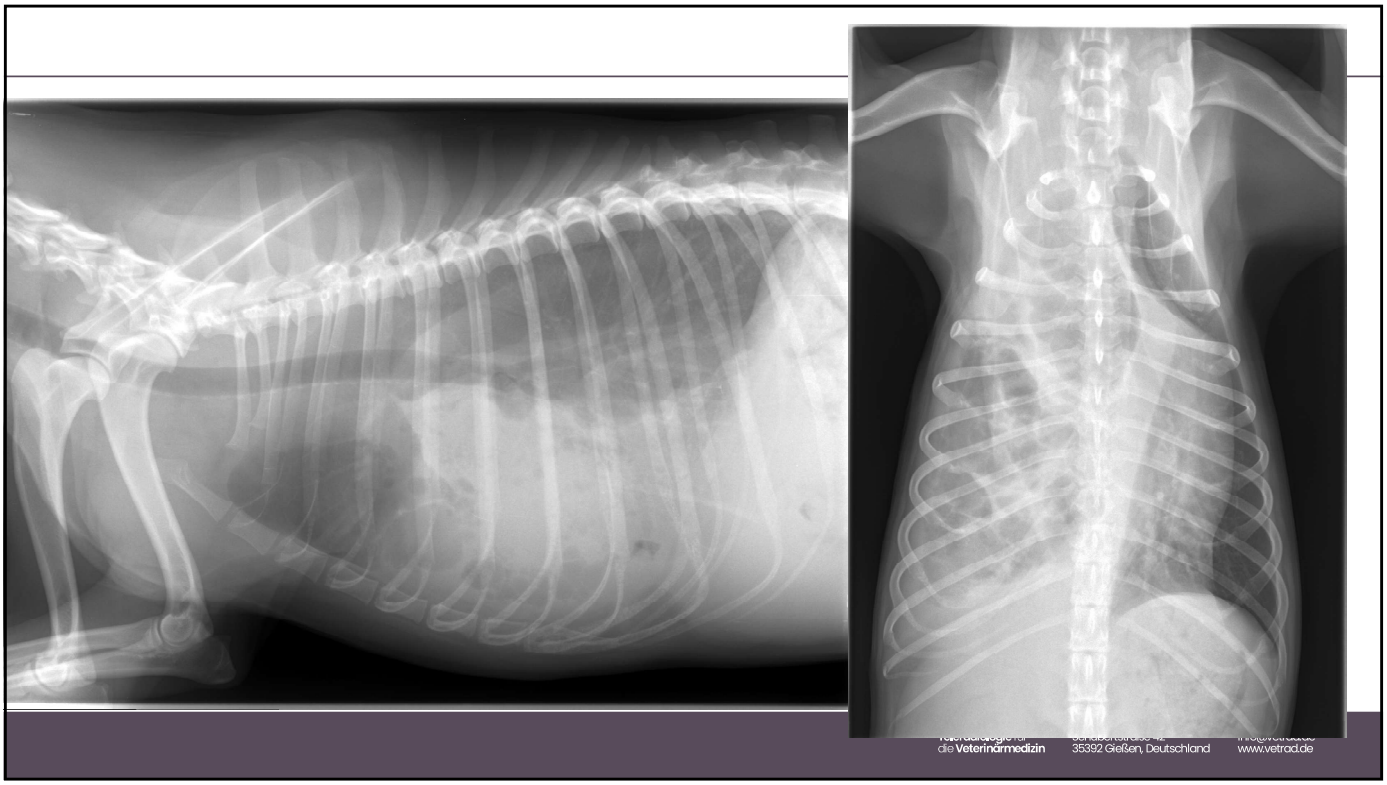
- Pulmonalarterien vergrößert
  - Pulmonale Hypertension
  - Pulmonaler Thrombembolismus
  - Herzwürmer
  - Große LR Shunts
  - Selten Lungenwürmer
  - AV Fisteln
- Pulmonalvenen vergrößert
  - Linksherzversagen
  - LR-Shunts
- Pulmonalarterien und -venen vergrößert
  - Linksherzversagen
  - LR-Shunts
  - Überinfusion
- Pulmonalarterien- und -venen verkleinert
  - Hypovolämie
  - Addison
  - Herzbeuteltamponade
  - Hgr. Pulmonalstenose
  - RL-Shunts

84

Fall 14

- Mix, 18 kg
- 3J
- M
- Vor 3 Wochen perforierende Verletzung an der Thoraxwand, wurde versorgt
- Zunehmende Mattigkeit, Inappetenz, angestrengte Atmung und Fieber

87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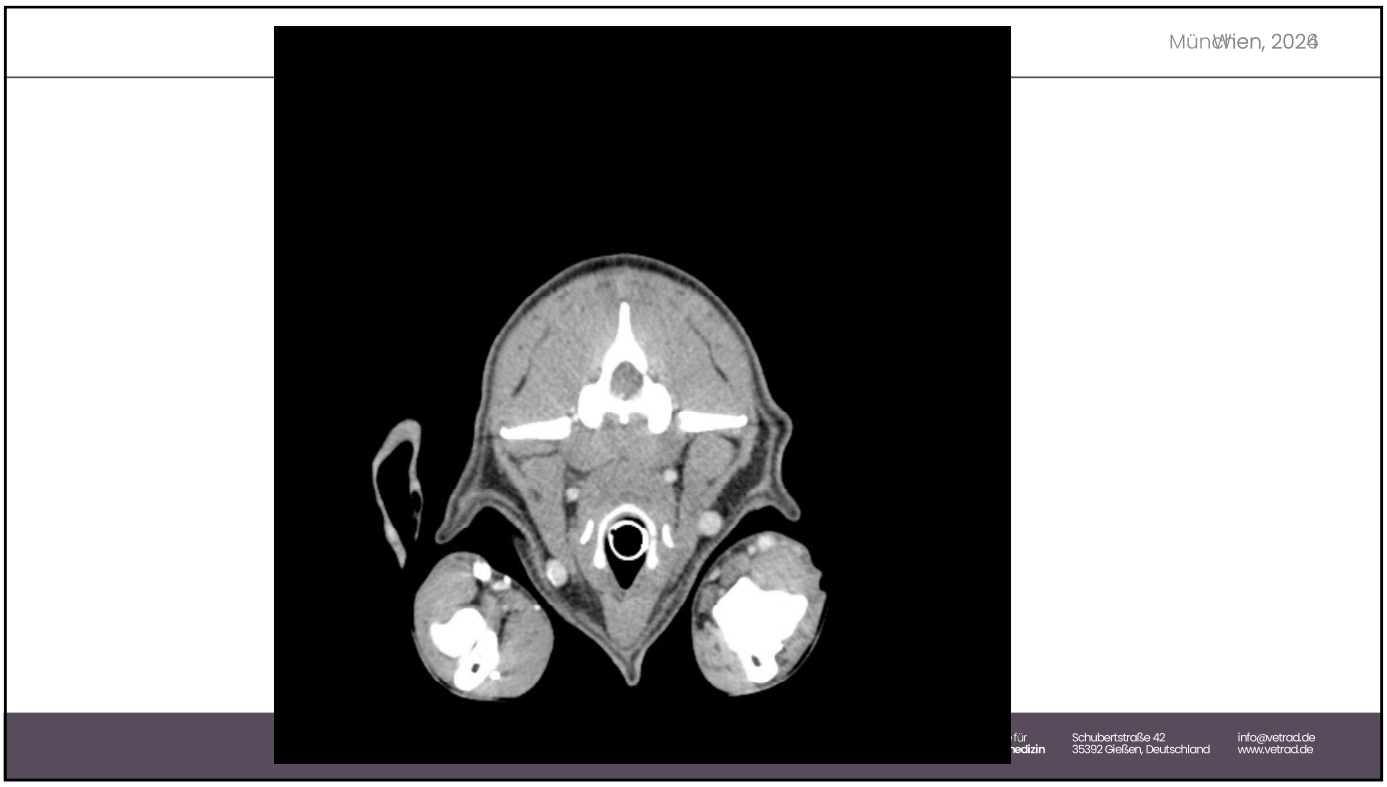
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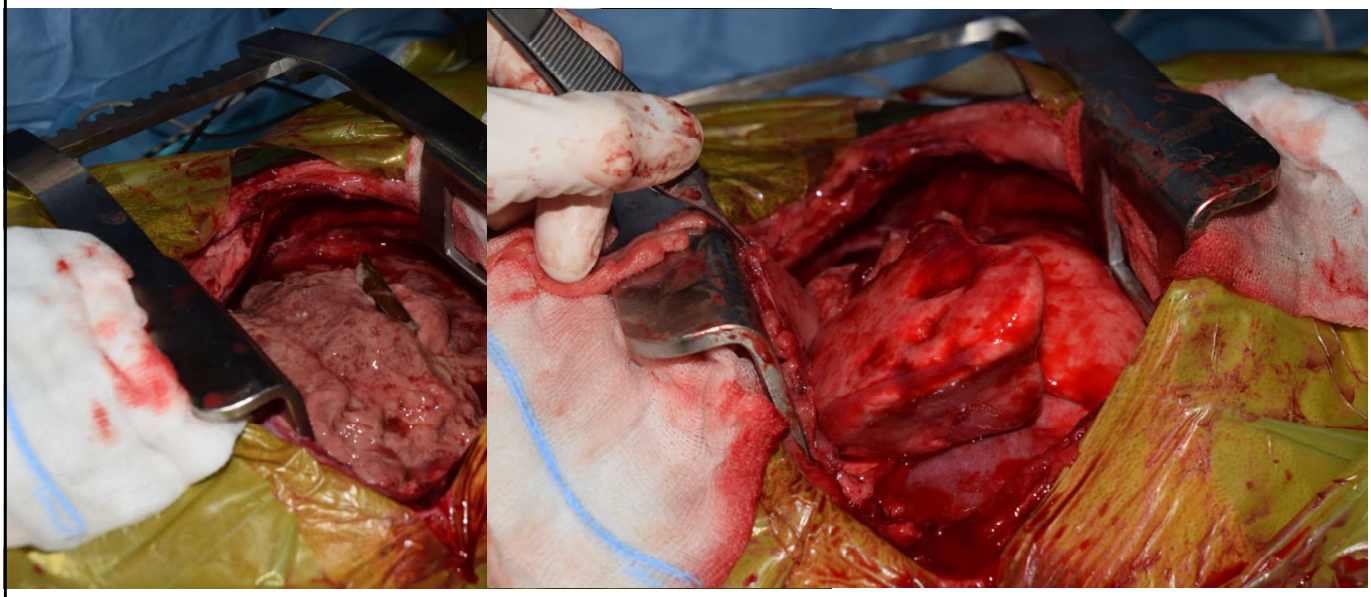

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Fall 16

- Berner Sennenhund
- 1.5 Jahre
- W
- Herzgeräusch, Leistungsintoleranz

94

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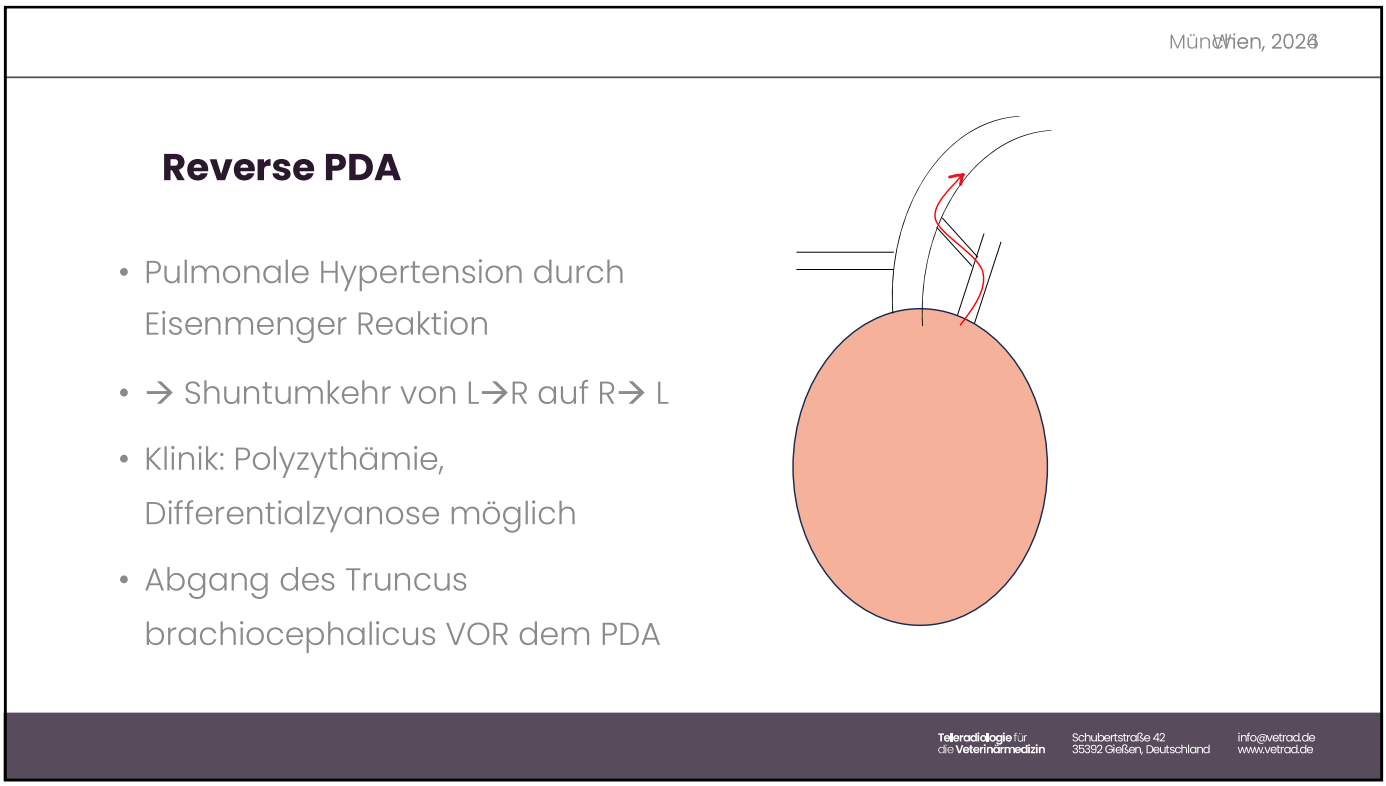
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Reverse PDA
• Pulmonale Hypertension durch Eisenmenger Reaktion
• → Shuntumkehr von L→R auf R→ L
• Klinik: Polyzythämie, Differentialzyanose möglich
• Abgang des Truncus brachiocephalicus VOR dem PDA
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Reverse PDA

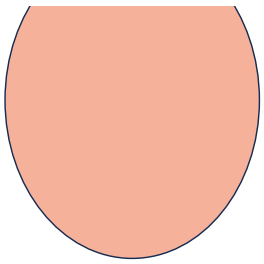
- Pulmonale Hypertensio Eisenmenger Reaktion
- → Shuntumkehr
- Klinik: Polyzythämie, Differentialzyanose möglich
- Abgang des Truncus brachiocephalicus VOR dem PDA

STANDARD ARTICLE | Open Access

Clinical features and outcome of dogs and cats with bidirectional and continuous right-to-left shunting patent ductus arteriosus

Victoria Greet, Elizabeth F. Bode, Joanna Dukes-McEwan, Pedro Oliveira, David J. Connolly, Julia Sargent

First published: 26 February 2021 | https://doi.org/10.1111/jvim.16072 | Citations: 9



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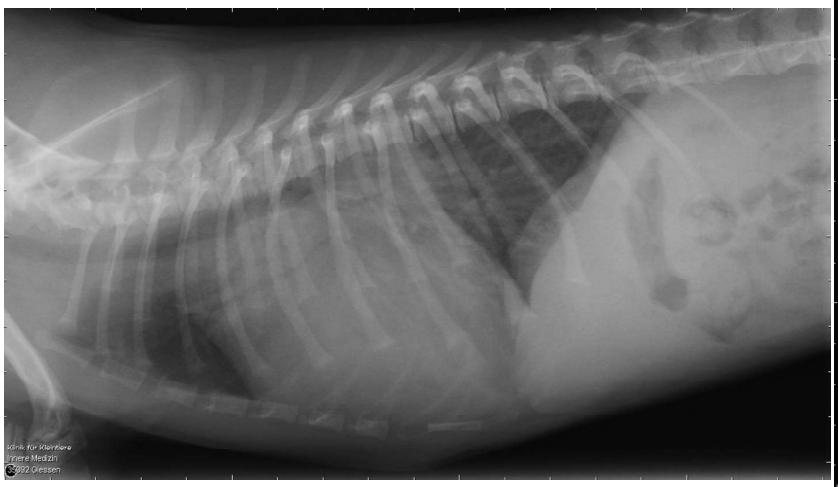

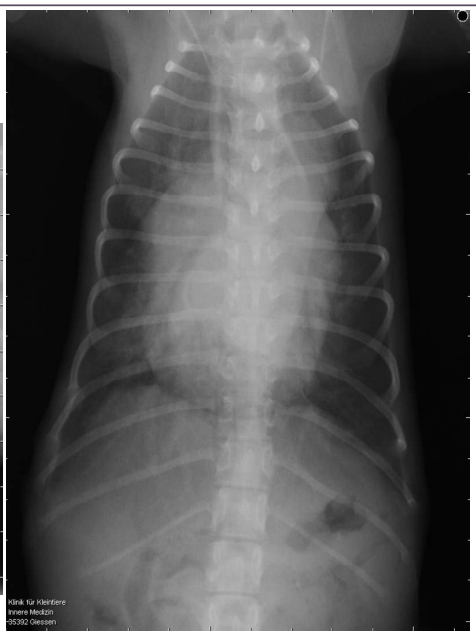

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Folientitel

München/Wien, 2026

Fall 17

- Husky
- Mk
- 6 Jahre
- Husten seit mehreren Wochen

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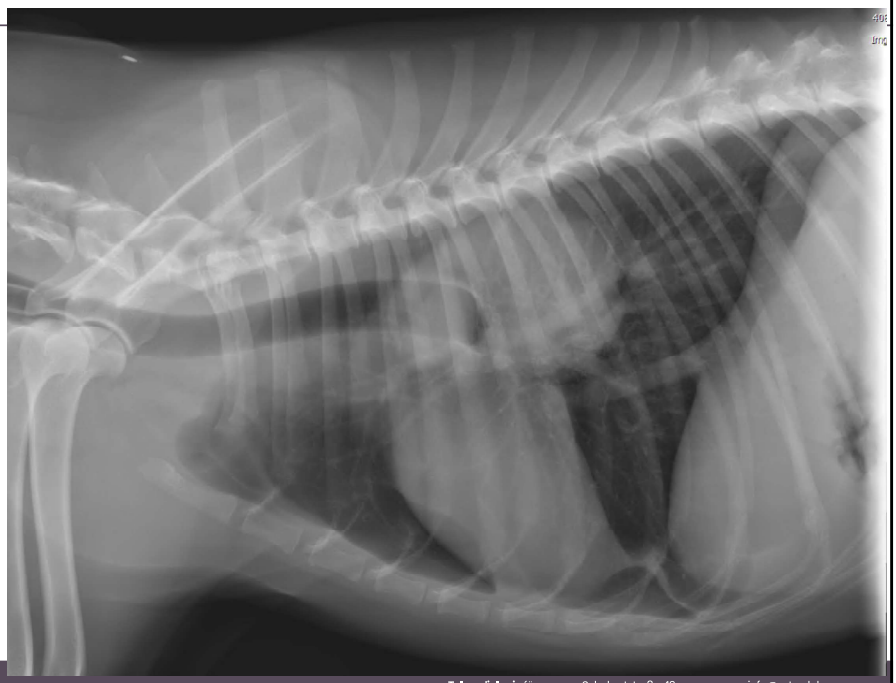

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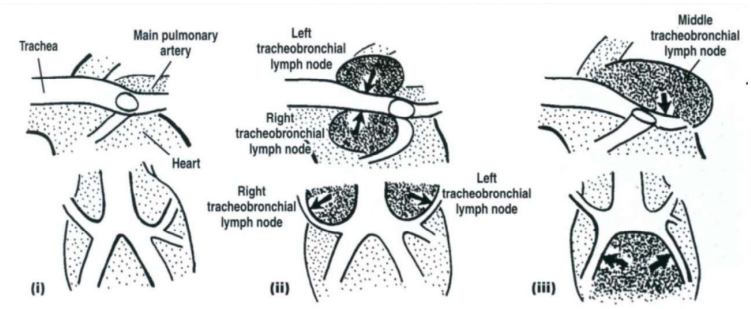

Aus: BSAVA Manual of Canine and Feline Thoracic Imaging

RELATIONSHIP BETWEEN RADIOGRAPHIC EVIDENCE OF TRACHEOBRONCHIAL LYMPH NODE ENLARGEMENT AND DEFINITIVE OR PRESUMPTIVE DIAGNOSIS

Brian G. Jones ✉, Rachel E. Pollard

First published: 23 July 2012 | https://doi.org/10.1111/j.1740-8261.2011.01921.x | Citations: 7

- Lymphom, histiozytäres Sarkom, metastasiertes AdenoCa
- Mykotische Infektionen

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Danke!

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Imaging the Diaphragm

Focusing on Radiography & Ultrasound

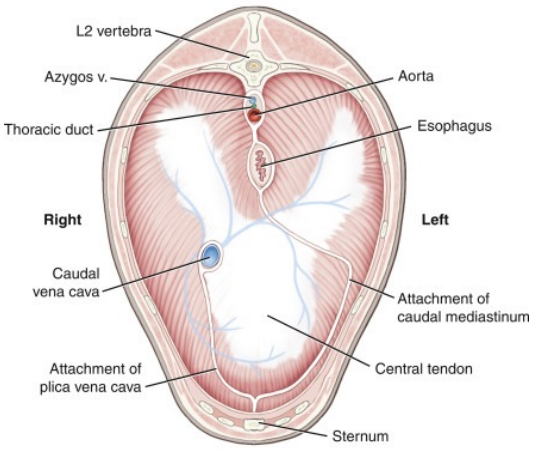
Nele Eley

1

Anatomy

- Muscle: R & L crus of the diaphragm
- Tendon: Cupola

- 3 Openings
  - Dorsal: Aortic hiatus (Ao, AzV, T-duct)
  - Central: Esophageal hiatus
  - Right ventral: Caval foramen

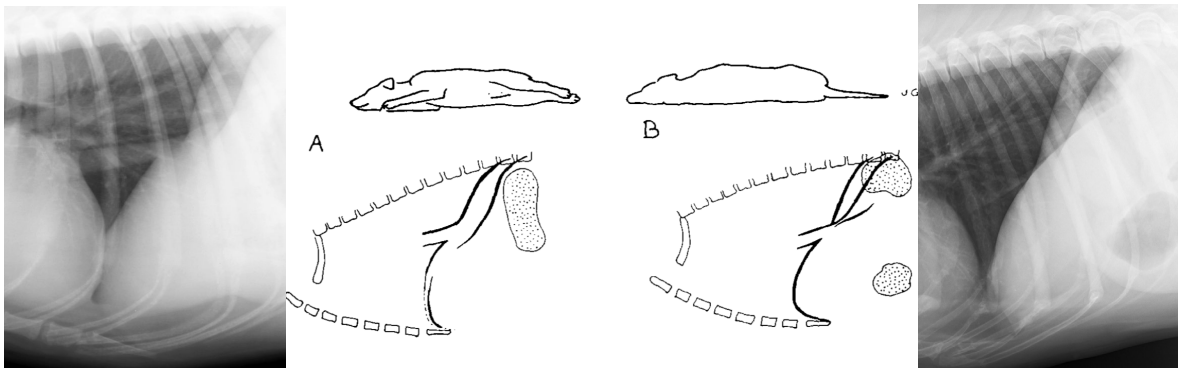


The Diaphragm

2

Radiographic anatomy

Right lateral



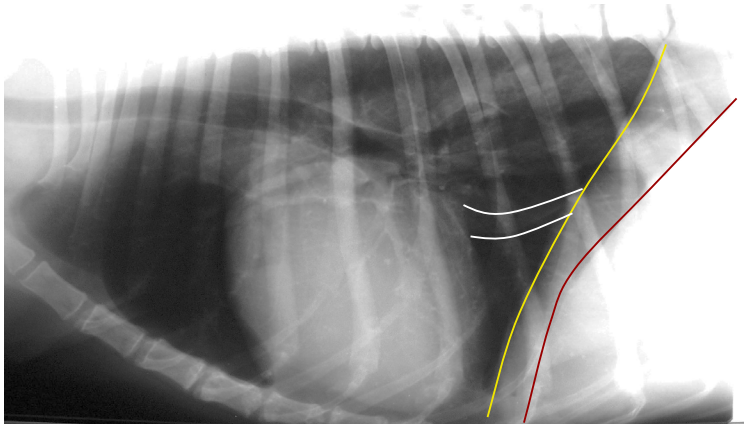
Left lateral

The Diaphragm

3

Radiographic anatomy

- Right lateral: Diaphragmatic crura run parallel



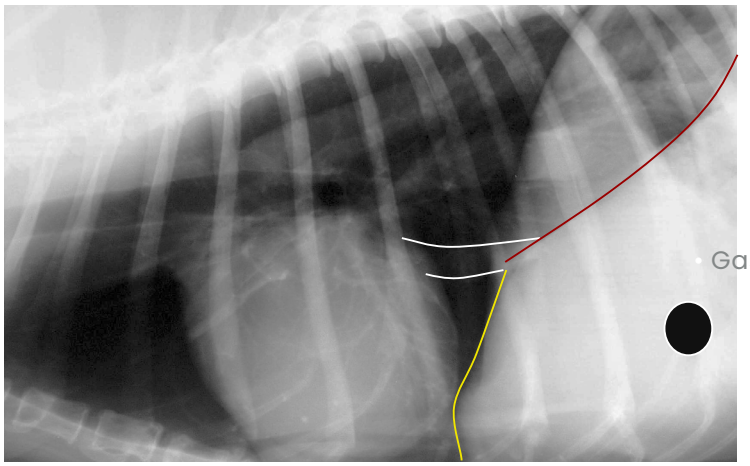
Right crus pushed cranially – V cava ends

The Diaphragm

4

Radiographic anatomy

- Left lateral: Diaphragmatic crura crossing



- Gas in pylorus

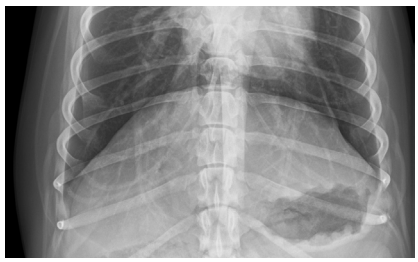
Left crus pushed cranially: V cava crosses over

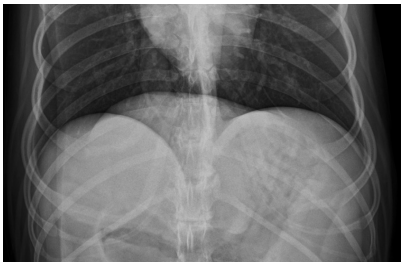
The Diaphragm

5

Radiographic anatomy

- DV / VD: Cupola at T8 – Lung / Crura T10



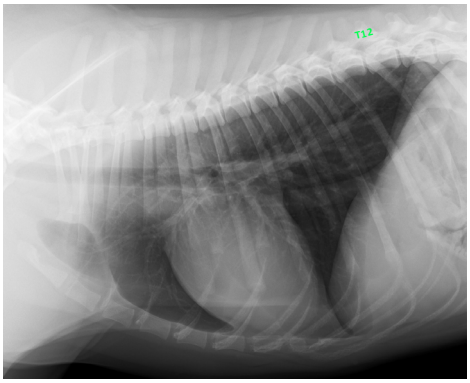


The Diaphragm

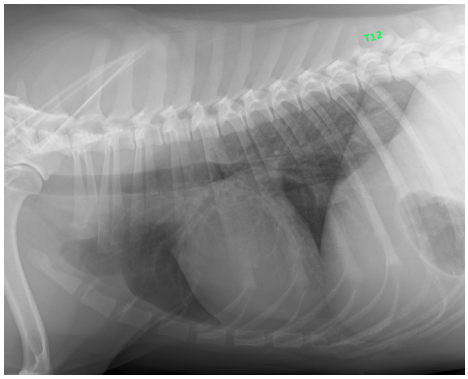
6

Radiographic anatomy

- Lumbodiaphragmatic recess approx. T11/12



Inspiratory



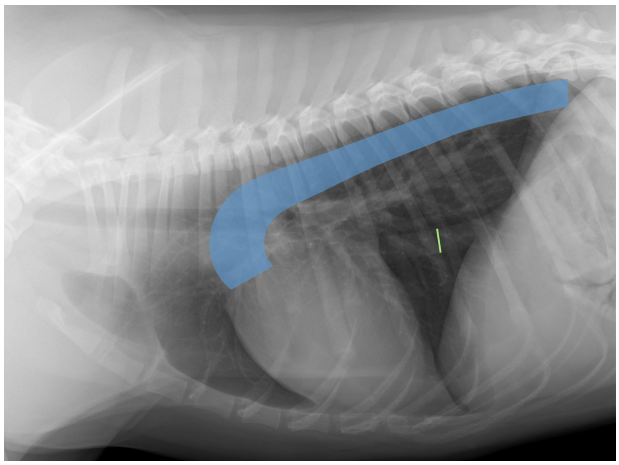
Exspiratory

The Diaphragm

7

Radiographic anatomy

- Aorta
- V cava: variable, depending on cadiac cycle & breathing

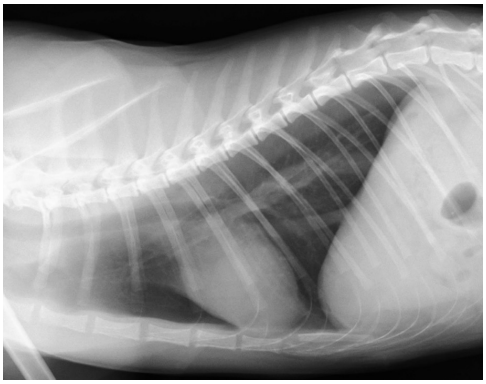


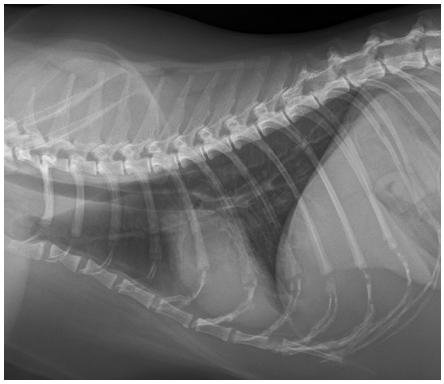
The Diaphragm

8

Radiographic anatomy

- Esophagus: Only visible when containing liquid or gas.

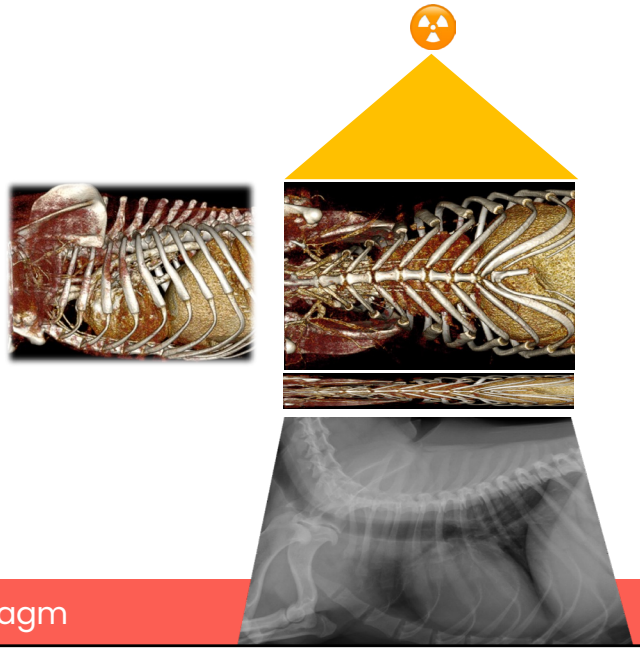




The Diaphragm

9

Radiographic anatomy ≠ Anatomy Book

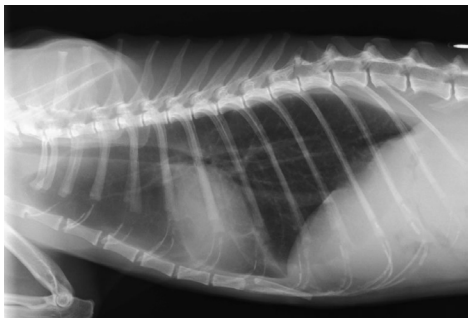


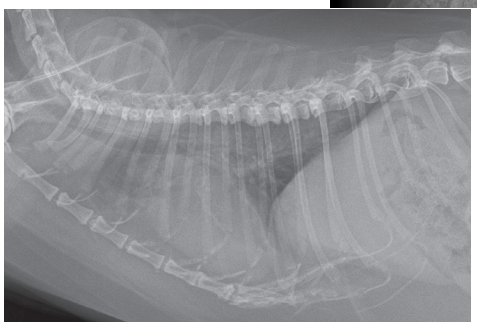
The Diaphragm

10

Body condition, resp. cycle, radiographic view, thoracic shape...

- X-ray anatomy

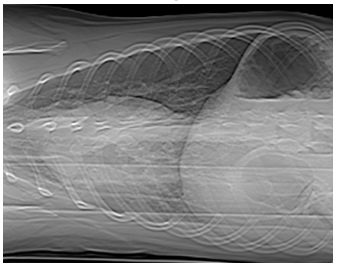


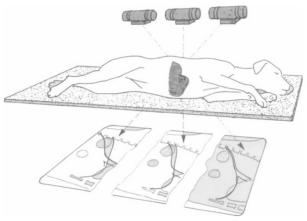


The Diaphragm

11

- X-ray anatomy

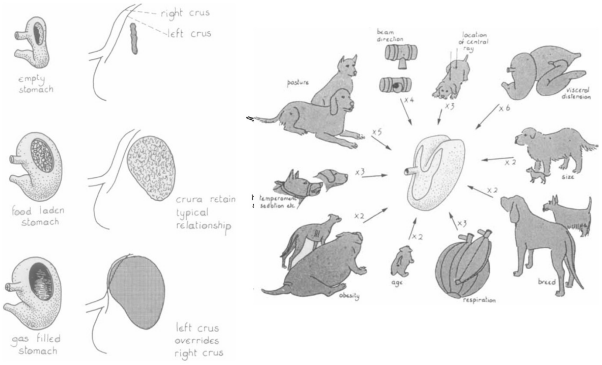




J. small Anim. Pract. (1974) 15, 1–17.

The radiology of the dog's diaphragm*

J. GRANDAGE
The Department of Veterinary Anatomy, University of Queensland, St. Lucia, Brisbane 4067, Queensland, Australia.

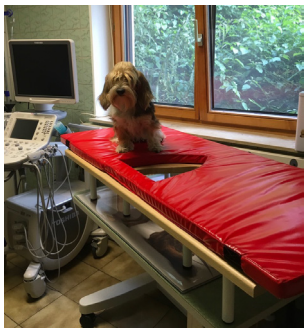


The Diaphragm

12

Ultrasound of the diaphragm

- Lateral recumbent position
- (Micro-)convex probe preferred
- Linear transducer possible
- Subxyphoidal/transhepatic
- Parasternal intercostal

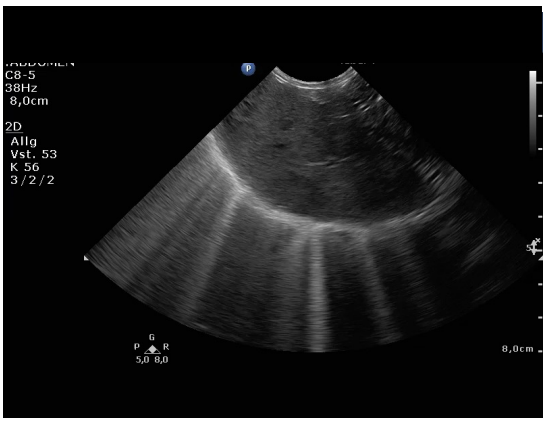


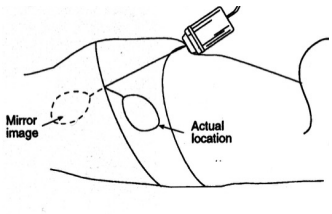
The Diaphragm

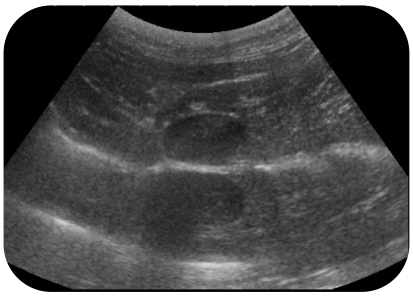
13

Diaphragm, Where Art thou?

- Ultrasonographic Anatomy





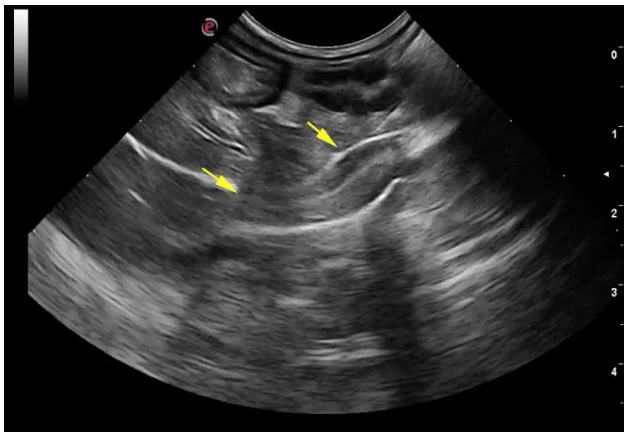


The Diaphragm

14

Esophageal hiatus - LES

- Ultrasonographic anatomy

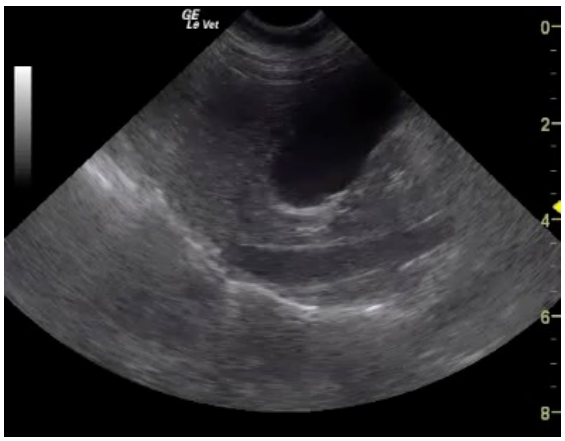


The Diaphragm

15

Vena cava

- Ultrasonographic Anatomy

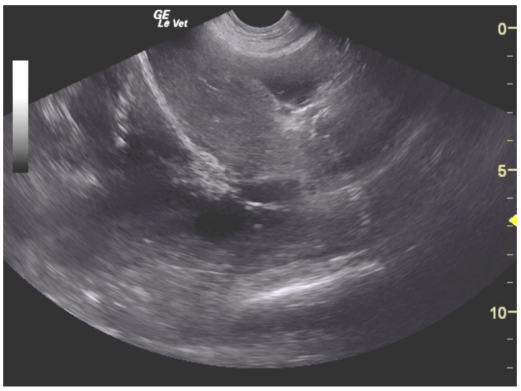


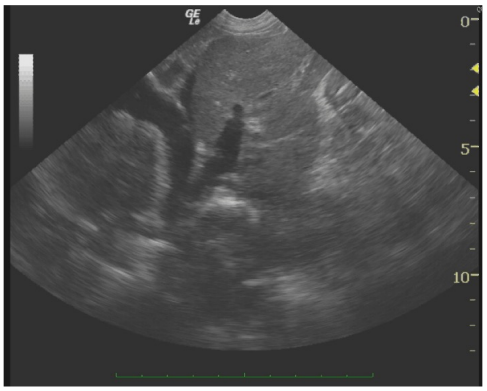
The Diaphragm

16

Vena cava & hepatic vein inflow

- Ultrasonographic Anatomy





The Diaphragm

17

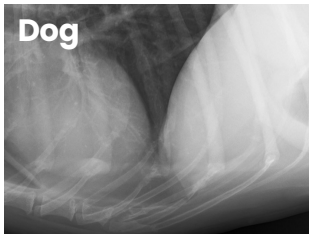
Pathologies of the Diaphragm

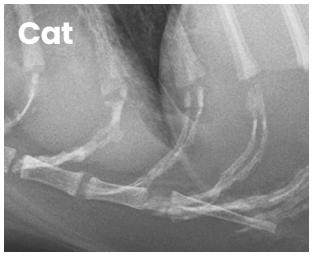
18

Traumatic rupture

Radiographic signs:

- Loss of diaphragmatic outline – can be anywhere
- Your helper in the Cat: Falciform fat
- Diplacement of abdominal viscera: Liver, stomach, intestines, spleen, omentum





The Diaphragm

19

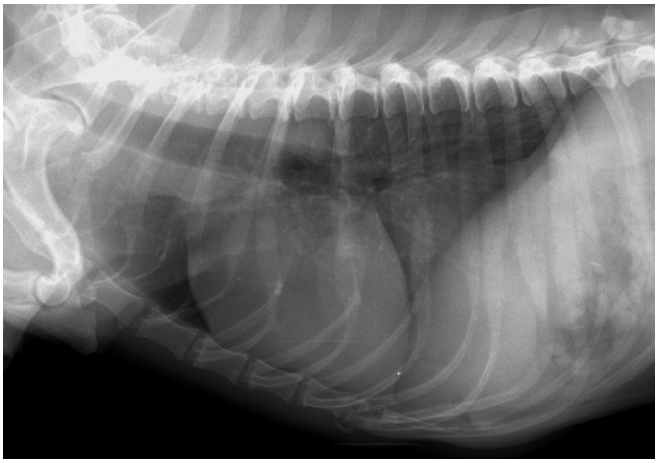
Traumatic rupture

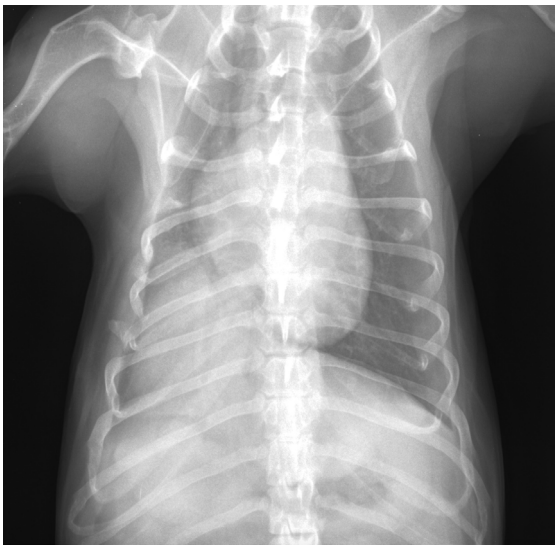
Radiographic signs:

- Pleural effusion
- Pulmonary atelectasis
- Displacement of heart and other mediastinal tissues
- Absence of organs in the abdomen
- +/- Fractures

The Diaphragm

20

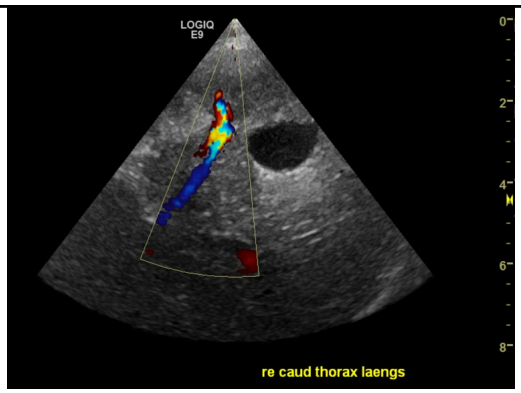


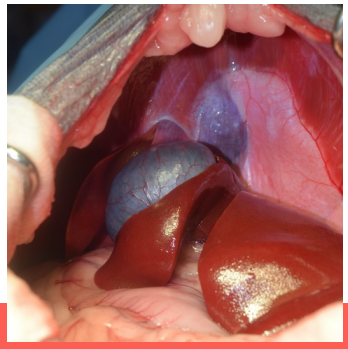


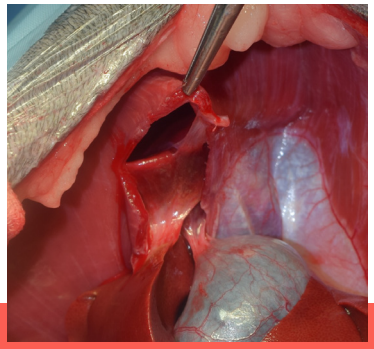
- 7y Dachshund, Hx of trauma

The Diaphragm

21







The Diaphragm

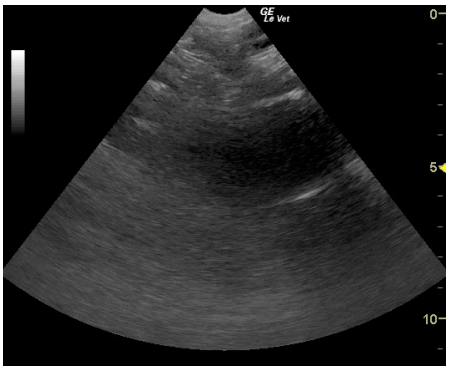
22

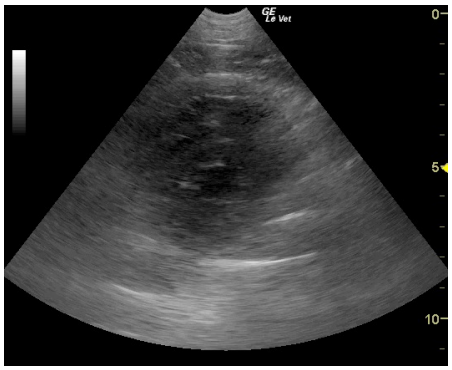
- 11y DSH, resp. distress

The Diaphragm

26

"Intestinal pathologies of the chest"

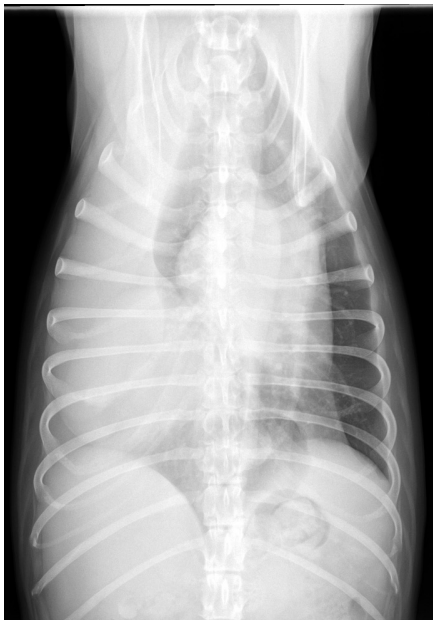


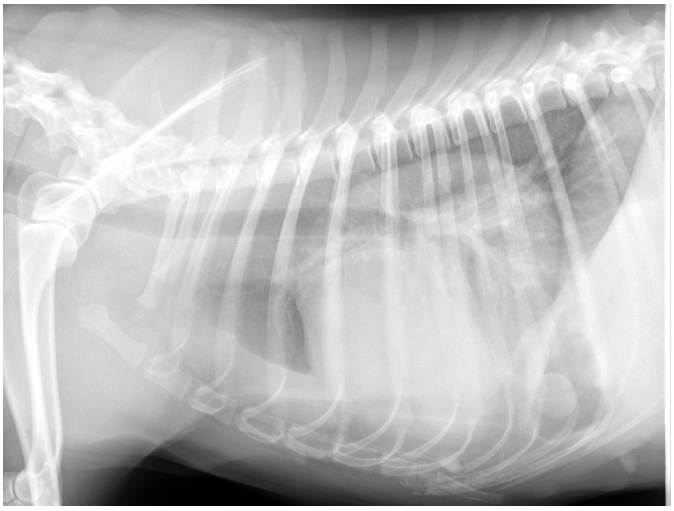


- 11y DSH, resp. distress

The Diaphragm

27

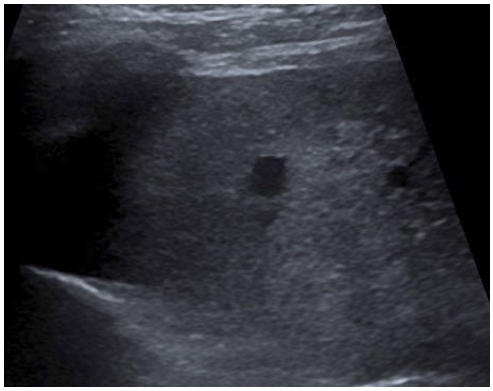


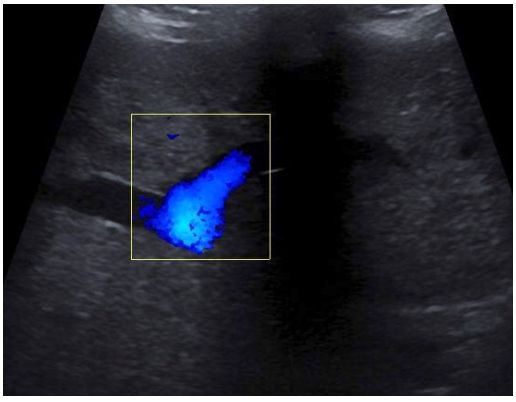


- 7y Border Terrier, Hx of trauma

The Diaphragm

28

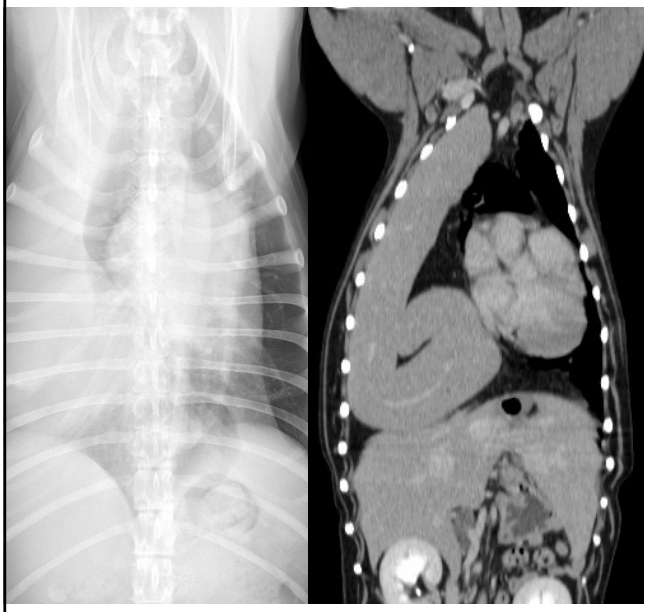


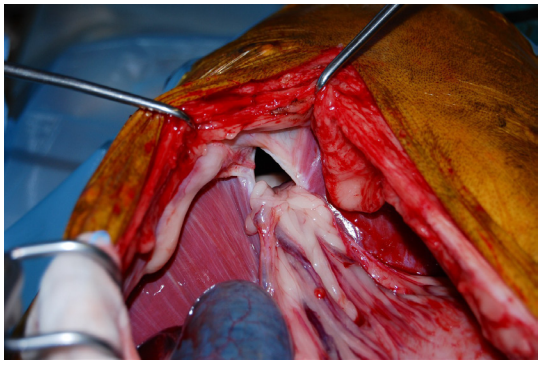


- 7y Border Terrier, Hx of trauma

The Diaphragm

29





- 7y Border Terrier, Hx of trauma

The Diaphragm

30

Traumatic rupture

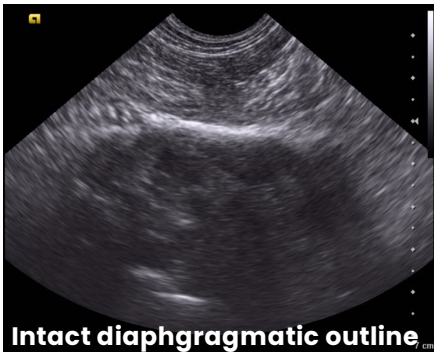
- **Ultrasonographic signs:**
  - Abdominal organs in the thorax
  - Interruption of the anechoic interface between liver and lungs
  - +/- Effusion: Can facilitate imaging of the diaphragm
  - Challenge: Lung Atelectasis vs. Liver
  - Mirror Artifact

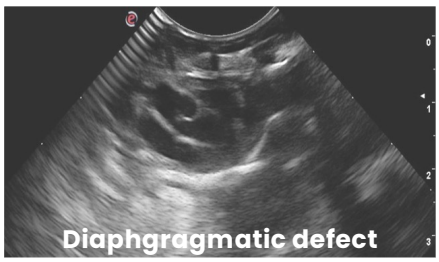
The Diaphragm

31

Traumatic rupture

- **Ultrasonographic pitfalls:**
  - Defect inconsistently seen
  - Pulmonary Atelectasis vs. Liver
  - Mirror Artifact





Traumatic rupture

Ultrasonographic Diagnosis

Vet Radiol Ultrasound. 2003 Mar-Apr;44(2):226-30.

Use of ultrasound to diagnose diaphragmatic rupture in dogs and cats.

Spattini G[1], Rossi F, Vignoli M, Lamb CR.

"Irregular or asymmetric cranial aspect of the liver and abdominal viscera in the thorax"

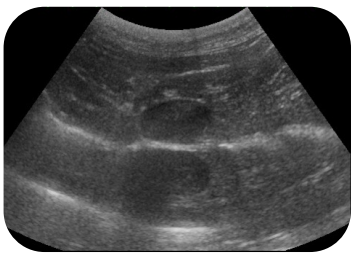
93 % accuracy (n = 25 / 27, 21 cats, 6 dogs)

Pitfalls:

Mirror image

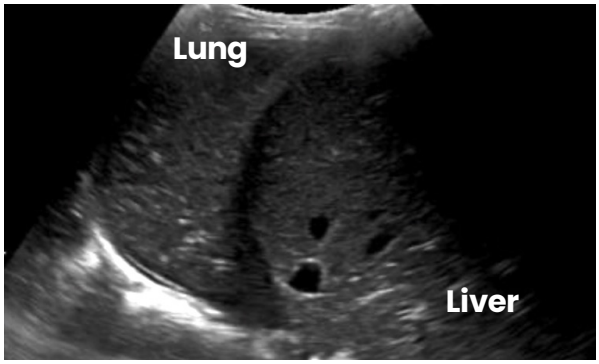
Adhesions in chronic rupture

Hepatized lung vs. liver

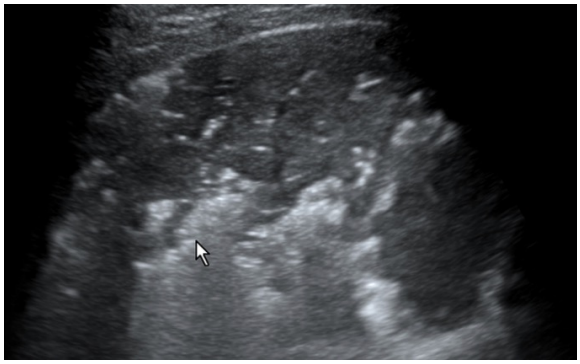


Hepatization of the lung

- Atelectasis
- Consolidation, infiltration, hemorrhage, edema….



Fluid bronchograms



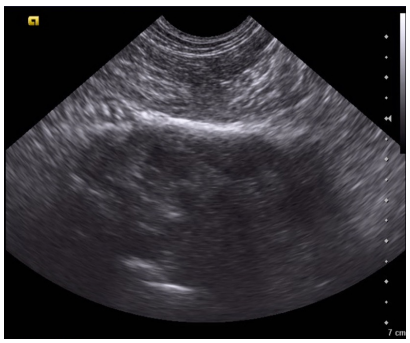
Air bronchograms

The Diaphragm

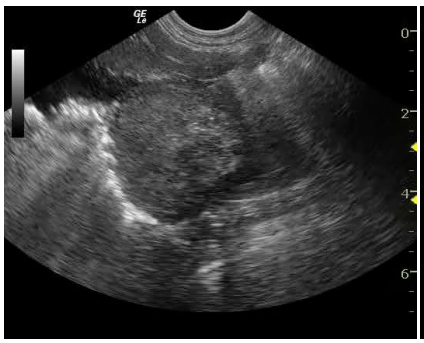
34

Hepatization of the lung

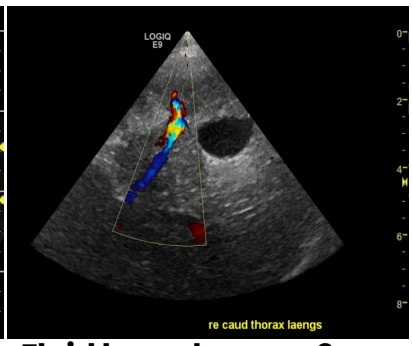
- Residual Gas: Look for the transition to aerated lung
- Direction of the bronchial/vascular tree
- Doppler



Pl. Eff. & D. outline



Pulm. mass & Br. tree



Fluid bronchogram?

The Diaphragm

35

Diaphragmatic hernia

Congenital: Agenesis or lack of fusion

Except: Hiatal hernia

The Diaphragm

36

Diaphragmatic hernia

Location

- Pleuroperitoneal remnant: Dorsal → Pleural space
- Peritoneo-piercardial (PPDH): Central → Pericardium
- Hiatal / Paraesophageal: Mediastinum
- Ventral & Aortic hiatus (rare)

The Diaphragm

37

Hiatal hernia

- Congenital & Permanent
  - Short esophagus
- Acquired, commonly gliding
  - Trauma, diseases of the upper respiratory tract or esophagus, neuromuscular disease.

The Diaphragm

38

Diaphragmatic hernia

Radiographic signs:

- LAT: Semicircular soft tissue opacity between Ao & V cava
- VD/DV: Mediastinal
- Effacement with liver
- +/- Gas, gastric folds
- +/- Aspiration pneumonia

The Diaphragm

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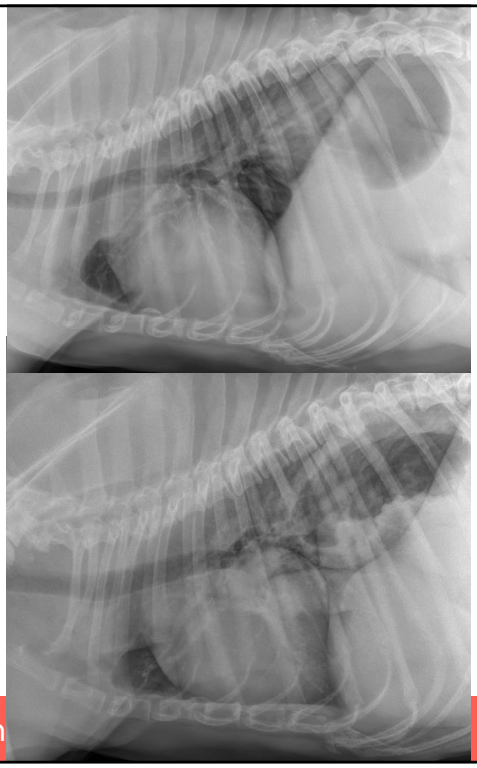
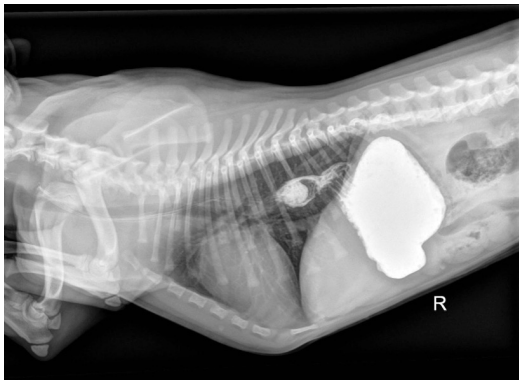
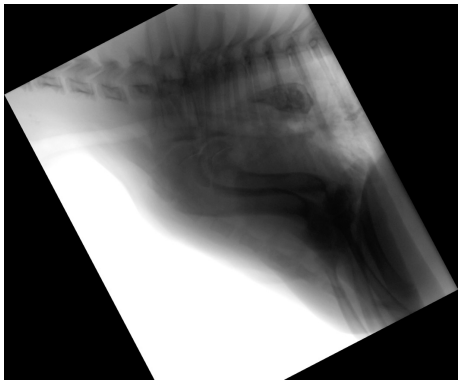


The Diaph

40

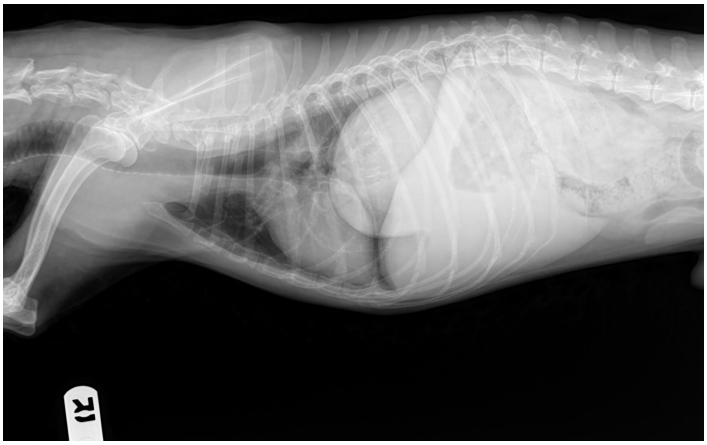




- 4m French Bulldog, regurgitation

The Diaphragm

41

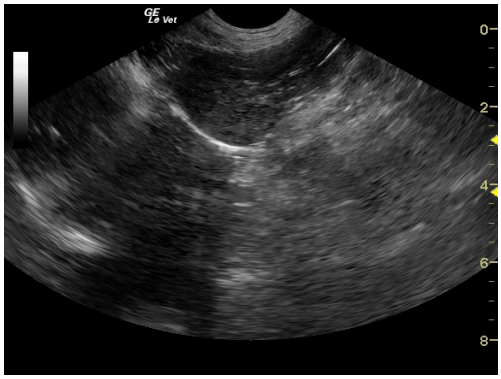


- 14y Poodle, preanesthetic Checkup

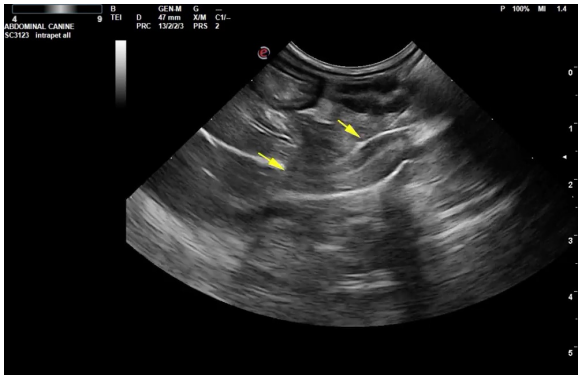
The Diaphragm

42

Hiatal hernia on US



Hernia



Normal

The Diaphragm

43

Peritoneopericardial diaphragmatic hernia (PPDH)

- Congenital
- Liver
- Stomach / Intestines, omentum
- +/- Concomitant sternal & cardiac defects

The Diaphragm

45

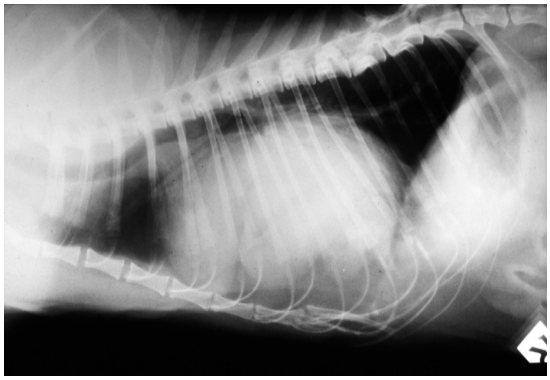
PPDH

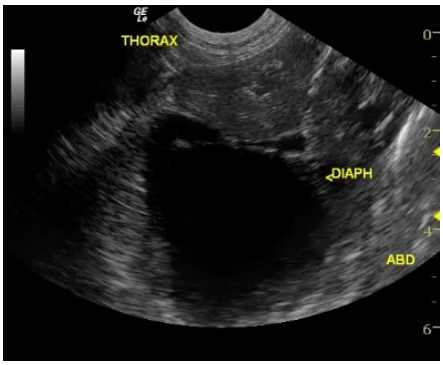
Radiographic signs:

- „Basketball heart / Cardiomegaly“
- Heterogeneous when fat or GIT involved
- Effacement cardiac silhouette & diaphragm
- No signs of congestion
- +/- Split Sternum

The Diaphragm

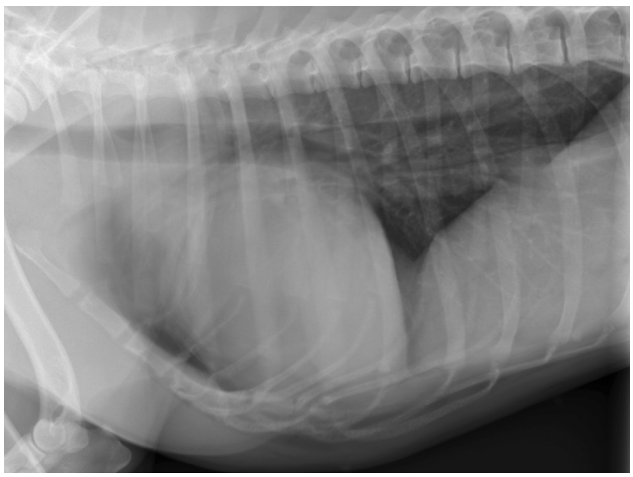
46





The Diaphragm

47



- 11m Rhodesian Ridgeback

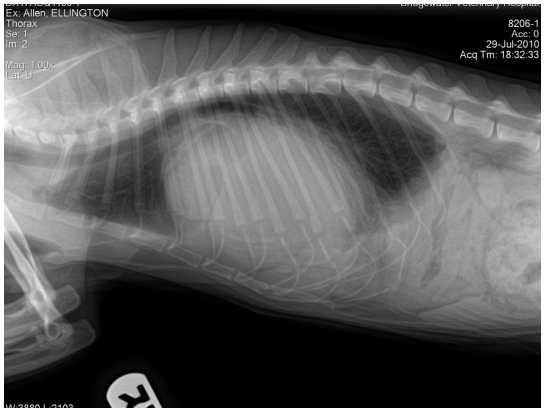
The Diaphragm

48

DDx PPDH?

1. **"Cardiomegaly"**
Signs of congestive heart failure? +/-

2. **Pericardial effusion**
Diaphragm contour defect? +/-

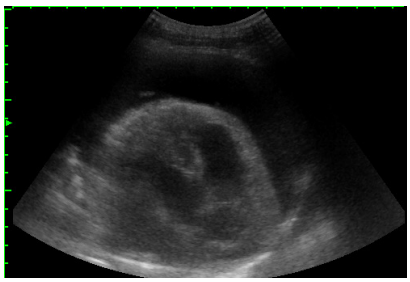


The Diaphragm

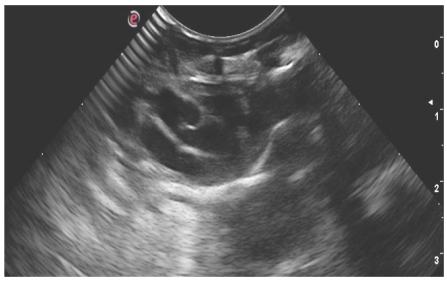
49

Pericardial effusion vs. PPDH

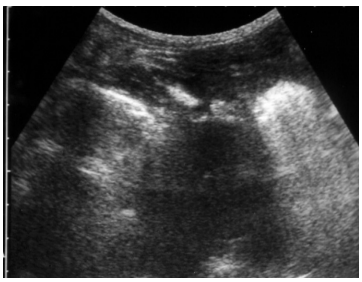
PE



PE



PPDH

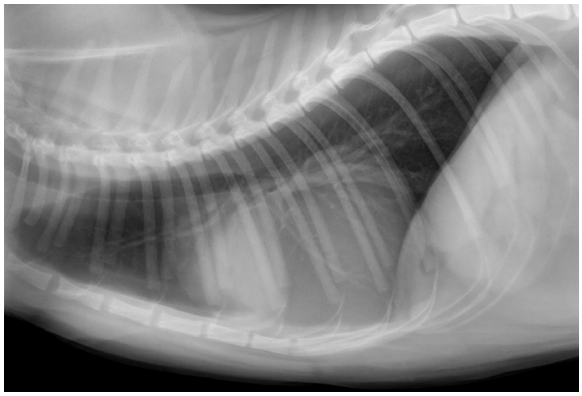


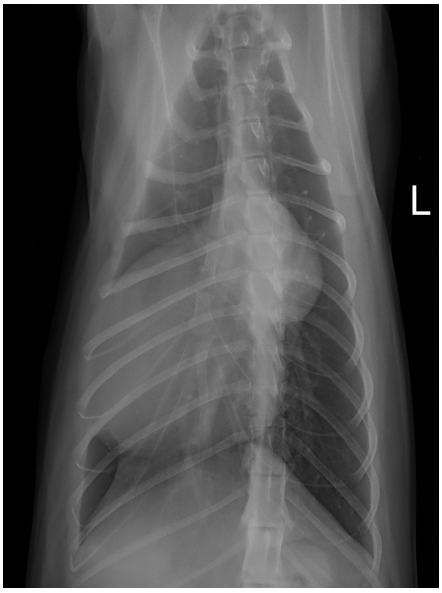
The Diaphragm

50

Is this a hernia?

- D outline?



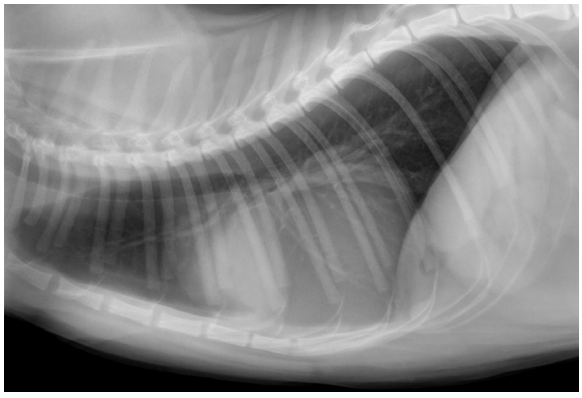


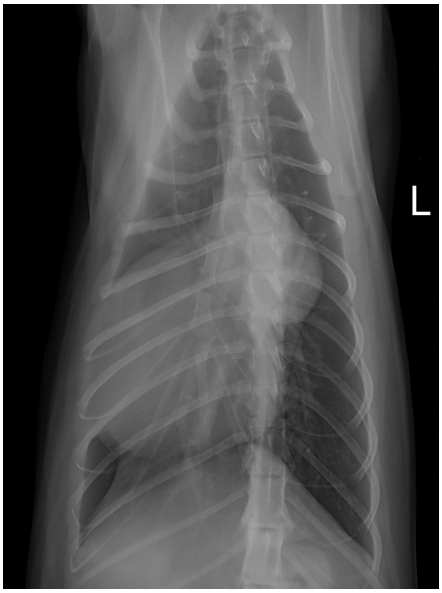
The Diaphragm

51

What is it then?

- Can you tell?





The Diaphragm

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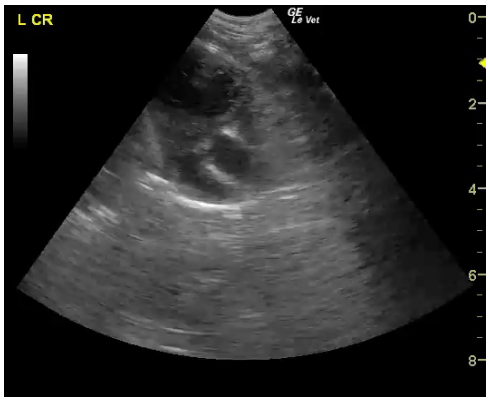
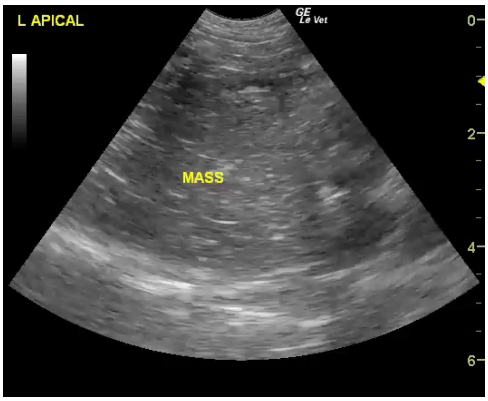
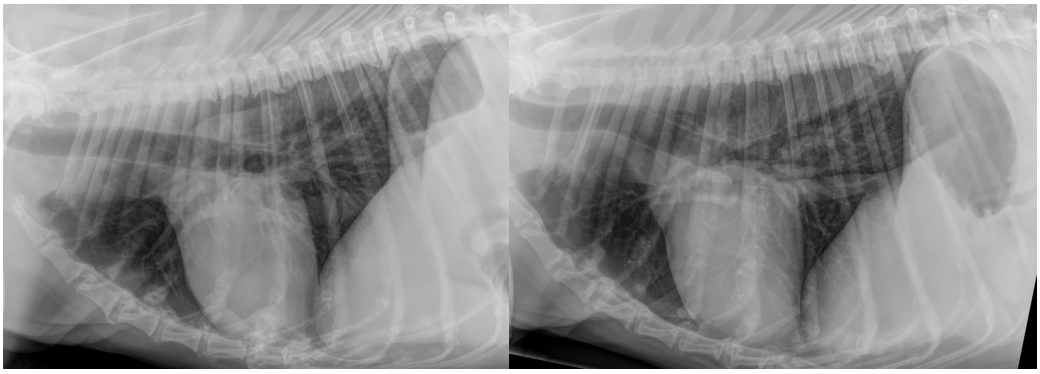




The Diaphragm

53

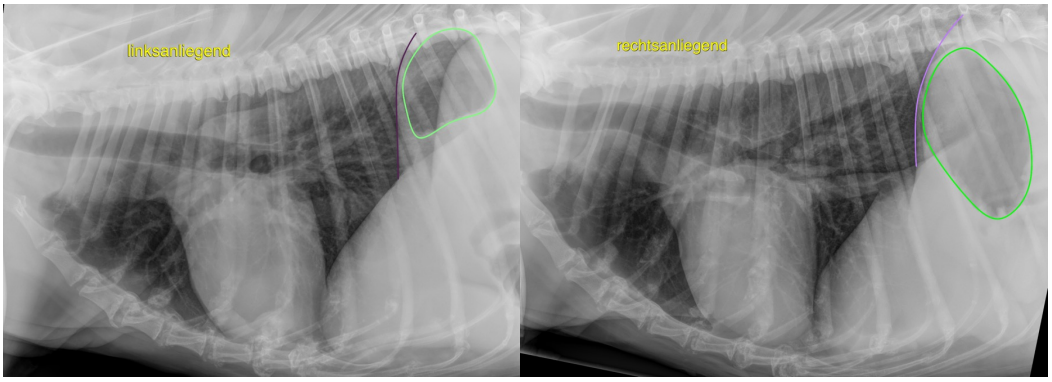
Diaphragmatic displacement



The Diaphragm

54

Diaphragmatic displacement



The Diaphragm

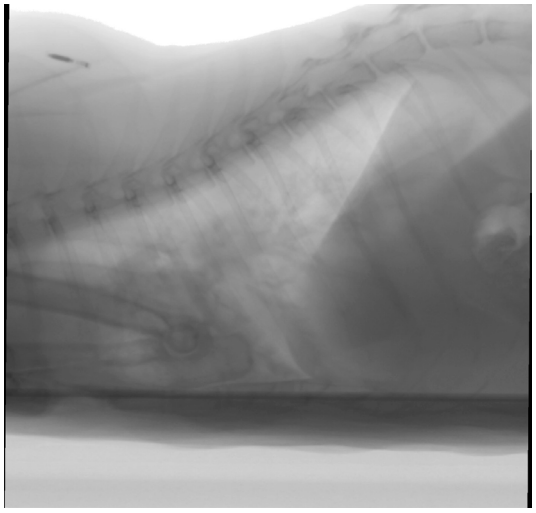
55

Diaphragmatic displacement

The Diaphragm

56

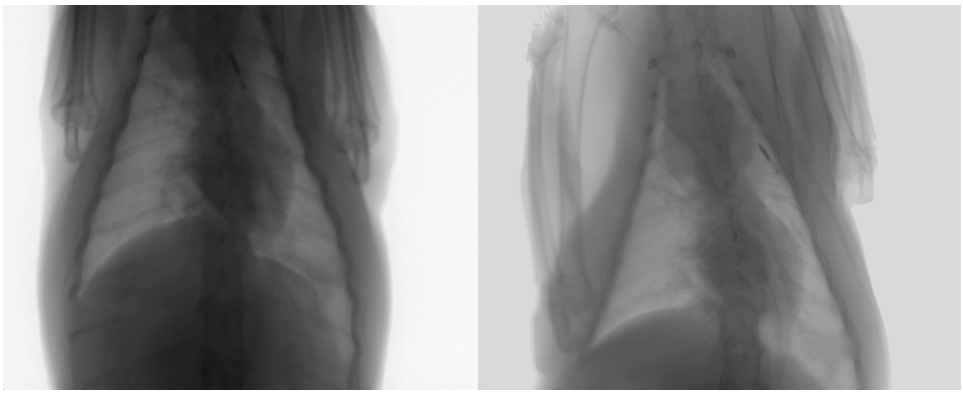
Diaphragmatic displacement



The Diaphragm

57

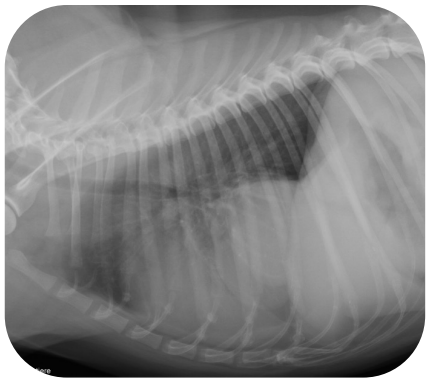
Diaphragmatic displacement



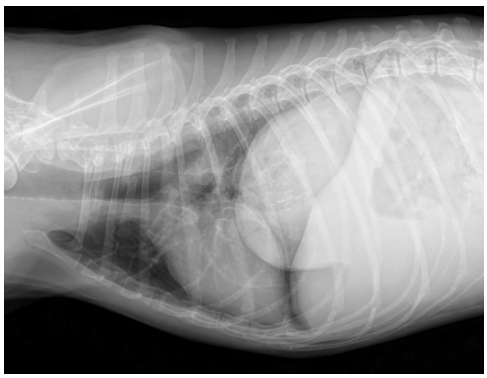
The Diaphragm

58

What to do when in doubt?



Rupture

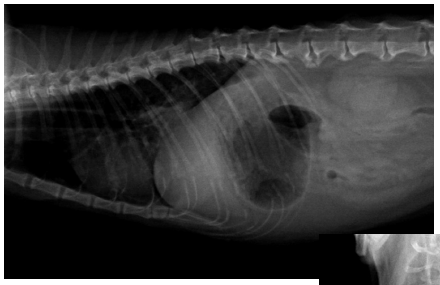


Hernia

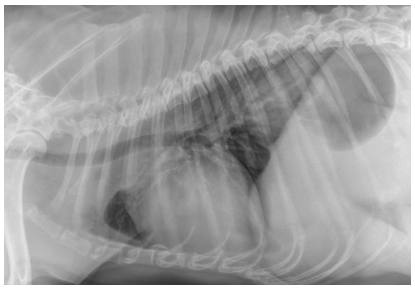
The Diaphragm

59

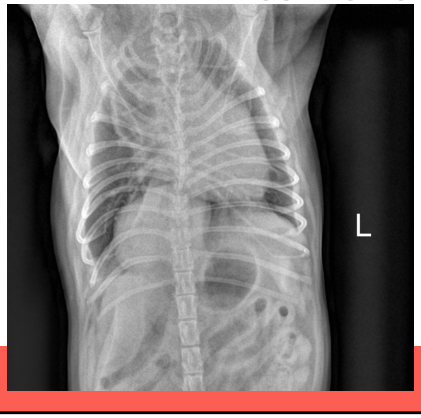
What to do when in doubt?



14y Cat, dyspnea, weight loss



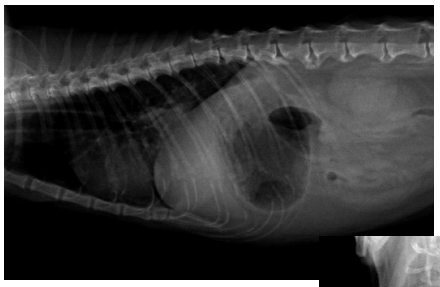
8y French Bulldogg, regurgitation



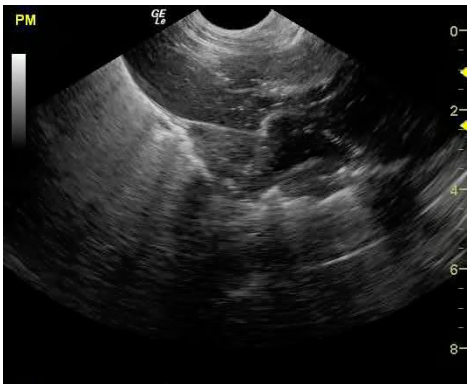
The Diaphragm

60

What to do when in doubt?



14y Cat, dyspnea, weight loss



Mineralized biliary CA

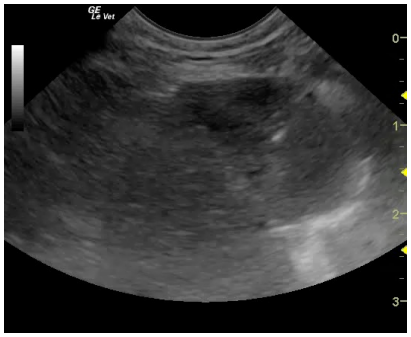
invasively growing through diaphragm

The Diaphragm

61

What to do when in doubt?

Needle!!!



The Diaphragm

65

- Don’t let one view fool you!

The Diaphragm

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Ultrasound of GI nodules and masses: Part I and II

Dominique Penninck, DVM, DACVR, DACVR, DECVDI
Professor, section of Diagnostic Imaging
Cummings School of Veterinary Medicine, Tufts University, USA

Introduction

These presentations are centered on evaluating the common features of gastrointestinal (GI) nodules or masses; that includes both neoplastic and non-neoplastic lesions.

Radiographs are helpful in assessing the presence of mass/thickening of the GI wall; however, the detection of such findings is highly dependent on the size, number and location of the lesion(s). Abnormal fluid/gas accumulation can also be detected proximal to the (sub)-obstruction site when the lesion creates significant narrowing of the lumen. The "gravel sign" is useful in identifying abnormal accumulation of heavy particles (like bony fragments) at a site of reduced transit.

Ultrasonography (US) of GI disorders has developed over the past 40 years and is now recognized as a reliable diagnostic method. The most common uUS features of GI diseases are wall thickening that can be paired with altered or lost wall layering. However, these findings are not specific and has been also reported in both tumoral and inflammatory changes.

In **part I**, the US features of the most common GI tumors are reviewed.

Alimentary **lymphoma** (involving the GI tract and/or the tributary lymph nodes) is one of the most common sites of occurrence for feline lymphoma. In cats, the most common US findings are transmural gastric or intestinal thickening associated with diffuse loss of normal wall layering, reduced wall echogenicity, localized decreased motility and regional lymphadenopathy. These features can be found in both the stomach, small intestines, and colon. Jejunal lymphadenopathy is a common finding in intestinal lymphoma, and in some instances, is responsible for most of the mass-effect palpated and/or seen on radiographs. Despite extensive wall involvement, mechanical ileus is rarely seen.

Other round cell tumors such as mast cell tumors can have similar features but are reported more often with asymmetric wall distribution, with or without wall ulceration.

Similar US features of transmural thickening of the GI wall with decreased echogenicity and loss of layering, decreased motility at the affected site and regional lymphadenopathy are present in dogs with round cell tumors.

Carcinomas are considered a common GI tumor in the dog. In the author's experience, gastric carcinoma appears to have an US distinction from those with an intestinal location.

Dogs diagnosed with gastric carcinoma commonly have transmural thickening (wide range from 10 to 30 mm) with altered wall layering. This altered layering appeared as a moderately echogenic zone surrounded by an outer and an inner poorly echogenic line. Because of this

appearance and to avoid confusion with the term “layering” usually reserved to describe the normal appearance of the GI wall, this feature was called “pseudo-layering”. This pseudo-layering seems to correlate with the unevenly layered tumor distribution noted histopathologically. This particular US feature, when present, may suggest gastric carcinoma, especially if an enlarged and target-shaped local lymph node is detected. The extent of the tumor and the presence of lymphadenopathy suggest that the diagnosis is made in the late stage of the disease with a consequently poor prognosis. Intestinal carcinoma is documented in dogs and cats. The most common ultrasonographic findings are transmural thickening with complete loss of layering, and often with associated lymphadenopathy. In most cases, the length of the lesion is short, and the lumen contour is irregular. Often, there is fluid accumulation proximal to the intestinal thickening/mass associated with mechanical ileus.
Intestinal carcinoma has several similar US features to intestinal lymphoma. Signalment, clinical presentation and ultrasonographic signs may support a tentative diagnosis, but a final histopathological confirmation remains necessary to diagnose the lesion type with certainty.
Smooth muscle tumors (leiomyoma,leiomyosarcoma) and GI stromal tumors (GIST) can be found incidentally in geriatric patients. Few intestinal leiomyomas have been reported in the literature; the tumor can be discrete, small (2 to 3 cm in diameter) and of uniform echogenicity; or at times, the tumor is large and cavitated. These tumors can be incidental findings, and frequently, they do not cause obstruction in the associated bowel segment. In geriatric patients, leiomyoma is infrequently an underlying cause for intussusception. Occasional cases of metastasis from tumors initially described as leiomyomas suggest that these typically benign lesions should, in fact, be monitored with sequential abdominal ultrasound examinations. Transcutaneous abdominal US is more sensitive than survey radiography in detecting GI smooth muscle tumors. Smooth muscle tumors often are large (>3 cm) at the time of detection. These tumors originate intramurally and grow out of the serosa as large eccentric, extraluminal masses, or less commonly project into the bowel lumen. Because of their common exophytic distribution and their large size, it can be difficult to assess the anatomical origin of the mass and even more so to determine the precise layer of tumor origin. During real-time evaluation, it is important to identify the gas and/or the small amount of fluid associated with the lumen within the mass. Large GI leiomyosarcomas tend to be inhomogeneous, with a mixed echogenic pattern. The presence of anechoic and hypoechoic foci within the mass may correlate with the areas of central degeneration and necrosis frequently found in these large lesions. In dogs, metastases from GI leiomyosarcomas, when they occur, frequently involve the liver and the jejunal lymph nodes.

GI nodules and masses are not necessarily tumoral; In **part II**, the non-neoplastic nodules or masses are discussed.
Gastric polyps are moderately echogenic proliferative lesions of variable size and number, and they project within the gastric lumen. If located in the pylorus, they can be obstructing the

outflow. Other proliferative, often circumferential (symmetrical or not) thickening centered at the pyloro-duodenal junction may be chronic hypertrophic pyloric gastropathy, especially in middle-age, small dogs. In young dogs (especially French Bulldog), congenital hypertrophic /hyperplastic polyps can mimic other disorders such as intussusception or foreign bodies. Meanwhile, in cats, adenomatous polyps are moderately echogenic luminal projections that resemble gastric contents. They tend to occur at the pylorus and proximal duodenum.
Granulomatous enteropathy of variable etiology (secondary to exuberant scaring reaction, viral (FIP), bacterial or fungal enteritis, lipogranulomatous lymphangitis) may appear as nodular to mass-like lesion (single or multiple) of mixed echogenicity.
Feline eosinophilic sclerosing fibroplasia can have a similar appearance, and sampling is key to differentiate these lesions from tumors.

Percutaneous US-guided fine-needle aspiration or automated microcore biopsy is a relatively safe and valid alternative to endoscopic or surgical biopsy depending on the size and location of the lesion(s). The guided techniques of fine-needle aspiration using either a 25 to 22-gauge needle , and of microcore automated biopsy using a 20 gauge Tru-cut needle assisted by an automated biopsy gun can be performed to obtain one or more samples.

VetRad

Advanced thoracic imaging

Nele Eley, Mareike-Kristin Marx

1

"Modern Imaging"

- In line with the latest scientific, or technical developments
- ≠ futuristic or experimental

2

Objective

- Diagnostic Progress / Diagnosis
- Treatment planning

- Reducing invasiveness
- Reduce effort
- Increase sensitivity and specificity

Use a test that delivers results

3

Standard Thoracic Diagnostics

Step 1: Clinical examination

Step 2: Stabilization if necessary

Step 3: X-ray / Ultrasound

Step 4: "Further diagnostics" if necessary

4

Lung ultrasound?!

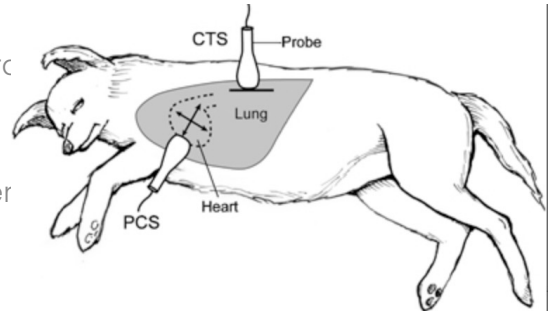
A/T	abdominal / thoracic
F	focused
A	assessment (with)
S	sonography (for)
T	trauma

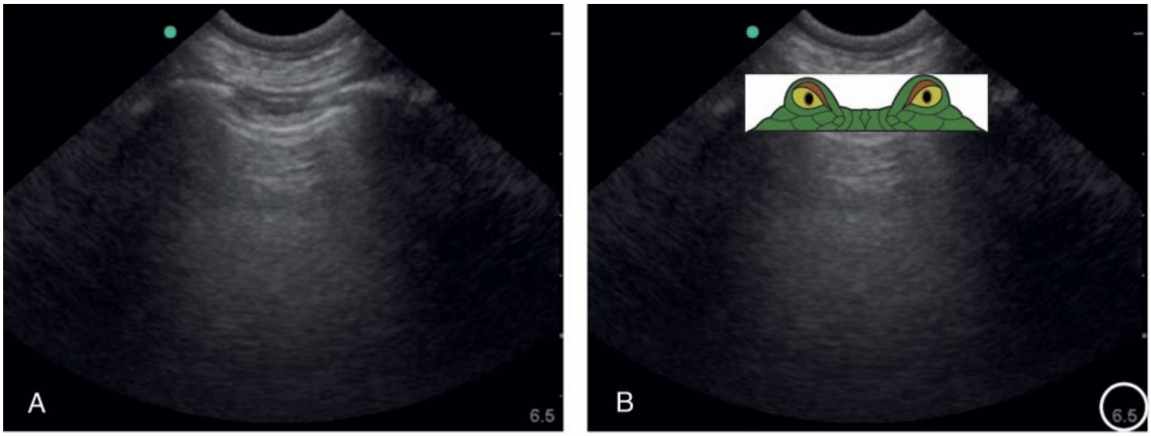
- Used on trauma patients as "TFAST"

Quick prelim. assessment, focused on unstable patients

TFAST Protocol

- In the lateral position
- CTS – chest tube site
  - 7th–9th intercostal space, dorsolateral
- PCS – pericardial site
  - 5th–6th intercostal space, ventrolateral

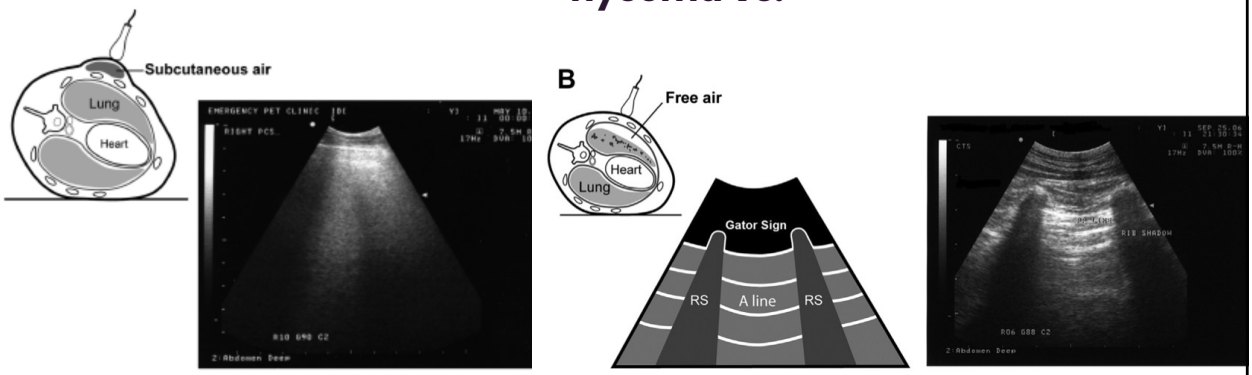




Normal: gator sign + glide sign, A-lines

7

TFAST – Subcutaneous Emphysema vs.



No Gator sign, no Glide sign
→ Subcutaneous emphysema

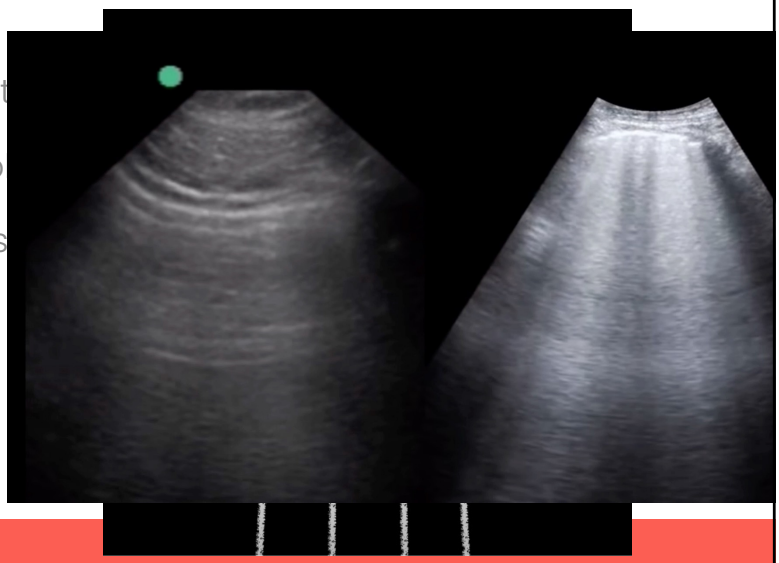
Gator sign, but no glide sign
→ Pneumothorax

Boysen SR, Lisciandro GR. The use of ultrasound for dogs and cats in the emergency room: AFAST and TFAST. Vet Clin North Am Small Anim Pract. 2013 Jul;43(4):773-97. doi: 10.1016/j.cvsm.2013.03.011

8

TFAST – Lung Changes

- B-lines (ring-down art
- Fluid between air bub
- → "wet lung" = contus



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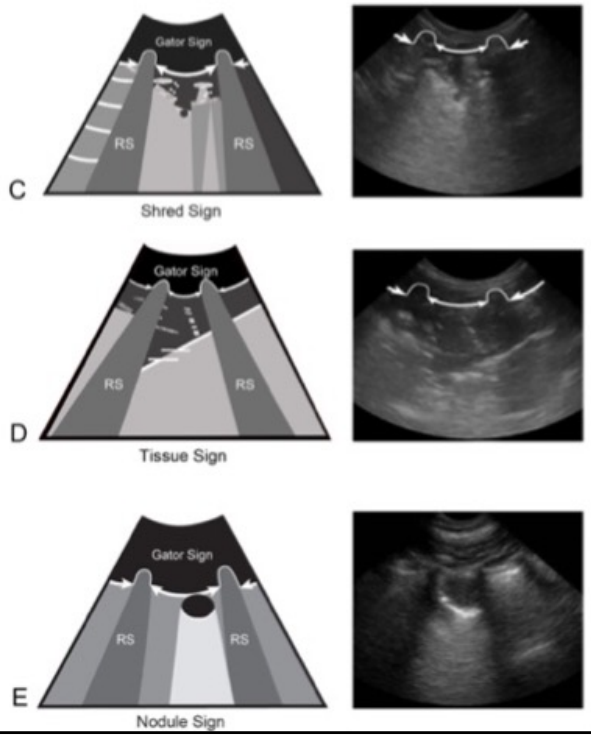
Peripheral lung lesions

- Shred sign: consolidation with gas in the bronchi
- Tissue sign: Consolidation without gas in the bronchi
- Nodule sign: Consolidation forming discrete nodules



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X-ray vs. CT

11

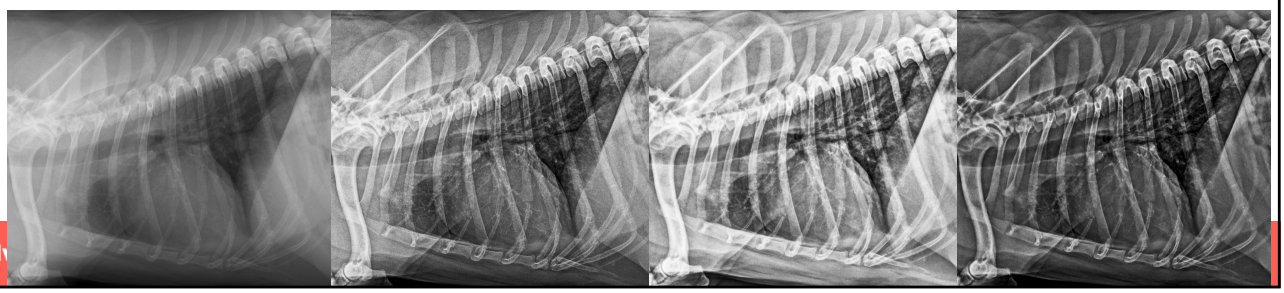
The good old chest X-ray

- Standard diagnostic tool
  - Clear
  - Available
  - Quick data acquisition
  - Less dependent on the examiner
  - High level of evidence

12

The good old chest X-ray

- Good sensitivity for lung changes
  - Note: Algorithm
- Low sensitivity for other intrathoracic changes, e.g.
  - tumors at the base of the heart



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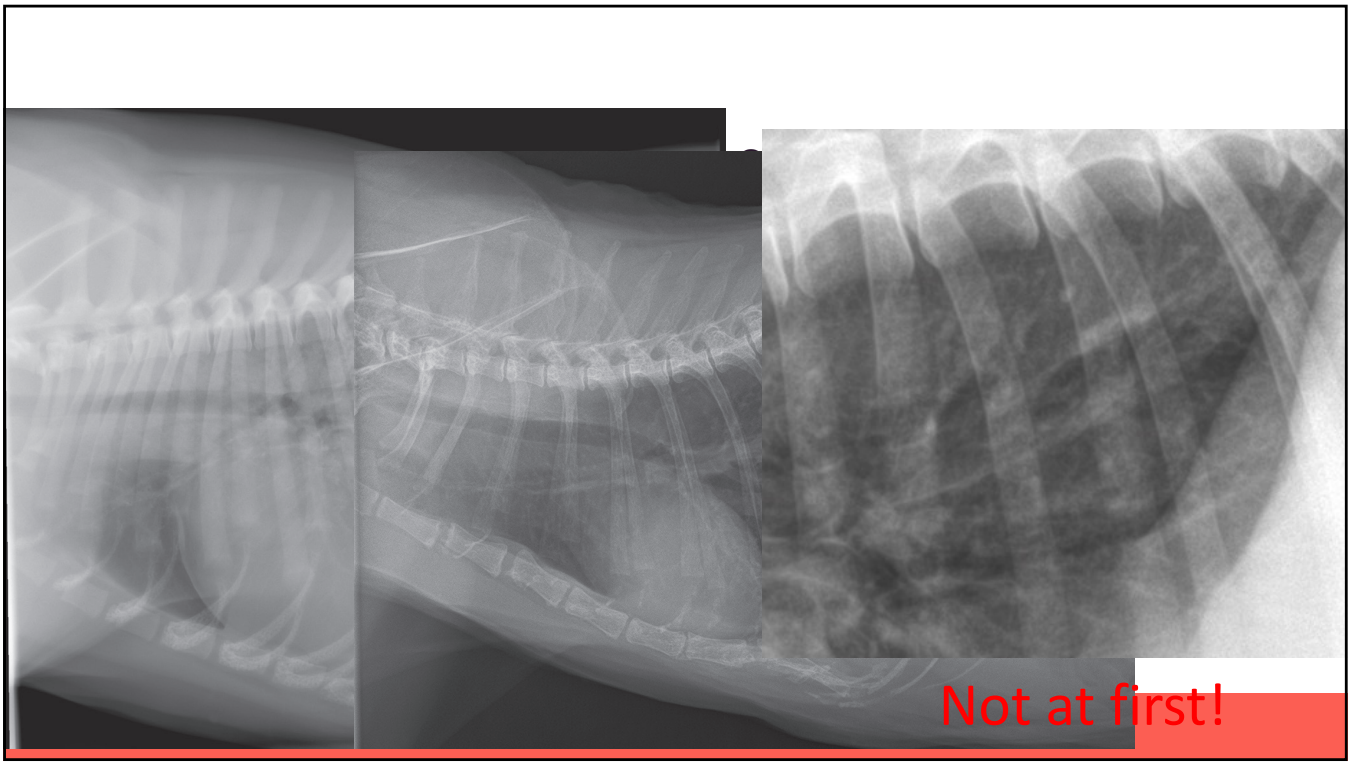

14

15

gh, tachypnea

16

Comparison of Thoracic Radiography and Computed Tomography in Calves with Naturally Occurring Respiratory Disease

Jennifer Fowler[1], Susanne M. Stieger-Vanegas[1], Jorge A. Vanegas[1], Gerd Bobe[2,3] and Keith P. Poulsen[4]*

[1] Department of Clinical Sciences, College of Veterinary Medicine, Oregon State University, Corvallis, OR, United States, [2] Department of Animal and Rangeland Sciences, College of Agricultural Sciences, Oregon State University, Corvallis, OR, United States, [3] Linus Pauling Institute, Oregon State University, Corvallis, OR, United States, [4] Wisconsin Veterinary Diagnostic Laboratory, Department of Medical Sciences, School of Veterinary Medicine, University of Wisconsin, Madison, WI, United States

- Calves with pneumonia
- CT (under sedation) vs. X-ray
- Pneumonia diagnosed using both modalities
- Extent of lesions somewhat better assessable on CT
- Additional information from a clinical perspective?

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Trauma patients?

Radiography is less sensitive relative to CT for detecting thoracic radiographic changes in dogs affected by blunt trauma secondary to a motor vehicle accident

Sumari C. Dancer[1] | Christelle Le Roux[1] | Geoffrey T. Fosgate[2] | Robert M. Kirberger[1]

- Imaging: lower sensitivity in detecting pulmonary contusions
- CT & X-ray: poor sensitivity in detecting a small pneumothorax or pleural effusion (note: awake CT)

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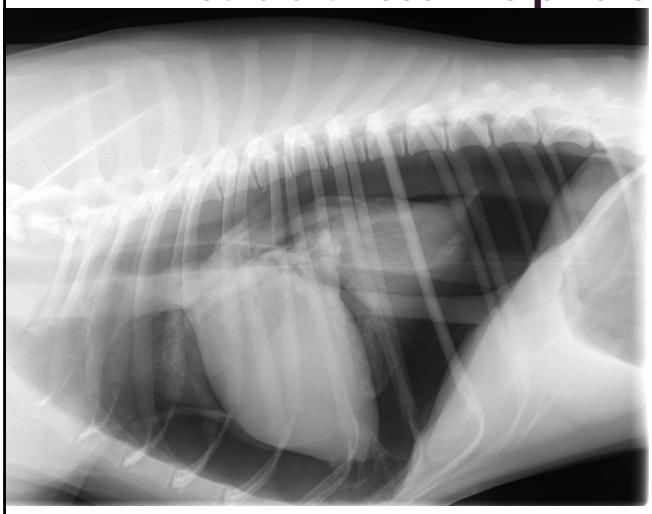
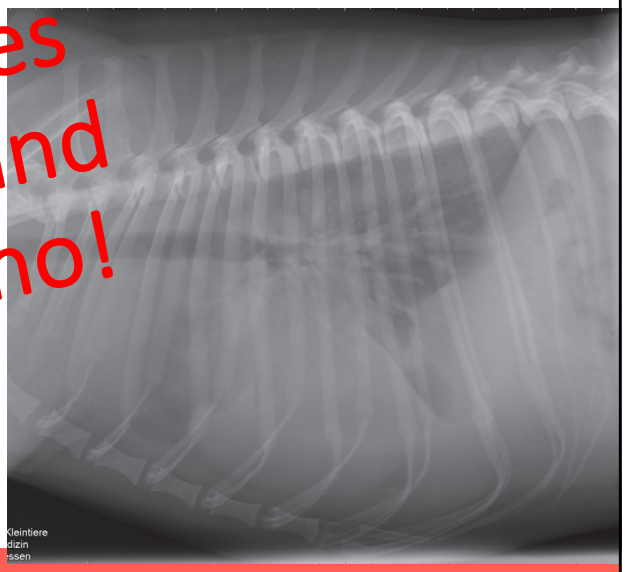
Would a CT scan help here?



Yes and no!



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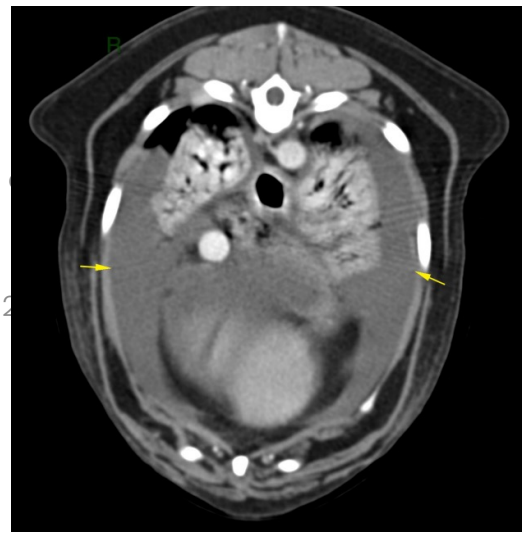
Preparation for the CT scan

- The lung must be inflated
  - Evacuate pneumothorax! Drain pleural
- "Positive pressure breath hold"
  - Hold your breath at approximately 10–12



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Which patients need a chest CT scan?

Comparison of examination of thoracic radiographs and thoracic computed tomography in dogs with appendicular osteosarcoma

N. Eberle, M. Fork, V. von Babo, I. Nolte and D. Simon

Small Animal Hospital, University of Veterinary Medicine Hannover, Hannover, Germany

Comparison of three-view thoracic radiography and computed tomography for detection of pulmonary nodules in dogs with neoplasia

Laura J. Armbrust, DVM, DACVR; David S. Biller, DVM, DACVR; Aubrey Bamford, BS; Ruthanne Chun, DVM, DACVIM; Laura D. Garrett, DVM, DACVIM; Michael W. Sanderson, DVM, MS, DACVMP

Survey radiography and computerized tomography imaging of the thorax in female dogs with mammary tumors

Carolina C Otoni[1*], Sheila C Rahal[1], Luiz C Vulcano[2], Sérgio M Ribeiro[3], Khadije Hette[1], Tatiana Giordano[1], Danuta P Doiche[2], Renée L Amorim[4]

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Screening for Metastases - X-ray vs. CT

Comparison of three-view thoracic radiography and computed tomography for detection of pulmonary nodules in dogs with neoplasia

Laura J. Armbrust, DVM, DACVR; David S. Biller, DVM, DACVR; Aubrey Bamford, BS; Ruthanne Chun, DVM, DACVIM; Laura D. Garrett, DVM, DACVIM; Michael W. Sanderson, DVM, MS, DACVMP

4 out of 21 dogs had lung metastases on CT

that were not visible on X-ray

	X-ray
Sensitivity	71–95%
Specificity	67–92%
Positive predictive value	83–94%
Negative predictive value	65–89%

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RR, 10 years old, wk, resection of the left caudal lung lobe due to adenocarcinoma 2 years ago

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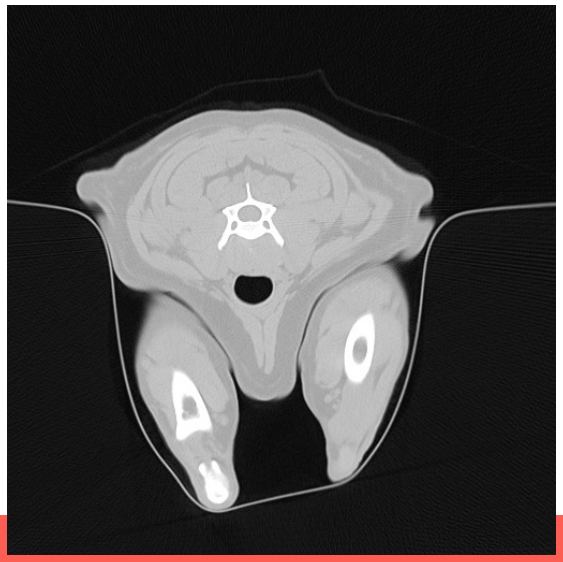
RR, 10 years old, male, resection of the left caudal lung lobe due to adenocarcinoma 2 years ago

CT scan to look for further metastases



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Maine Coon, 13 years old, cough

Advanced thoracic imaging

25

Maine Coon, 13 years old, cough

Advanced thoracic imaging

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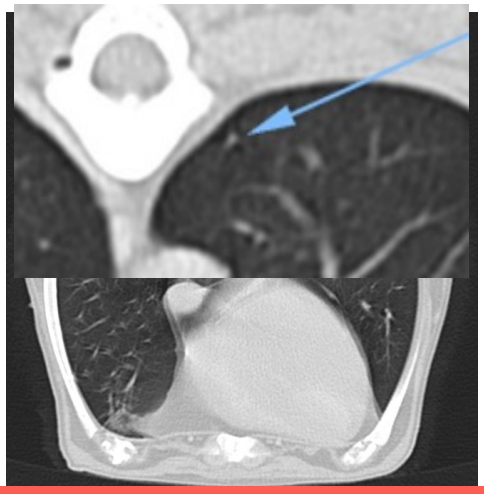
Are all the lesions on the chest CT scans metastases?

- "Ditzel"
- 1–2 mm hyperattenuating foci
- Differential diagnoses:
  - Pulmonary osteoma
  - Granulomas (e.g., fungal)
  - Metastases
- Follow-up scan after 4–6 weeks, if necessary



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Pulmonary Mass vs. Mediastinal Mass

Ruby, J, Secrest, S, Sharma, A. Radiographic differentiation of mediastinal versus pulmonary masses in dogs and cats can be challenging. *Vet Radiol Ultrasound*. 2020; 61: 385–393.

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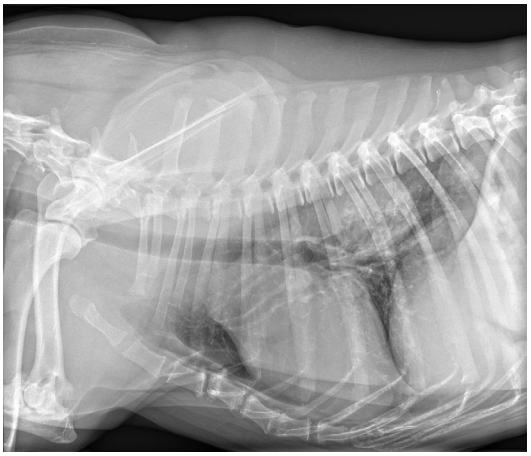
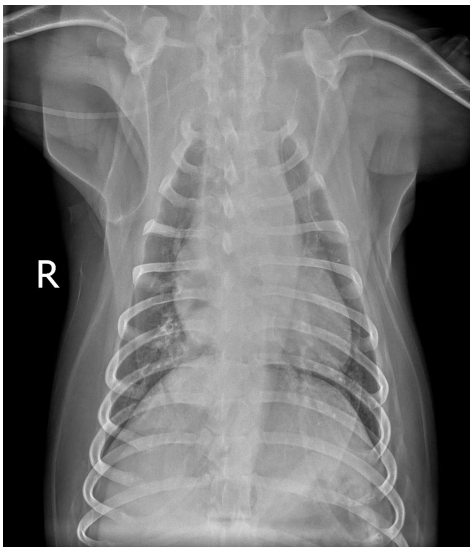
Labi, 10 years old, regurgitation





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Labi, 10 years old, regurgitation

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CT- or ultrasound-guided punctures

- Sedation/anesthesia
- Very good control
- Complication rate sometimes > 30%
  - Pneumothorax, bleeding
  - mostly minor complications
- Puncture through the ventilated lung possible on CT

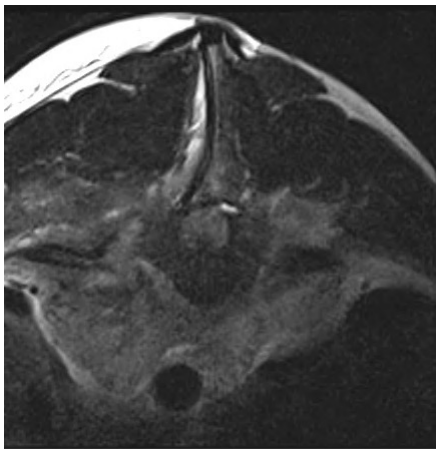
› Vet Radiol Ultrasound. 2005 May-Jun;46(3):200-4. doi: 10.1111/j.1740-8261.2005.00043.x.

Computed tomography-guided fine-needle aspirate and tissue-core biopsy of intrathoracic lesions in thirty dogs and cats

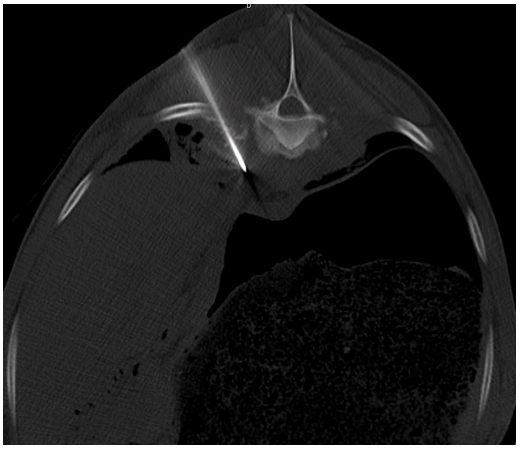
Lisa J Zekas [1], Jason T Crawford, Robert T O'Brien

31

Lama, paravertebral mass



MRI, T2-weighted



Bone reconstruction CT

32

Angiograms

- Dual- or Triple-phase
- Arterial phase!
- Injection via the forelimb using a power injector
- Timing based on "empirical values," bolus tracking, or test bolus
- ECG-gated for cardiac issues

Advanced thoracic imaging

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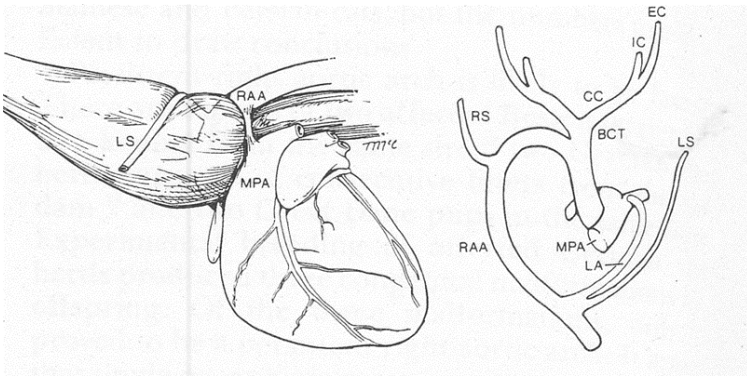
Angiography

Vascular malformations

- Vascular ring anomalies
  - Right aorta
  - Aberrant subclavian artery
  - Double aortic arch
- PDA



Advanced thoracic imaging

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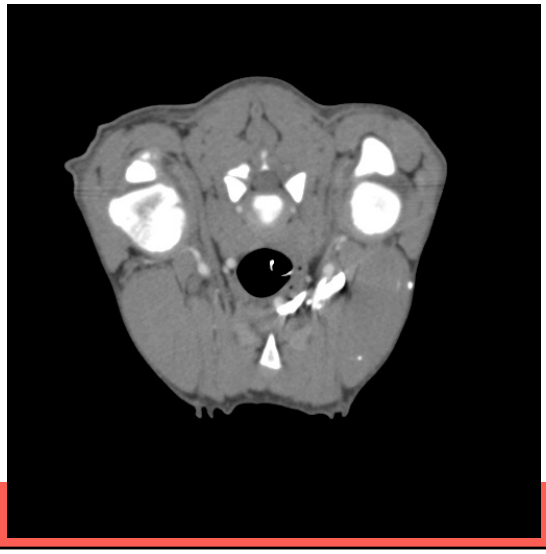
DSH, 4 months old, female, regurgitating



Advanced thoracic imaging

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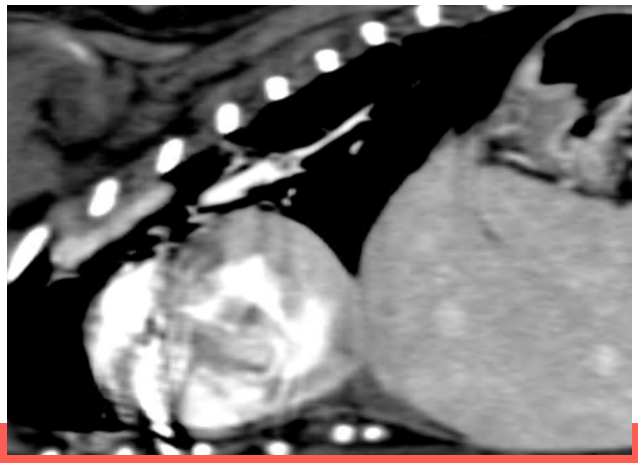
Angiography

- Pulmonary thromboembolism



Advanced thoracic imaging

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Lymphangiography

- Diagnosis of patients with chylothorax

1) Ultrasound-guided injection into the mesenteric lymph nodes

2) Injection distributed across the metatarsal/pad area – HIND LIMBS

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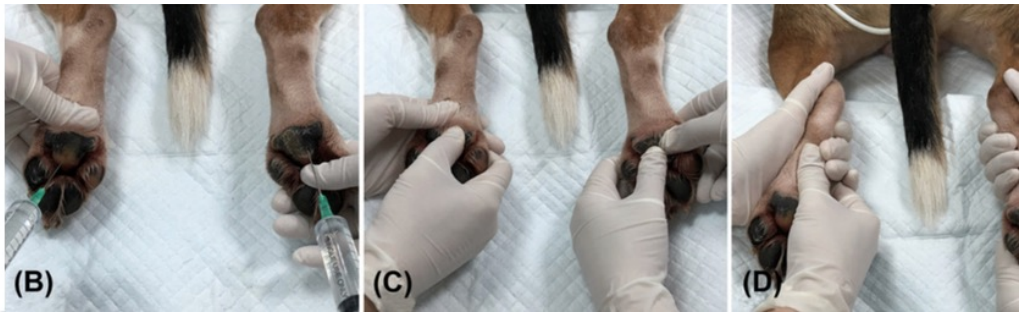
Lymphangiography Technique



- Prior to IV contrast
- 1 ml/kg iodinated contrast medium
- Half the amount per side
- Massage hind limbs for 3–4 min
- Scan after approx. 5 min

Lin, L-S, Chiu, H-C, Nishimura, R, Fujiwara, R, Chung, C-S. Computed tomographic lymphangiography via intra-metatarsal pad injection is feasible in dogs with chylothorax. *Vet Radiol Ultrasound*. 2020; 61: 435–443.

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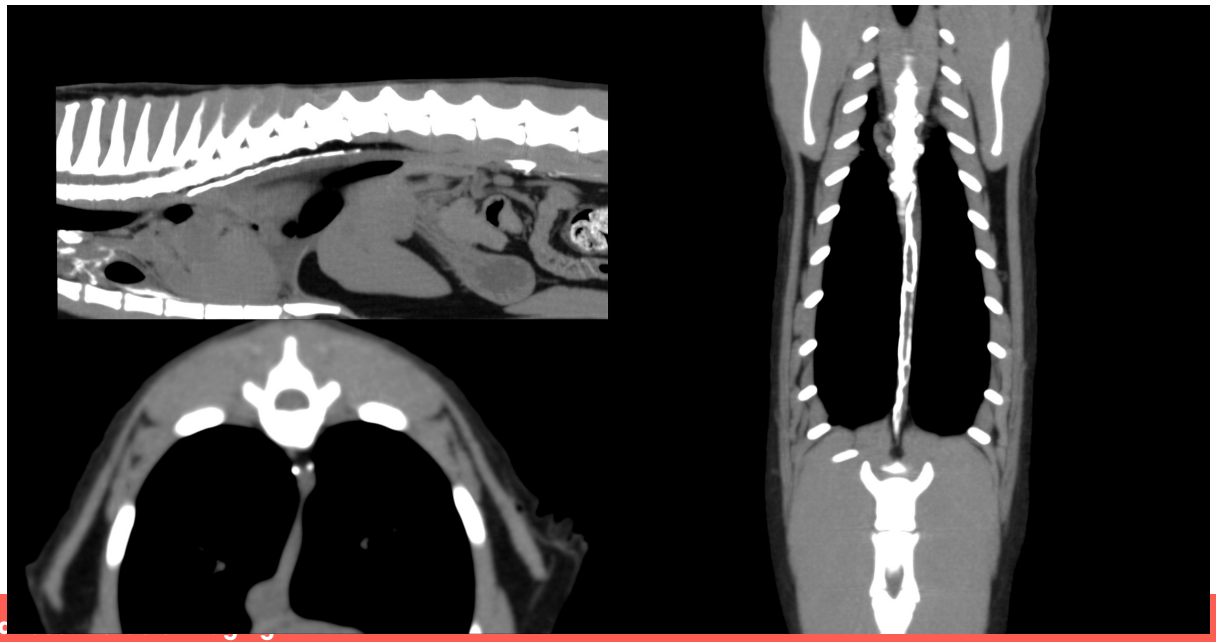

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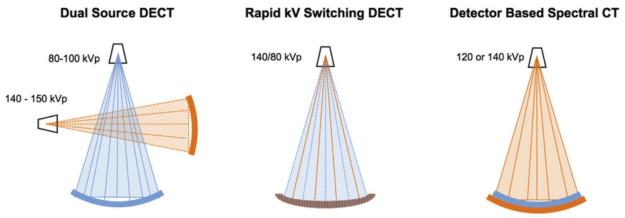
Dual-energy CT

- Uses different energy spectra
- Photoelectric effect vs. Compton e
- Increased radiation exposure?
- Contrast-enhanced imaging
- Examples in people
  - Pulmonary thromboembolism and perfusion changes
  - Classification and follow-up of lung tumors



Grajo JR, Sahani DV. Dual-Energy CT of the Abdomen and Pelvis: Radiation Dose Considerations. J Am Coll Radiol. 2018 Aug;15(8):1128-1132. doi: 10.1016/j.jacr.2017.08.012. Epub 2017 Sep 22. PMID: 28958720.

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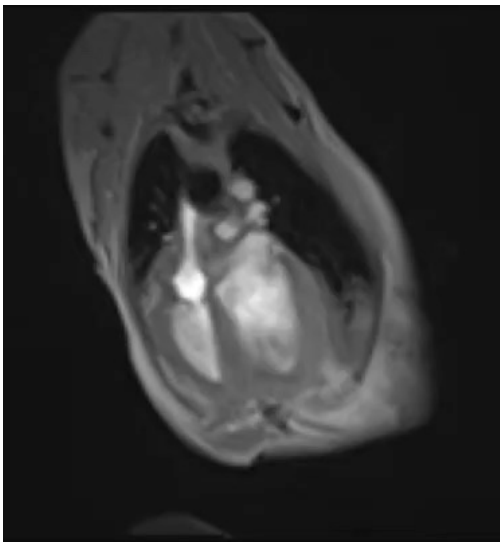
Thoracic MRI

- Cardiac MRI/MRTA: commonly used in human medicine
- Limitations
  - Respiratory and cardiac motion
  - Acquisition time
- Applications in veterinary medicine
  - Cardiomyopathies
  - Cardiac tumors
  - Congenital malformations
  - Valvular insufficiencies



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Conclusion

- Modern Thoracic Imaging?
- Diffuse pulmonary opacities: often no added value from cross-sectional imaging
- Surgical planning, Define extent and orirgin of lesions, organ involvment, metastasis screening„„ → CT

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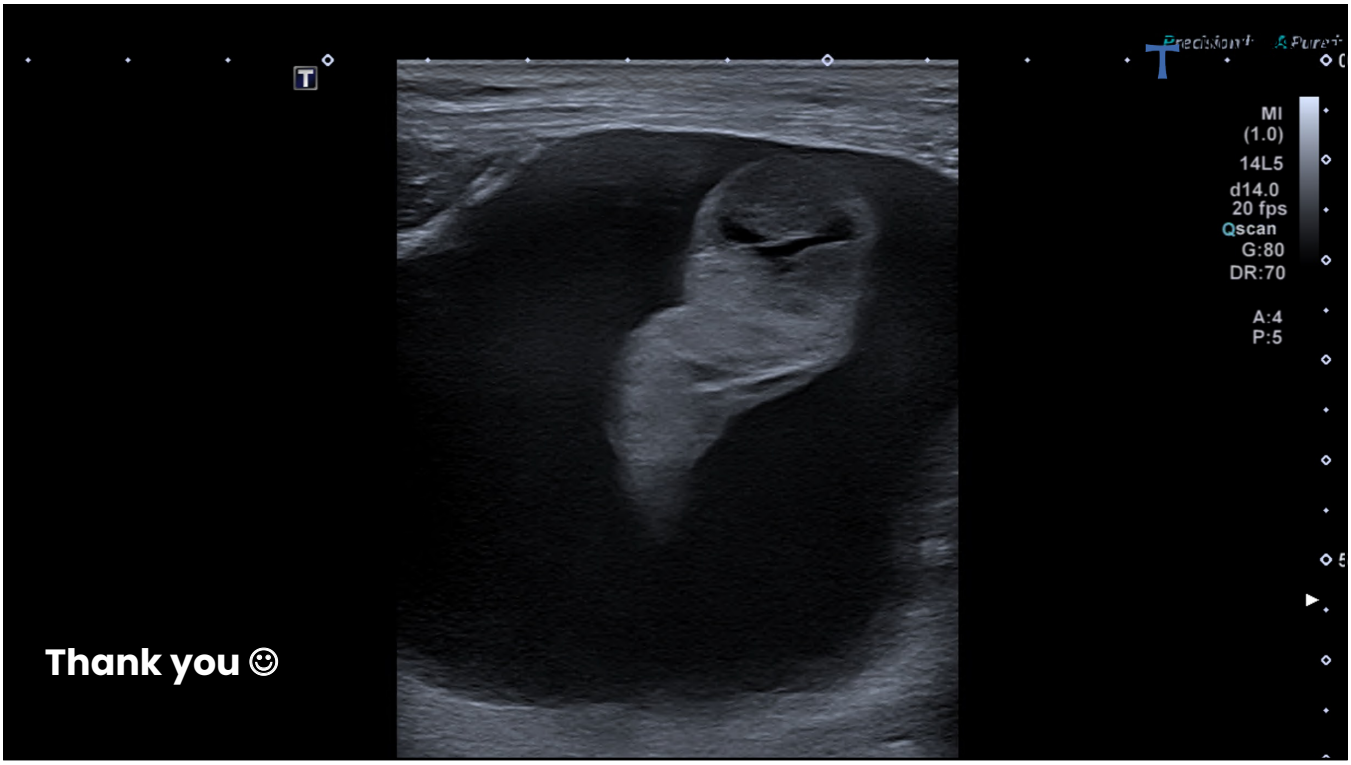

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Neoplasia, inflammation, or else? Thoracic imaging across modalities

Nele Eley, Christiane Schürmann

1

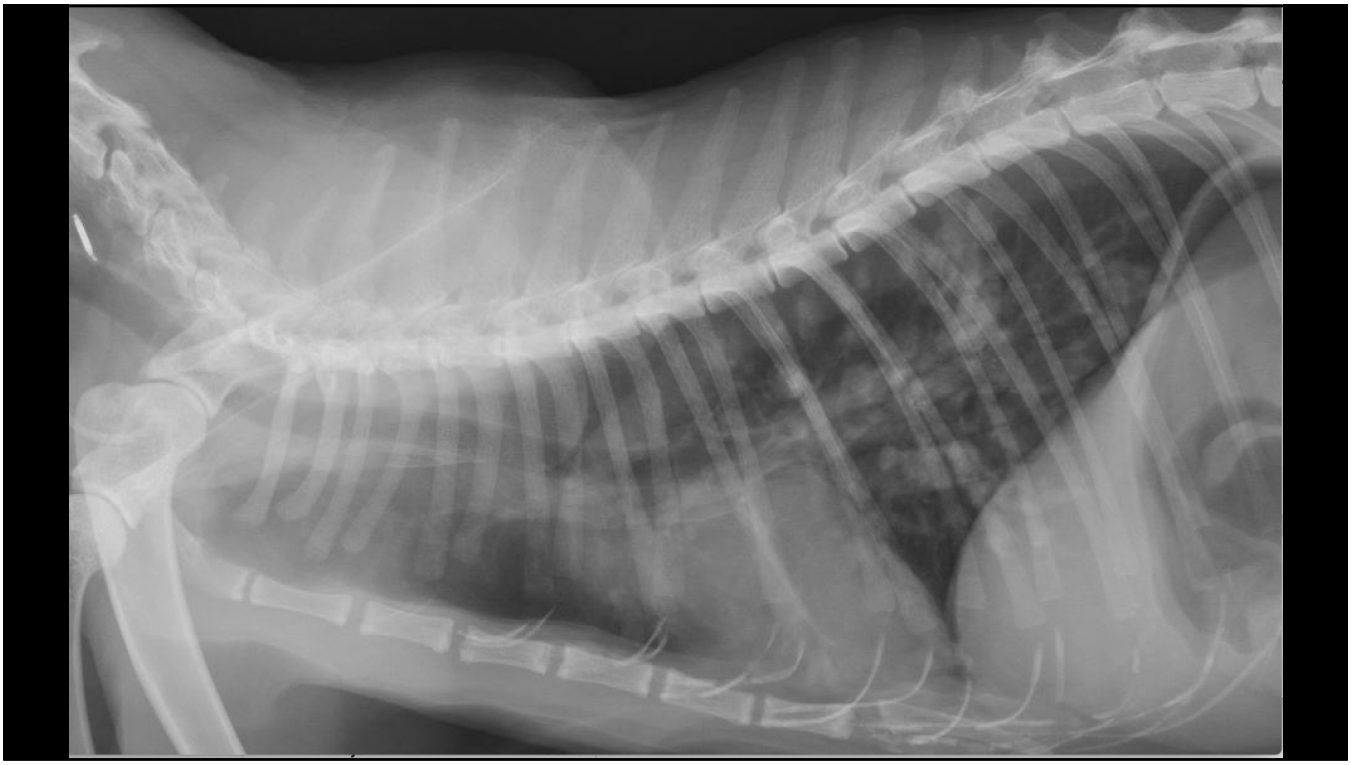
Big picture

- Radiography is the screening tool
- CT is powerful — but not definitive
- CT is excellent for lesion detection, localization, and characterization
- BUT: considerable overlap exists between inflammatory and neoplastic disease

2

When should we use CT?

3



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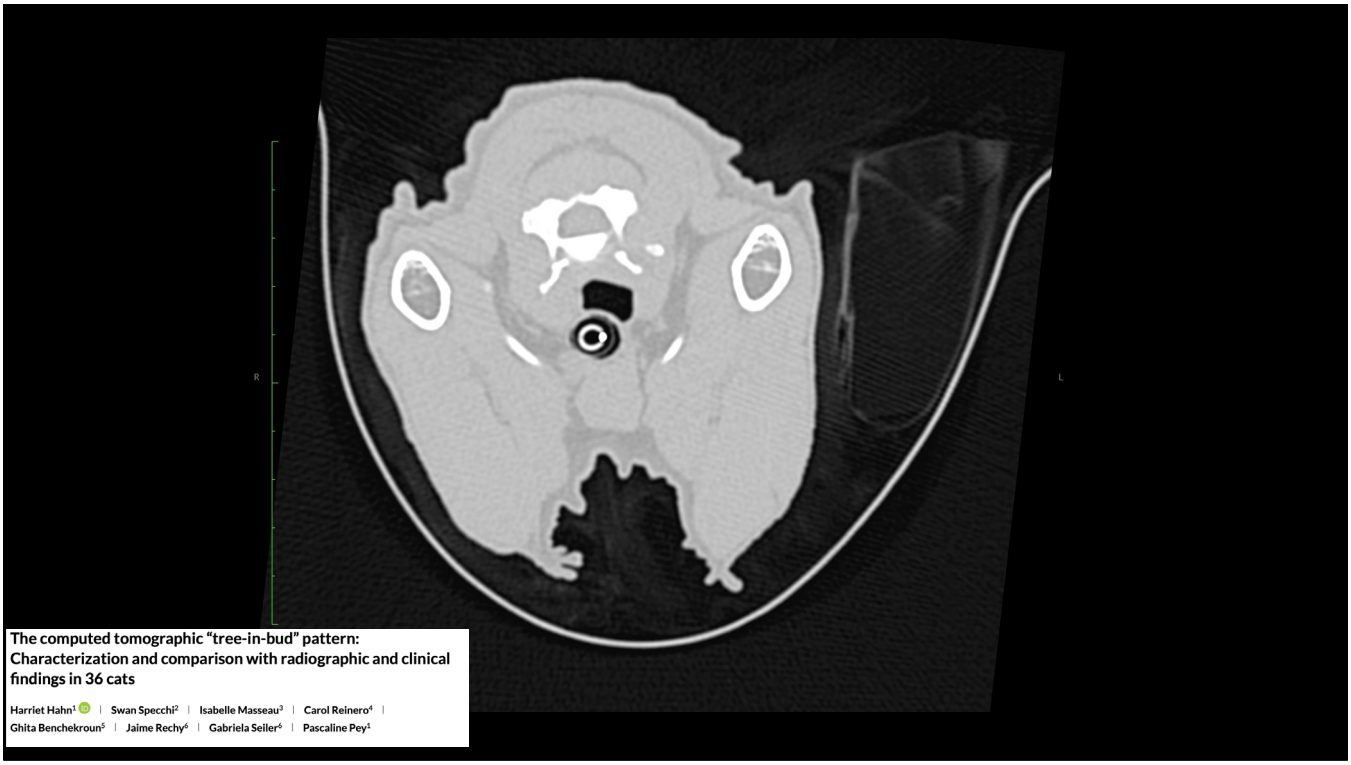
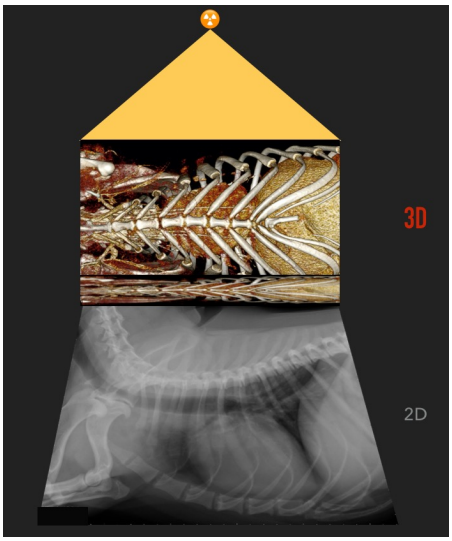

The computed tomographic "tree-in-bud" pattern: Characterization and comparison with radiographic and clinical findings in 36 cats
Harriet Hahn[1] | Swan Specchi[2] | Isabelle Masseau[3] | Carol Reinero[4] | Ghita Benchekroun[5] | Jaime Rechy[6] | Gabriela Seiler[6] | Pascaline Pey[1]

6

Pulmonary CT

Indications



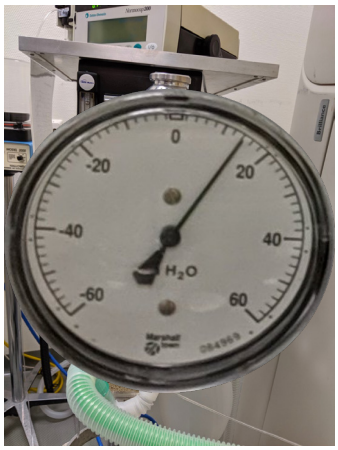
→ When an X-ray leaves questions unanswered

7

7

Pulmonary CT

How to



- In the prone or supine position
- Limbs not included in the scan field
- If possible, perform with positive pressure during apnea
- In exceptional situations, the patient may remain awake if necessary...

Thoracic high resolution CT using the modified VetMousetrap™ device is a feasible method for diagnosing canine idiopathic pulmonary fibrosis in awake West Highland White Terriers

Saila Holopainen, Elina Rautala, Liisa Lilja-Maula, Hannes Lohi, Minna M. Rajamäki, Anu K. Lappalainen

First published: 07 June 2019 | https://doi.org/10.1111/vru.12779 | Citations: 9

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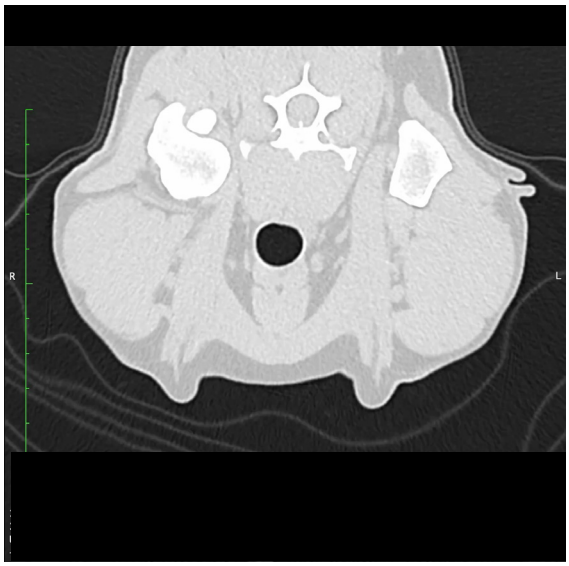
Pulmonary CT



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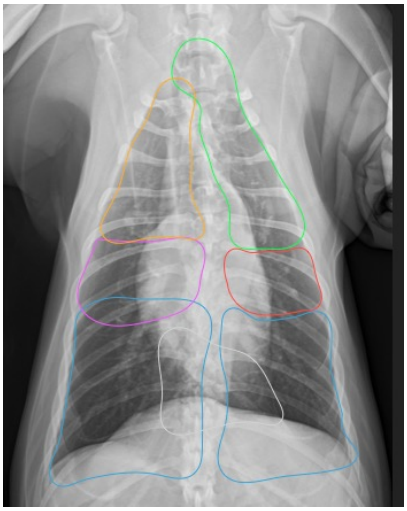
Pulmonary CT

Anatomy

Dogs & Cats: 6 Lung Lobes

- Four lung lobes on the right
- Left: two lung lobes



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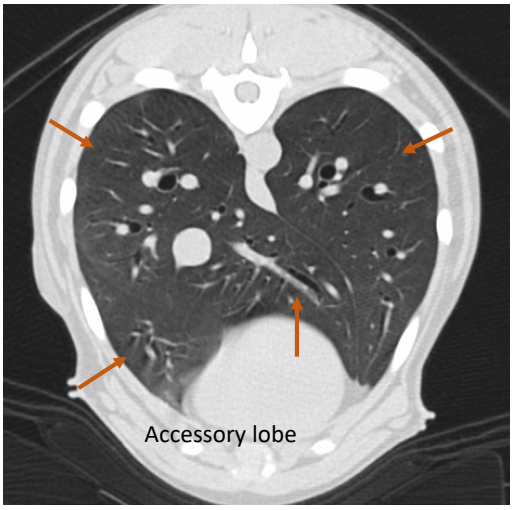
Pulmonary CT

Anatomy

Right caudal lobe



Left caudal lobe

Right middle lobe

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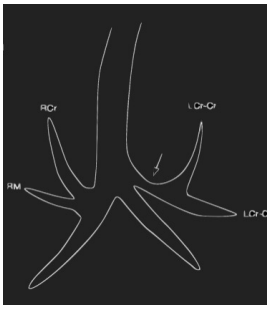
Pulmonary CT

Anatomy

Bronchial tree:

- Left and right main bronchi
- Lobar bronchi
- Segmental bronchi
- Bronchioles



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Pulmonary CT

Lung imaging

Core principle: Radiographs and CT provide **probability patterns**, not definitive diagnosis

Pattern-based approach (standard CT interpretation)

CT findings are grouped into:

Increased attenuation (consolidation, ground-glass)
Decreased attenuation (air trapping, emphysema)

Nodular/Mass-like disease
Alveolar, bronchal, interstitial patterns

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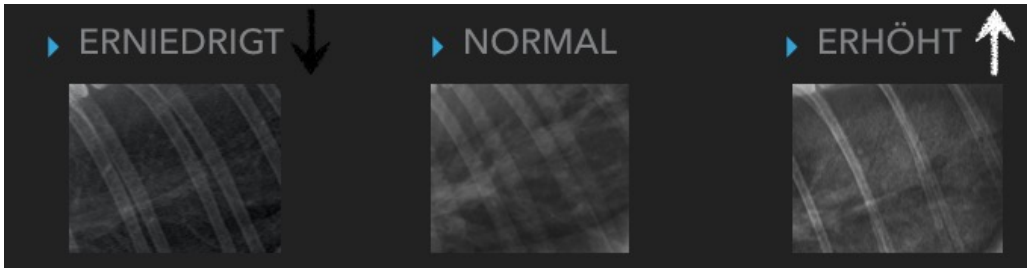
Pulmonary CT

Lung imaging

The classification of the image is done exactly the same way as in an X-ray!

So, first question: What is the density?



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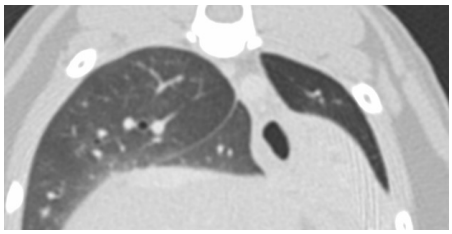
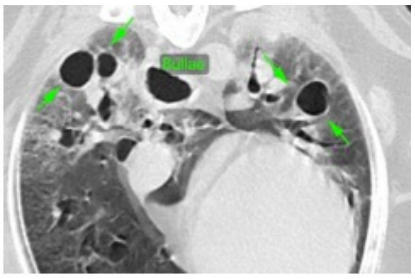
Pulmonary CT

Lung pattern – reduced density





Differential diagnoses for reduced density:

- Bullae – typically smooth-walled
- Cavitary lung lesions
- Emphysema
- Hypoperfusion
- Air trapping

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Pulmonary CT

Lung pattern – increased density

Peripheral lung dystelectasis is common, depending on positioning

→ This may mask underlying pathologies

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Pulmonary CT

Lung pattern – increased density

Increased lung density

White background
- Lung vessels not visible
- Air bronchograms
- Homogeneous soft-tissue-dense, cloudy opacity – “trees in the fog”

Alveolar

Black background
- Lung vessels visible

Interstitial / Bronchial

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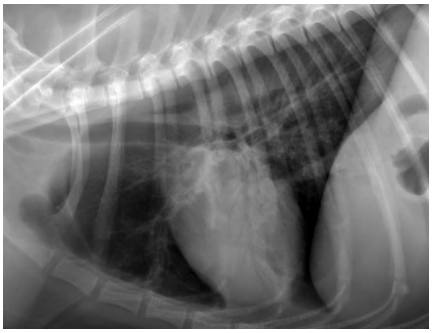
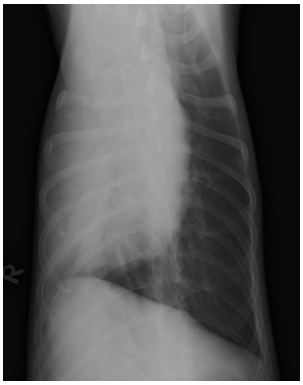
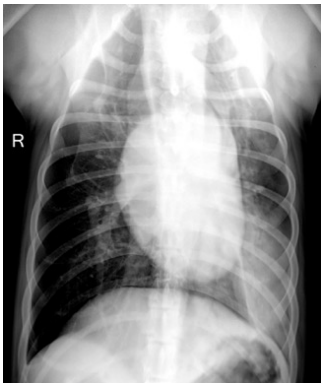
Pulmonary CT

Lung pattern – Alveolar







Alveolar lung pattern: Alveoli either collapsed or filled with fluid or cells

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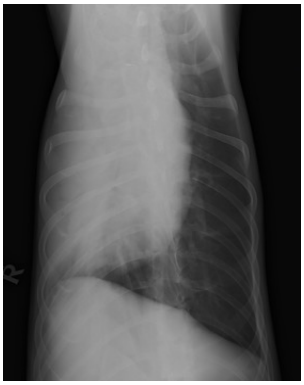
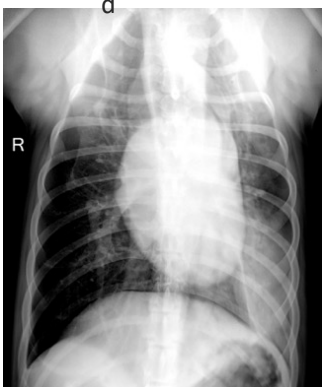
Pulmonary CT

Lung pattern – Alveolar

decreased



preserved



Alveolar lung pattern: Alveoli either collapsed or filled with fluid or cells

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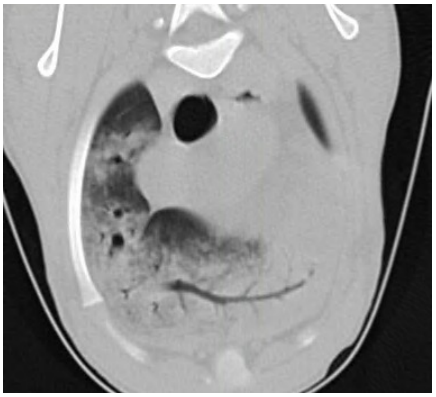
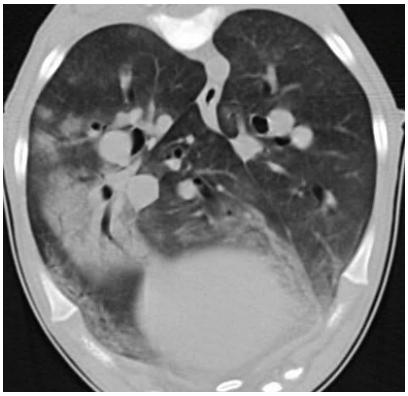
Pulmonary CT

Lung pattern – alveolar

preserved





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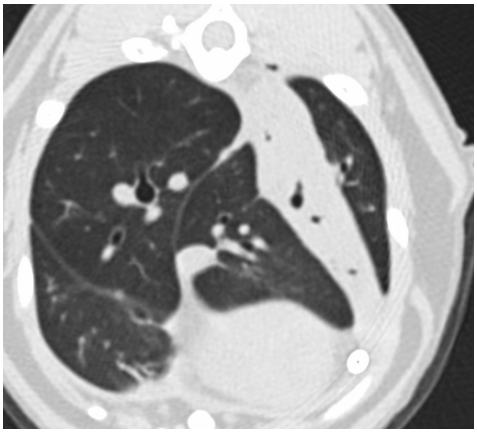
Pulmonary CT

Lung pattern – alveolar

decreased



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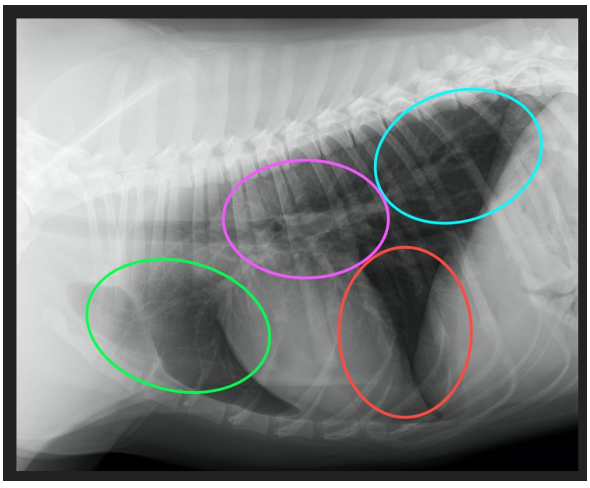
Pulmonary CT

Lung pattern – alveolar

Important for the differential diagnosis list:

- Cranioventral
- Caudoventral
- Perihilar
- Caudodorsal



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Pulmonary CT

Lung pattern – Alveolar – Differential diagnoses

Cranioventral	Caudodorsal	Perihilar	Peripheral	Diffuse
Pneumonia (aspiration?)	Cardiogenic pulmonary edema	Cardiogenic pulmonary edema (dog)	Parasitic	Bleeding
Neoplasia	Non-cardiogenic pulmonary edema		Infarction(s)	ARDS
Bleeding	Inhaled foreign body			Atelectasis
				Cardiogenic pulmonary edema

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Pulmonary CT

Lung pattern – Atelectasis – Differential diagnoses

Types of atelectasis:

1. Relaxation atelectasis – the lung cannot fully expand
   Pneumothorax, pleural effusion, extrapleural mass, positional

2. Resorption atelectasis – Gas is absorbed from the lung due to an obstructed airway
   Neoplasm, mucus plug, foreign body, bronchitis, ciliary dyskinesia

3. Adhesive atelectasis – Alveoli collapse
   Surfactant problem – neonatal respiratory distress syndrome, ARDS, PTE

4. Cicatricial atelectasis - Fibrotic changes in the pleura
   Pulmonary fibrosis, chronic pleural effusion, chronic pneumonitis

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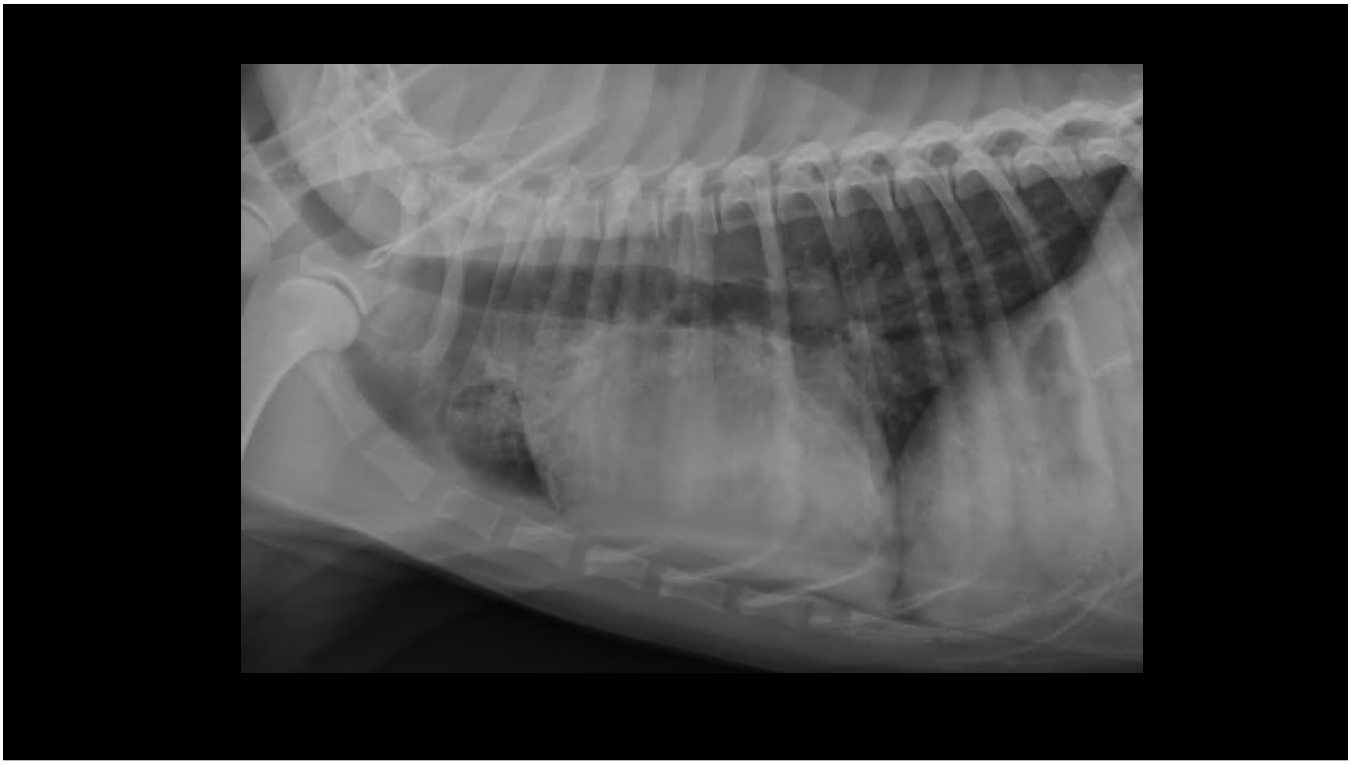

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4 y German wirehaired Pointer
Hyperthermia & coughing for 3 days

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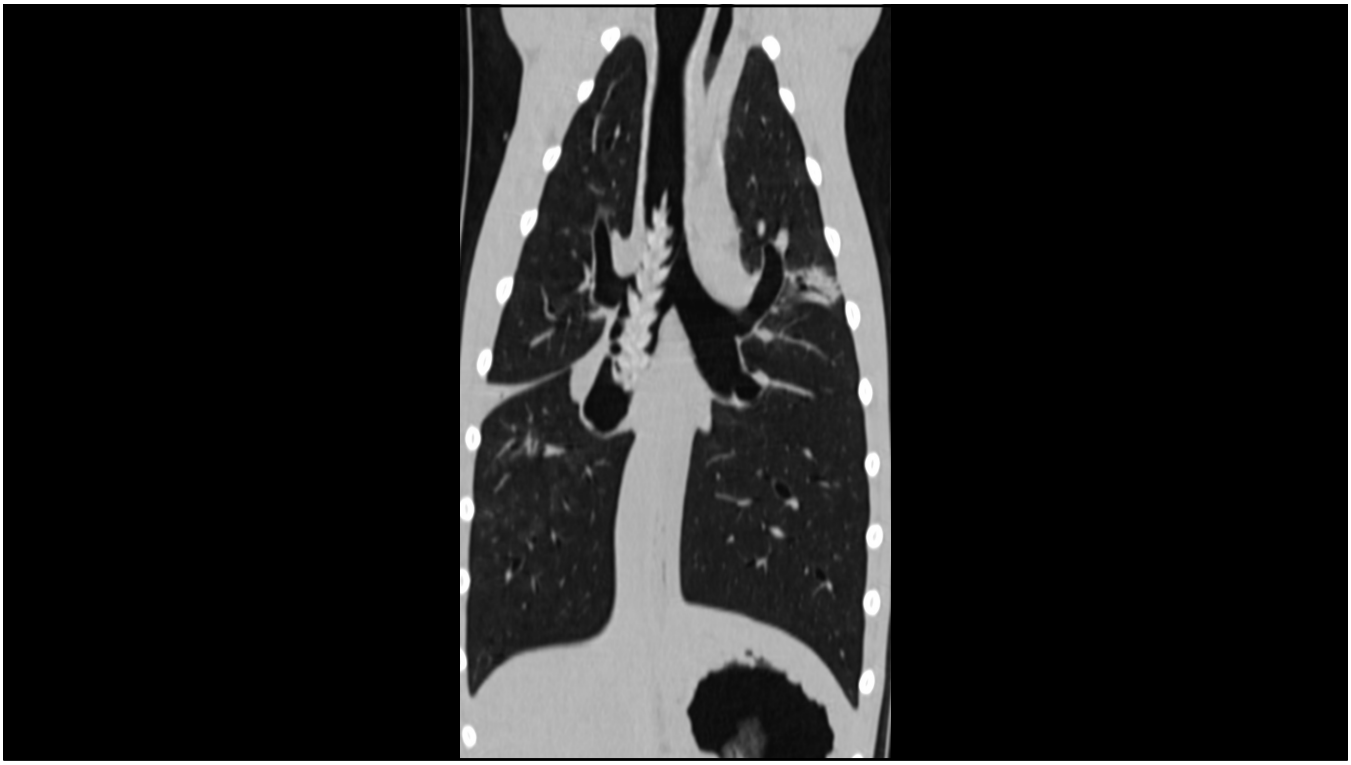

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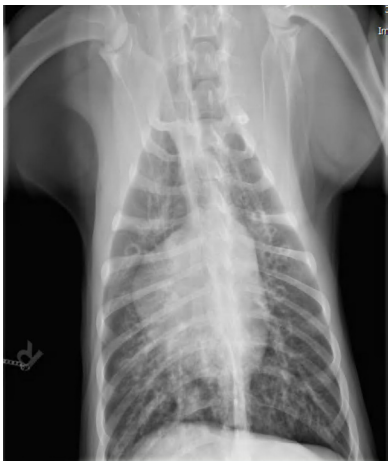
Pulmonary CT

Lung imaging – Bronchial

Bronchial tree with increased visibility
- Thickened bronchial walls, mineralizations, bronchiectasis

Ring shadows (“doughnuts”) and tram lines
- Thin and smooth/cauliflower-like – mineralized
- Soft-tissue-dense thickening – inflammatory/infiltrative
- Bronchiectasis—may be difficult to detect



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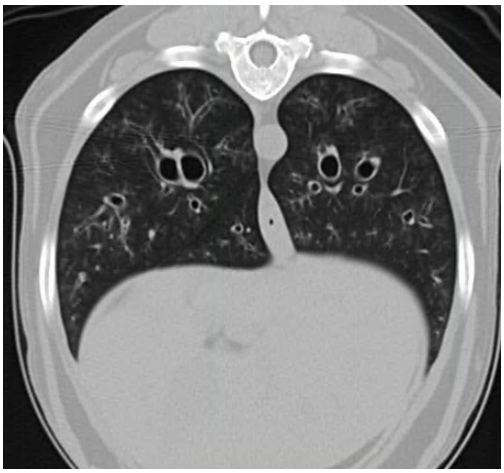
Pulmonary CT

Lung imaging – Bronchial



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Pulmonary CT

Lung imaging – Bronchial differential diagnoses

Mineralized	Soft-tissue density thickening	Bronchiectasis
Degenerative (age-related)	Bronchitis (infectious vs. non-infectious)	Congenital (ciliary dyskinesia)
Cushing	Edema	Acquired (chronic inflammatory, radiation)
Broncholithiasis	Neoplasm	

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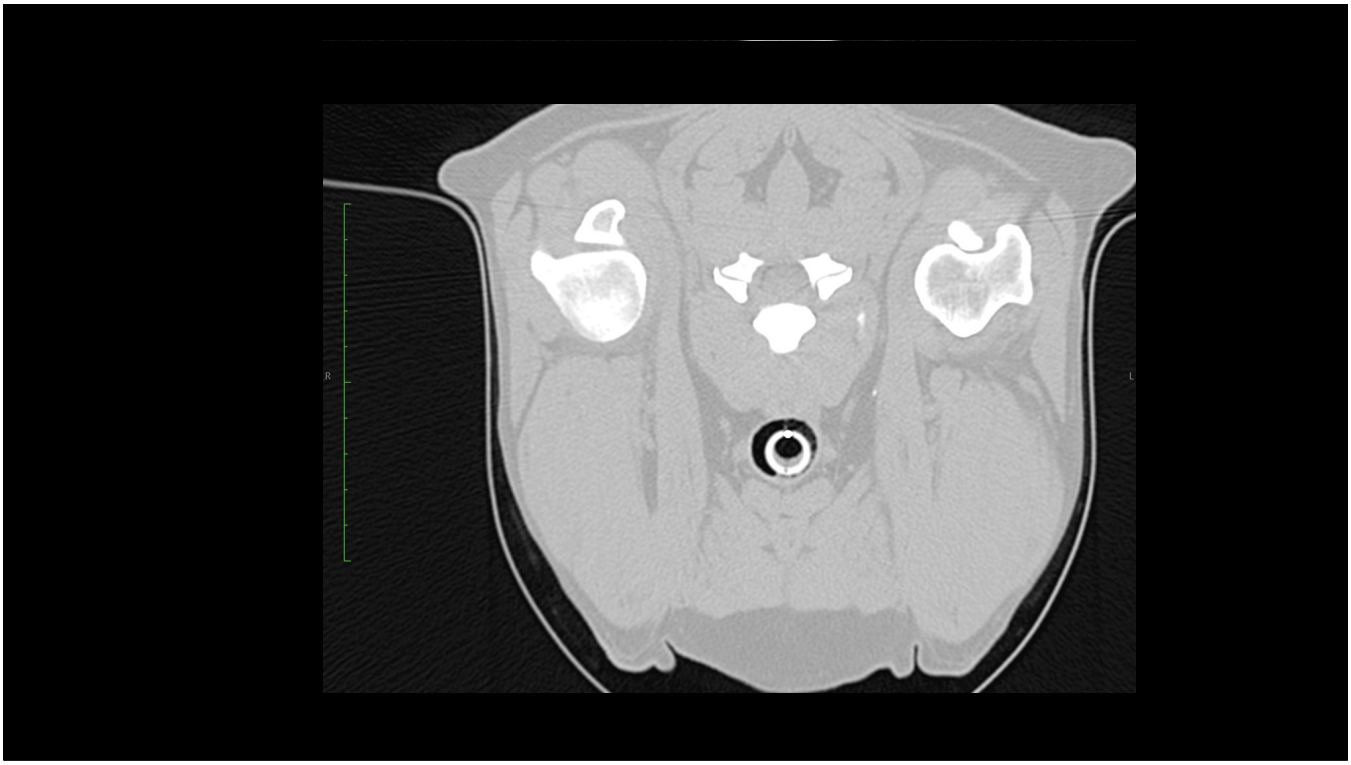

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CT scan of the lungs

Eosinophilic bronchopneumopathy

- Young dogs, 4–6 years old
- Siberian Husky, Malamute
- But also Rottweilers, German Sheph
  Labradors
- Cough is the most common clinical s

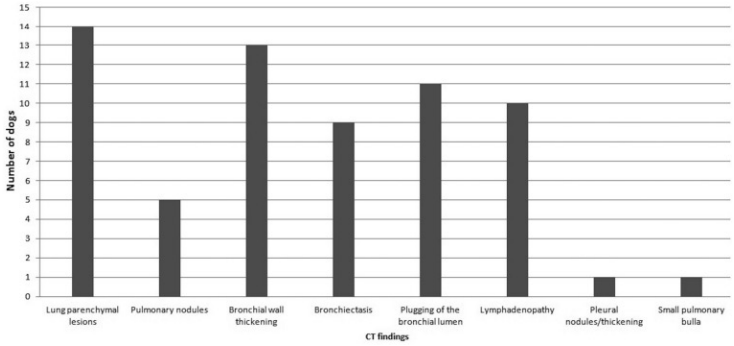
Vet Radiol Ultrasound. 2015 Jan-Feb;56(1):33-9. doi: 10.1111/vru.12187. Epub 2014 Aug 15.

Computed tomographic findings in 15 dogs with eosinophilic bronchopneumopathy

Luis Mesquita [1], Richard Lam, Christopher R Lamb, J Fraser McConnell

Affiliations + expand

PMID: 25124052 DOI: 10.1111/vru.12187



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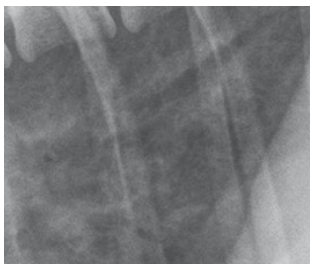
Pulmonary CT

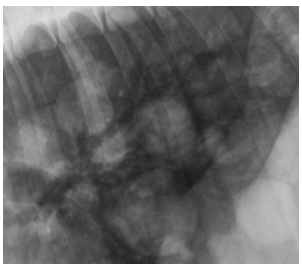
Lung pattern – Interstitial

Unstructured



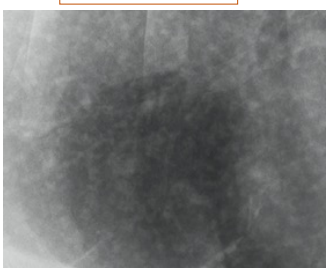
- Reticulated
- Vessels still distinguishable but blurred
- Nonspecific

Structured/nodular



- Nodular interstitial
- One or more lesions
- Nodules < 3 cm
- Mass > 3 cm

Miliary



- Fine interstitial nodules (<5 mm)

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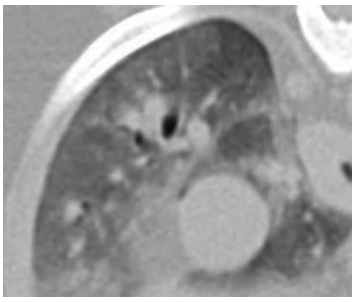
Pulmonary CT

Lung pattern – Interstitial – Unstructured

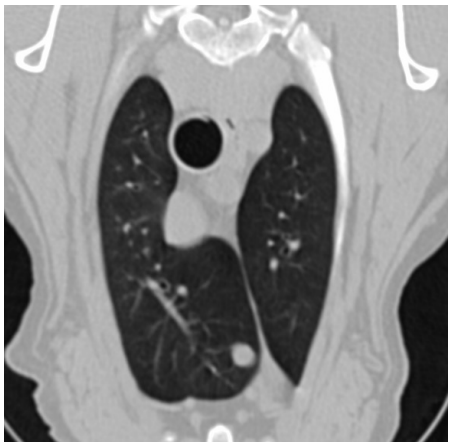


37

37

Pulmonary CT

Lung pattern – interstitial-nodular



38

38

Pulmonary CT

Lung pattern – Interstitial – Differential diagnoses

Unstructured	Structured nodular	Miliary
Technical (Exhalation, Exposure, Obesity)	Neoplasm	Metastases
Age-related	Cyst	Granulomatous pneumonia/mycosis (lymphadenopathy?)
Fibrosis	Hematoma	
Transitional conditions (pneumonia, edema, hemorrhage)	Granuloma (lymphadenomegaly?)	
Pneumonitis (viral, bacterial, parasitic, metabolic)	Hematosel	
Neoplasm (lymphoma)	Abscess	
	Thoracic wall?	

39

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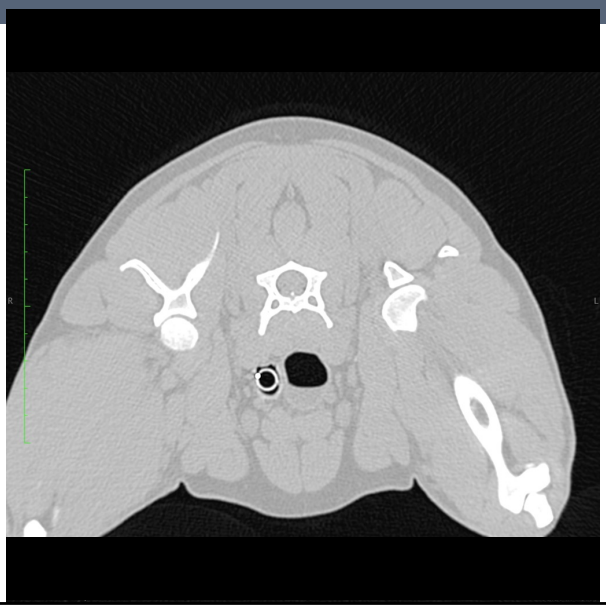
Pulmonary CT

Lung pattern – Interstitial – Fibrosis



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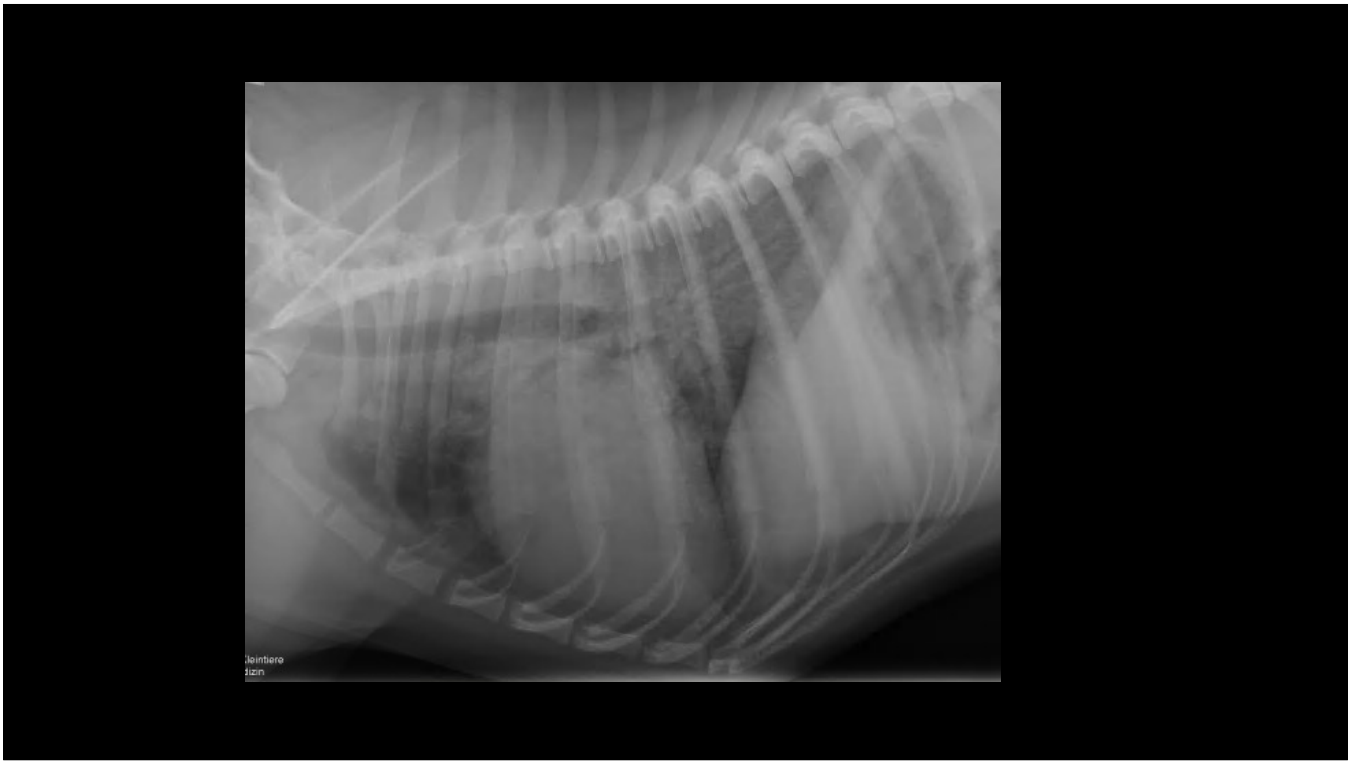

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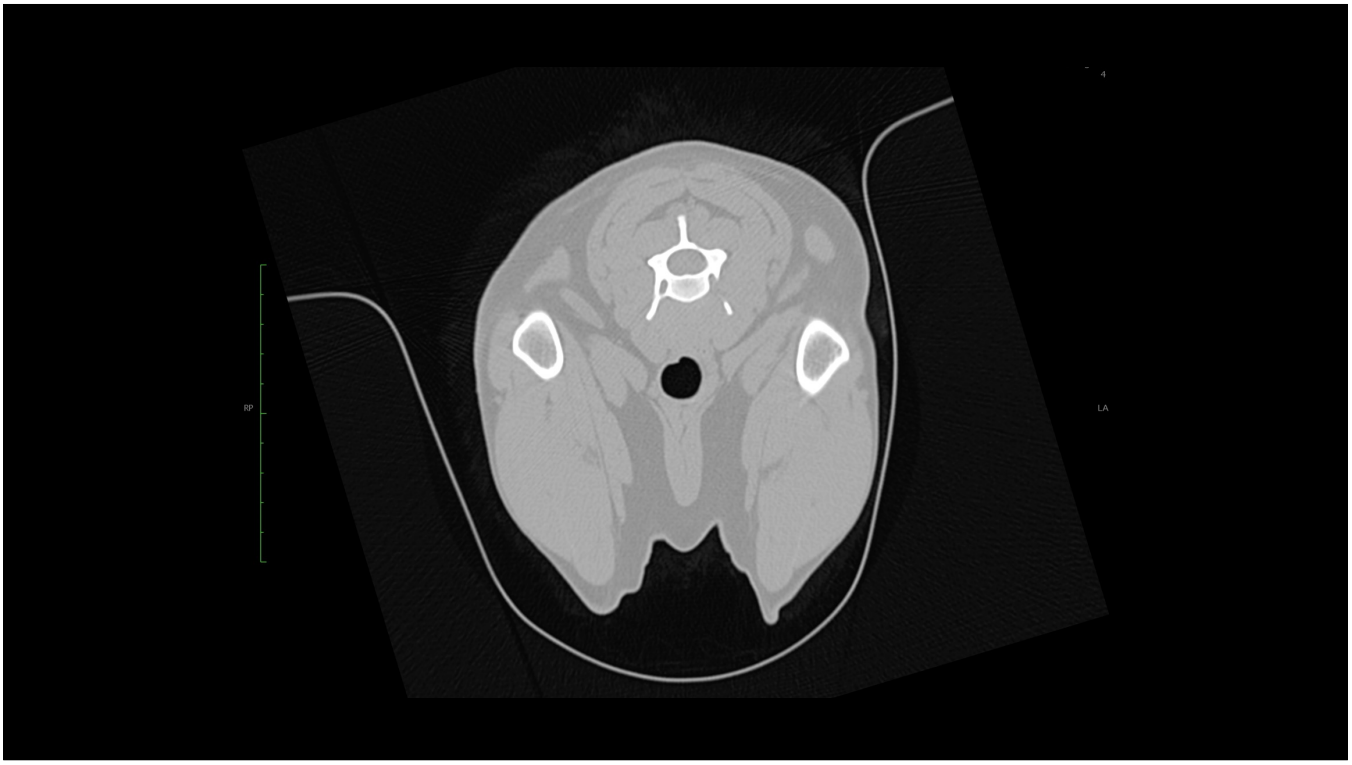
42



43

Pulmonary CT

Spontaneous pneumothorax

> Vet Radiol Ultrasound. 2020 Nov;61(6):641-648. doi: 10.1111/vru.12905. Epub 2020 Sep 8.

Computed tomography in two recumbencies aides in the identification of pulmonary bullae in dogs with spontaneous pneumothorax

Rachel Dickson [1], Valery F Scharf [1], Nathan C Nelson [2], Nicholas Petrovitch [2], Erin K Keenihan [2], Kyle G Mathews [1]

CT is helpful for the detection and presurgical planning of lung perforation in dogs with spontaneous pneumothorax induced by grass awn migration: 22 cases

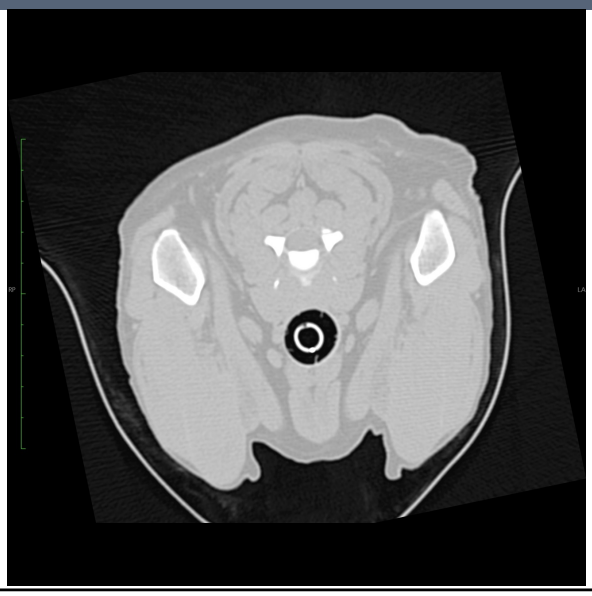
Clément Baudin Tréhiou [1], Sophie Gibert [1], Paul Sériot [1], Antoine Dunié-Mérigot [1], Laurent Blond [1]

44

44

Pulmonary CT

Spontaneous pneumothorax

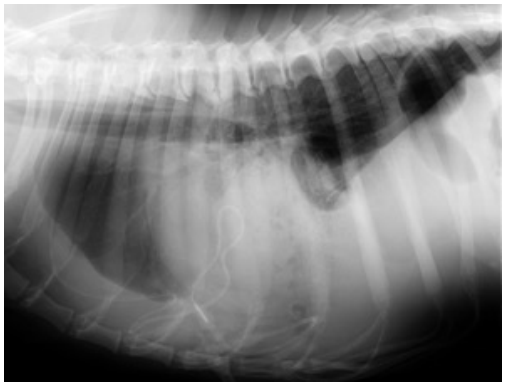


45

45

Pulmonary CT

Lung Diseases - Lung Lobe Torsion



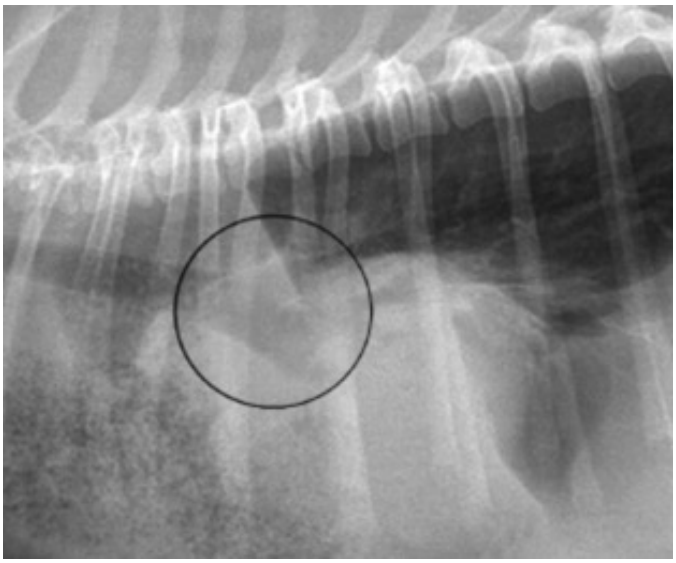
- “Salt & Pepper”
- Caused by vesicular emphysema
- May be progressive as seen in consecutive images
- In conjunction with pleural effusion, pathognomonic for lung lobe torsion

46

46

Pulmonary CT

Lung Diseases - Lung Lobe Torsion

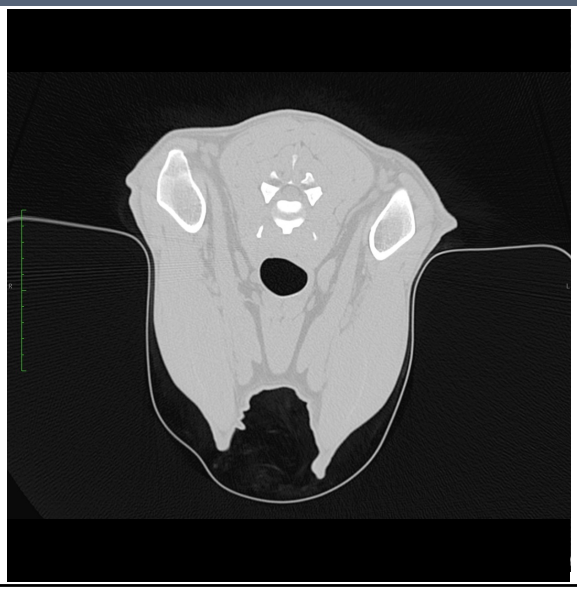


47

47

Pulmonary CT

Lung Diseases - Lung Lobe Torsion



48

48

Pulmonary CT

Lung Diseases - Lung Lobe Torsion

› Vet Radiol Ultrasound. 2008 Nov-Dec;49(6):504-8. doi: 10.1111/j.1740-8261.2008.00435.x.

Computed tomographic features of lung lobe torsion

Gabriela Seiler [1], Tobias Schwarz, Massimo Vignoli, Daniel Rodriguez

Affiliations + expand

PMID: 19051638 DOI: 10.1111/j.1740-8261.2008.00435.x

TABLE 1. CT Findings in Nine Dogs with Complete Lung Lobe Torsion

Rotated Lung Lobe		Other Lung Lobes		Thoracic Cavity	
Findings	*n*	Findings	*n*	Findings	*n*
Abrupt ending bronchus	9	Lobar compression	8	Mediastinal shift	8
Enlargement	8	Displacement	6	Pleural effusion generalized	6
Consolidation	8	Deviated bronchi	4	Pneumothorax	3
Emphysema	8	Compressed bronchi	2	Pleural effusion focal	3
Abnormal position	5			Mediastinal lymphadenopathy	1
Twisted bronchus	3				
Abnormal course of vessels	2				

49

Pulmonary CT

Lung Diseases - Lung Lobe Torsion

Lung lobe torsion in 15 dogs: Peripheral band sign on ultrasound

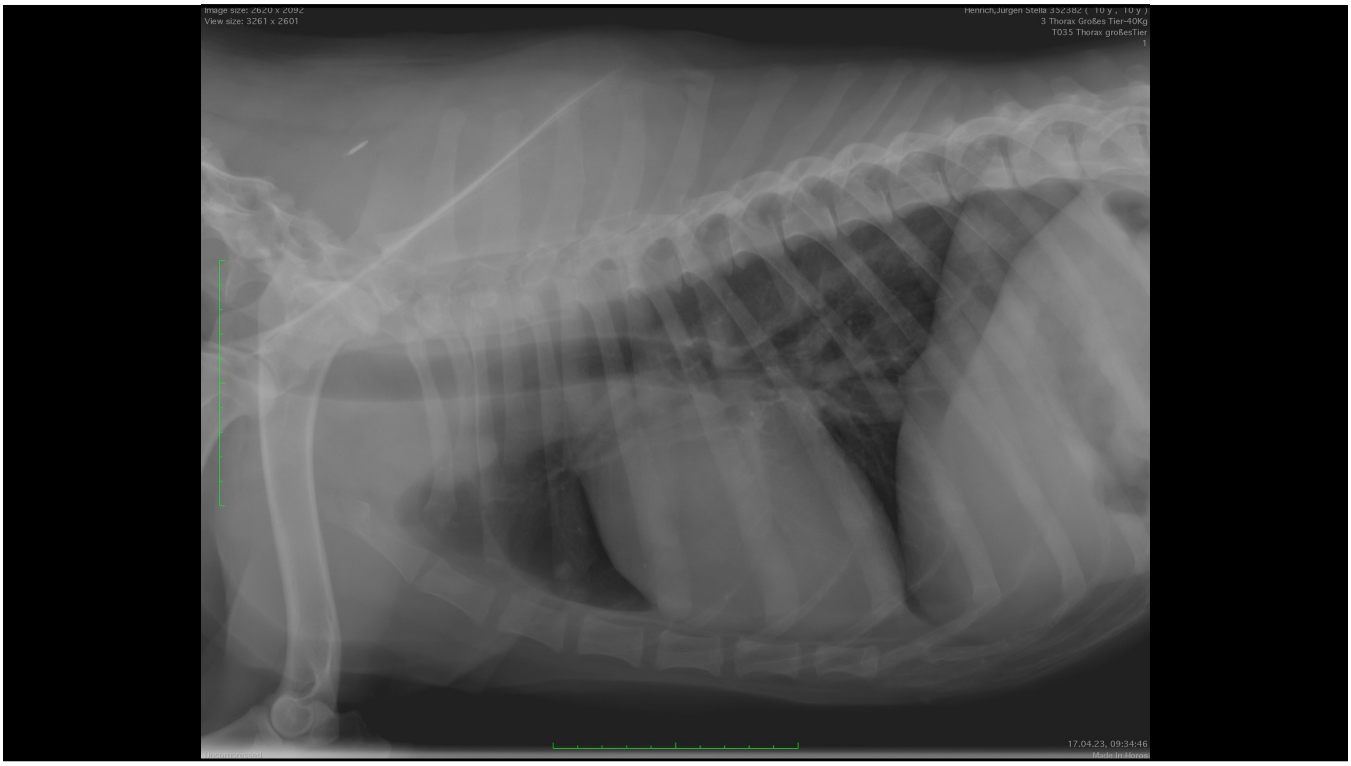
Audrey Belmudes, Guillaume Gory, Eddy Cauvin, Anaïs Combes, Hélène Gallois-Bride, Laurent Couturier, Delphine N. Rault

First published: 31 October 2020 | https://doi.org/10.1111/vru.12918 | Citations: 2

No EQUATOR checklist was used for preparing this manuscript

50

50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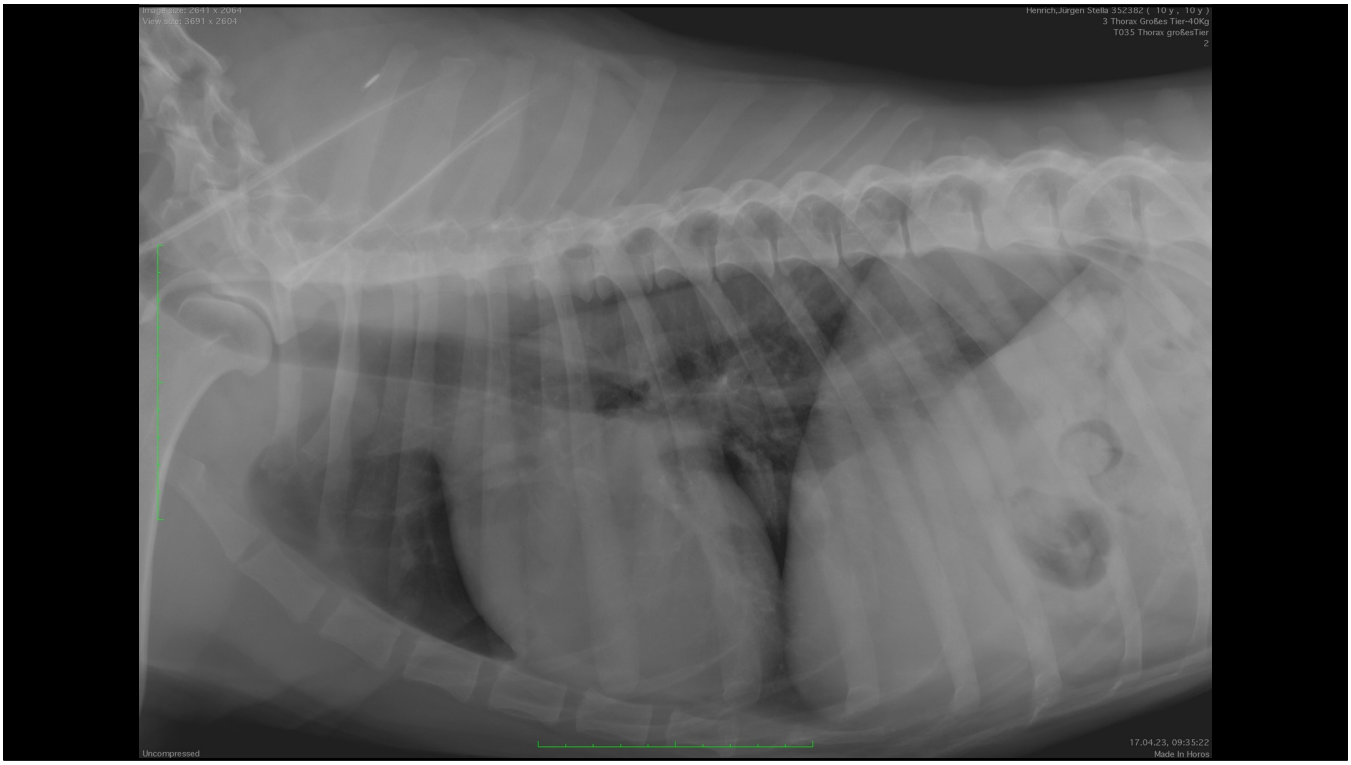
View size: 3261 x 2601
Henrich,Jürgen Stella 352382 (10 y , 10 y)
3 Thorax Großes Tier-40Kg
T035 Thorax großesTier
1
17.04.23, 09:34:46
Made In Horos

51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T035 Thorax großesTier
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Made In Horos

52

Image size: 2218 x 2542
View size: 2272 x 2591
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T035 Thorax großesTier
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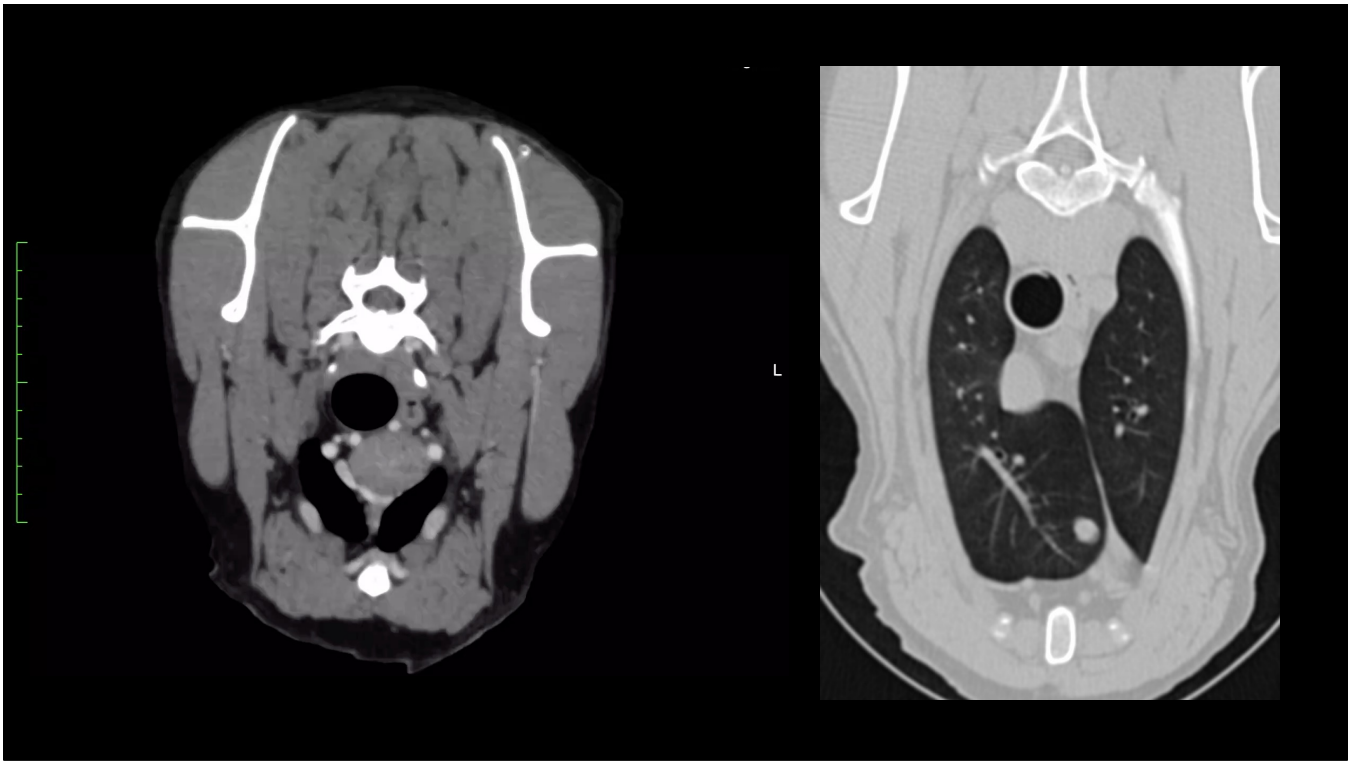

L

54

Pulmonary CT

Lung Diseases – Primary Lung Neoplasms

COMPUTED TOMOGRAPHIC APPEARANCE OF PRIMARY LUNG TUMORS IN DOGS

ANGELA J. MAROLF, DEBRA S. GIBBONS, BRENDAN K. PODELL, RICHARD D. PARK

First published: 02 November 2010 | https://doi.org/10.1111/j.1740-8261.2010.01759.x | Citations: 39

Address correspondence and reprint requests to Angela J. Marolf, at the above address. E-mail: angela.marolf@colostate.edu

- Usually well-defined
- Often heterogeneous contrast uptake
- Intraläsional calcifications
- 26% pulmonary metastases
- Metastasis to the tracheobronchial lymph nodes is possible

55

55

Pulmonary CT

Lung Diseases – Primary Lung Neoplasms

Computed tomographic findings in 57 cats with primary pulmonary neoplasia

Stacie Aarsvold [1], Jennifer A Reetz, Jean K Reichle, Ian D Jones, Christopher R Lamb, Maria G Evola, Michele A Keyerleber, Angela J Marolf

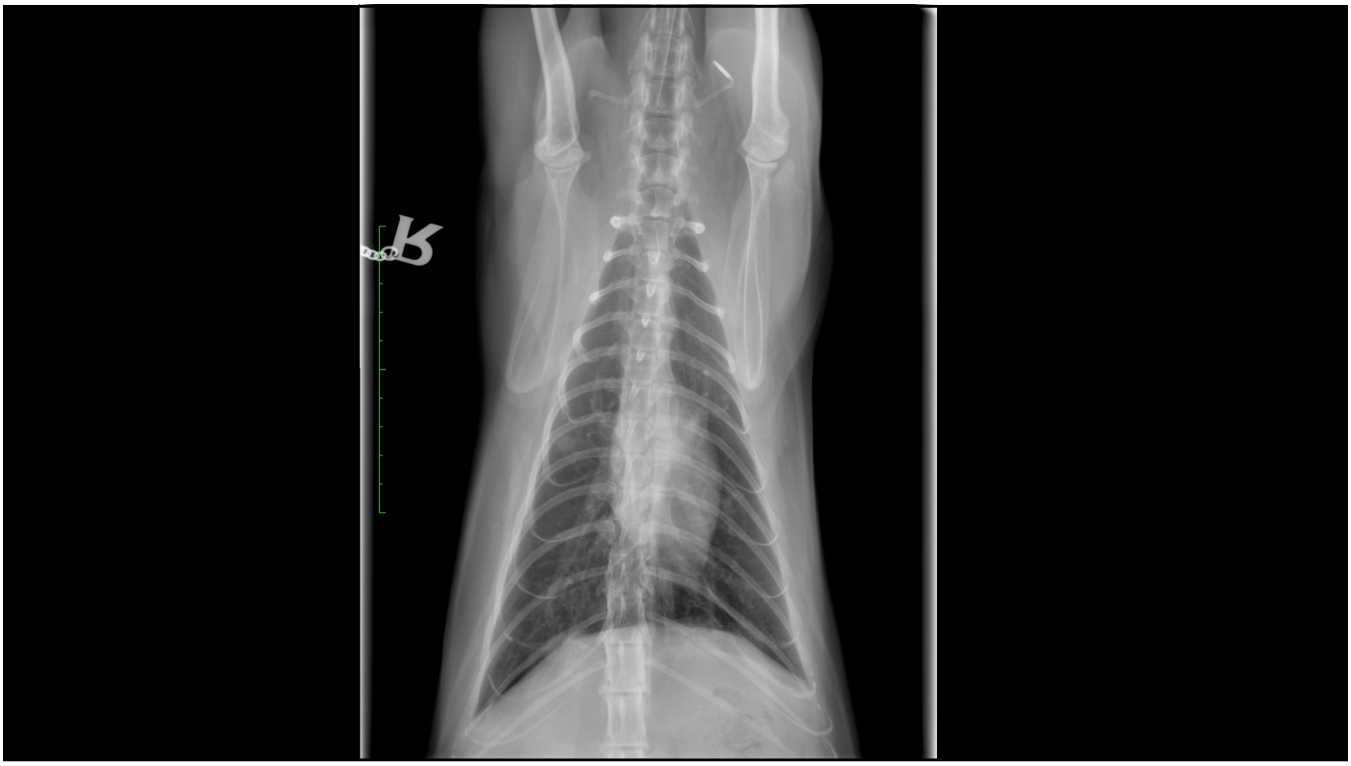
Affiliations + expand

PMID: 25605501 DOI: 10.1111/vru.12240

- Incidental finding in 9% of cats
- Most common in the caudal lung lobes
- Compression of the bronchus is common
- Mineralization is common
- 53% metastases
- 30% pleural effusion
- Most common tumor type: adenocarcinoma

56

56



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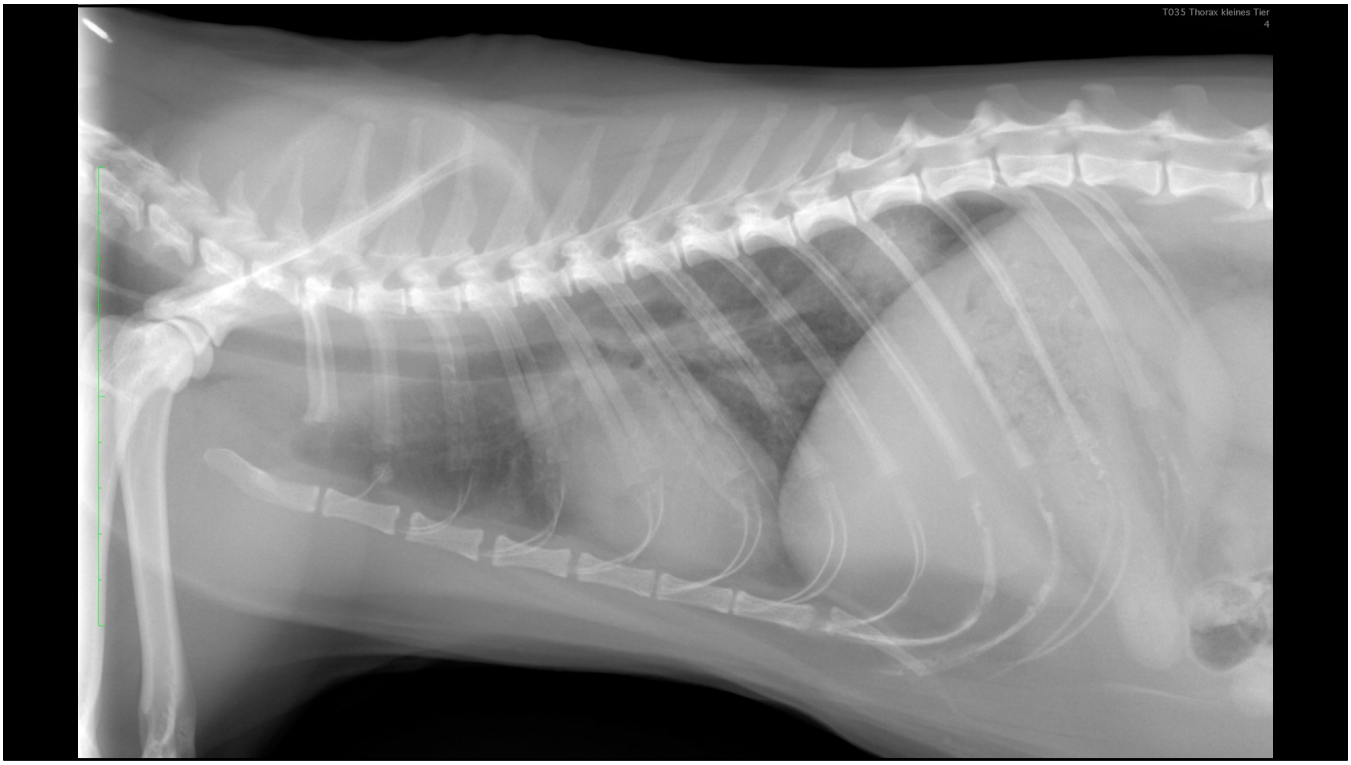

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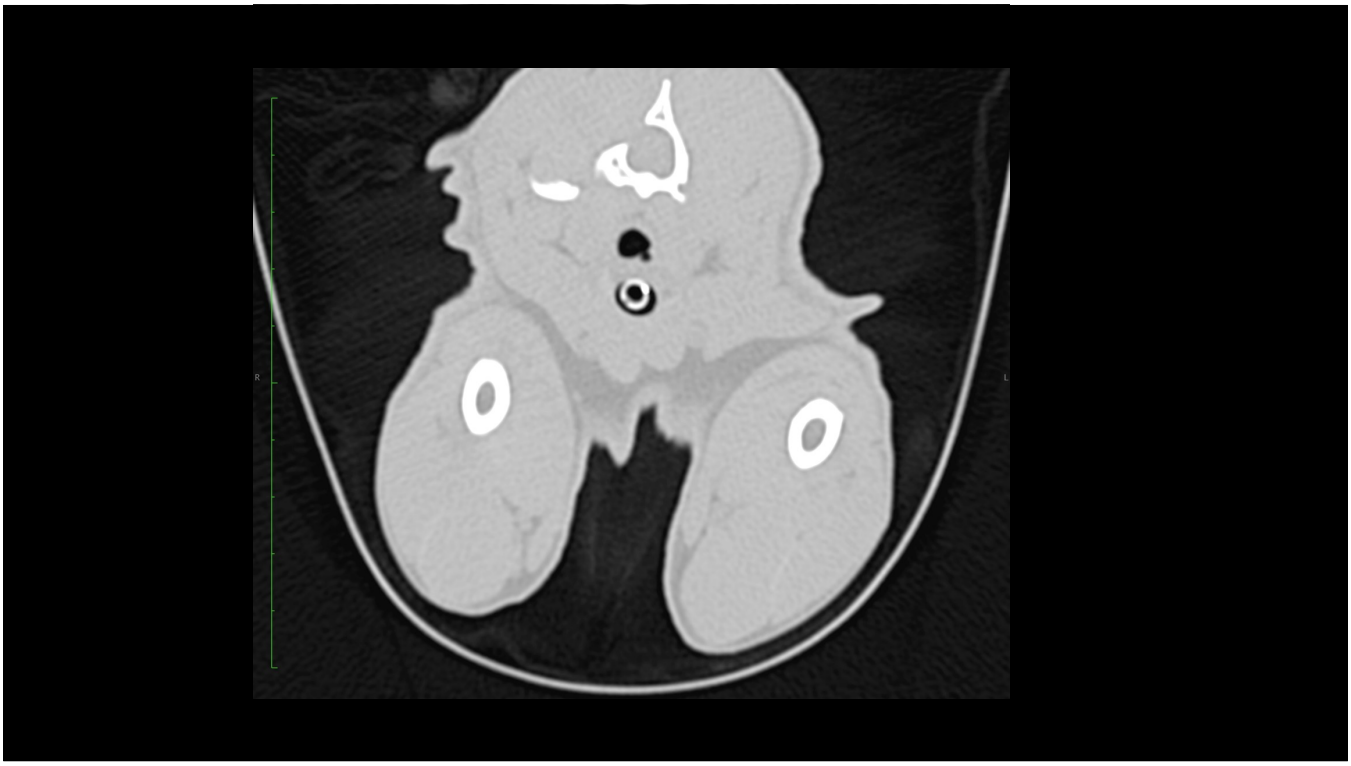
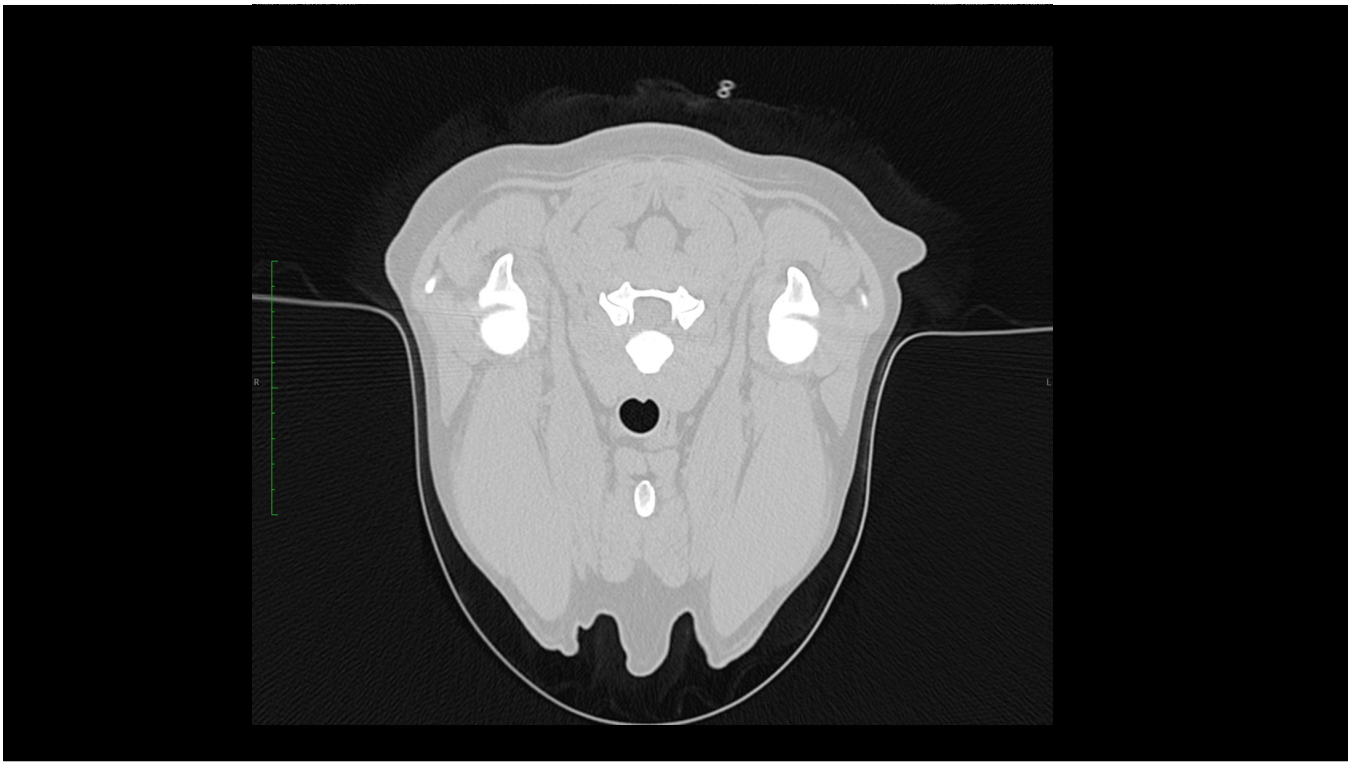


59

13 year old mixed breed
Reduced general condition Tachypnea
occasional cough

60



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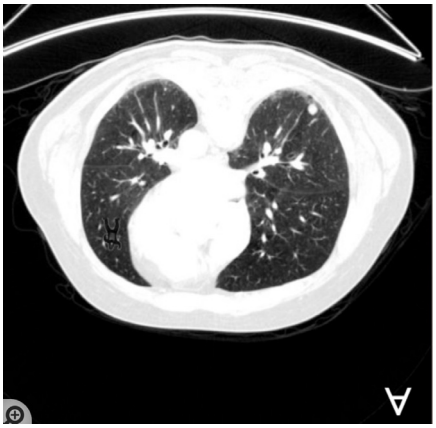
Pulmonary CT

Lung Diseases – Metastases

--> One of the most common indications for a chest CT scan: to rule out pulmonary metastases!



"The invisible gorilla strikes again: Sustained inattentional blindness in expert observers"
Trafton Drew,[a] Melissa L. H. Võ, and Jeremy M. Wolfe
› Author information › Copyright and License information Disclaimer

- Examine the entire lung
- In all 3 planes

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Pulmonary CT

Lung diseases – Metastases

ORIGINAL INVESTIGATION

Prevalence of pulmonary nodules in dogs with malignant neoplasia as determined by CT

Correction(s) for this article

Christopher R. Lamb, James Whitlock, Andrew T. L. Foster-Yeow

First published: 19 February 2019 | https://doi.org/10.1111/vru.12723 | Citations: 9

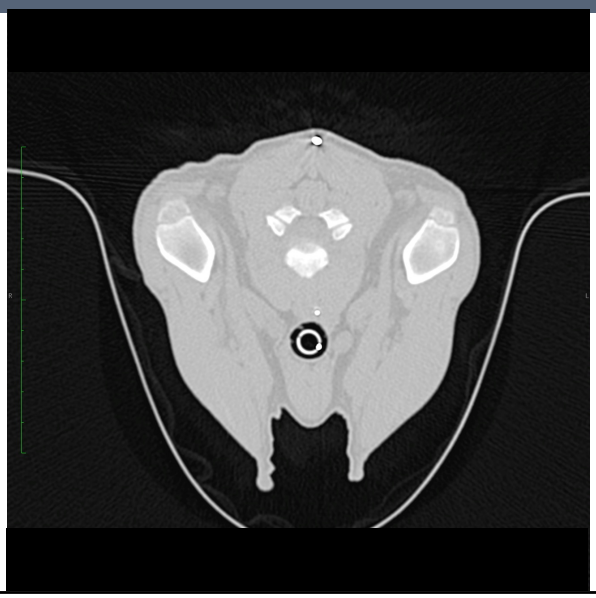
- Hemangiosarcoma: the tumor type with the highest incidence of pulmonary metastasis in this study
- Mast cell tumors are very rare
- Solitary pulmonary nodular lesions represent a nonspecific finding
- In 5 out of 9 dogs, the lesion remained stable; in 2 of these, it even disappeared completely
- In 4 out of 9 dogs, the lesion grew larger or additional lesions appeared

63

63

Pulmonary CT

Lung diseases – congenital malformations



64

64

Features suggesting neoplasia

- Solitary mass or dominant lesion
- Heterogeneous contrast enhancement
- Lymphadenopathy (especially asymmetric)
- Mineralization in a mass(some tumor types)
- cavitation possible

65

Features suggesting inflammatory / infectious disease

- Diffuse or multifocal distribution
- Ground-glass opacity
- Tree-in-bud / bronchiolar pattern
- Air bronchograms in non-mass-like consolidation

66

Vignoli et al., 2021 (dogs & cats, n=62)
Diagnostic yield ~69% diagnostic samples
Accuracy of FNA ~67–68%
Accuracy of TCB ~95%

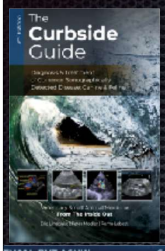
→ Rads & CT offer probabilities

→ Histopathology & laboratory tests remain Gild standard

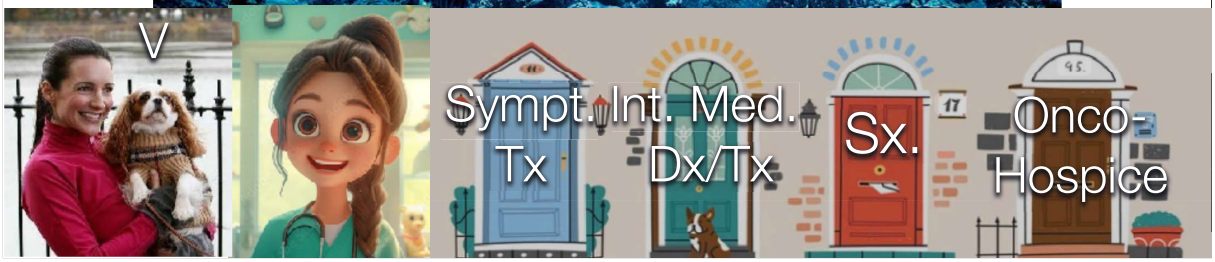
67

Mastering abdominal ultrasound imaging: A Standardised Sonographic Diagnostic Efficiency Protocol (SDEP®) for never missing a lesion

An Evolutionary Point in Clinical Sonography



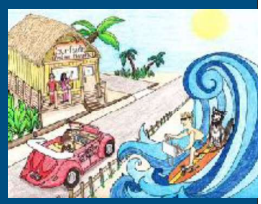
Eric Lindquist DMV, DABVP (CFM), Cert. IVUSS
CEO/Founder SonoPath.com



What is SDEP®?

Sonographic **D**iagnostic
Efficiency **P**rotocol

Innovated on the road of mobile sonography in New Jersey, with hundreds of sonograms per month for many years.



SDEP® was the first published standardized protocol for abdominal ultrasound.

Presented at EVDIC (European Veterinary Diagnostic Imaging Congress) in 2019,
Published in Veterinary Radiology & Ultrasound in October, 2019

SDEP® meets & exceeds all criteria in ACVR and ECVDI consensus statement for the standardization of the abdominal ultrasound examination.

Seiler GS, Cohen EB, d'Anjou M-A,et al.
ACVR and ECVDI consensus statement for the standardization of the abdominal ultrasound examination. Vet Radiol Ultrasound. 2022;63:661–674

SonoPath
Clinical Sonography & Telecytology
EDUCATIONAL TELECONSULTATION SERVICES

Why SDEP® as a standardized abdominal sonographic protocol?

Resolve traditional inconsistencies regarding variable sonographic protocols. “Take the same road to Rome” concept.

What IS a complete sonogram? SDEP™ helps define a standard.

SDEP™: Consistent, Repeatable, Efficient, Complete, Referable locally, internationally & historically.

SDEP™ provides consistency in standard, alternative, & challenging views that are subject to omission in traditional protocols.

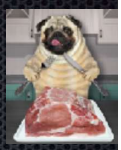
Additional multiple angle & high resolution imaging of abnormal findings & clinically relevant organ systems.

More on Why SDEP®?

- More information to evaluate than traditional still image protocols.
- 2000-3500 still image equivalent in each study of 17-30 SDEP videos.
- Intrinsic redundancy in organ/adjacent organ approaches all structures whether recognized by the sonographer or not.
- Workable study file size of 200-600 mb.

More on Why SDEP®?

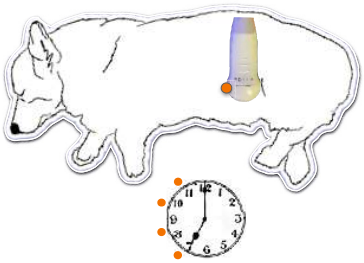
- Complete & efficient interpretation by over-reading specialist. More *"Meat On The Bone"* reporting.



- Patient comfort & higher image resolution owing to manual probe hand compression technique.
- Excellent complete sonographic protocol for emergency settings.

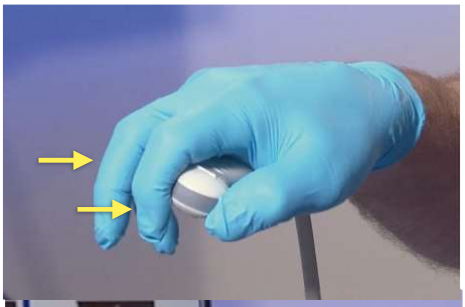
Starting your scan:
Finger and hand positions.

SonoPath



The marker is always between
7 and 11 o'clock,
toward the head of the patient.

Use the back of your hand to *gently* push against the body to
"Minimize the real estate"



- Use wide pressure points to "pet & scan" your patient
- Work with the pet to create your own

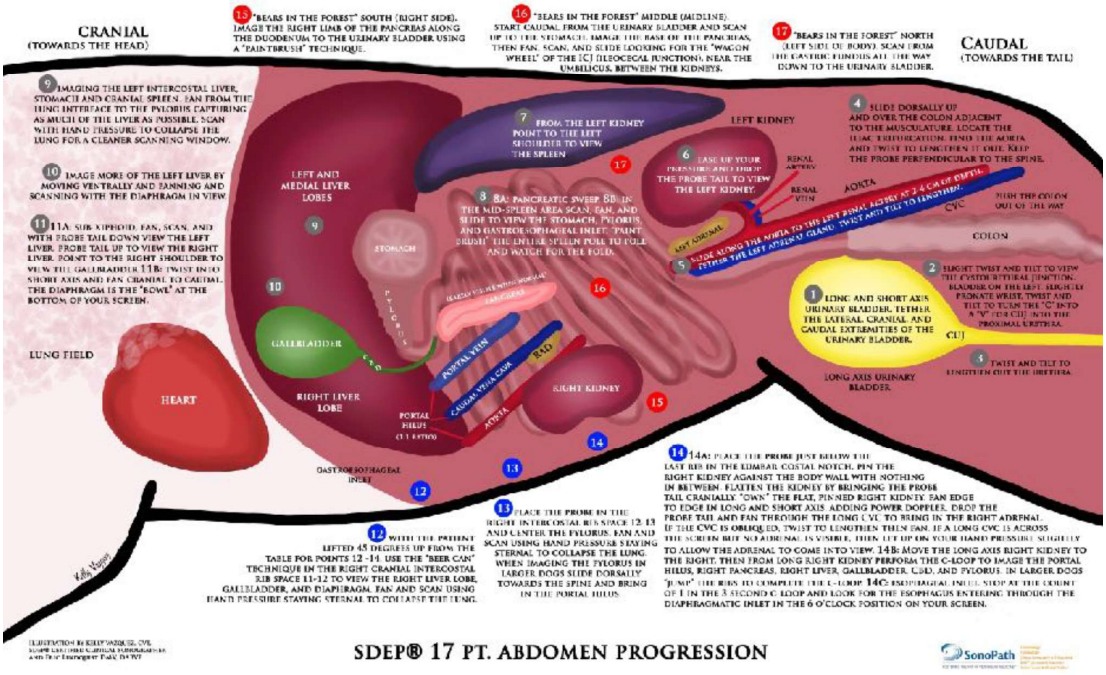
  acoustic windows.

- **Don't poke and prod your patient**

The probe is just along for the ride.

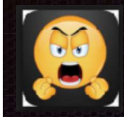
Progressive Image Optimization & Adaptation To The Physics Of The Patient

SDEP 17 POINTS, FOLLOW THE POSTER

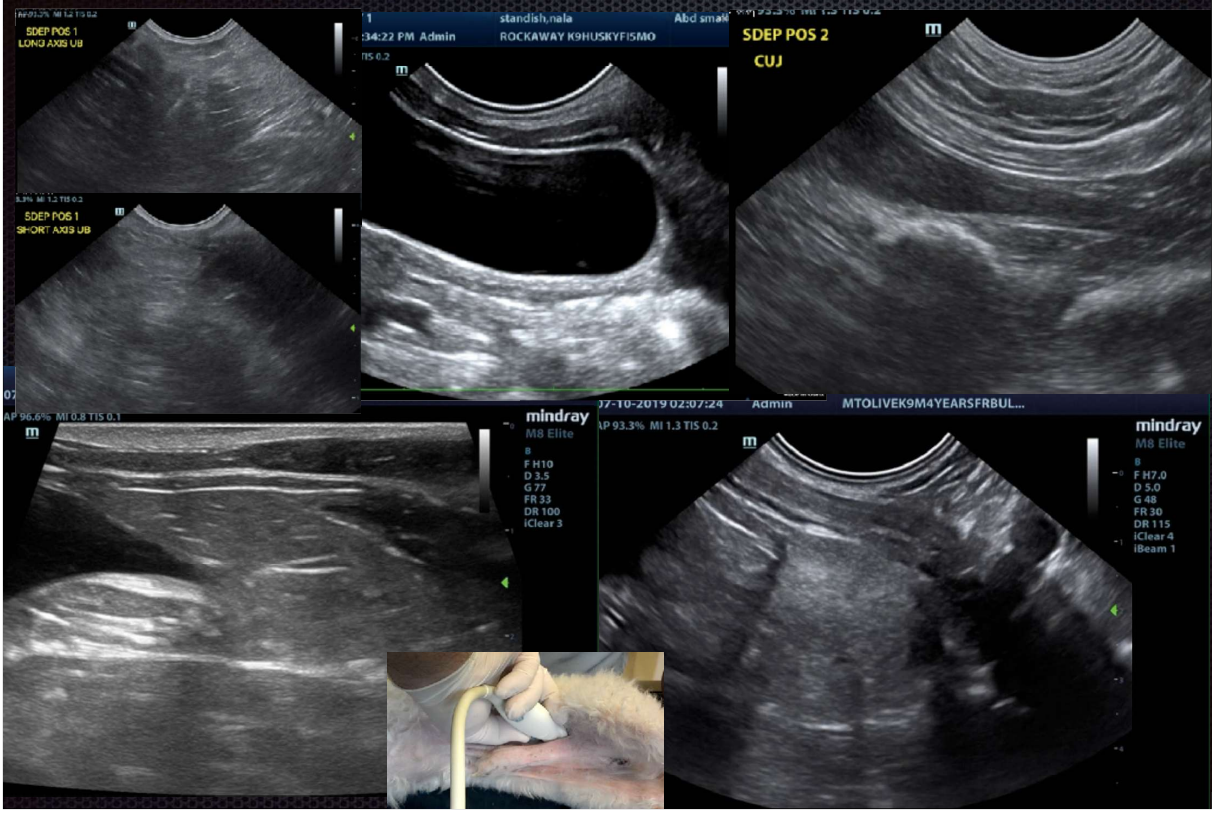


SDEP® Probe Manuality

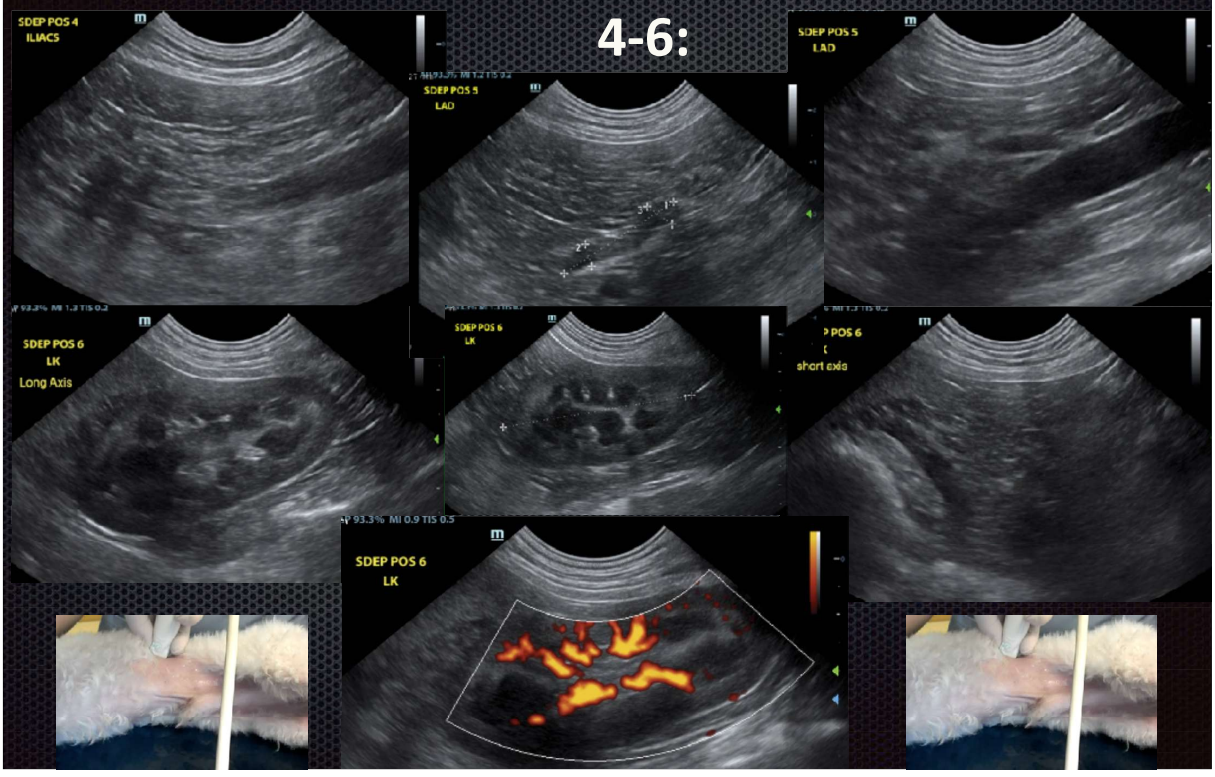
Patient Comfort
Tissue Compression
Harmonic Sonographic Medium
Artifact displacement
Key Structures Imaged At 4 cm Depth or Less

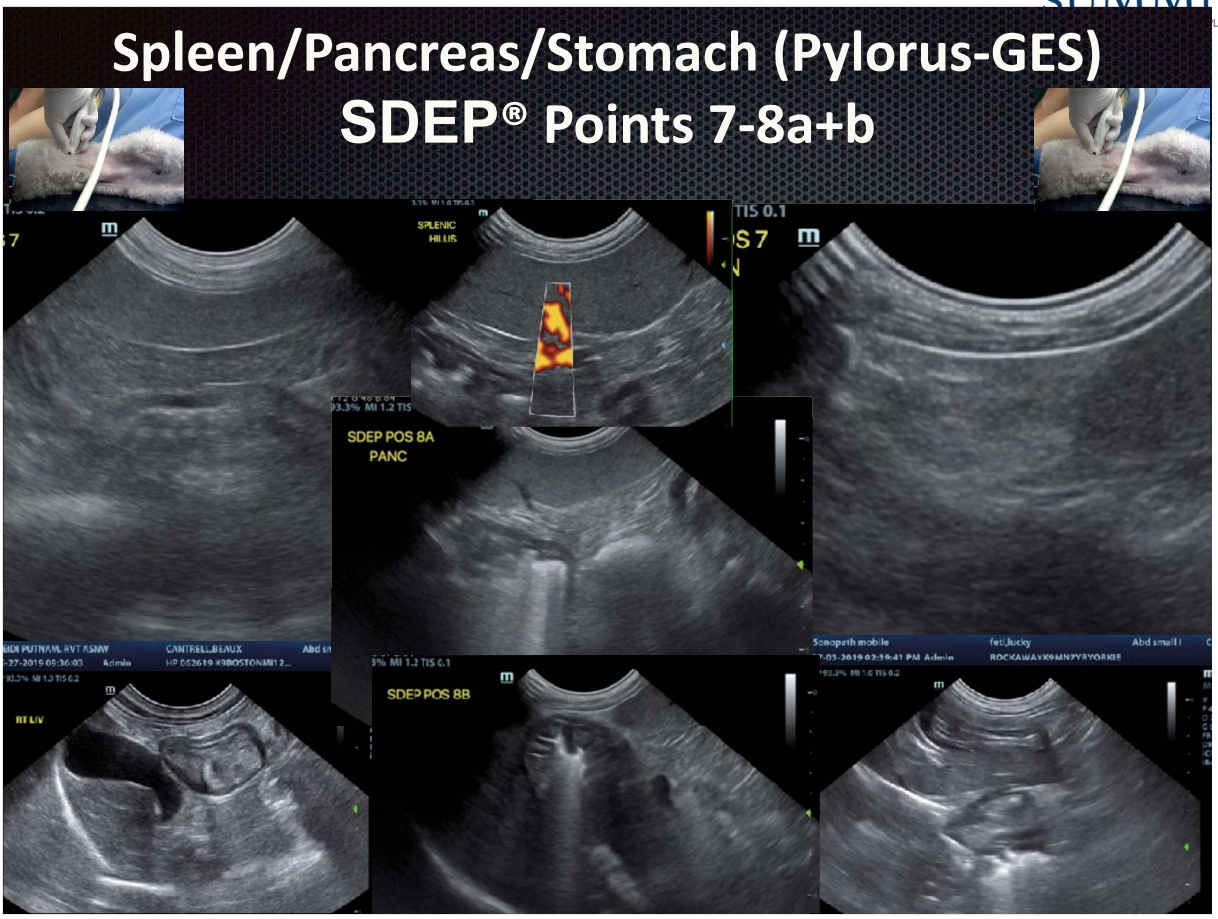


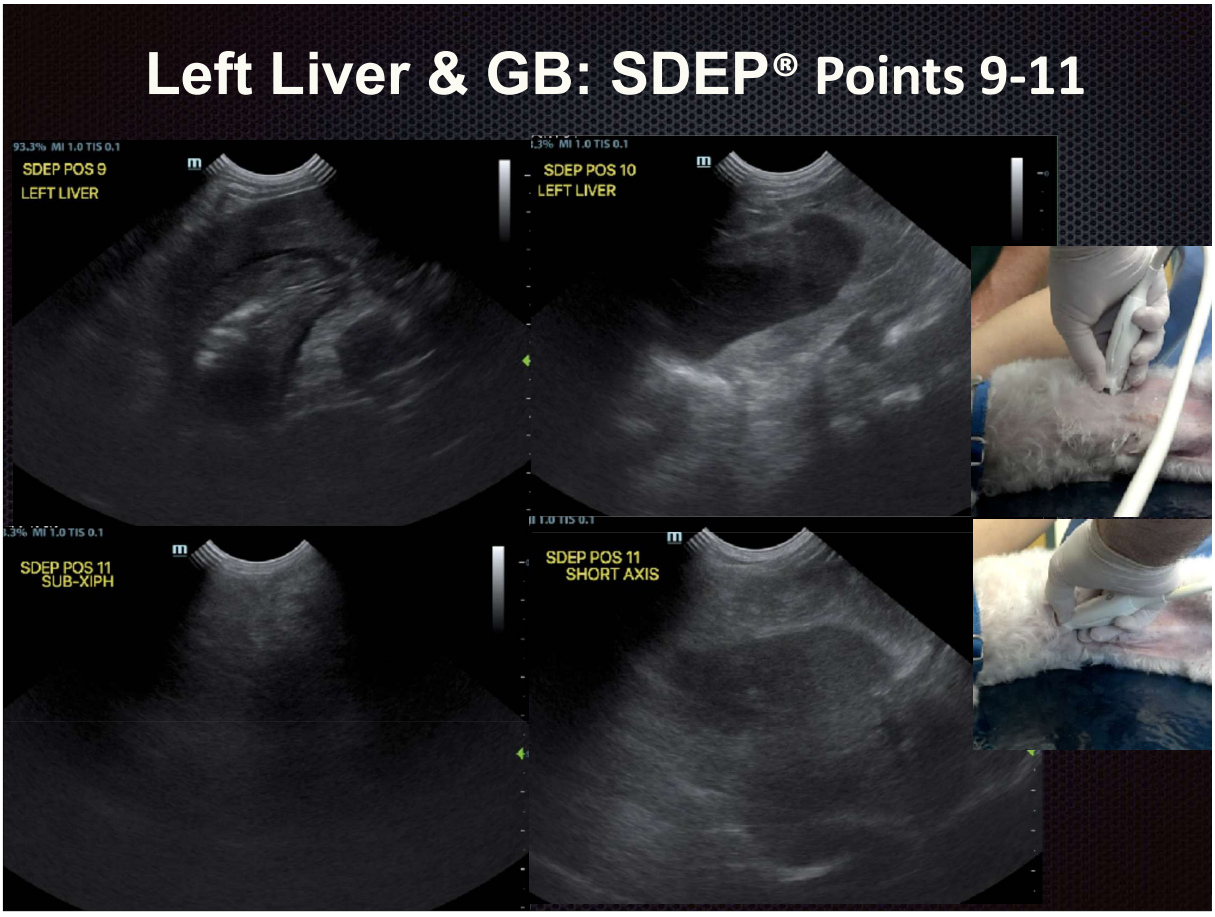
SDEP® Points 1-3 : Lower Urinary



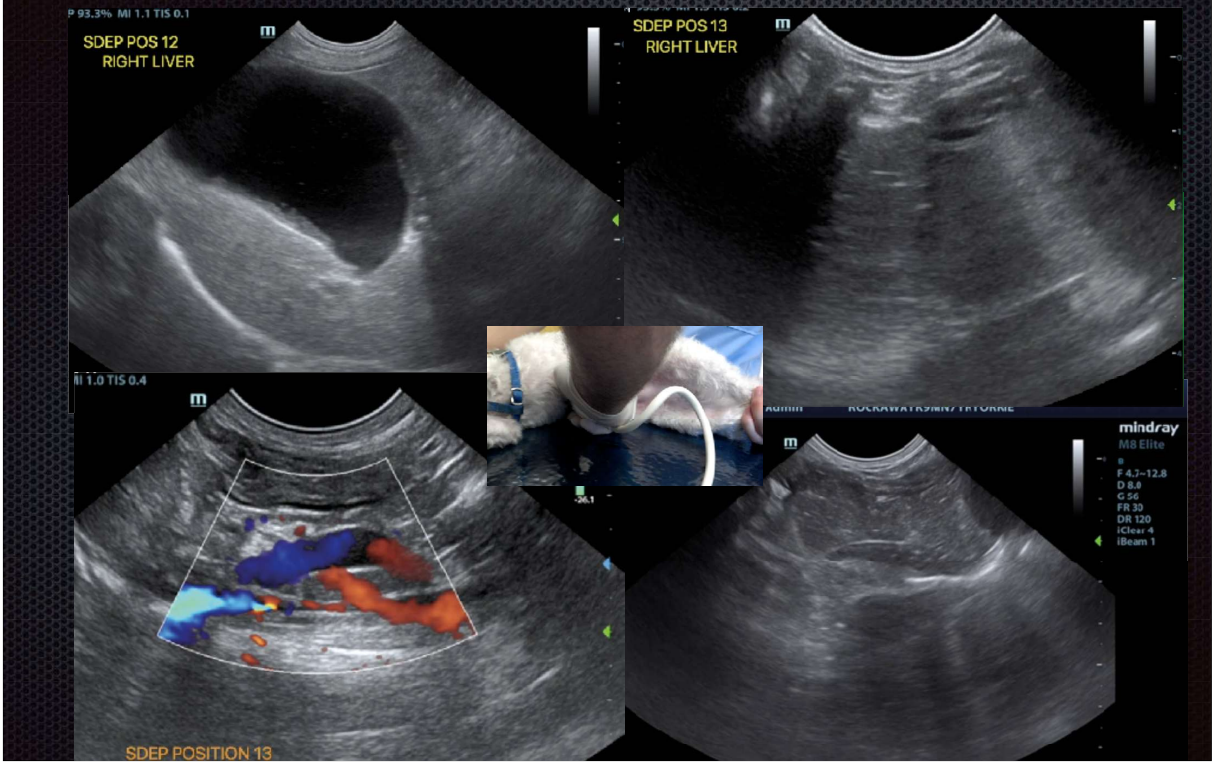
Iliac/Ao/Left Adrenal/Left Kidney SDEP® Points 4-6:




Spleen/Pancreas/Stomach (Pylorus-GES)
SDEP® Points 7-8a+b
SPLENIC HILUS
SDEP POS 8A
PANC
SDEP POS 8B

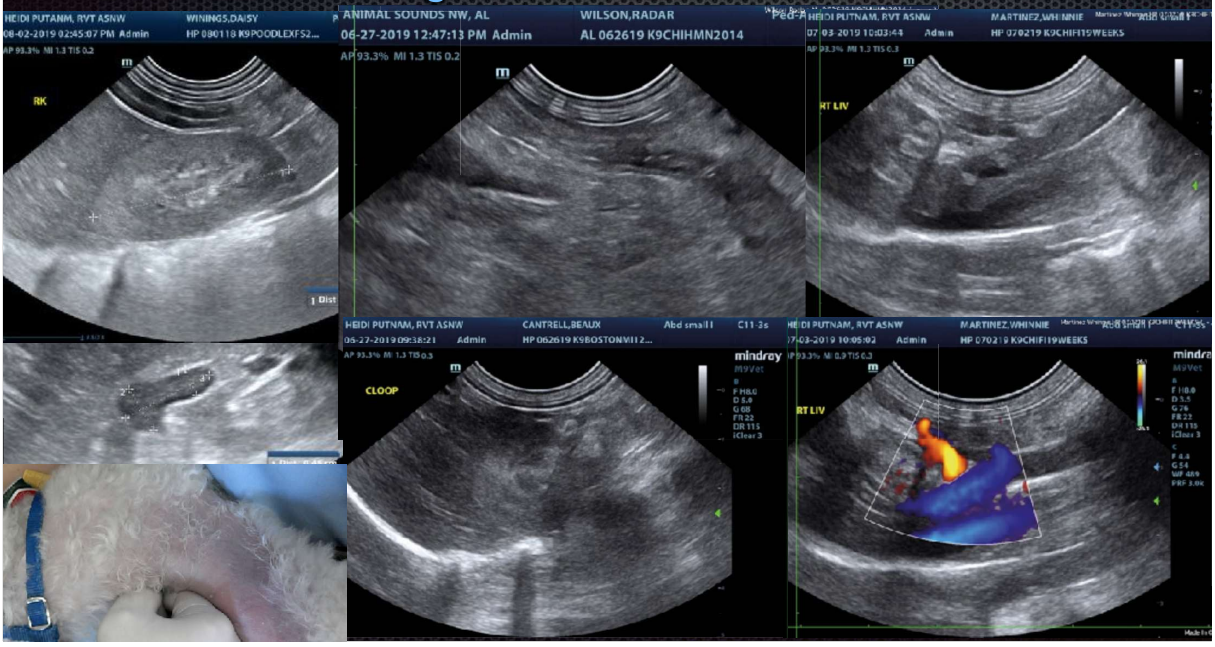

Left Liver & GB: SDEP® Points 9-11
SDEP POS 9
LEFT LIVER
SDEP POS 10
LEFT LIVER
SDEP POS 11
SUB-XIPH
SDEP POS 11
SHORT AXIS

Right Liver/Portal Hilus/Pylorus
SDEP® Points 12-13



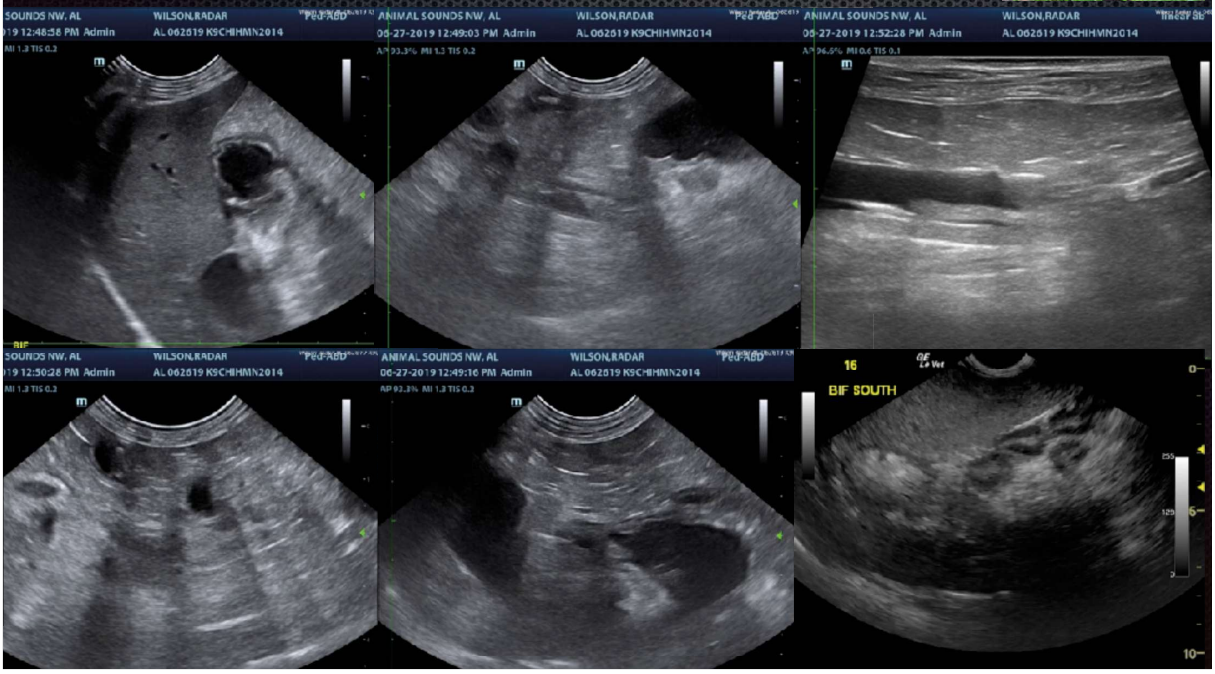
Position 14:
Right Kidney, Right Adrenal & "C-Loop"

C-Loop: RK, RT Liver, Portal Hilus, GB, Pylorus, Right Pancreatic Base



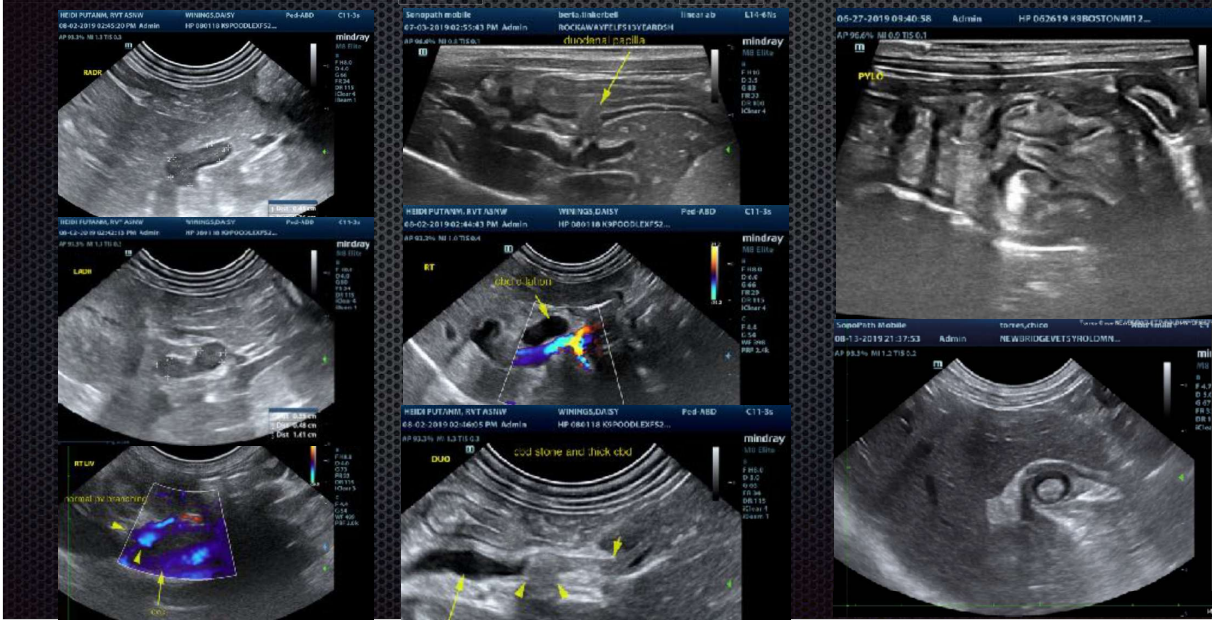
Positions 15-17: “Bears In The Forest”

Light pressure video sweeps through the mid abdomen to evaluate GI, LN, ICJ & structures displaced in prior steps 1-14



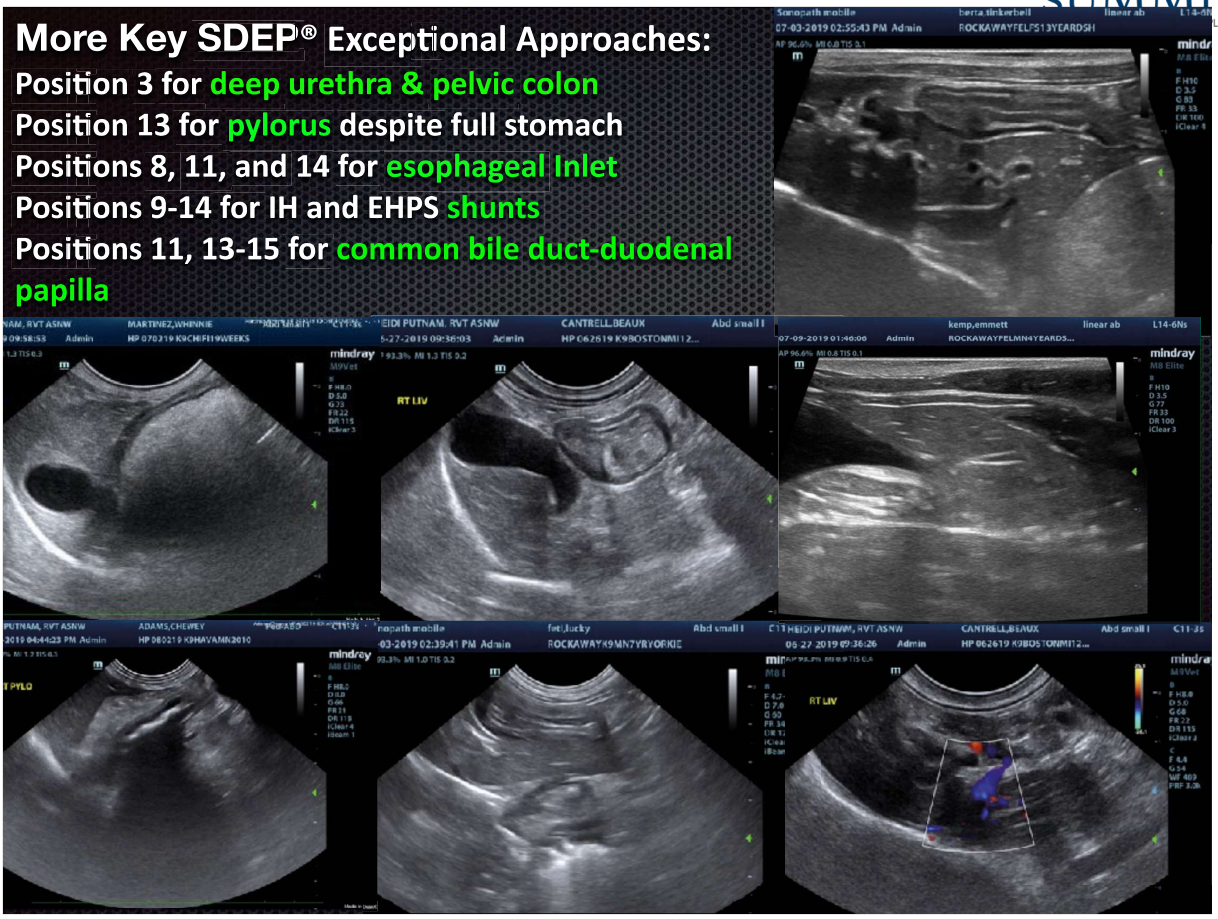
Some Key Diagnostic Images Included In SDEP®

Portal Hilus: CBD, Duodenal Papilla, PV, CVC
Pylorus, Gastroesophageal Junction, Ileocecal Junction
Pelvic Urethra/Pelvic Colon
Every Adrenal Gland Every Time



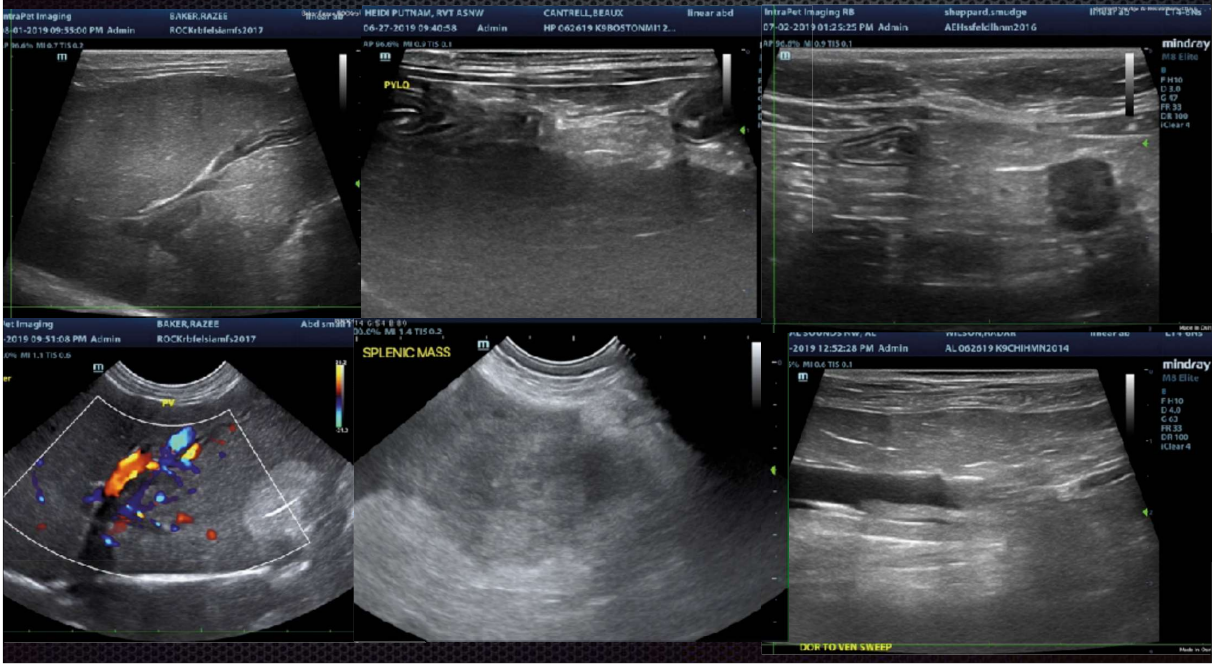
More Key SDEP® Exceptional Approaches:

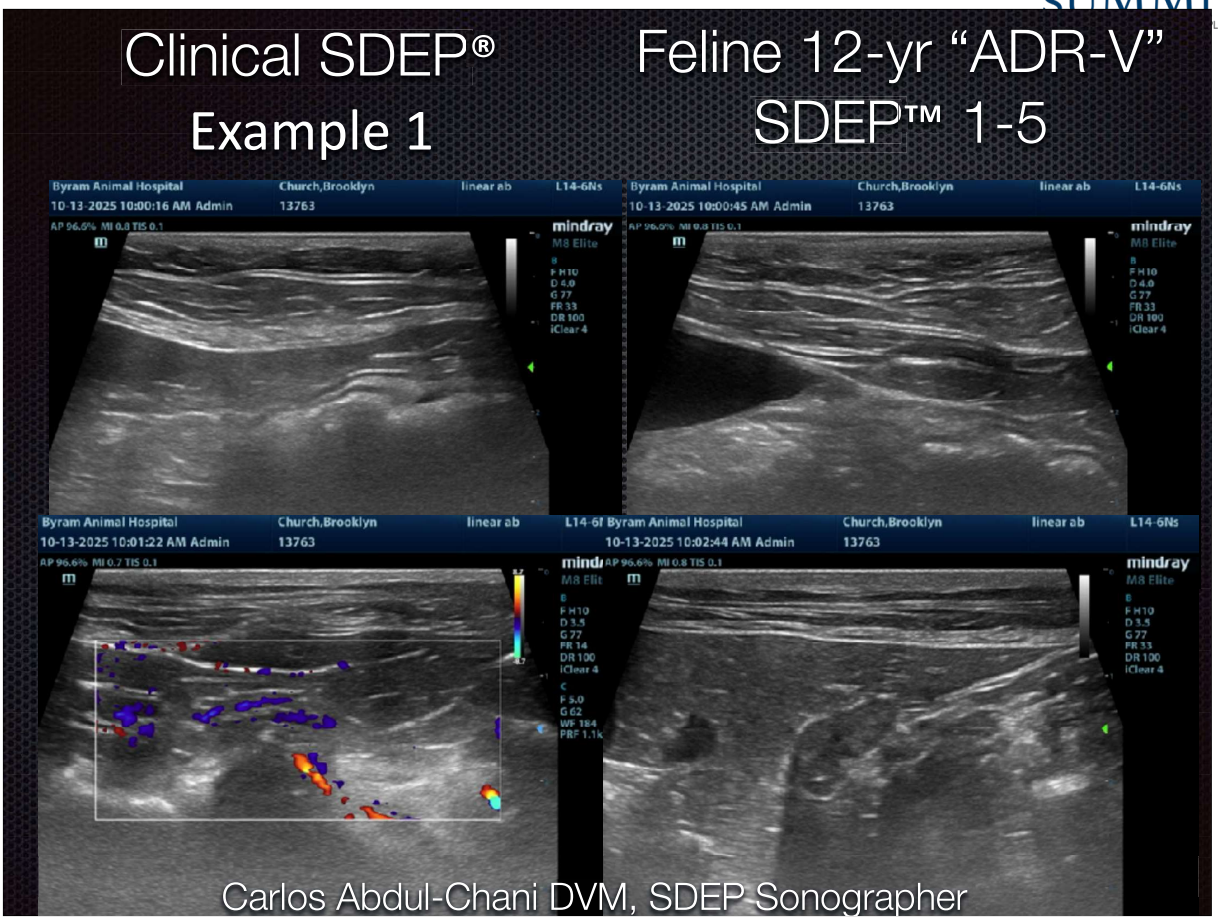
Position 3 for deep urethra & pelvic colon
Position 13 for pylorus despite full stomach
Positions 8, 11, and 14 for esophageal Inlet
Positions 9-14 for IH and EHPS shunts
Positions 11, 13-15 for common bile duct-duodenal papilla

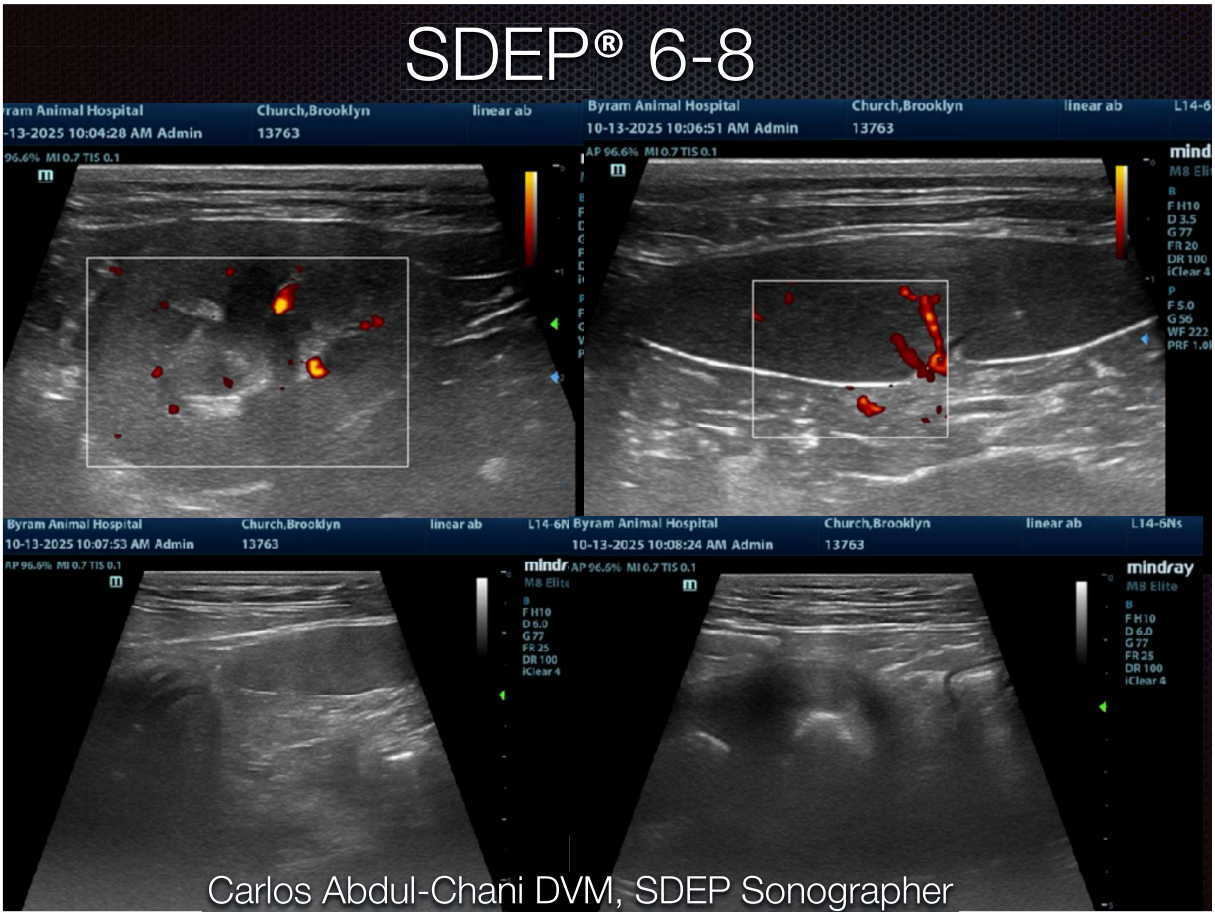


Clinically Pertinent & Pathology Refinement Views

4+ Angular Approach Views of Abnormal Structures
Hi Resolution & Zoom Images of "Clinical" Organs




Clinical SDEP®
Example 1
Feline 12-yr "ADR-V"
SDEP™ 1-5
Carlos Abdul-Chani DVM, SDEP Sonographer


SDEP® 6-8
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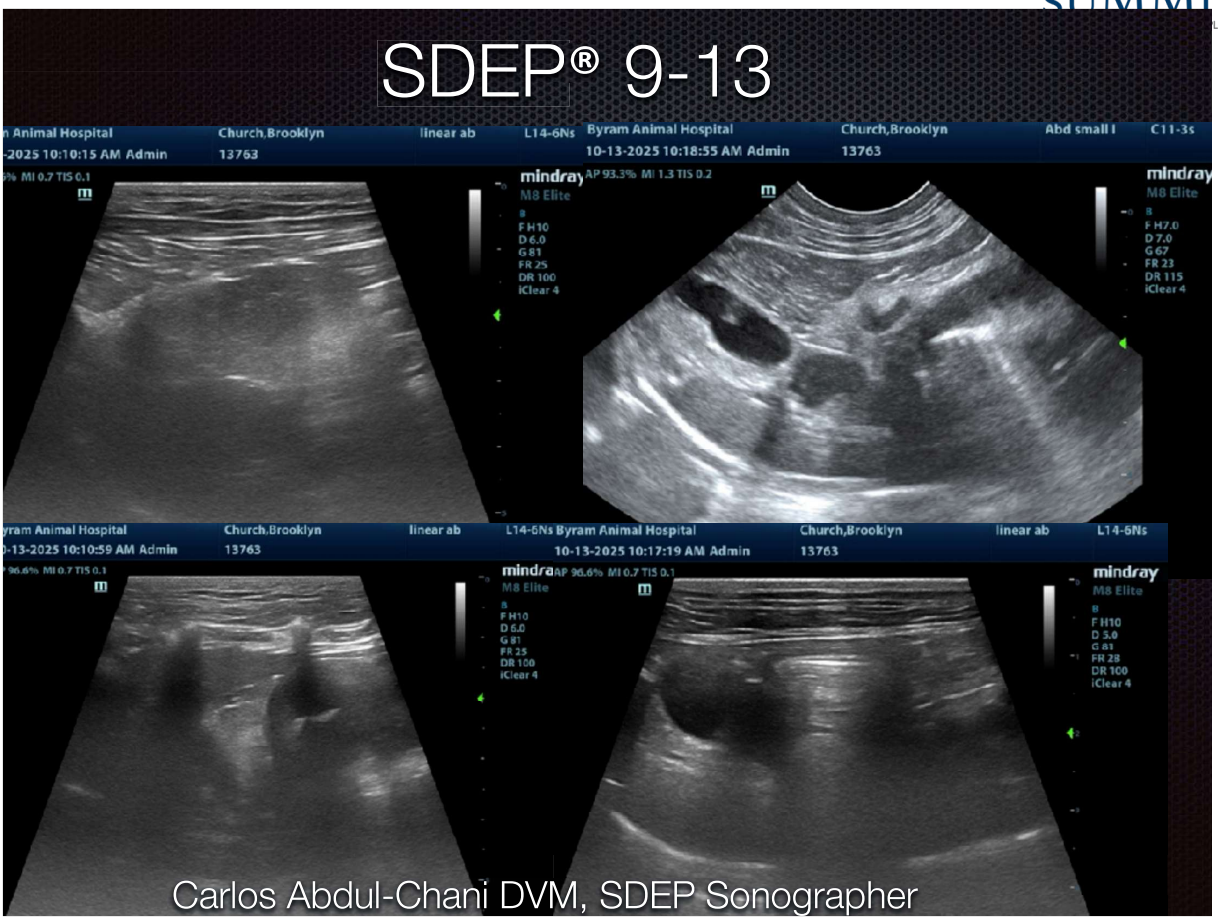
SDEP® 9-13
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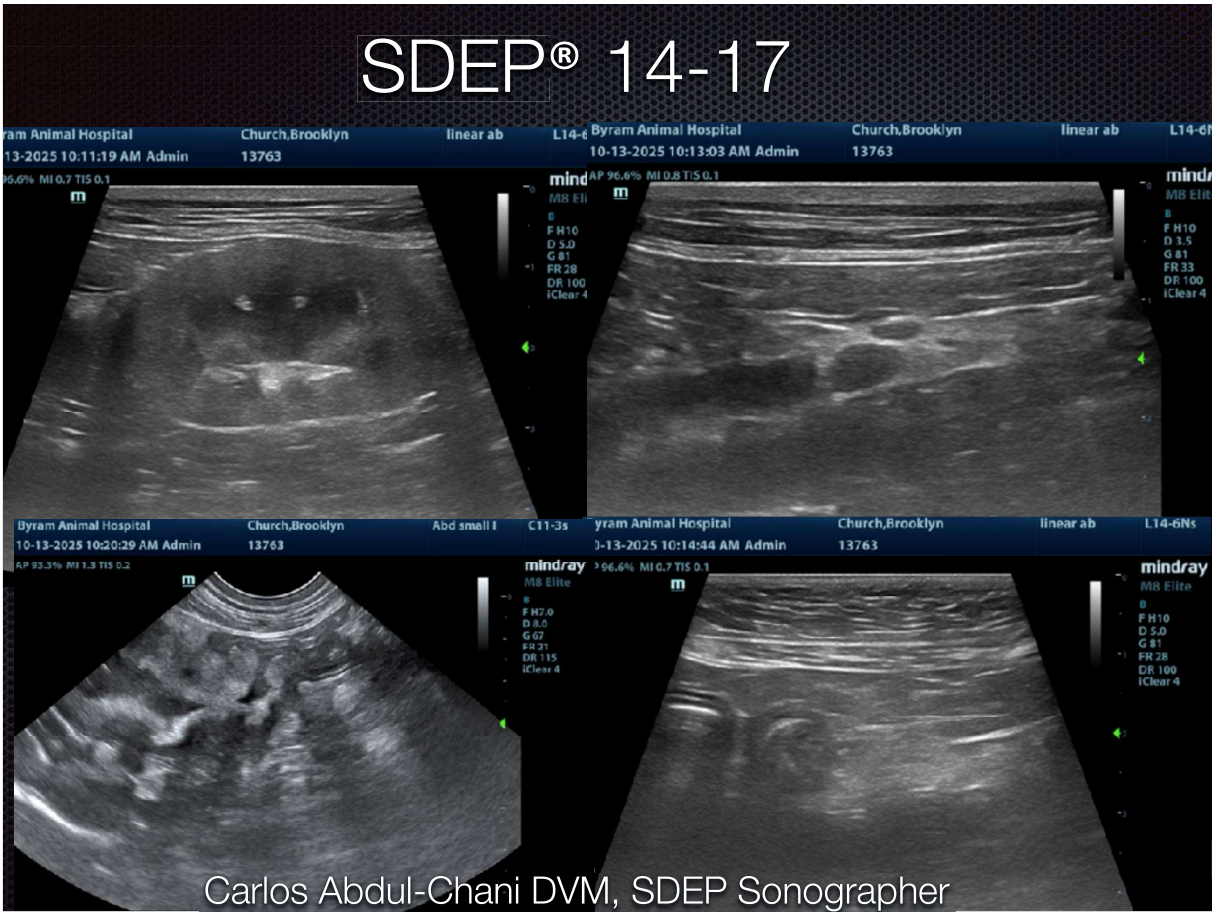
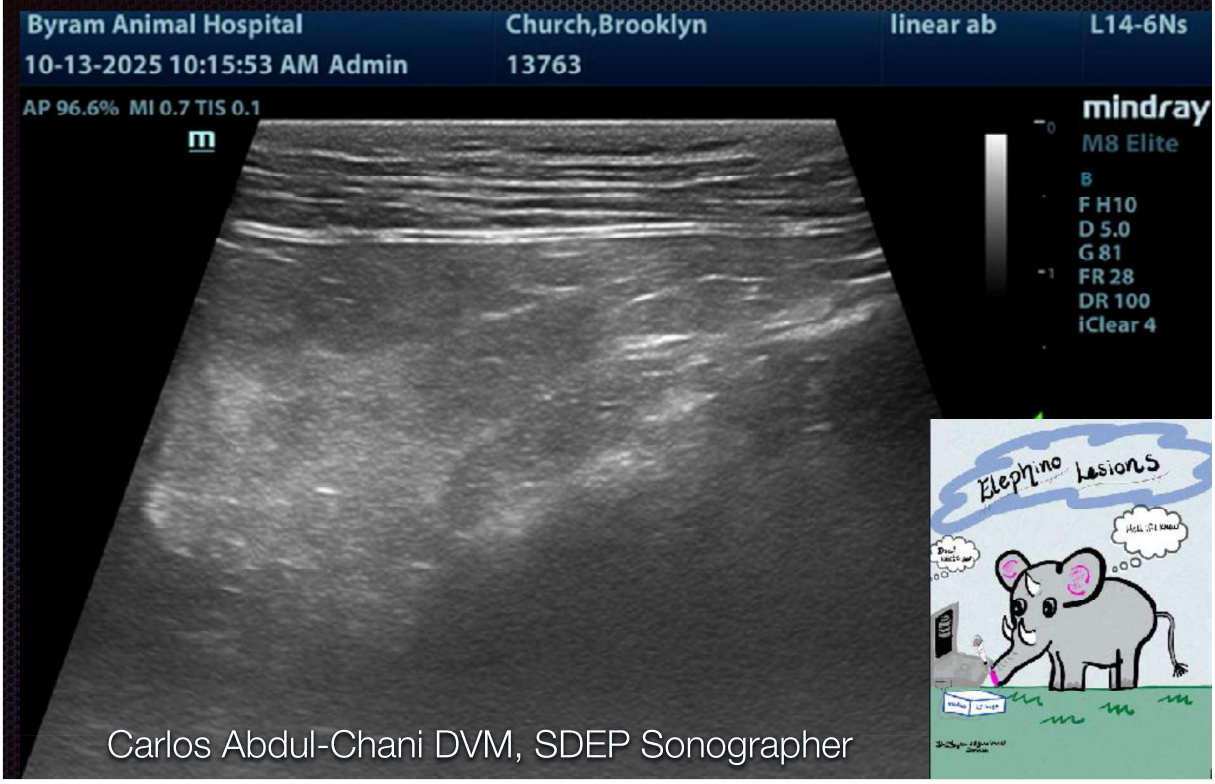

SDEP® 14-17
Carlos Abdul-Chani DVM, SDEP Sonographer

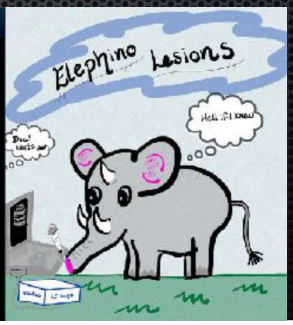
SDEP® Refinement



Carlos Abdul-Chani DVM, SDEP Sonographer

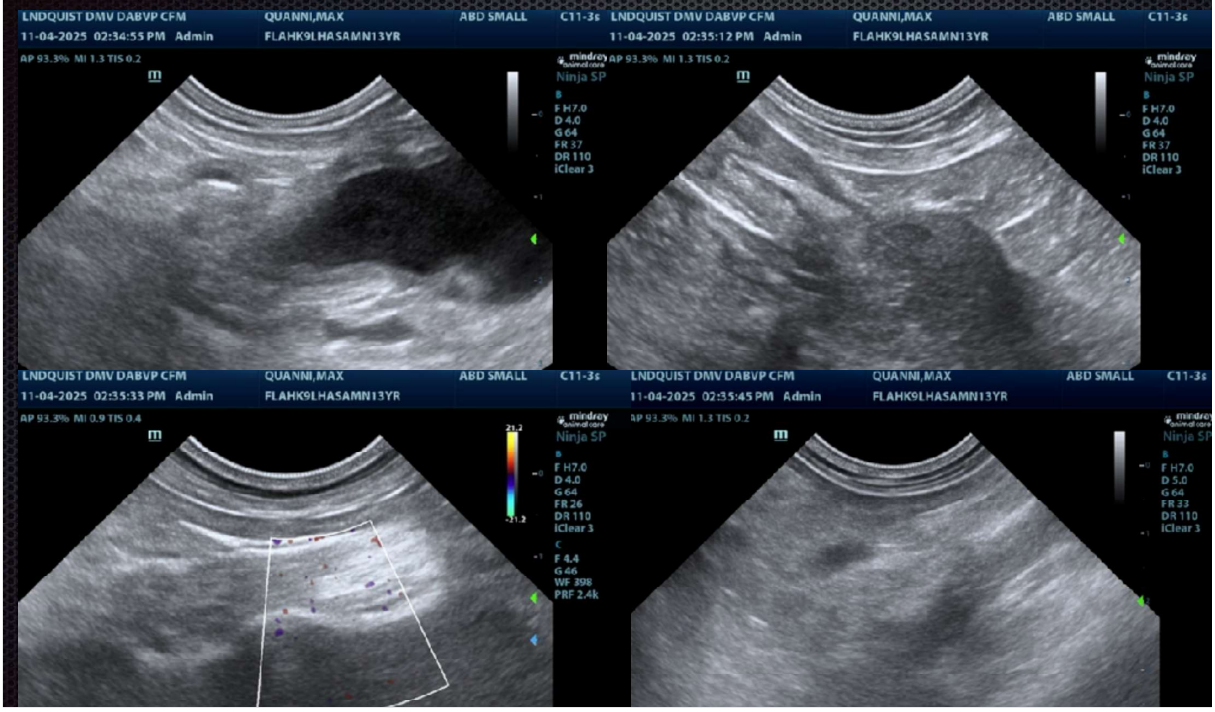
Feline 12-yr "ADR-V"

- Gastric Infiltrative Pattern - Neoplastic Criteria
- Regional Lymphadenopathy (Rounded)- Neoplastic Criteria
- Mild Splenomegaly
- Plan : 25g FNA spleen, 22g FNA Gastric Wall
- Ddx: LSA likely, Fibroplasia or Granulomatous Possible

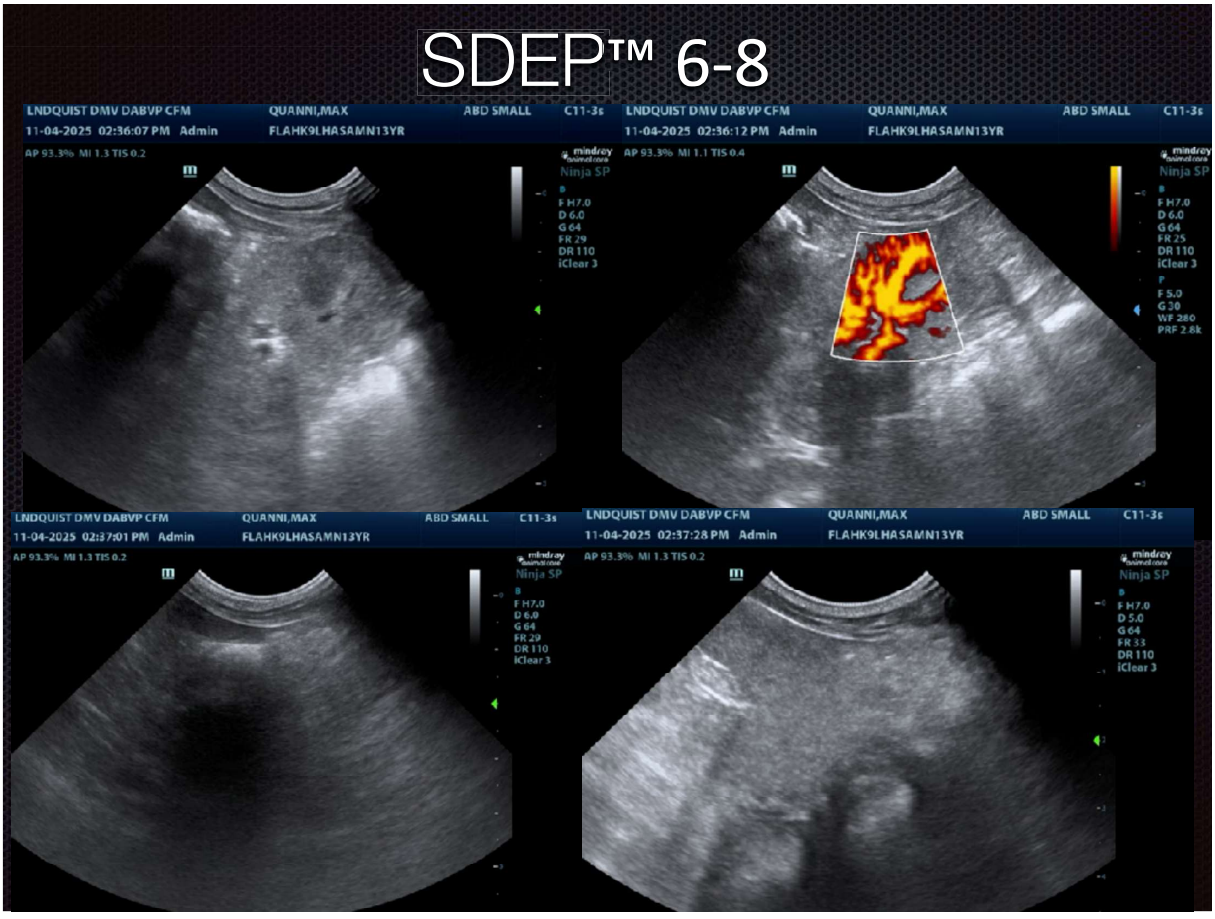


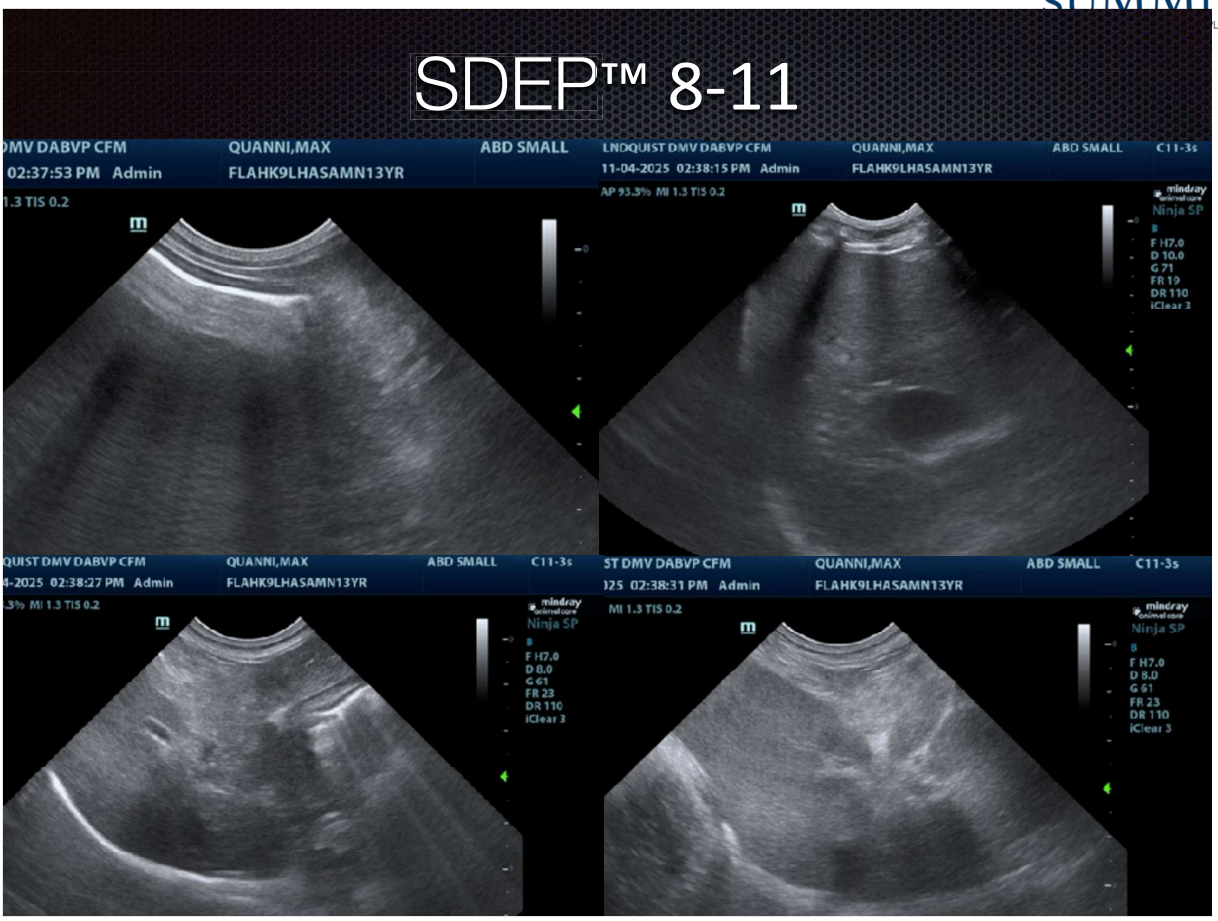
Clinical SDEP® Example 2

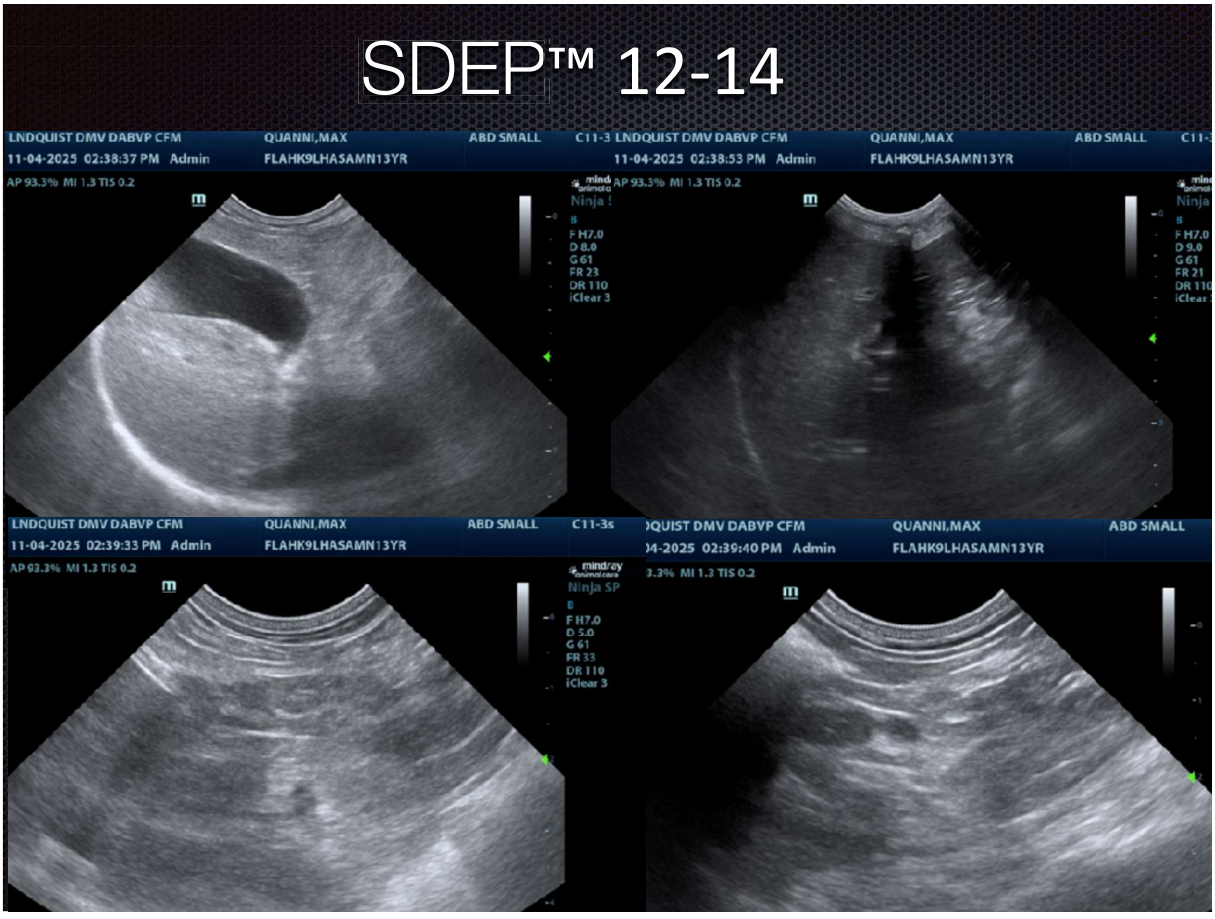
13-yr Lhasa Dog Geriatric Scan LEs, Occasional V SDEP™ 1-5



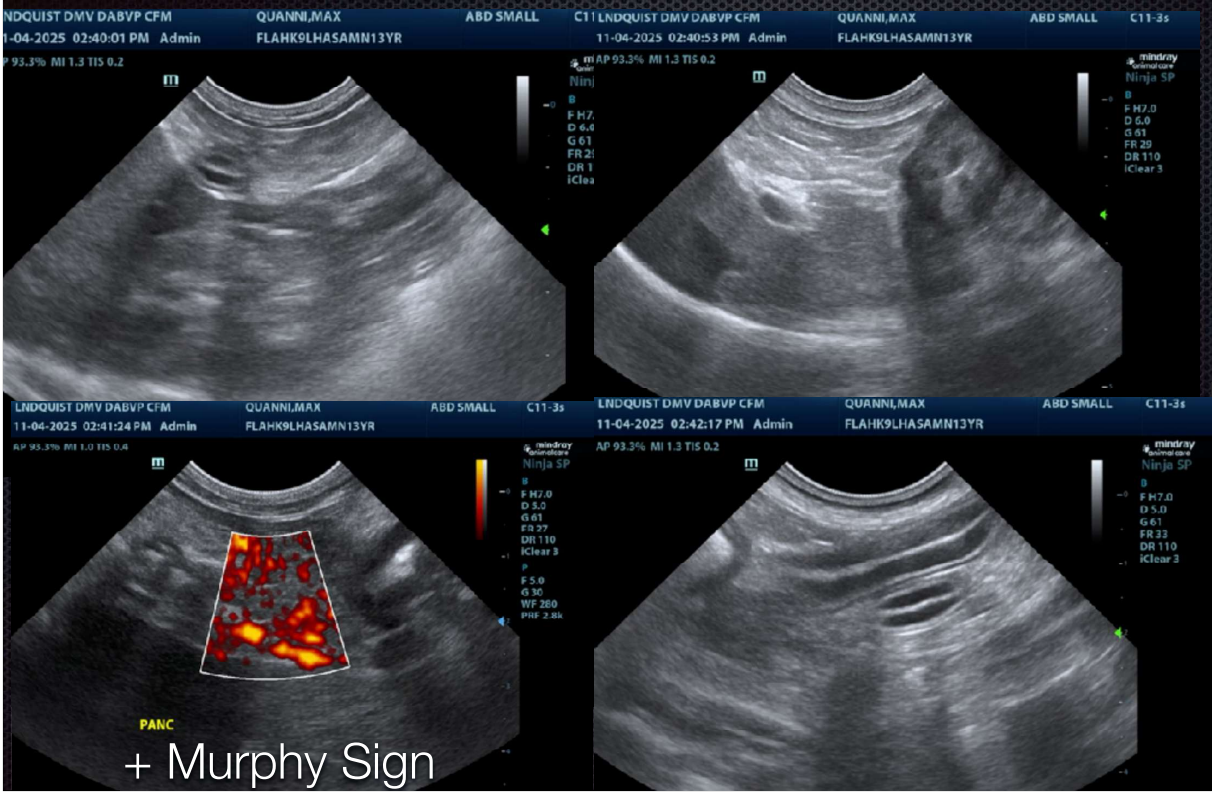
SDEP™ 6-8




SDEP™ 8-11

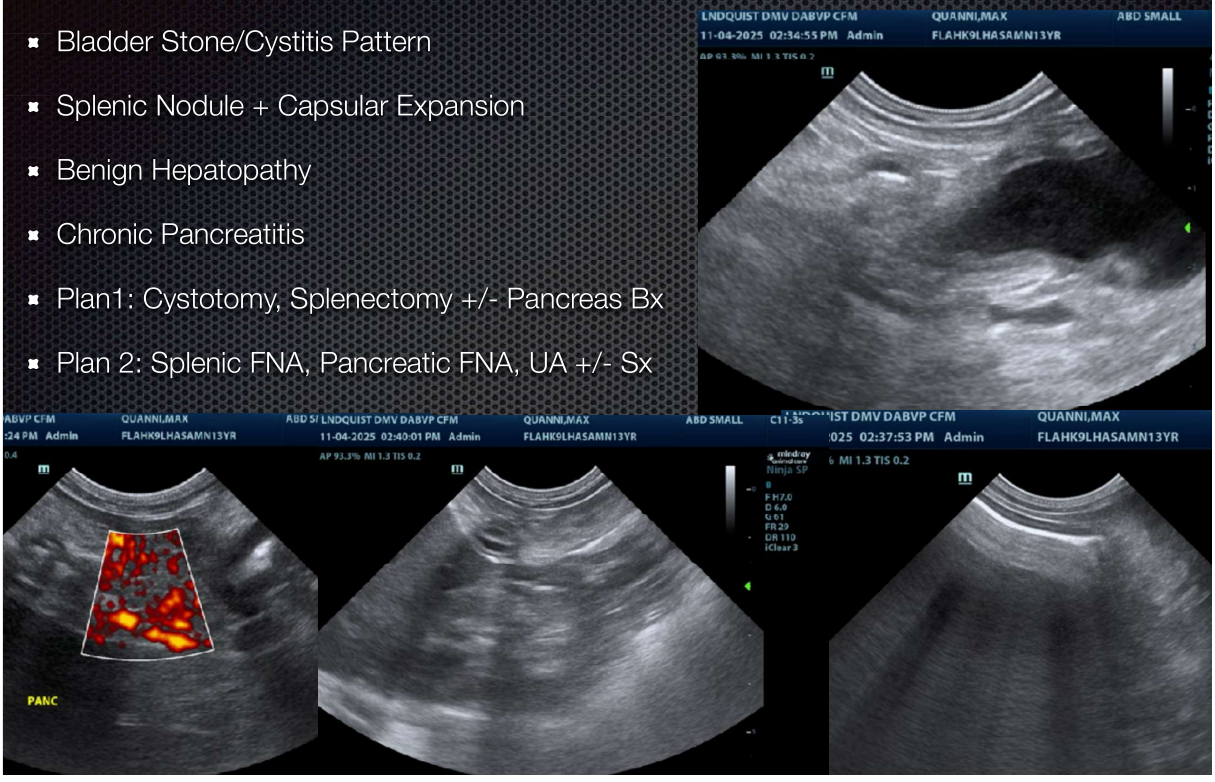

SDEP™ 12-14

SDEP® 14-17

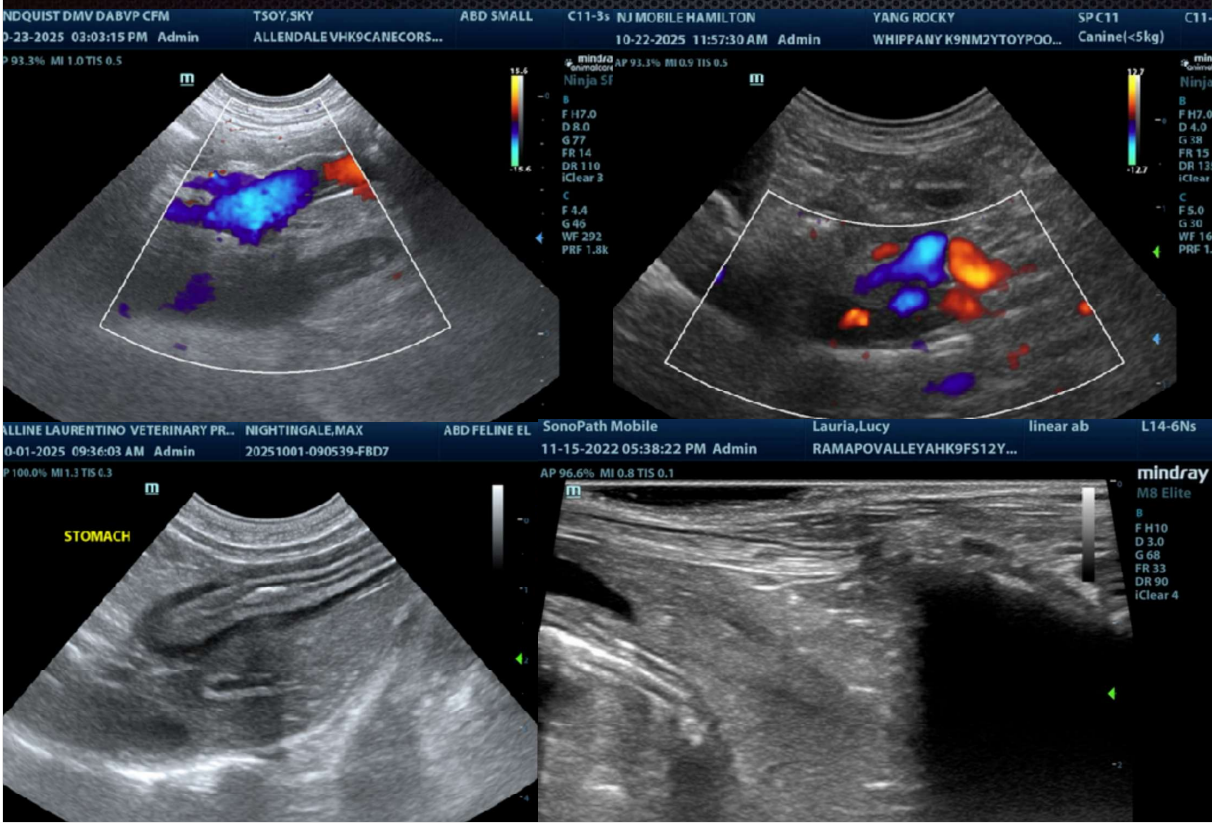


13-yr Lhasa Dog Geriatric Scan

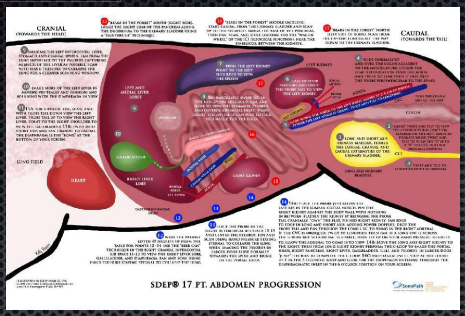
- Bladder Stone/Cystitis Pattern
- Splenic Nodule + Capsular Expansion
- Benign Hepatopathy
- Chronic Pancreatitis
- Plan1: Cystotomy, Splenectomy +/- Pancreas Bx
- Plan 2: Splenic FNA, Pancreatic FNA, UA +/- Sx



SDEP® Typical Cool Critical Views



SDEP® Conclusions



SDEP™ Provides full spectrum scanning from beginning to advanced sonographer levels for telemedicine & direct or remote educational purposes.

SDEP™can be utilized in direct & remote settings with a numbering system.

SDEP™ Ultrasound protocol is a universally repeatable, thorough, referable, & efficient protocol with complete levels of adjunctive diagnostic information.

SDEP™limits diagnostic error potential by including crucial views in the direct and telemedicine venues when performed properly by the sonographer.

SDEP™ provides clinically based imaging protocols to enhance the interpreter's ability to provide enhanced clinical value.

SDEP®

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New Jersey Mobile

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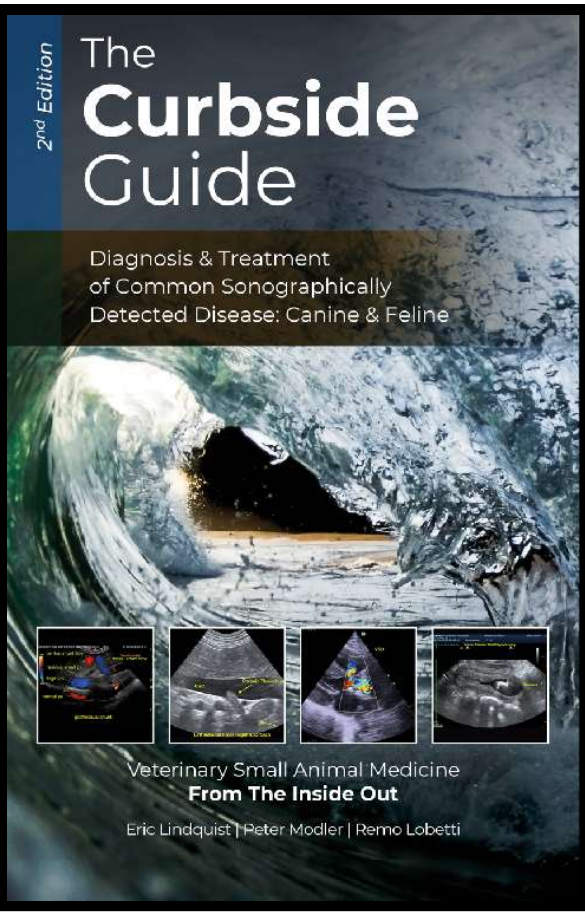
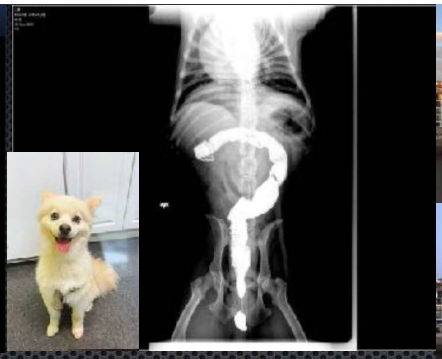
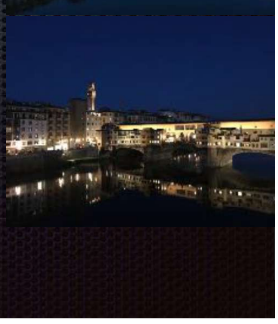


Stay Curious … Sonopath

info@sonopath.com





Questions?

info@sonopath.com

Special Thanks:

The SonoPath Mobile Sonographer Staff:
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Kelly Vazquez CVT, SDEP Cert.
Kelly Reschny CVT SDEP Cert.
Shari Reffi CVT, SDEP Cert.

Intrapet Imaging:
Andi Parkinson RDMS
Rachel Brilhardt RDMS

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VetRad

Imaging of feline bronchial disease — Structured overview

Nele Eley

1

The mulitple faces of Feline asthma

Imaging Feline Asthma

2

Epidemilogy of feline asthma

- Young to middle-aged adult cats
- typically 2–8 years

- Kittens rare
- Les common in older cats (>10 years) — more likely to be:
  - Chronic bronchitis
  - Neoplasia
  - Cardiac disease mimics

- Key point: Asthma is not primarily a geriatric disease

3

Epidemilogy of feline asthma

- Reported overrepresentation in studies and clinical series:
- Siamese cats (most consistently reported)
- Possibly: Oriental breeds (Siamese-related lines)
- Important nuance: Most affected cats are still Domestic shorthair / mixed breed

4

Epidemilogy of feline asthma

- No strong sex predispositon
- Strong clinical trend overweight cats
- Lifestyle: Indoor only, cigarette smoke and other allergens (dust, litter)

5

Asthma + chronic bronchitis - Spectrum disease

- Chronic inflammation leads to
  - Epithelial edema
  - Mucus hypersecretion
  - smooth muscle hypertrophy
  - Airway remodeling

- **Imaging correlate: Bronchial thickening + hyperinflation**

6

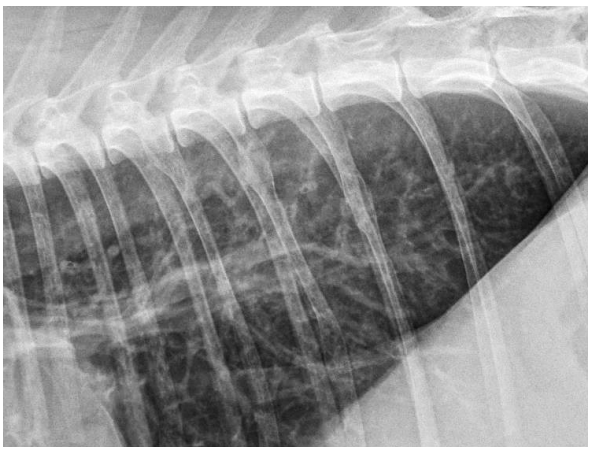
Imaging hallmark

- Bronchial wall thickening due to
  - inflammation + mucus → bronchial pattern
- Radiographs often show
  - Bronchial pattern alone or mixed patterns

7

Typical findings

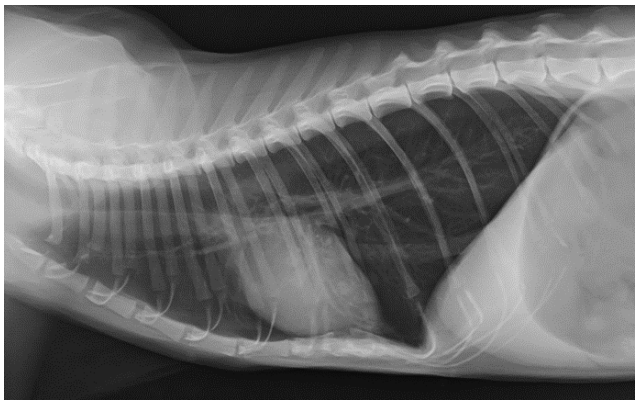
- Bronchial pattern
- "Donuts" and "tramlines"



8

Typical findings

- Signs of hyperinflation
- Flattened diaphragm
- Increased pulmonary lucency



Imaging Feline Asthma

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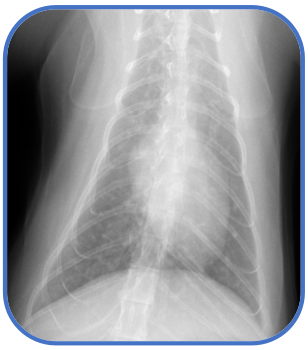
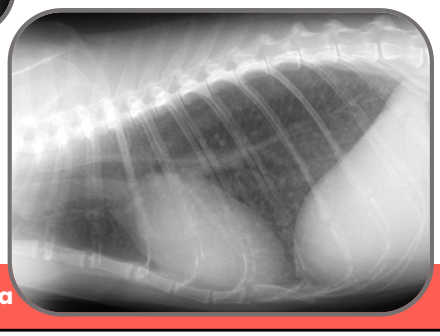
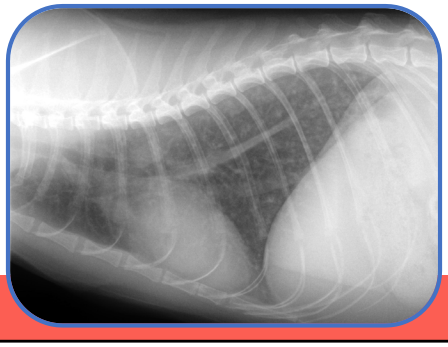
Introducing: Tilly & Tiger

- Which one has ASTHMA?





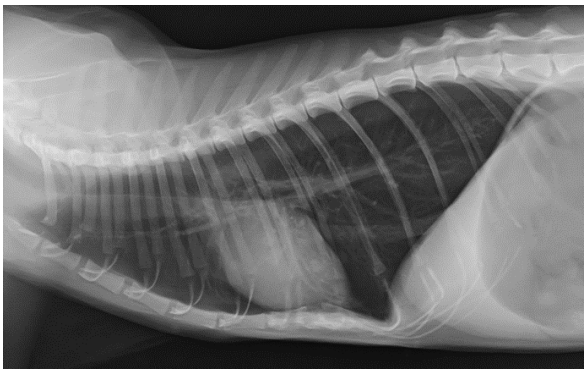


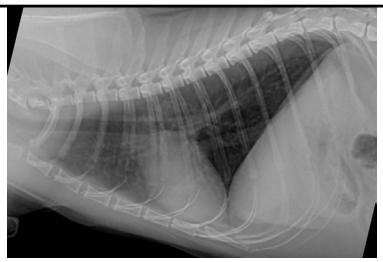
Imaging Feline Asthma

10

Typical findings

- Shape of chest



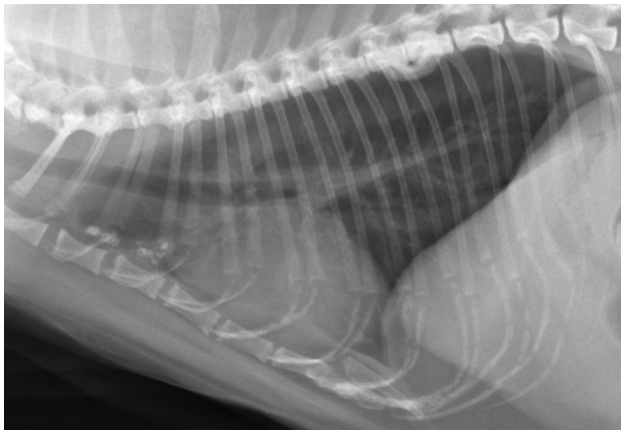


Imaging Feline Asthma

11

Typical findings

- Broncholithiasis

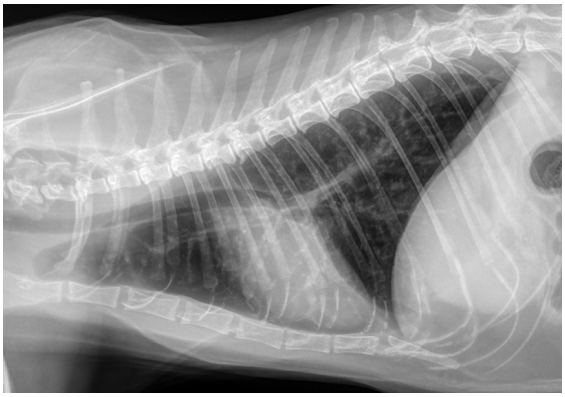


Imaging Feline Asthma

12

Typical findings

- Lobar atelectasis



Imaging Feline Asthma

13

Typical findings

- R middle & bilateral cranial lobes

Imaging Feline Asthma

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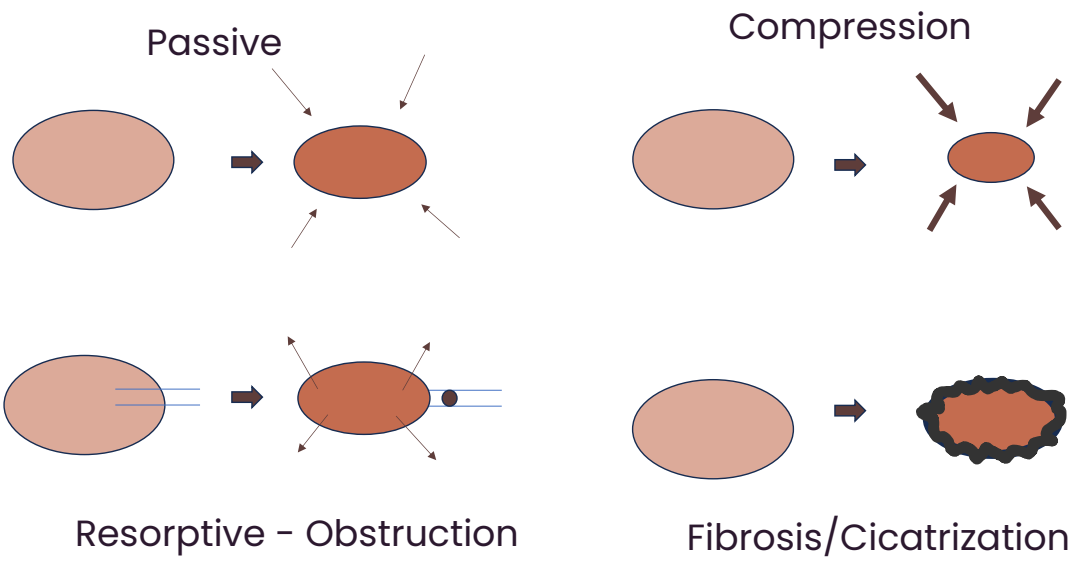
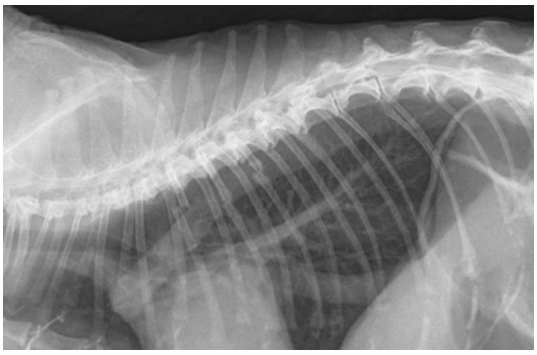


Imaging Feline Asthma

15

Less common findings

- Non-traumatic rib fractures
- from severe, sustained coughing and chronic, intense respiratory



Imaging Feline Asthma

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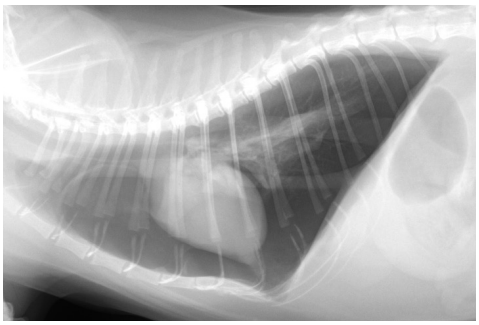
Pneumothorax



- Retrospective case series
  - 5 cats with confirmed feline asthma
  - **Secondary spontaneous pneumothorax**
  - Survival rate 4/5

Pneumothorax in cats with a clinical diagnosis of feline asthma: 5 cases (1990–2000)

Edward S. Cooper VMD, Rebecca S. Syring DVM, DACVECC, Lesley G. King MVB, DACVECC, DACVIM

Imaging Feline Asthma

17

Pathomechanism

- Small airway obstruction in feline asthma can cause:
- air trapping
- increased alveolar pressure
- alveolar rupture
- emphysema
- → secondary spontaneous pneumothorax

Imaging Feline Asthma

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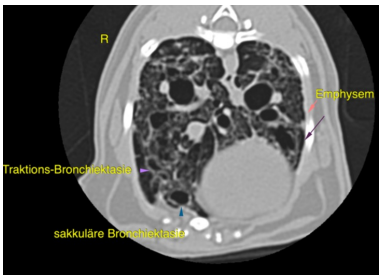
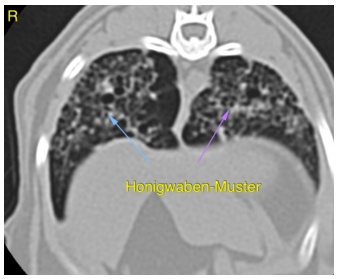
Secondary interstitial fibrosis

- Fibrotic remodeling
- Reduced pulmonary compliance
- Interstitial scarring/cicatrizazion, traction bronchiectasis, (pulmonic hypertension)



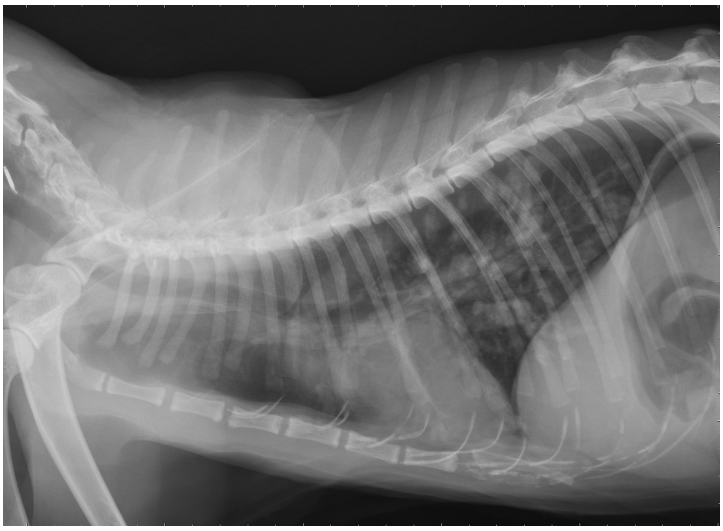


19

Miles

- Maine Coon
- Mn
- 13y
- Chronic cough
- Acute resp. disrtess

20



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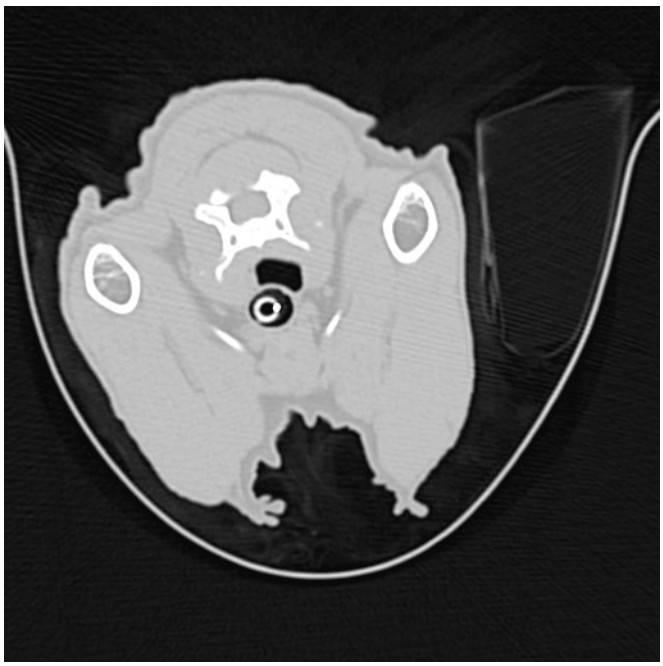

Imaging Feline Asthma

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Tree in bud pattern

- Tree-in-bud corresponds to
  - Small airway disease / bronchiolar plugging with mucus
- Majority linked to
  - Feline bronchial disease (Asthma / Chronic bronchitis)

Imaging Feline Asthma

23

Tree in bud - One major pitfall

- Can appears as soft tissue pulmonary nodules

Radiographs vs CT:

- Lesion number underestimated in 24/36 cats
- Completely missed in 6/36 cats

Comparative Study > Vet Radiol Ultrasound. 2018 Jan;59(1):32-42. doi: 10.1111/vru.12564. Epub 2017 Oct 9.

The computed tomographic "tree-in-bud" pattern: Characterization and comparison with radiographic and clinical findings in 36 cats

Harriet Hahn [1], Swan Specchi [2], Isabelle Masseau [3], Carol Reinero [4], Ghita Benchekroun [5], Jaime Rechy [6], Gabriela Seiler [6], Pascaline Pey [1]

Imaging Feline Asthma

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Tree in bud - One major pitfall

Radiographs:

- Underestimate lesion number
- May miss lesions entirely
- Often misinterpreed as nodules: metastases or granulomas

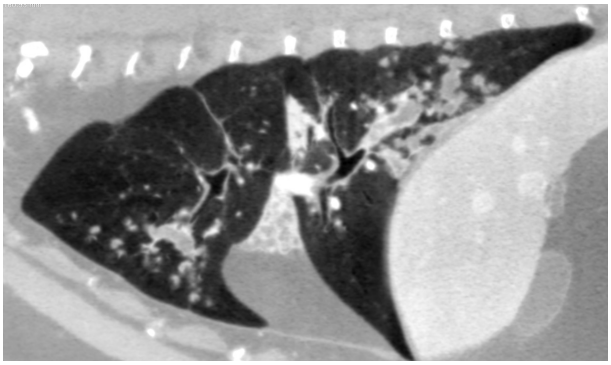
Comparative Study > Vet Radiol Ultrasound. 2018 Jan;59(1):32-42. doi: 10.1111/vru.12564. Epub 2017 Oct 9.

The computed tomographic "tree-in-bud" pattern: Characterization and comparison with radiographic and clinical findings in 36 cats

Harriet Hahn [1], Swan Specchi [2], Isabelle Masseau [3], Carol Reinero [4], Ghita Benchekroun [5], Jaime Rechy [6], Gabriela Seiler [6], Pascaline Pey [1]

25

Tree in bud - CT



Comparative Study > Vet Radiol Ultrasound. 2018 Jan;59(1):32-42. doi: 10.1111/vru.12564. Epub 2017 Oct 9.

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Imaging Feline Asthma

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General imaging limitations

- No correlation between
  - Radiographic severity and clinical severity of feline asthma

J Feline Med Surg. 2019 Sep 4;22(7):649–655. doi: 10.1177/1098612X19872428

Comparison of signalment, clinical, laboratory and radiographic parameters in cats with feline asthma and chronic bronchitis

Maike Grotheer [1,✉], Johannes Hirschberger [1], Katrin Hartmann [1], Noemi Castelletti [2], Bianka Schulz [1]

J Vet Intern Med. 2023 Sep 20;37(6):2443–2452. doi: 10.1111/jvim.16874

Correlation of clinical and radiographic variables in cats with lower airway disease

Hannah Gareis [1,✉], Lina Hörner-Schmid [1], Yury Zablotski [1], Jelena Palić [2], Silke Hecht [3], Bianka Schulz [1]

27

Limitations

- Normal radiographs possible
  - Poor specificity
- Cannot distinguish
  - Asthma vs chronic bronchitis
  - Infectious vs inflammatory disease
- High interobserver variability

J Am Vet Med Assoc. 2009 Feb 1;234(3):367-75. doi: 10.2460/javma.234.3.367.

Radiographic abnormalities in cats with feline bronchial disease and intra- and interobserver variability in radiographic interpretation: 40 cases (1999-2006)

Julie Gadbois [1], Marc-André d'Anjou, Marilyn Dunn, Kate Alexander, Guy Beauregard, Jérôme D'Astous, Myriam De Carufel, Luc Breton, Guy Beauchamp

28

Imaging Takeaways

- Radiography
  - First-line, but moderate sensitivity (≈70–90%)
  - Hallmark: bronchial pattern + hyperinflation
- CT
  - More sensitive, detects early / subtle disease
  - Best for bronchiectasis + small airway disease
  - Tree in bud
- Key limitation
  - Imaging cannot classify disease subtype

29

Important clinical-imaging correlations

- Radiographs ≠ clinical disease severity
- Cannot differentiate:
  - Asthma vs chronic bronchitis
  - Inflammatory vs infectious causes
- Sensitivity is limited, can look normal
- Even experienced readers miss cases or overcall patterns

30

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EXPLORING THE PANCREAS WITH ULTRASOUND

Dominique Penninck, DVM, DACVR, DACVR, DECVDI
Professor, section of Diagnostic Imaging
Cummings School of Veterinary Medicine, Tufts University, USA

Ultrasonography (US) is a routine diagnostic tool for evaluating pancreatic disorders in small animals. Knowledge of pancreatic anatomy and adjacent structures is paramount to US imaging of the pancreas.

Technique and Normal Pancreas:

The pancreas is a thin, elongated organ made of 3 segments (left and right lobes and body), located along the greater curvature of the stomach and the mesenteric border of the descending duodenum.
The anatomic landmarks used to locate the right pancreatic lobe are the right kidney, the descending duodenum with its straight course along the right abdominal wall, and the pancreatico-duodenal vein paralleling the descending duodenum. The right pancreatic lobe can be imaged from a ventral or lateral approach.
The pancreatic body can be imaged from ventrally or from the right side with the animal in a dorsal, left or right lateral recumbent position by moving the scan plane cranio-medial to the proximal descending duodenum and caudal to the pyloric antrum.
The portal vein represents a useful landmark as it is located just dorsal and near the body of the pancreas. A transverse scan just caudal to the porta hepatis and pylorus may be used to locate this vein and the body of the pancreas. The left pancreatic lobe is more difficult to image in dogs, because of gas interference in the adjacent stomach and transverse colon. However, in cats, the left lobe can be more easily identified than the right lobe.
The normal pancreas is nearly isoechoic to slightly hyperechoic to the adjacent liver lobes, and to the surrounding mesenteric fat.
In cats, the reported mean thickness measurements for the right pancreatic lobe, body, and left pancreatic lobe are 4.5mm (range 2.8 - 5.9), 6.6mm (range 4.7 - 9.5), and 5.4mm (range 3.4 - 9.0) respectively. The pancreatic duct has a mean diameter of 0.8mm (range 0.5 - 1.3).
In medium size dogs (Beagle dog for example), the pancreas thickness is about 1 cm. The thickness varies with the animal's weight.

Pancreatic Disorders:

Most pancreatic disorders result in (focal or diffuse) thickening, with decreased echogenicity of the pancreas.
Pancreatitis has various US appearances depending on the severity, duration and extent of pancreatic and peri-pancreatic tissue inflammation.

In *acute pancreatitis*, the pancreas appears enlarged and diffusely hypoechoic while the surrounding fat appears moderately hyperechoic as the result of fat saponification. In dogs, the right limb of the pancreas tends to be most affected while in cats the changes tend to be more severe in the body and left lobe. Thickened gastric/duodenal /transverse colonic wall can be seen in association with pancreatitis.
Occasionally, the enlarged pancreas creates compression of the cystic/common bile duct. In these animals, the common bile duct is dilated (over 4 mm) and tortuous up to the duodenal papilla.
In cats, pancreatic enlargement, and diffuse change in pancreatic and surrounding fat echogenicity might be less obvious.
In severe *hemorrhagic necrotizing pancreatitis*, irregular hypoechoic area(s) represent necrosis and hemorrhage of part of the pancreas and peripancreatic tissue. When these complications are detected, it is recommended to perform recheck US to assess response to treatment.
Pancreatic edema appears as numerous nearly anechoic stripes demarcating pancreatic lobulation and dissecting the enlarged pancreas.
Focal acute pancreatitis may contain combined areas of pancreatic necrosis, hemorrhage and surrounding inflamed mesentery. The hypoechoic and anechoic areas corresponding to collections of hemorrhage and necrotic tissue may, with chronicity, become more organized and develop into pseudocyst or abscess.
Pseudocysts associated with pancreatitis are uncommon complications in dogs and cats, they are fluid-filled masses surrounded by a capsule of granulation and fibrous tissue. The fluid is pancreatic secretion that escapes from a ruptured duct. They can appear as anechoic/hypoechoic masses with inconsistent acoustic enhancement and varying amounts of internal echoes.
Pancreatic abscess(es) appear as hypoechoic focal lesions containing pus and necrotic tissue. US differentiation between pancreatic abscess and pseudocyst is not possible.
In *chronic pancreatitis*, the pancreas can be within normal range for size, and the parenchyma often is inhomogeneous. In cats, chronic pancreatitis is twice more frequent than acute pancreatitis. Chronic pancreatitis characterized by interstitial fibrosis with acinar atrophy and lymphocytic infiltrates is rarely suspected clinically. Most of the cases encountered are presented with vague clinical signs and non-specific laboratory values.
In cats, The US features of pancreatitis are less consistent, but when present, the left limb of the pancreas is usually easier to visualize.
In cats, the pancreatic duct can be dilated in both acute and chronic pancreatitis, or even in cats without pancreatic disorders. In a retrospective study, we found an incidence of 7.2% of cats diagnosed with dilated pancreatic duct in the population of cats seen in US and was mostly seen in older cats. In over 40% of all cats, the dilation was likely considered of no clinical significance. Therefore, a dilated pancreatic duct is not a reliable indicator of pancreatic disease.
In cats, as concurrent conditions such as hepatic lipidosis, cholangiohepatitis, enteritis, diabetes mellitus, and even interstitial nephritis are commonly seen in cats with pancreatitis, US of the entire abdomen should be performed to provide information that can contribute to the overall prognosis.

Pancreatic nodular hyperplasia is occasionally seen in the pancreas of older dogs and cats. Well-or ill-defined hypoechoic to isoechoic nodules that can vary in size can be disseminated throughout the pancreas. With improved equipment, these changes are nowadays commonly encountered.
Tumors of the pancreas are divided in 2 categories: exocrine and endocrine tumors.
Pancreatic exocrine tumors such as adenocarcinoma arise from acinar cells or ductal epithelium. Even though these tumors are rare, they are the most common type of pancreatic neoplasia in small animals. They tend to develop in the central portion of the gland. As they grow, they may compress the common bile duct, invade the adjacent gastric and duodenal segments, and frequently metastasize to the liver and/or the adjacent lymph nodes or mesentery. They often are poorly echogenic nodules or masses; at times they are partially mineralized.
Insulinomas are the most encountered endocrine tumors in dogs. The US detection rate varies depending on the size and distribution of the lesions, the equipment quality and the operator's experience. Insulinomas can present as a solitary nodule, multiple nodules or an ill-defined area of abnormal echogenicity. The size of the pancreatic lesions varies greatly, but most of the lesions tends to be less than 2.5 cm and be poorly echogenic. The overall detection rate of insulinoma is suspected to be quite low; other imaging techniques such as computed tomography angiography, and MRI are preferred to pre-operatively detect these lesions.
Exocrine pancreatic insufficiency can appear as a thin pancreas with a dilated pancreatic duct (with or without calculi), and at times the intestines can be dilated with echogenic fluid and hyperperistaltic (malabsorption?).

The place of interventional procedures such as fine-needle aspirations, drainage or biopsies will be briefly discussed during the presentation.

Exploring the hepatobiliary system with Ultrasound

Dominique Penninck, DVM, DACVR, DACVR, DECVDI
Professor, section of Diagnostic Imaging
Cummings School of Veterinary Medicine, Tufts University, USA

Introduction

Hepato-biliary diseases in small animals can be complex and challenging to diagnose. Some of these disorders include congenital anomalies (ductal plate anomalies), inflammatory diseases (cholecystitis, choledochitis, cholelithiasis), extra-hepatic biliary obstruction (EHBO), and hepatobiliary neoplasia.

Anatomy

Normal anatomy (and variant) of the hepato-biliary tract of the dog and cat relevant to clinical applications will be reviewed.
The biliary system is relatively similar in dogs and cats. The GB, occasionally bilobed or septate in cats, represents the bile reservoir and is an anechoic teardrop-shaped structure extending into the cystic duct. The GB volume can vary markedly in size and becomes quite large in anorexic animals. The GB volume alone cannot be used as a reliable sign of biliary obstruction. Yet, monitoring its post-prandial reduction may help assessing bile outflow compromise.
The wall of the normal GB is thin and smooth, measuring up to 1 mm thick in cats and dogs.

Biliary sludge is often recognized in the GB of asymptomatic dogs or cats, although this may indicate a delay in GB emptying. GB sludge can be seen with increased liver enzymes and total bilirubin, but it may also be encountered without evidence of biliary disease.

The intrahepatic biliary tree, composed of biliary canaliculi and larger biliary ducts, is not seen in normal dogs and cats. The common bile duct (CBD) can be seen more easily in cats than dogs. It can measure up to 4 mm wide in normal cats and considered normal when up to 3-4mm in dogs. It parallels the portal vein over a few centimeters before entering into the duodenum through the major duodenal papilla. The wall of the CBD is often barely visualized and should not exceed 1mm in thickness.

Congenital anomalies

These anomalies are uncommon, they can include gallbladder agenesis, Caroli's disease, and various forms of ductal plate abnormalities. When the lesions are centered on the larger bile ducts and the intra-hepatic ducts, they are categorized under Caroli's disease. Choledochal cysts affect mostly the CBD. Anomalies of the pancreatico-biliary ductal junction are also described.

Inflammatory diseases

Cholangitis, cholangiohepatitis and cholecystitis are common inflammatory/infectious diseases. Their ultrasonographic features include enlargement with diffusely hypoechoic or hyperechoic

or mixed echogenicity liver. Subjectively normal liver size and echogenicity do not rule out hepatitis.
Also, depending on the origin of inflammation, thickening (smooth or irregular) and increased echogenicity of the biliary tract walls, and changes in echogenicity of the bile (echogenic sludge, calculi) can be encountered.
It is important to assess as much as possible all the components of the biliary system (intra- and extra-hepatic), up to the duodenal papilla. Evaluating other abdominal systems (gastrointestinal tract, pancreas, kidneys) is important as concurrent disorders can be encountered; this is especially observed in cats with triaditis.

EHBO is reported both in dogs and cats. The most common reported causes of EHBO are tumors and/or inflammation of the common bile duct, pancreas or duodenum, and choledocholithiasis. The common clinical signs are non-specific and include decreased appetite, anorexia, lethargy and vomiting.
A common bile duct diameter larger than 5 mm is a useful feature supporting EHBO in cats. On the contrary, gallbladder dilation is not a reliable sign of EHBO as it is encountered in less than 50% of cats. Dilation of intrahepatic and/or extrahepatic ducts along with the common bile duct may assist the detection of biliary obstruction.
However, dilation of intrahepatic and/or extrahepatic ducts is not a pathognomonic sign of extrahepatic biliary obstruction as it can associated with non-obstructive hepatobiliary diseases; therefore, these findings should always be interpreted in the light of clinical and biochemical changes as well as other ultrasonographic findings that might support EHBO.
Obstructive choledocholithiasis can reliably be diagnosed; mineralized and non-mineralized choleliths can be distinguished based on their ultrasonographic features. Most obstructive choleliths are in the distal common bile duct near the duodenal papilla.
In absence of obstructive cholelith, it is often not possible to accurately differentiate an inflammatory disease from a tumor, as size, shape, echogenicity and location of the lesions can be similar in the 2 groups.
Pancreatic diseases (as cause of EHBO) include pancreatitis and/or pancreatic mass such as carcinoma.

Mucocele

GB mucoceles typically affect older dogs of small and medium-sized breeds and represent an important cause of biliary obstruction, although it can be found “incidentally” in dogs. Intraluminal mucinous plugs can extend or migrate into the CBD and cause obstruction. In affected GB, a characteristic accumulation of hypoechoic mucus is seen bordering the inner margin of the wall, centrally displacing the echogenic biliary sludge, which becomes immobile. As the mucocele is progressively formed in the GB, *stellate pattern* and *kiwifruit-like pattern* are described. Mucus fragments may also detach from the wall and appear as anechoic to hypoechoic structures floating in hyperechoic biliary sludge. The GB wall may also appear thickened, hyperechoic, and irregular because of edema, inflammation, and/or necrosis. GB wall rupture is suspected with the presence of hyperechoic fat at the periphery of the GB and the presence of peritoneal effusion. At times, the wall disruption is seen, but it is uncommon.
Mucoceles have seldomly been reported in cats.

Hepatobiliary Tumors

Hepatic nodules or mass(es) can affect primarily the hepatic parenchyma or the biliary system. Some of the nodular lesions such as nodular hyperplasia, granulomas are benign; while others are malignant, such as hepatocellular carcinoma, lymphoma, mast cell tumors, metastases. Tumors can at times affect diffusely the liver and be more challenging to detect.

GB polyps (pedunculated echogenic projections) should not be confused with tumors of the GB (rare). Biliary cystadenomas (and carcinomas) are commonly encountered in the liver parenchyma of elderly cats. They may appear as single or multiple "sponge-like" nodule(s) or mass(es).

CBD carcinomas are especially challenging to detect and diagnose as they can be of small size and mimic hyperplastic changes near the duodenal papilla region.

Evaluation of the entire abdomen, especially the liver parenchyma and lymph nodes, can help in differentiating benign from malignant processes, although tumor and inflammation often share similar sonographic features.

Interventional procedures

Common ultrasound-assisted procedures will be reviewed during the presentation.

Fine-needle aspiration or (core) biopsy is recommended if abnormal tissue can be safely reached. Regional tissues (liver, lymph nodes) should also be targeted if abnormal but safely reachable.

US-guided cholecystocentesis can be used to sample bile for culture or in a few cases, as palliative measure for GB decompression in animals with extrahepatic biliary obstruction.

Pericardial Diseases
&
Cardiac Tumors in Dogs

John D Bonagura, DVM, MS, DACVIM (Cardiology, Internal Medicine), FASE

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Adjunct Professor – Cardiology, Colorado State University College of Veterinary Medicine
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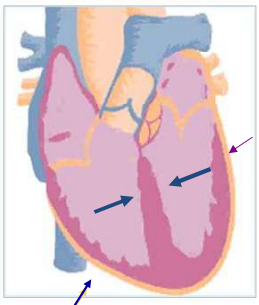
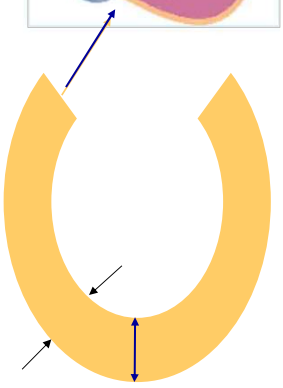
Adjunct Professor of Cardiology, North Carolina State University College of Veterinary Medicine
jdbonagu@ncsu.edu

1

1

Pericardium





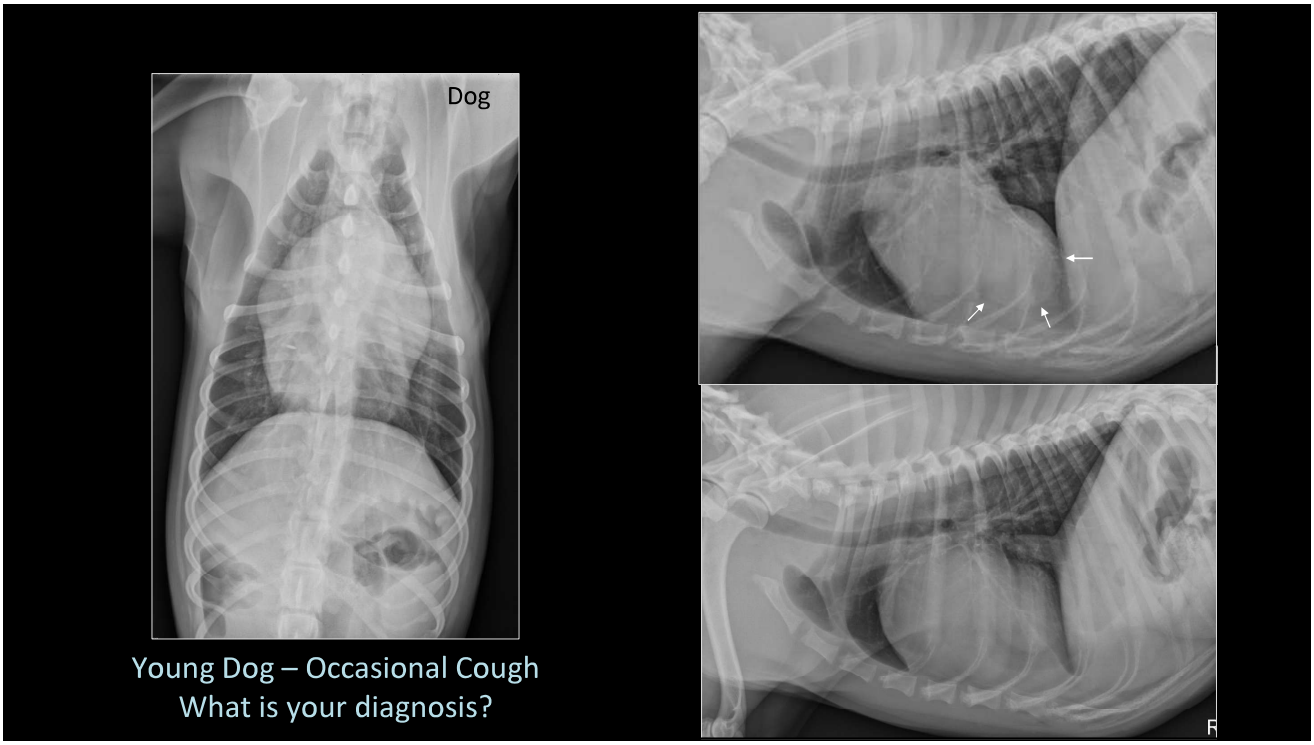
Functions

- Limits cardiac dilatation
- Ventricular compliance → filling
- Ventricular interdependence (RV ↔ LV)
- Barrier functions
- But…..can be removed (pericardiectomy)

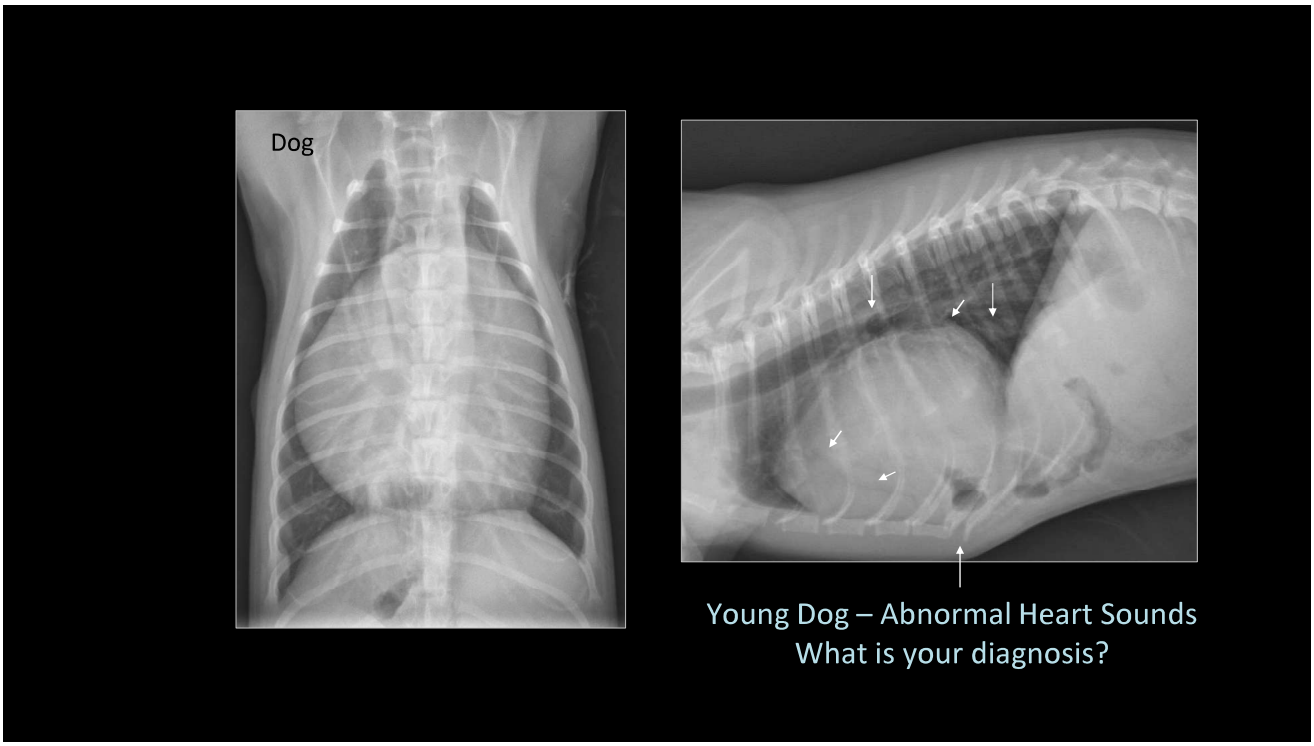
Anatomic considerations

- Two mesothelial membranes
- Parietal pericardium &
  Visceral pericardium (epicardium)
- Pericardial space (fluid)

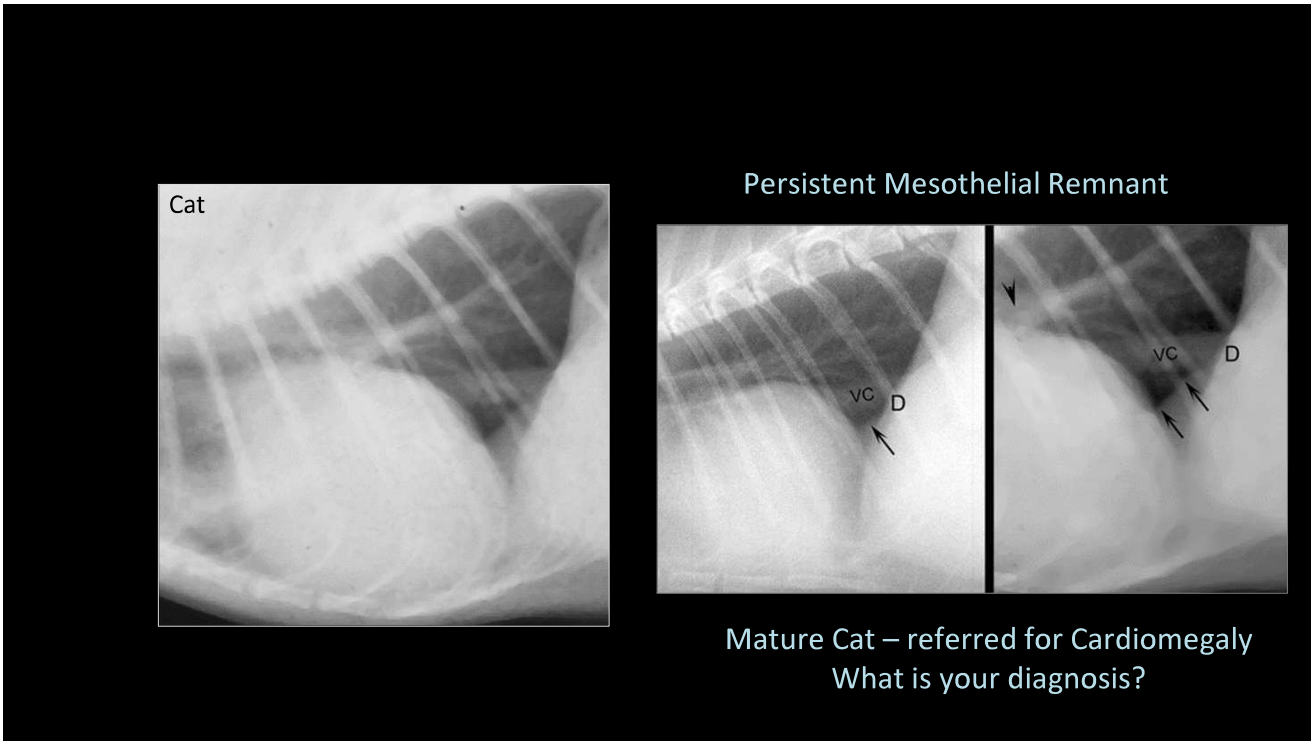
2


Dog
Young Dog – Occasional Cough
What is your diagnosis?

3

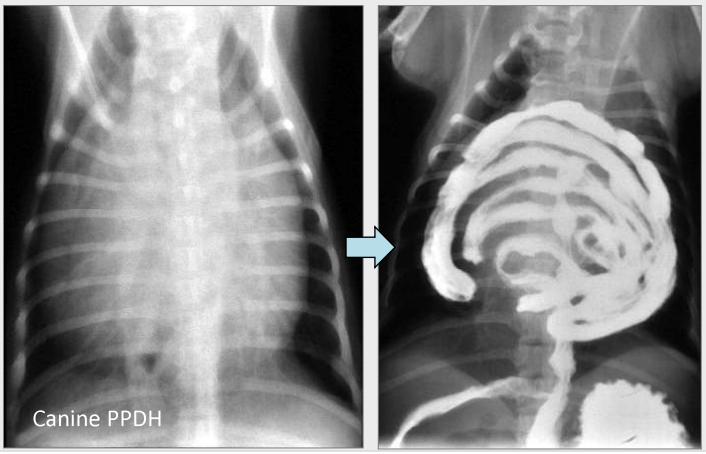

Dog
Young Dog – Abnormal Heart Sounds
What is your diagnosis?

4



5

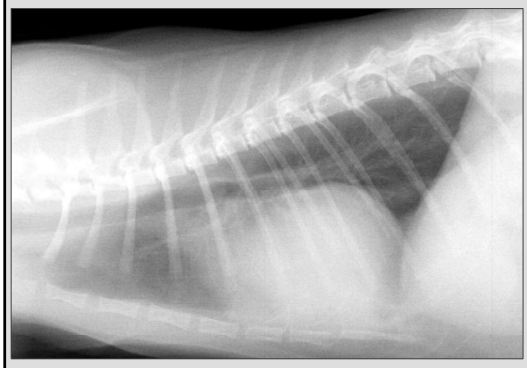
Peritoneopericardial Diaphragmatic Hernia



- Defect of the septum transversum – has occurred within litters
  Persistent communication between peritoneal & pericardial cavities
- Clinical signs – Tachypnea | Abnormal auscultation (but often none)
- Comorbidities: umbilical hernia | sternal deformity | biliary maldevelopment

6

PPDH



Case #1

Diagnosis: Can confirm with Ultrasound

7

BJVM Brazilian Journal of Veterinary Medicine

Braz J Vet Med. 2021 Mar 23;43:e001820. doi: 10.29374/2527-2179.bjvm001820

Show available content in: English | Portuguese

Peritoneopericardial diaphragmatic hernia in a healthy adult feline (*Felis catus domesticus*): diagnosis to surgical treatment - Case report

Ana Carolina de Souza Campos [1,*], Lucas Rabaça dos Santos [2], Fernando Elisio Torres [3], Juliana Le... Marques [4], Caroline Lopes Martini [5], Stéfani Franco de Sá Menezes [6], Gabriela Moscatel Fevrier [7], Vi... Gomes [8]

Surgical Repair of PPDH
vs.
Conservative "Therapy"

J Am Vet Med Assoc. 2013 Mar 1;242(5):643-50. doi: 10.2460/javma.242.5.643.

Surgical and nonsurgical treatment of peritoneopericardial diaphragmatic hernia in dogs and cats: 58 cases (1999–2008)

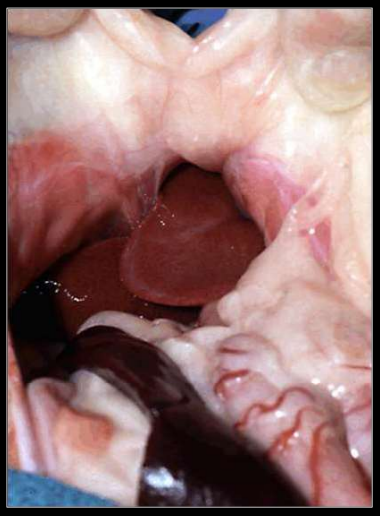
Colby G Burns [1], Mary Sarah Bergh, Mary A McLoughlin

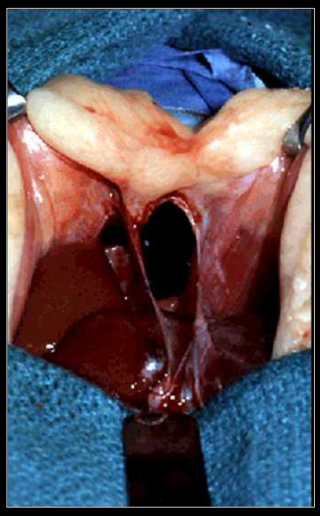
Outcome after surgical and conservative treatments of canine peritoneopericardial diaphragmatic hernia: A multi-institutional study of 128 dogs

Keaton R S Morgan [1], Ameet Singh [1], Michelle A Giuffrida [2], Ingrid M Balsa [2], Galina Hayes [3], Margaret L Chu [3], Christopher B Thomson [4], Shiori Arai [4], Daniel D Smeak [5], Eric Monnet [5], Laura E Selmic [6], Megan Cray [7], Janet A Grimes [8], Taylor Morris [1], J Brad Case [9], Jeffrey J Biskup [10], Jason Haas [10], Kelley Thieman-Mankin [11], Milan Milovancev [12], Mathieu Gatineau [13]

8

PDDH – Surgical Reduction
With Caution & Consultation



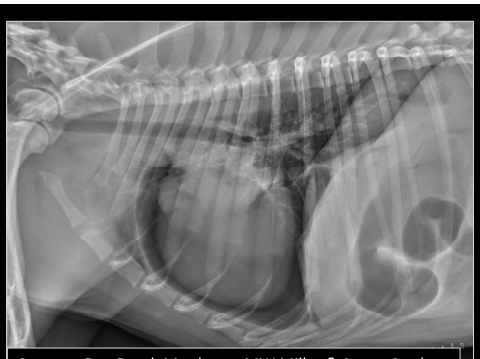


<u>When to consider surgery</u>

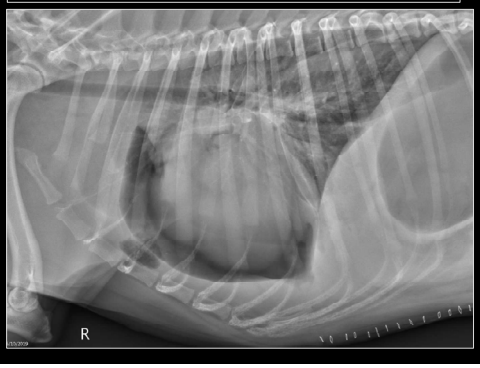
- Different viewpoints
- Younger animal
- Strangulation
  - Bowel or liver lobe
- Related effusion
- Massive displacement
- Presence of intestines
- Respiratory signs

9

Young Dog: Post operative
What is your diagnosis?



Courtesy Drs. Derek Matthews, MW Miller & Sonya Gordon



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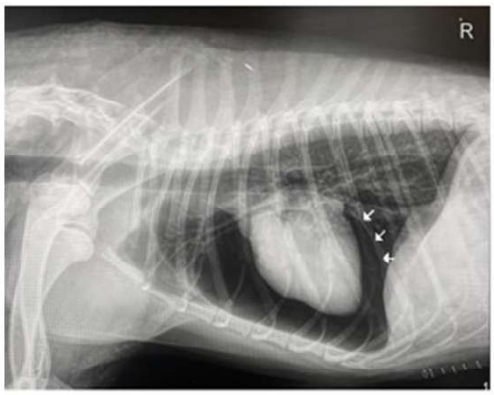

Case Reports > J Vet Cardiol. 2022 Oct:43:101-103. doi: 10.1016/j.jvc.2022.08.002.
Epub 2022 Aug 22.

Pneumopericardium after peritoneopericardial diaphragmatic hernia repair in a dog

M L Wang [1], L A Murphy [2], R K Nakamura [3]
Affiliations + expand
PMID: 36116206 DOI: 10.1016/j.jvc.2022.08.002

Required pericardiocentesis

11

Pericardial Diseases & Cardiac Tumors in Dogs – Goals for this Presentation –

1. Brief overview of peritoneopericardial diaphragmatic hernia & congenital pericardial malformations in dogs & cats
2. Comprehensive review of causes of pericardial effusions & cardiac-related tumors in dogs
3. Highlight pathologic – clinical correlations
4. Emphasize examination & diagnostic studies
   "Diagnostic tips" & Case examples
5. Review therapeutic options & prognosis
6. Consider *uncertainties*

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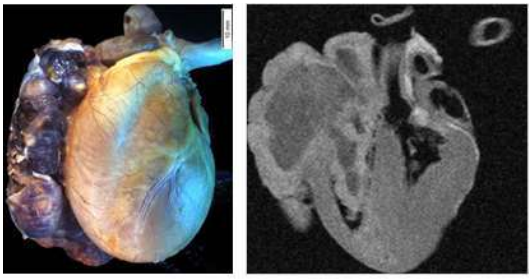
Pericardial Diseases & Cardiac Tumors in Dogs
– Topics –

1. Introduction | Malformations
2. Pericardial effusion
   - Causes
   - Pathophysiology → Clinical Signs
   - Diagnosis of Pericardial Effusion & Cardiac tumors in Dogs
     - Imaging & Other Diagnostic tests
3. Management Approaches
   - Pericardiocentesis
   - Medical & Surgical Treatment Options



PM images Courtesy:
Phil Fox, DVM, DACVIM, DACVECC

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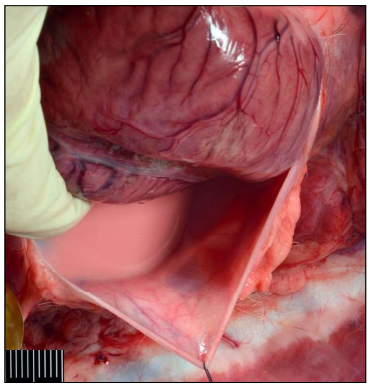
Pericardial Effusion

- Abnormal accumulation of fluid in pericardial space
- Cytologic classification:
  - Transudate
  - Exudate
    - Septic or Sterile
  - Hemorrhage
  - Chyle
- Various causes – primary & secondary
- Etiology influenced by canine breed & age



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Pericardial Effusions – Types & Causes (1)

Transudates - often incidental finding

- Hernia, cysts, CHF, systemic disease
- Hypoproteinemia (severe)
- Heart base mass (uncommon)

Modified transudates | Exudates

- FB perforation
- Bacterial or fungal (including Coccidiomycosis)
- Other causes (systemic inflammation, idiopathic)

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Journal of Veterinary Cardiology (2018) 20, 123–128

ELSEVIER

Journal of Veterinary Cardiology
ESVC

www.elsevier.com/locate/jvc

Case Report

Pericardial effusion associated with systemic inflammatory disease in seven dogs (January 2006 – January 2012)

Heather L. Covey, VetMB*, David J. Connolly, PhD

16

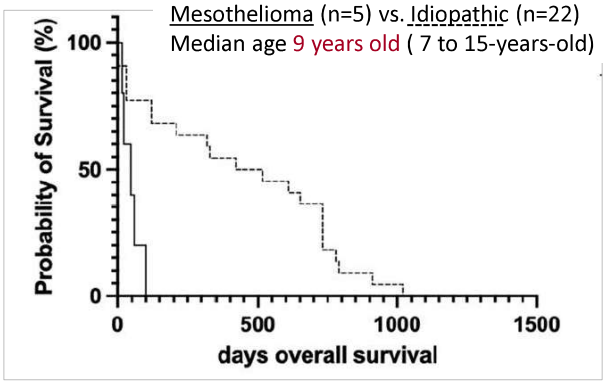
Idiopathic Pericarditis

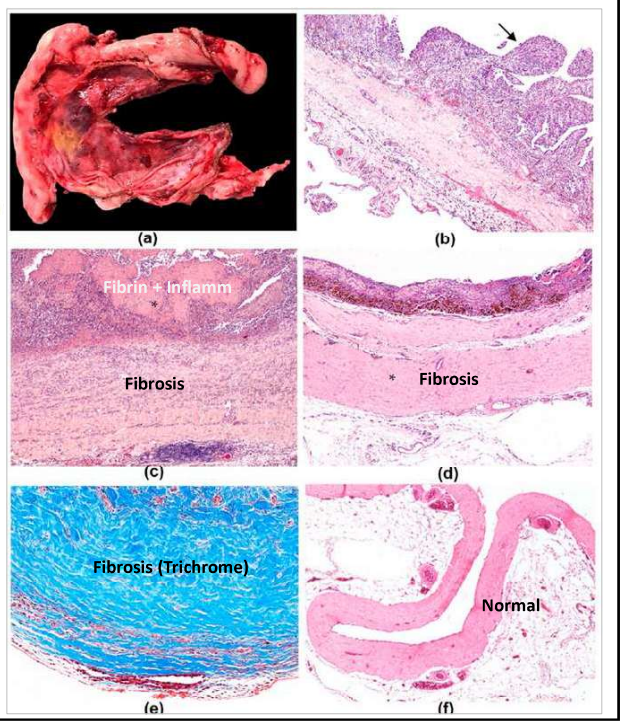
Pathological Findings of Canine Idiopathic Pericarditis and Pericardial Mesotheliomas: Correlation with Clinical and Survival Data

Michela Levi [1], Federico Parenti [1], Luisa Vera Muscatello [1,4], Stefano Battaia [2,3], Roberto Santilli [3,4], Manuela Perego [2,3], Vincenzo Montinaro [2], Federico Massari [2,5], Giuseppe Sarli [1] and Barbara Brunetti [1]

Levi M, et al. Vet. Sci. **2021**, 8, 162.

Mesothelioma (n=5) vs. Idiopathic (n=22)
Median age 9 years old (7 to 15-years-old)





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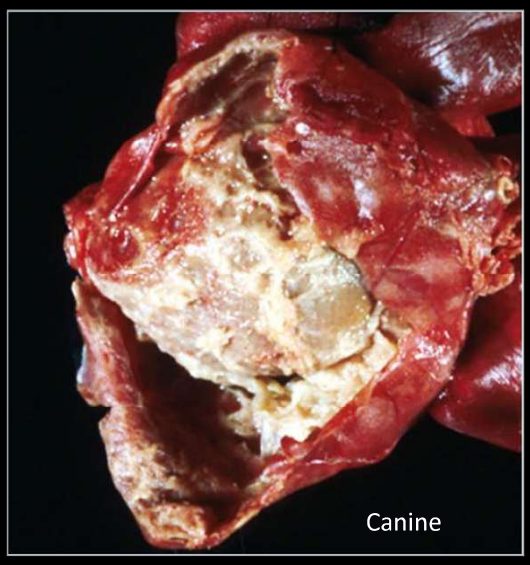
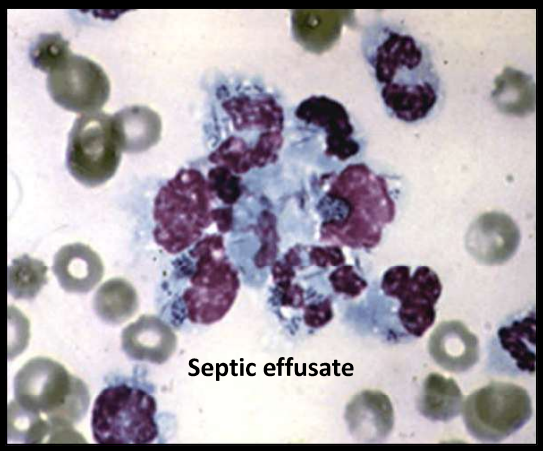
Septic Pericarditis





Outcomes:

- Sepsis & septic shock ±Tamponade (compression)
- Constrictive pericardial disease

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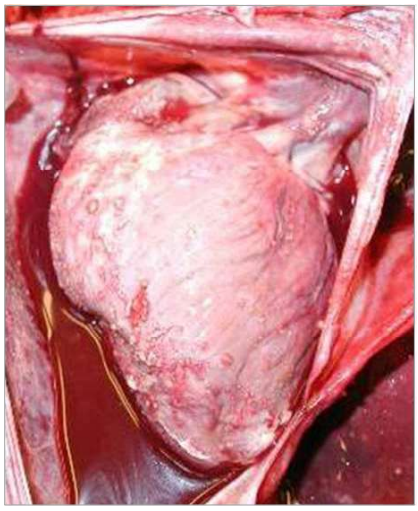
Pericardial Effusions – Types & Causes (2)

Hemorrhagic Effusions

- Idiopathic
- Neoplastic – Cardiac or heart base
  - Hemangiosarcoma
  - Chemodectoma (Aortic body tumor)
  - Neuroendocrine tumors (unspecified)
  - Mesothelioma
  - Ectopic thyroid CA | Lymphoma
  - Metastatic neoplasia
- Ruptured Left Atrium
- Others – Coagulopathies



Mesothelioma

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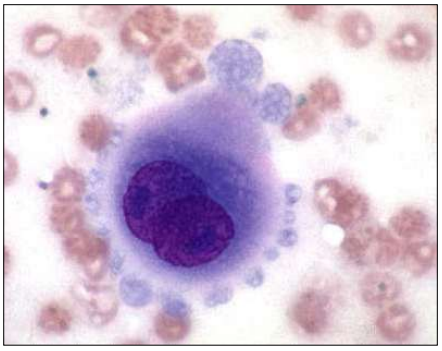
Idiopathic Pericardial Hemorrhage



"Reactive", binucleate Mesothelial cells

- Non-neoplastic, intra-pericardial hemorrhage
- Most common in younger dogs
- Diagnosis of *exclusion*
- Good long-term prognosis (UK & UCD retrospective studies)

20

Idiopathic Pericardial Hemorrhage in Dogs

J Small Anim Pract. 2006 Jul;47(7):387-91.

Idiopathic pericarditis in dogs: no evidence for an immune-mediated aetiology.

Martin MW, Green MJ, Stafford Johnson MJ, Day MJ.

School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington Campus, Sutton Bonington, Leicestershire, UK.

J Small Anim Pract. 2018 Apr;59(4):248-252. doi: 10.1111/jsap.12817. Epub 2018 Jan 22.

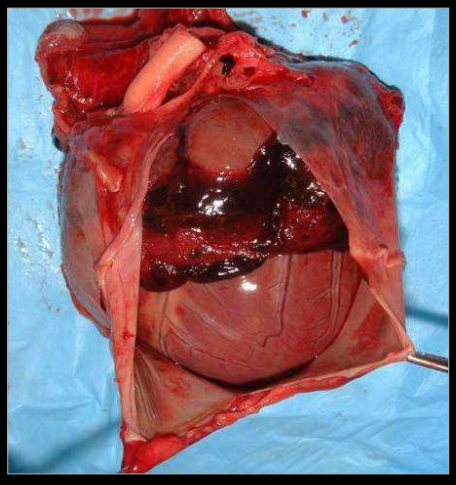
PCR evaluation of selected vector-borne pathogens in dogs with pericardial effusion.

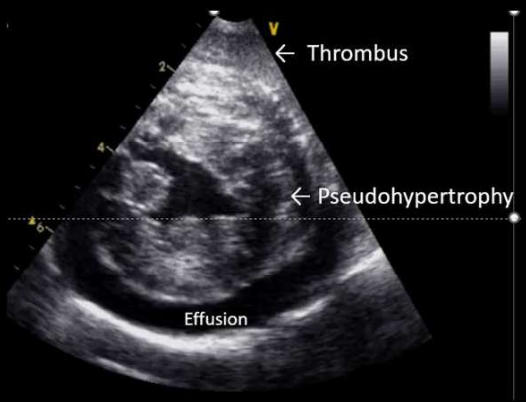
Tabar MD[1], Movilla R[2], Serrano L[3], Altet L[3], Francino O[4], Roura X[2].

Limited studies related to viral and other infectious agents have been performed (PCR & other molecular studies) – Results are **inconclusive** (also see Zini et al., Vet Journal, 2009)444

21

Hemopericardium (Ruptured LA)

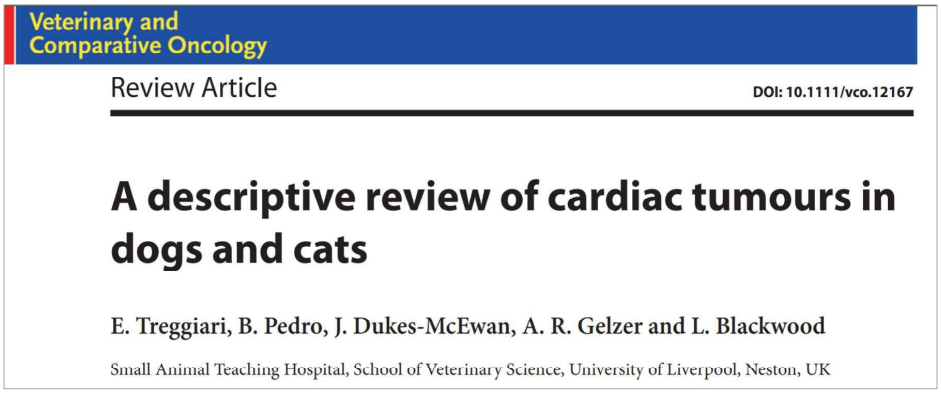




Complication of severe, chronic mitral valvular regurgitation
Left atrial stretch ⇒ Linear tears ⇒ Transmural splitting

22

Pericardial Effusion:
Cardiac Neoplasia is a frequent cause



Veterinary and Comparative Oncology

Review Article DOI: 10.1111/vco.12167

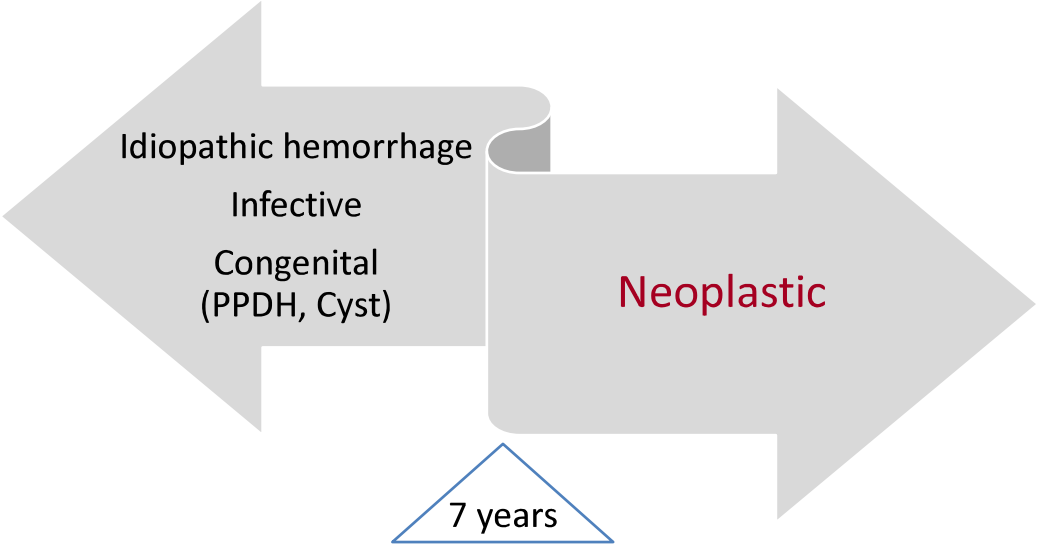
A descriptive review of cardiac tumours in dogs and cats

E. Treggiari, B. Pedro, J. Dukes-McEwan, A. R. Gelzer and L. Blackwood

Small Animal Teaching Hospital, School of Veterinary Science, University of Liverpool, Neston, UK

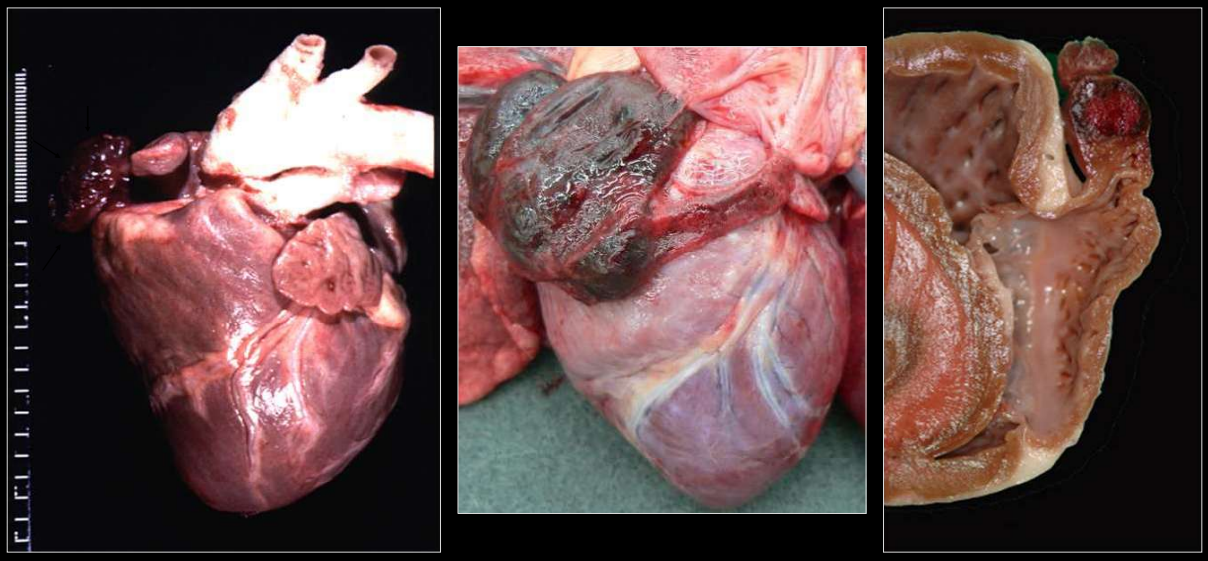
23

Age strongly influences the risk of pericardial effusion from cardiac-related neoplasia



24

Cardiac Hemangiosarcoma



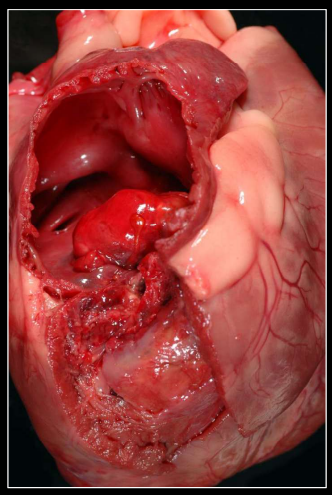
25

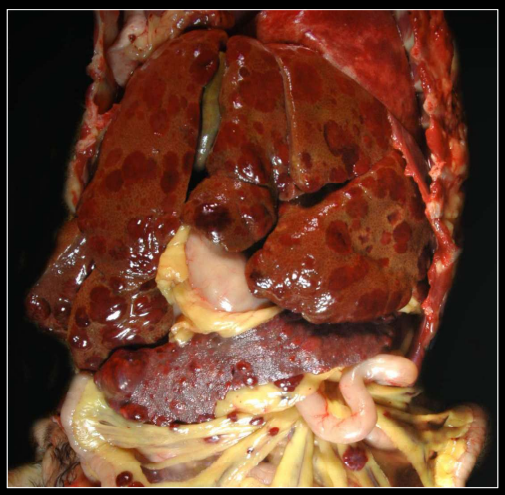
Cardiac Related Tumors Can Obstruct Blood Flow

Hemangiosarcoma (intracardiac)

26

Hemangiosarcoma ⇒ Metastasis

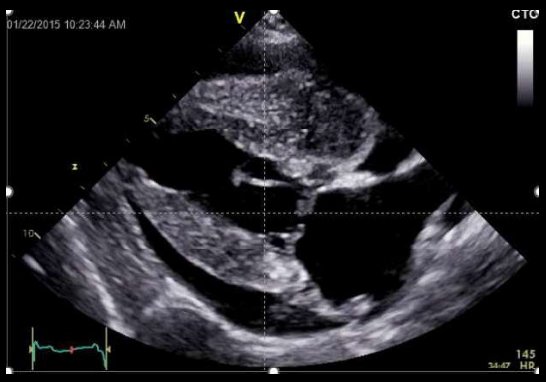




27

Pericardial Effusion (Canine)

Video

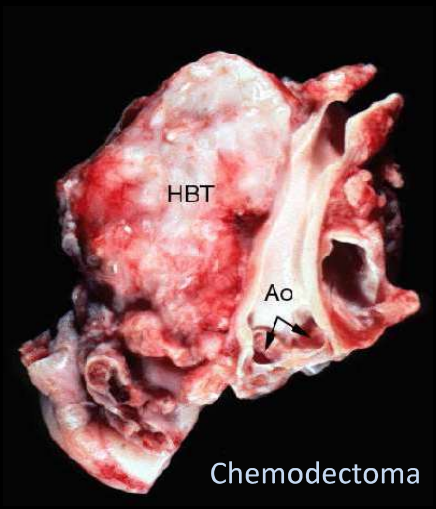


Pericardial Effusion
Right atrial mass lesion
HSA until otherwise proven

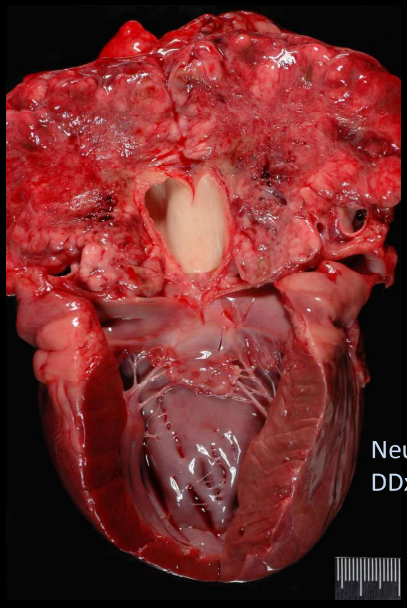
<u>Uncommon tumors to consider</u>:
Myxo(sarc)oma, Rhabdomyo(sarc)oma,
Undifferentiated sarcomas
Leiomyo(sarc)oma

28

Heart Base Tumors



Aortic body tumor, paraganglioma
Cells of neural crest origin



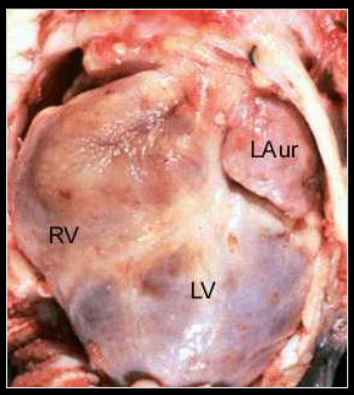
Neuroendocrine
DDx: Ectopic thyroid

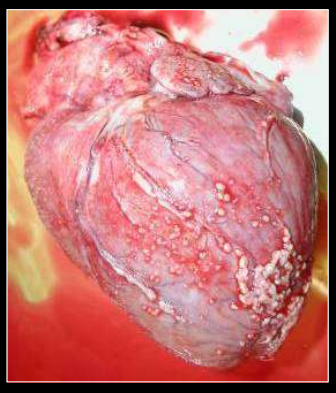
29

Mesothelioma

Neoplasm of cells lining the pericardial space

- Diffuse, infiltrative or multiple small nodules
- Diagnosis requires surgical biopsy
- Histologic diagnosis can be confusing
- New cell markers?





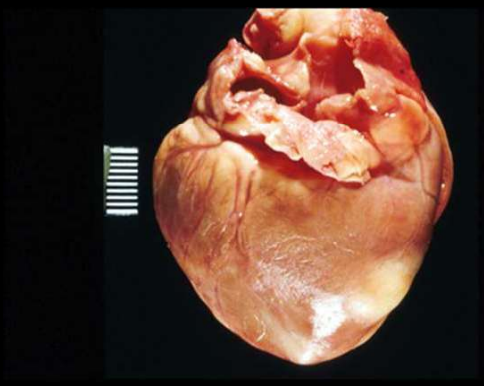
J Small Anim Pract. 2018 May;59(5):261-271. doi: 10.1111/jsap.12830. Epub 2018 Apr 2.

Immunohistochemical differentiation of reactive from malignant mesothelium as a diagnostic aid in canine pericardial disease.

Milne E[1], Martinez Pereira Y[1], Muir C[2], Scase T[2], Shaw DJ[1], McGregor G[1], Oldroyd L[3], Scurrell E[4], Martin M[5], Devine C[6], Hodgkiss-Geere H[7].

30

Lymphoma



LSA is more common in cats than in dogs with PE

Lymphosarcoma in Effusate

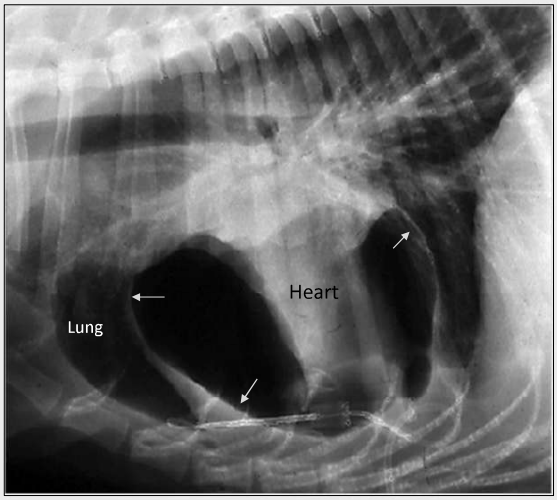
31

Pericardial Diseases & Cardiac Tumors in Dogs
– Topics –

1. Introduction | Malformations
2. Pericardial effusion
   - Causes
   - *Pathophysiology → Clinical Signs*
   - Diagnosis of Pericardial Effusion & Cardiac tumors in Dogs
     - Imaging & Other Diagnostic tests
3. Management Approaches
   - Pericardiocentesis
   - Medical & Surgical Treatment Options

32

Cardiac Tamponade – Both a Clinical & Echo Diagnosis

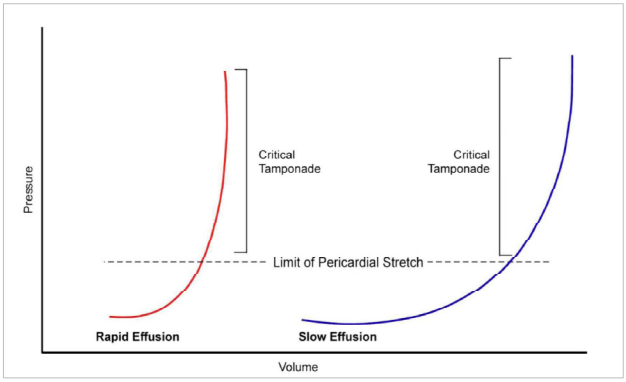


Cardiac compression by an external fluid (gas)
[In this case CO_2 from an old "diagnostic" pneumopericardiogram]

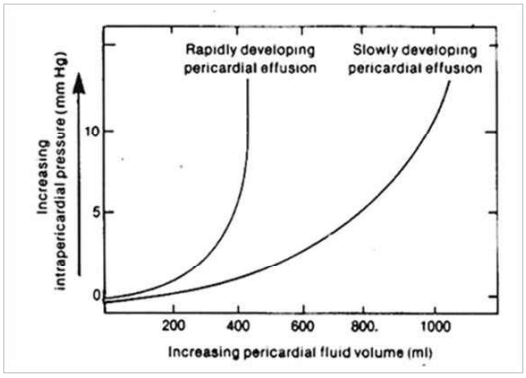
33

Intrapericardial Pressure vs. Volume

Am Soc Echocardiography 2013



Canine Data



Removing even a portion of the pericardial effusion leads to rapid relief of tamponade

34

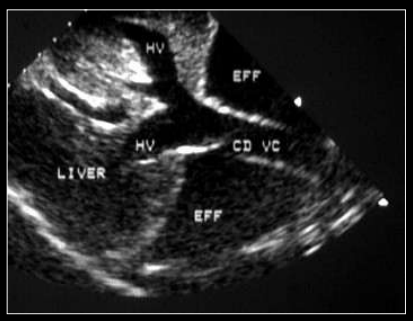
Cardiac Tamponade

- Traditionally a *clinical diagnosis*
- Echo correlates of cardiac compression (RA, RV collapse)
- Practically: patients present with either acute vs. chronic CT

↑ Fluid volume → ↑Intra-pericardial Pressure → **↓Cardiac filling Rt > Left** → **↓Cardiac output** (Hypotension) → **↑SNS, ⇑Renal Na+** → ⇑ Venous pressures (CHF)

35

Elevated systemic venous pressures → Right-sided CHF

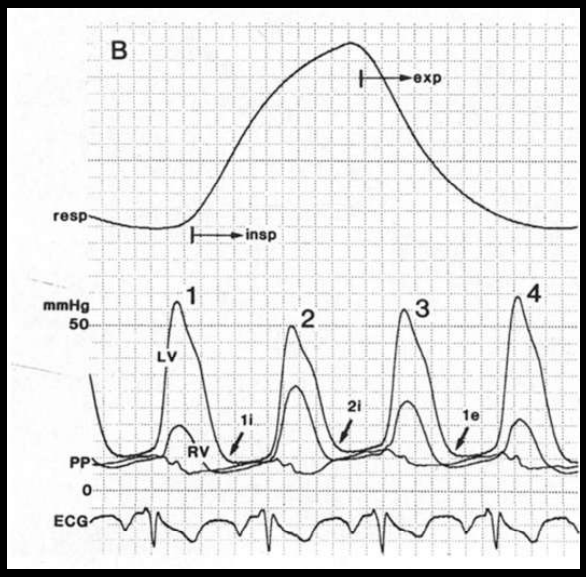


- Effusion
- Dilated Hepatic Veins
- Distended Caudal VC
- Minimal respiratory variation

Ascites from Right-sided CHF

36

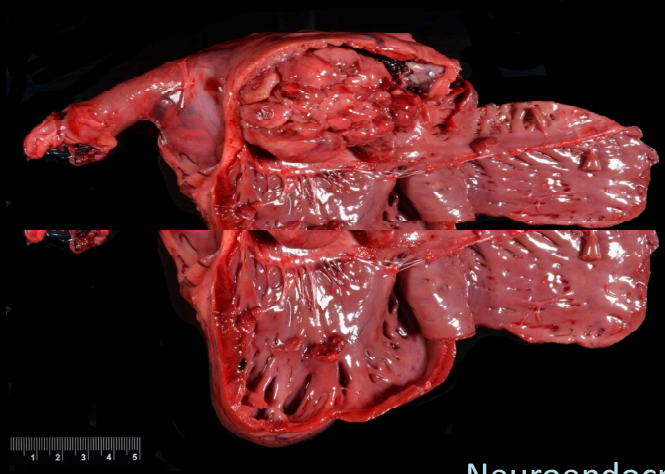
Hemodynamics of Cardiac Tamponade in a Dog



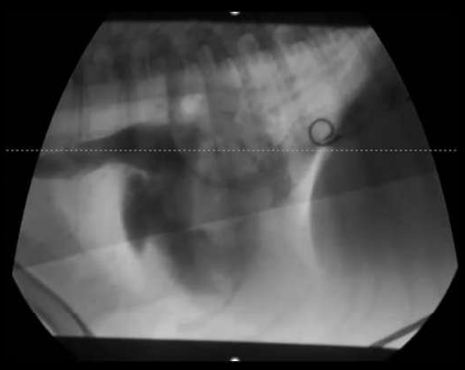
Gonzalez MS, Basnight MA, Appleton CP. Experimental cardiac tamponade: a hemodynamic and Doppler echocardiographic reexamination of the relation of right and left heart ejection dynamics to the phase of respiration. J Am Coll Cardiol. 1991 Jul;18(1):243-52.

37

Pathophysiology: Obstruction of Systemic Venous Return



Neuroendocrine Tumor



Angiography

38

Tumor Pathophysiology: Obstruction to Blood Flow

Vena Caval Obstruction

- **Caudal**: Hepatic congestion + Ascites
- **Cranial**: Pleural effusion (chylothorax)
  Facial or "brisket" edema

Atrial Mass Lesion – Inflow Obstruction

- Tricuspid or Mitral **AV stenosis**

Branch Pulmonary Artery Stenosis
Pulmonary venous obstruction

- **Redistribution** of pulmonary flow (X-ray)
- Right-sided **CHF** (supravalvular PS)
- Lobar lung edema (uncommon)

Hemangiosarcoma
Intracardiac (RA)

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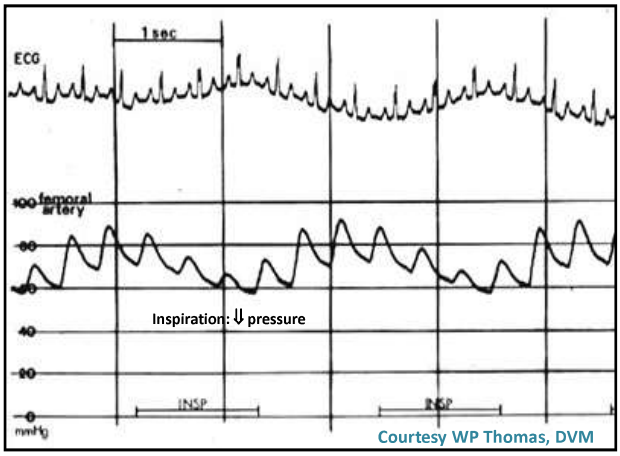
Pericardial Diseases – Clinical Findings
From Acute or Chronic Cardiac Compression or Mass Lesions

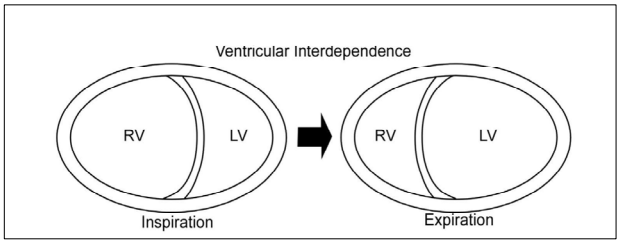
- History: Collapse (acute), tachypnea or abdominal swelling
- Vomiting (≈50%) & cough are common signs – multiple reasons
- Classic "triad" of cardiac tamponade:
  - Distant heart sounds
  - Elevated jugular venous pressure
  - Abnormal BP profile (Pulsus paradoxicus)
- Clinical Signs of right-sided CHF
  - ± Sinus tachycardia (reflexes in pericardium)
  - Hepatomegaly + ascites and rarely subcutaneous edema
  - Pleural effusion ⇒ Tachypnea or Distress
- From: venous obstruction, inflammation, ?reflexes, neoplasia

40

Pericardial Disease – Pulsus Paradoxicus – *Why*?



Courtesy WP Thomas, DVM



Am Soc Echocardiography 2013

Exaggerated inspiratory fall in ABP from cyclical ventricular filling
↑RV filling shifts ventricular septum⇒ ↓LV filling ABP during inspiration

41

Pericardial Effusion – *Review of Key Points*

- Most clinically relevant effusions are hemorrhagic
- Most common causes are:
  - **Idiopathic** pericardial hemorrhage (younger > older dogs)
  - **Tumor-associated** HSA, Chemodectoma (ABT), mesothelioma
- **Pathophysiology**: impaired filling ⇒ cardiac tamponade (R>L)
- **Mass lesions**: hemorrhage, obstructed blood flow, metastasis
- **Most common Presentations**: Acute (**collapse**) Chronic (**R-CHF**)
- **Classic PE triad**: **Distant heart sounds, ↑JVP, Pulsus paradoxicus**
- **Pleural effusion** is common

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Pericardial Diseases & Cardiac Tumors in Dogs

– Topics –

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   - Causes
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   - Pericardiocentesis
   - Medical & Surgical Treatment Options

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Electrocardiogram in Pericardial Disease

- Small complexes in all leads (*inconsistent*)
- ST segment elevation – pericarditis (uncommon)
- Electrical alternans – large effusion (*insensitive*)
  The heart "swings" within the pericardial space
- Cardiac rhythm disturbances
  Atrial arrhythmias (PACs, AFib) & PVCs ⇒ V Tachycardia

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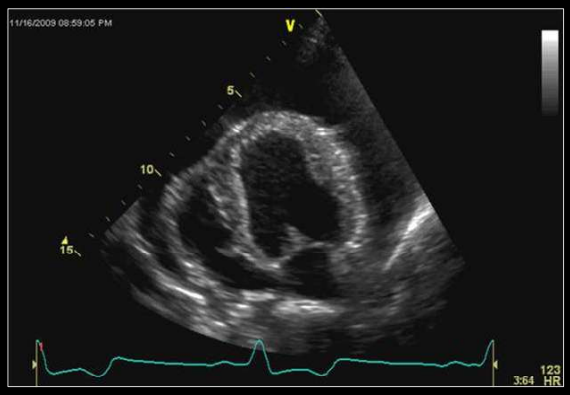
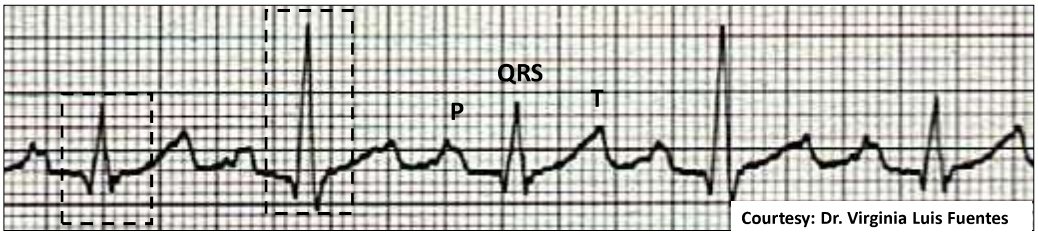
Mechanism of Electrical Alternans



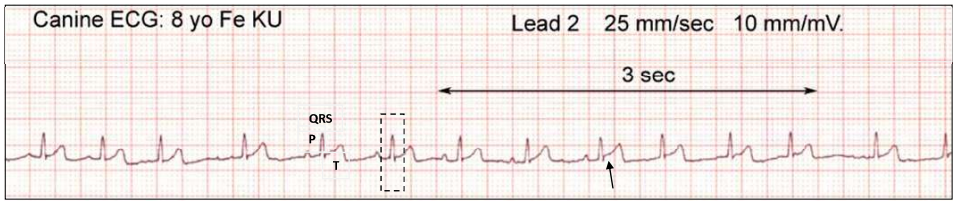
45

ECG in Pericardial Disease



Courtesy: Dr. Virginia Luis Fuentes

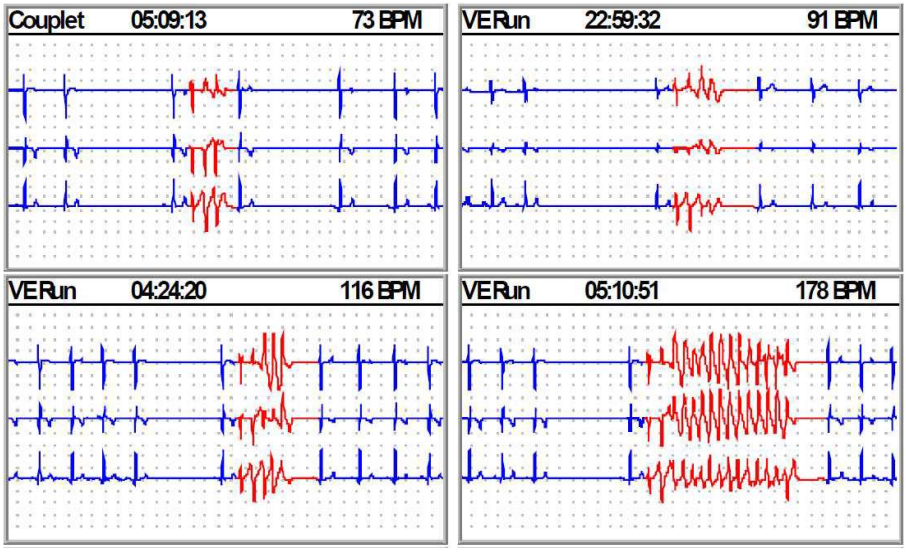
Electrical Alternans: *What is DDx?*



⇓ QRS voltages with ST ↑

46

ECG in Cardiac Neoplasia



One consideration for nonresponsive ventricular arrhythmia

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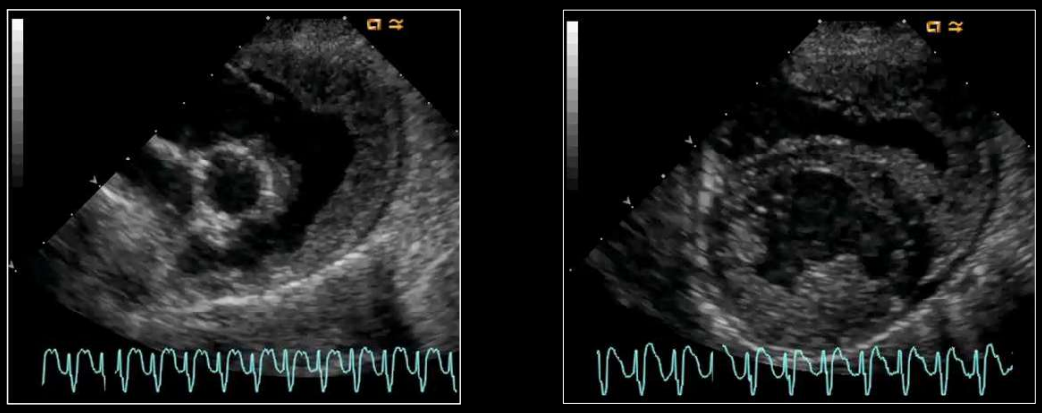
Cardiac Lymphosarcoma



Courtesy Wendy A Ware, DVM, DACVIM

Nonresponsive ventricular arrhythmias in older dogs – consider cardiac cancer

48

Clinical Laboratory Tests

Comparison of plasma cardiac troponin I concentrations among dogs with cardiac hemangiosarcoma, noncardiac hemangiosarcoma, other neoplasms, and pericardial effusion of nonhemangiosarcoma origin

Ruthanne Chun DVM, DACVIM, Heidi B. Kellihan DVM, DACVIM, Rosemary A. Henik DVM, DACVIM, and Rebecca L. Stepien DVM, DACVIM

View More +

DOI: https://doi.org/10.2460/javma.237.7.806

Volume/Issue: Volume 237: Issue 7 Online Publication Date: 01 Oct 2010

>0.25 ng/ml

J Vet Intern Med. 2004 May-Jun;18(3):322-4. doi: 10.1892/0891-6640(2004)18<322:ctiati>2.0.co;2.

Cardiac troponins I and T in dogs with pericardial effusion

Scott P Shaw [1], Elizabeth A Rozanski, John E Rush

Affiliations + expand

PMID: 15188818 DOI: 10.1892/0891-6640(2004)18<322:ctiati>2.0.co;2

Journal of Veterinary Cardiology (2006) 8, 19–23

Journal of Veterinary Cardiology

ELSEVIER

www.elsevier.com/locate/jvc

Pilot study on cardiac troponin I levels in dogs with pericardial effusion

Annika Linde, DVM [a,1,*], Nuala J. Summerfield, BSc, BVM&S, MRCVS, Dipl ACVIM [a,2], Margaret M. Sleeper, VMD, Dipl ACVIM [a], Fe B. Wright, DVM [a], Craig A. Clifford, DVM, MS, Dipl ACVIM [b,3], Tonatiuh Melgarejo, DVM, MS, PhD [c,1], David H. Knight, DVM, MS, Dipl ACVIM [a]

J Small Anim Pract. 2018 Apr;59(4):248-252. doi: 10.1111/jsap.12817. Epub 2018 Jan 22.

PCR evaluation of selected vector-borne pathogens in dogs with pericardial effusion.

Tabar MD[1], Movilla R[2], Serrano L[3], Altet L[3], Francino O[4], Roura X[2].

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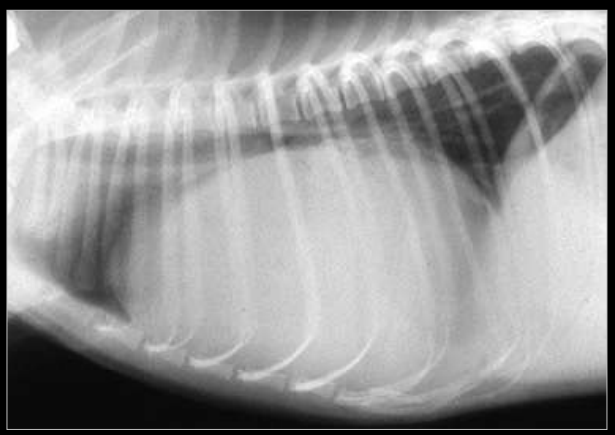
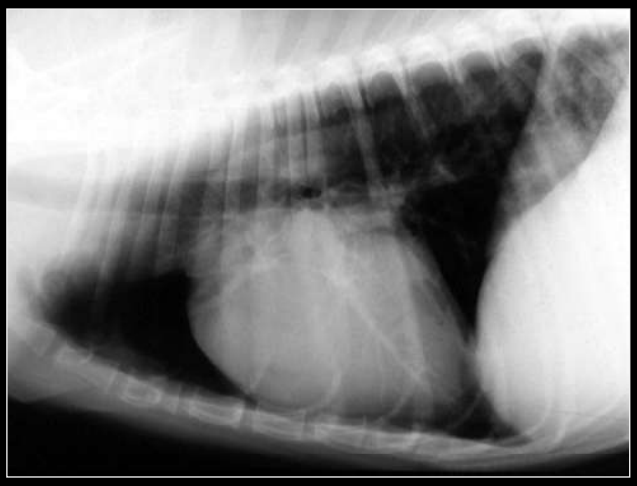
Pericardial Effusion & Cardiac-Related Tumors: Radiographic Features

- "Cardiomegaly" to Globoid
- Sharp edges
- Rounding near left atrium
- ↓ Pulmonary vascularity
  ± Redistribution of flow
- ± Pleural effusion
- ± Mass effects



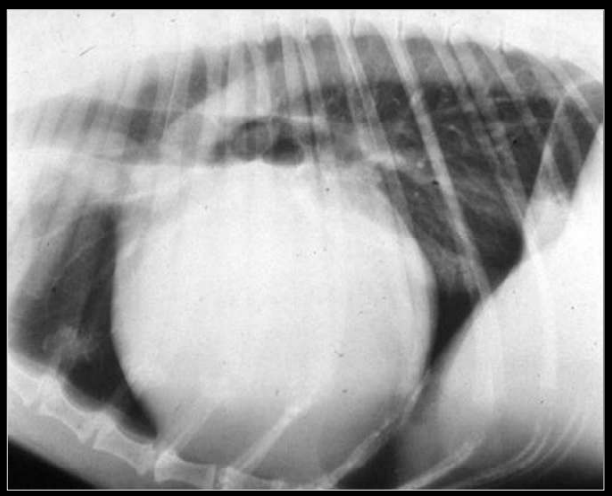
50

Pericardial Effusion



Small pericardial effusions might lead to
poorly-defined “cardiomegaly”

51



Pericardial Effusion:
Rounded cardiac contour
Sharp borders
↓ Pulmonary vasculature

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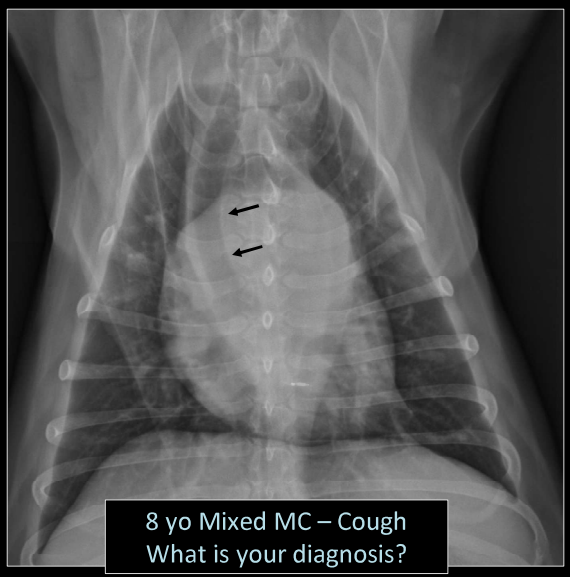
Cardiac Neoplasia without Effusion

Chemodectoma (aortic body tumor)

Tracheal deviation



Evaluate lung for redistribution of blood flow

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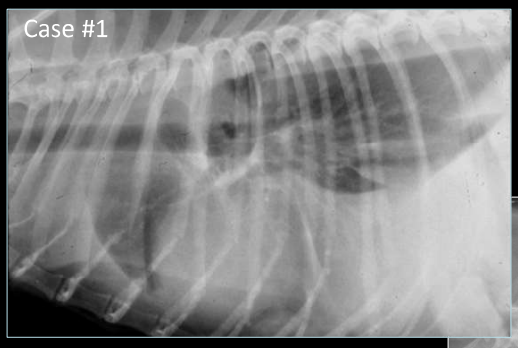
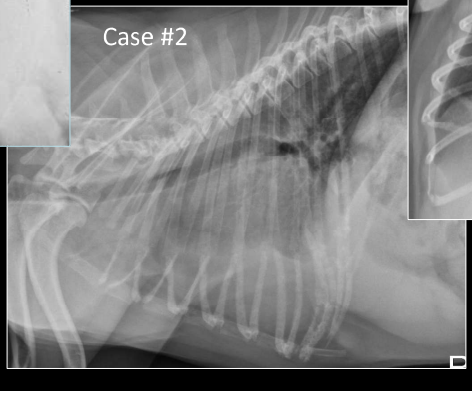
Pericardial Diseases – Other Findings

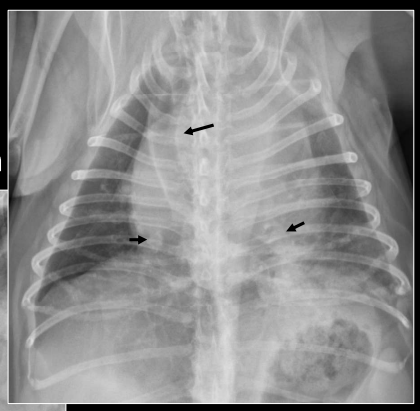
Pleural Effusion | Mass effects | Redistribution of flow



Moderate-large pleural effusion

Tracheal deviation
Right PA obstruction





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Pericardial Effusion: Echocardiography

- Echo-free space
- Mixed echoic = ↑ cellular fluid
- RA Compression
- RV Compression
- Mass lesions
  - Extra-cardiac
  - Intra-cardiac & mural (invasive)

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Key Points:

Infective pericarditis is uncommon to rare in dogs and cats

- Signs of systemic inflammation might dominate
  - Volume depletion might mask elevated JVP
- Tamponade might or might not be present
- Fluid is usually echogenic (view & echo system dependent) – "tags" suggest inflammation
- In older dogs, DDx: mesothelioma
- High-risk of effusive constrictive disease
- Foreign bodies should be considered
- *What can we learn from other species?*

56

Rocky

- 13-year-old M/C Mixed breed dog (9 kg)
- Grade 2/6 systolic murmur (left apex)
- History of intermittent cough and recent vomiting
- Radiographic cardiomegaly at RDVM – referred for echocardiography & evaluation
- Echocardiographic images recorded (next slide)

57

Rocky – Echocardiogram

Right Parasternal

Hybrid View – Left Cranial

Videos

Straightforward diagnosis: Pericardial Effusion
Intramural Cardiac (RA) mass – likely Hemangiosarcoma

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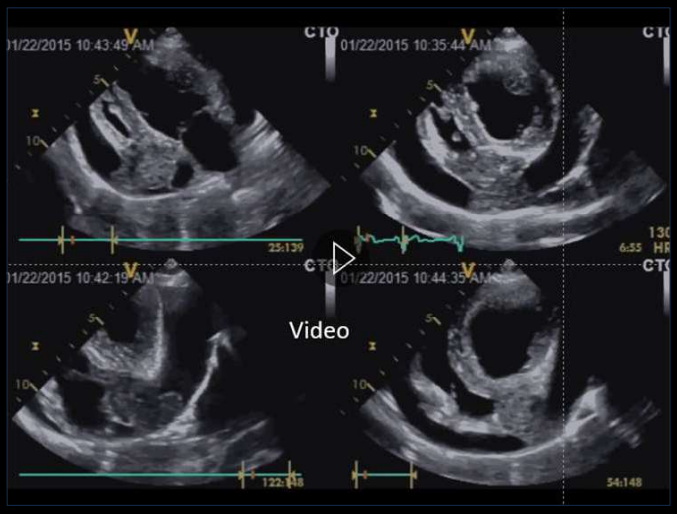
Often the Type of Mass Lesion is Suspected or Unknown



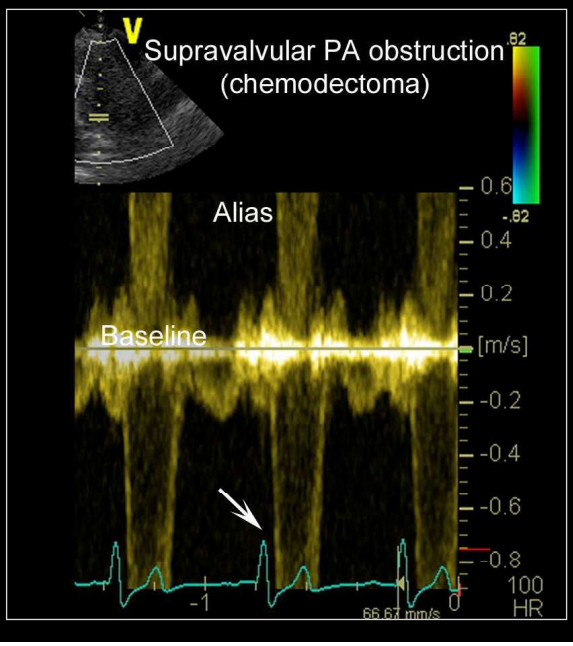
DDx: Thrombus or granuloma

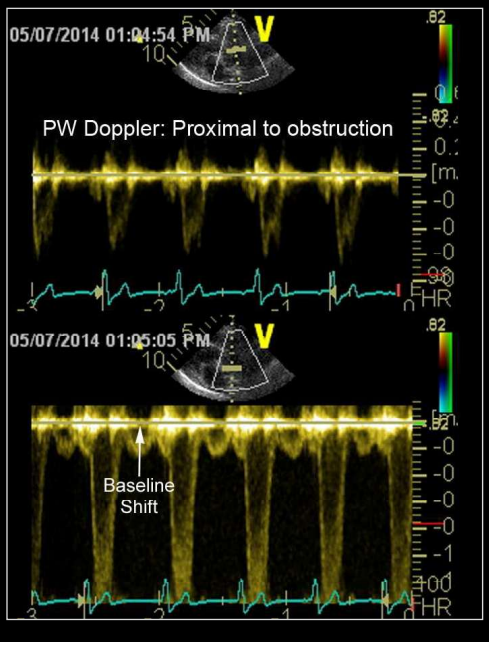
DDx: Hemangiosarcoma, Neuroendocrine, Others

Often multiple views are needed to characterize the mass & obstructions

59

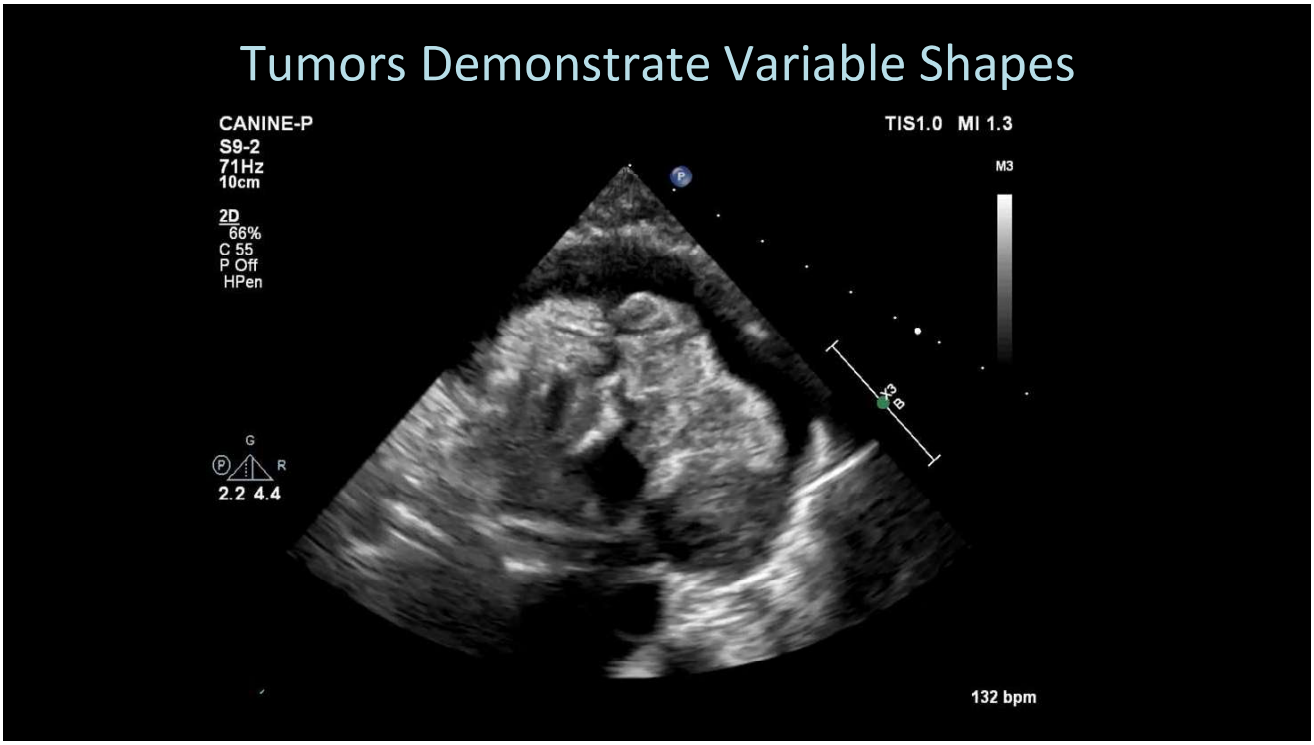
Recorded from the Right Parasternal positions



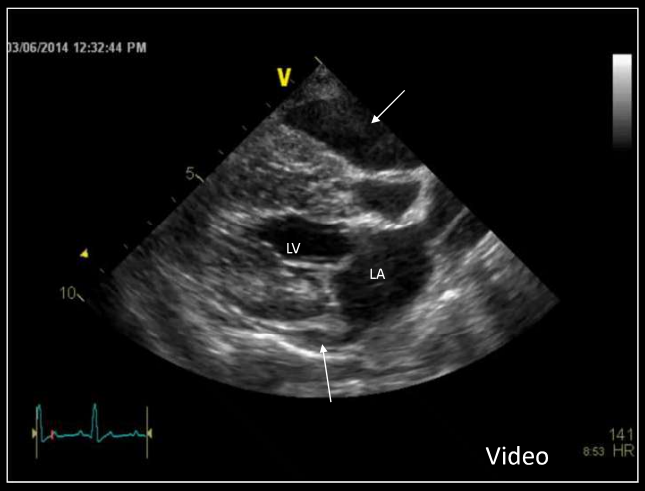


60

Tumors Demonstrate Variable Shapes



61



Older Dog: Findings? DDx?

62

Alternative Imaging – cMR & CT

J Vet Intern Med 2011;25:1003–1009

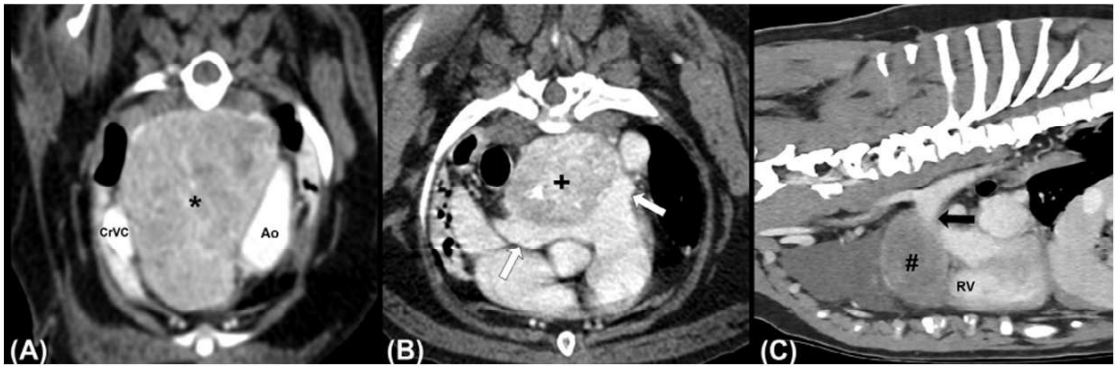
Cardiac Magnetic Resonance in the Differentiation of Neoplastic and Nonneoplastic Pericardial Effusion

K.N. Boddy, M.M. Sleeper, C.D. Sammarco, C. Weisse, S. Ghods, and H.I. Litt

MRI not superior to ECHO in this small study

63

Computerized Tomography – Useful



Vet Radiol Ultrasound. 2024 Sep;65(5):477-485. doi: 10.1111/vru.13378. Epub 2024 May 6.

Computed tomographic findings in canine and feline heart base tumors (25 cases)

Laura Ruiz de Alejos Blanco [1], Kelsey Brust [2], Balázs Szladovits [3], Randi Drees [1]

Affiliations + expand

PMID: 38706413 DOI: 10.1111/vru.13378

64

J Am Vet Med Assoc. 2009 Dec 15;235(12):1456-61.

Echocardiographic and clinicopathologic characterization of pericardial effusion in dogs: 107 cases (1985-2006).

MacDonald KA, Cagney O, Magne ML.

Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California-Davis, Davis, CA 95616, USA. macdoka@yahoo.com

- MacDonald, et al: JAVMA 2009
- 107 dogs with pericardial effusion evaluated by surgery (48), necropsy (44), or both (15)
- Masses identified in 61/107 cases
- Sensitivity / Specificity (about 20 – 25% missed)
  - 82% / 99% for detection of a RA mass
  - 74% / 98% for detection of a heart base mass
- High rate of metastasis for all cardiac masses found at surgery and necropsy

65

Pericardial Diseases & Cardiac Tumors in Dogs

– Topics –

1. Introduction | Malformations
2. Pericardial effusion
   - Causes
   - Pathophysiology → Clinical Signs
   - Diagnosis of Pericardial Effusion
     - Imaging & Other Diagnostic tests

3. Management Approaches
   - Pericardiocentesis
   - Medical & Surgical Treatment Options

66

Initial Management: *Pericardiocentesis*

- *Consider*: If hypotensive – IV fluid bolus (10 ml/kg)
- *Consider*: Sedation for the procedure (butorphanol)
- Puncture of the pericardial space – *various approaches*
  - *Diagnostic & Therapeutic* procedure
- Collect fluid ⇒ *inspect* (color, clotting) ⇒ *cytology* ±C&S
- Fluid analysis ⇒ Most are hemorrhagic:
  - Cytology useful to rule out septic inflammation & lymphoma
  - Low sensitivity / specificity for diagnosis of common tumors: (Hemangiosarcoma, Chemodectoma, Mesothelioma)
  - Specialized analyses (immunocytochemistry, microbiologic tests)

67

Pericardiocentesis – Different Methods are Used

Gather materials for the procedure

Prepare pericardiocentesis catheter

68

Pericardiocentesis

- Position Patient
  LLR ±elevated spine
- Insert IV
- Attach ABP cuff
- ECG electrodes (PVCs)
- Palpation & US guidance of puncture site

69

Pericardiocentesis

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Pericardiocentesis

What to do when the fluid flow “stops” ?
When is a saline contrast echo helpful?

71

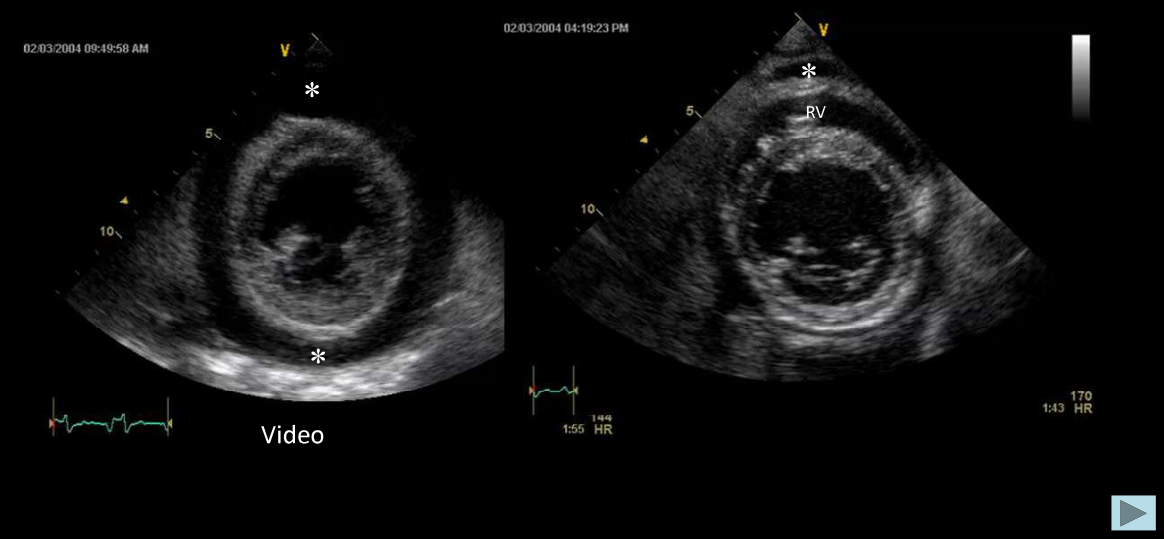
Pericardiocentesis

- Aspirate effusion
- Retain a small amount to observe for clotting
- Quantify volume
- Recheck Echo
- Retain samples for cytology (± culture)

± Specialized cell analyses

72

Pre- and Post-Pericardiocentesis



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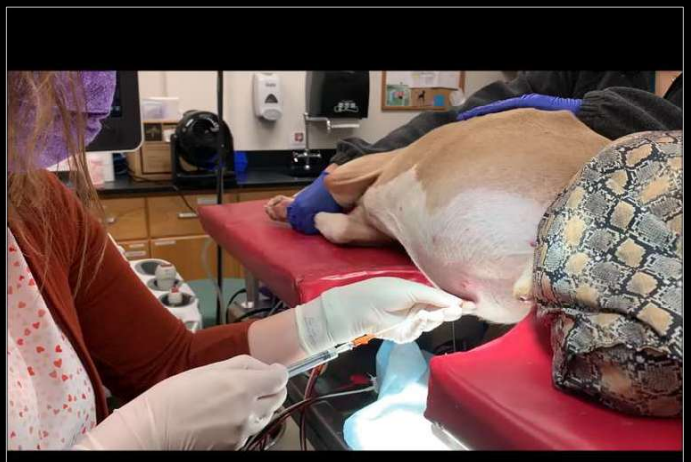
Abdominocentesis – For Tense Ascites



Video

Most dogs will experience a marked diuresis following pericardiocentesis

74

Do “Hemostatics” Work?

- Yunnan Baiyao
- Aminocaproic acid
- Tranexamic acid

75

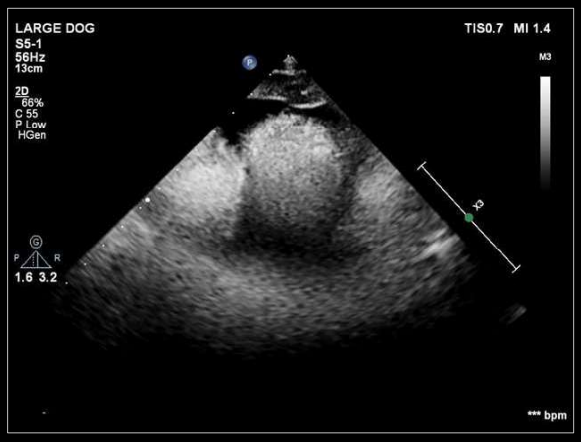
Pericardial Effusion – Management Principles

- Pericardiocentesis: tap → monitor → ±repeat (alt. catheter)
  - Crystalloid infusion (10 ml/kg) for low BP (<100 systolic)
  - ±Cytology or US guided needle biopsy if cause is uncertain
- Determine most-likely cause – Age/breed, US, X-ray, CT
- Major Decision: *conservative* “watchful waiting” versus surgical approaches (explore pericardium, thoracoscopy)
- Medical treatments: diuretics, antibiotics, corticosteroids, anti-fibrotic drugs generally are not proven useful
- Septic pericarditis: drainage, anti-microbials, pericardiectomy

76

Sunny: 12-year-old Mc mixed breed dog

- 20 kg dog
- Referred for signs of
  Right-sided CHF
- Ascites
- Jugular venous distension
- Muffled heart sounds
- Echocardiography performed
  (Next slide)



77

Sunny Echocardiogram

Multiple views were obtained, and no mass was found
What should be done in this type of case?

78

Management of Cardiac-related Tumors

- Consultation – with an Oncologist
- Options:
  - Palliative care
  - Pericardial procedures to address new/recurrent effusions
  - Uncommonly: surgical resection
  - Stereotactic radiation therapy
  - Chemotherapy
  - Stenting of obstructive lesions
  - Others - ? Laser

Branch pulmonary artery stent placement in a dog with heart base neoplasia

C M Bussadori [1], M Claretti [2], S Borgonovo [1], E Boz [1], M Papa [1], C Rossi [1], F Martelli [1], M Aimi [1], S Signorelli [1], R Marinelli [1]

Affiliations + expand

PMID: 32619933 DOI: 10.1016/j.jvc.2020.05.002

Clinical Trial > J Vet Intern Med. 2002 Sep-Oct;16(5):541-6.
doi: 10.1892/0891-6640(2002)016<0541:pbpaat>2.3.co;2.

Percutaneous balloon pericardiotomy as a treatment for recurrent pericardial effusion in 6 dogs

J A Sidley [1], C E Atkins, B W Keene, T C DeFrancesco

Affiliations + expand

PMID: 12322703 DOI: 10.1892/0891-6640(2002)016<0541:pbpaat>2.3.co;2

Free article

Toceranib (Palladia®)
Prospective Studies Needed

frontiers in Veterinary Science

ORIGINAL RESEARCH

A Multi-Institutional Retrospective Analysis of Toceranib Phosphate for Presumed or Confirmed Canine Aortic Body Chemodectomas

Giovanna M. Coto [1], Margaret L. Musser [1]*, Melissa A. Tropf [1], Jessica L. Ward [1], Yeon-Jung Seo [2], Jonathan P. Mochel [2] and Chad M. Johannes [1]

> Vet Comp Oncol. 2019 Dec;17(4):465-471. doi: 10.1111/vco.12491. Epub 2019 Jun 18.

Retrospective evaluation of canine heart base tumours treated with toceranib phosphate (Palladia): 2011-2018

Felicia H Lew [1 2], Bobbi McQuown [1 3], Juan Borrego [4], Suzanne Cunningham [1], Kristine E Burgess [1]

Affiliations + expand

PMID: 31069932 DOI: 10.1111/vco.12491

ELSEVIER

Journal of Veterinary Cardiology

Volume 44, December 2022, Pages 38-42

Case Report

Toceranib phosphate resolves right heart obstruction secondary to a heart base neoplasm in a dog ☆

J. Gregory DVM, J. Thomason DVM, S. Hocker DVM

"…median survival time of 478 days was found for those receiving toceranib alone (n = 14), which was not statistically different from those treated with additional modalities (521 days)"

Reference: Stereotactic Body Radiation

> J Vet Cardiol. 2020 Feb:27:62-77. doi: 10.1016/j.jvc.2020.01.002. Epub 2020 Feb 3.

A retrospective analysis of stereotactic body radiation therapy for canine heart base tumors: 26 cases

C R Kruckman-Gatesy [1], M K Ames [2], L R Griffin [3], M-K Boss [3], S Rao [2], D Leary [3], S M LaRue [3]

"The median overall survival time was 404 days (95% CI: 239-554 days).

…majority of dogs experienced a partial response (25%) or stable disease (60%) for a median duration of 333 days (95% CI: *94-526* days).

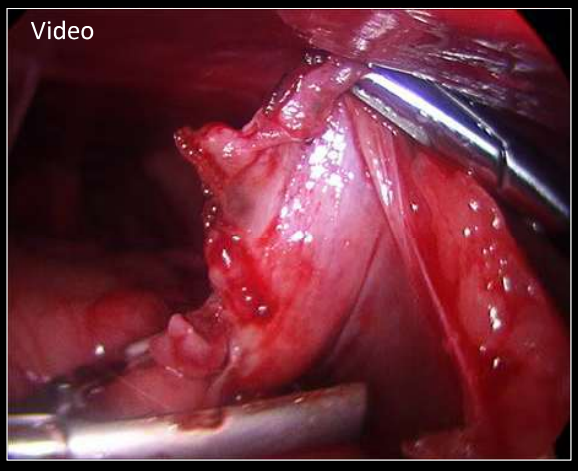
…Three dogs had progressive disease within six months of SBRT.

Radiographic pneumonitis was identified in 7 of 23 dogs, and clinical pneumonitis was identified in 4 dogs"

Kruckman-Gatsey, et al. JVC (2020) 27:62

81

Surgical Options & Outcomes



←Scope-aided Pericardiectomy

Vet Surg. 2019 Jun;48(S1):O105-O111. doi: 10.1111/vsu.13129. Epub 2018 Dec 5.

Outcome in dogs with presumptive idiopathic pericardial effusion after thoracoscopic pericardectomy and pericardioscopy.

Carvajal JL[1], Case JB[1], Mayhew PD[2], Runge J[3], Singh A[4], Townsend S[1], Monnet E[5].

> J Am Vet Med Assoc. 1998 Apr 15;212(8):1276-80.

Analysis of prognostic indicators for dogs with pericardial effusion: 46 cases (1985-1996)

D Dunning [1], E Monnet, E C Orton, M D Salman

Affiliations + expand

PMID: 9569169

J Am Vet Med Assoc. 2013 Feb 15;242(4):493-8. doi: 10.2460/javma.242.4.493.

Outcome evaluation of a thoracoscopic pericardial window procedure or subtotal pericardectomy via thoracotomy for the treatment of pericardial effusion in dogs.

Case JB[1], Maxwell M, Aman A, Monnet EL.

82

Thoracotomy – Auriculectomy

83

Reference: Surgical Options for Pericardial Effusion

- Main indications for surgery:
  - Reduce risk of **constriction** (pericarditis or recurrent hemorrhage)
  - **Exploratory** (FB, tumor) & **biopsy** procedures (mesothelioma)
  - **Therapeutic** procedure(s)
- Subtotal pericardiectomy:
  - Septic |inflammatory **effusion**| recurrent **IPH** (?) | Tumor **resection**
  - Idiopathic hemorrhage: UK retro study: MST (Sx) **1218** vs. 532 days
- Minimally-invasive approaches to pericardial space:
  - **Thoracoscopy** & "Mini"– thoracotomy – to explore + "**windows**"
  - Balloon catheter dilation pericardiotomy (little data)

84

Treatment Options – Evidence Based

Conclusion: ”Because of the low quality of evidence of the studies included in this systematic review and the variability of the outcomes, *there is not sufficient evidence to recommend one treatment option* rather than another.”

85

Reference: Systematic Review of Treatment Options

- “One hundred eight of the 641 unique articles that were identified and evaluated met inclusion criteria…
- Most articles included were case studies (68.2%) or retrospective case series (25.2%)…
- …with all articles providing a low level of evidence. ”
- **Conclusion:** Because of the low quality of evidence of the studies included in this systematic review and the variability of the outcomes, there is not sufficient evidence to recommend one treatment option rather than another.”

Scheuermann LM, et al. Vet Surg (2021); 50:28

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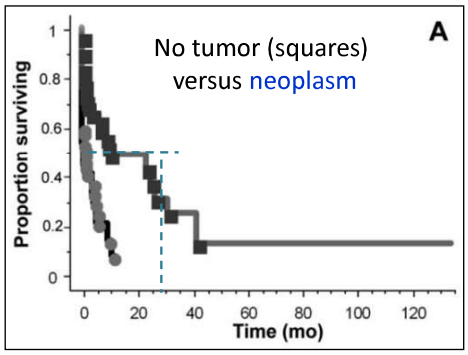
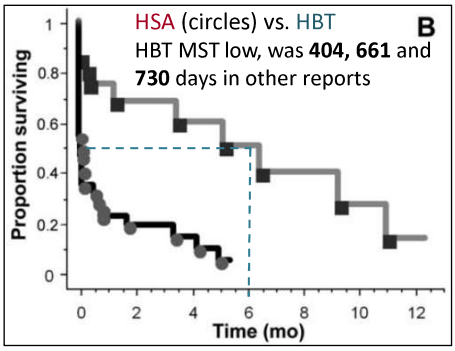
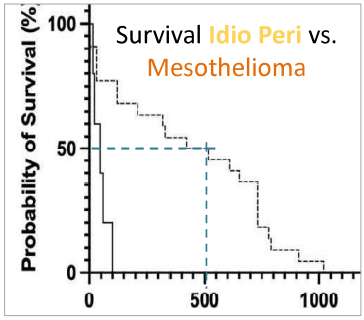
Prognosis





Data from: **MacDonald K**, et al., JVIM 2009



Data from: **Levi,** et al., Vet Sci, 2021

Other: MST for chemodectoma with surgery: 730 days (**Ehrart N**, et al. *Vet Surg 2002)*

Idiopathic hemorrhagic (young dogs): Very good if follow-up ± surgery

Idiopathic pericarditis (including older dogs): Variable; numerous factors

Infection: guarded (risk of constriction)

Mesothelioma: probably poor (reports are confusing; see Levi, 2021)

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Pericardial Effusion & Cardiac Tumors in Dogs – Summary

- Five main pathophysiologic – clinical settings:
  1. Acute tamponade – acute cardiac compression + tamponade
  2. Chronic cardiac compression – right-sided CHF ± pleural effusion
  3. Pericarditis – signs of systemic inflammation + variable cardiac findings
  4. Cardiac mass lesion causing obstruction to blood flow
  5. Pericardial effusion as a co-morbidity (CHF, systemic inflammation)
- Clinical findings: Relate to underlying pathophysiology
  - Classic triad (Beck): hypotension (paradoxicus), ↑JVP + ↓heart sounds
- Initial treatment: Pericardiocentesis + supportive care
- Determine etiology & management plan
- Chronic management – Depends on etiology

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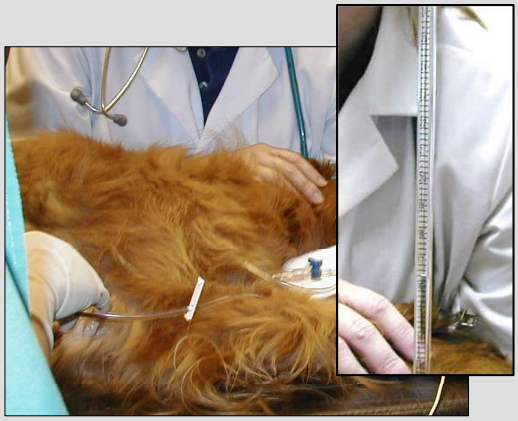
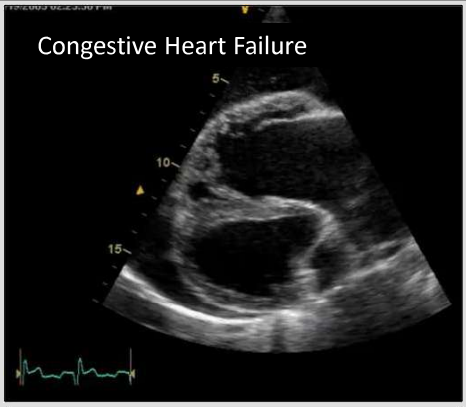
Pericardial Disease: Other Issues



Effusive – Constrictive Pericarditis



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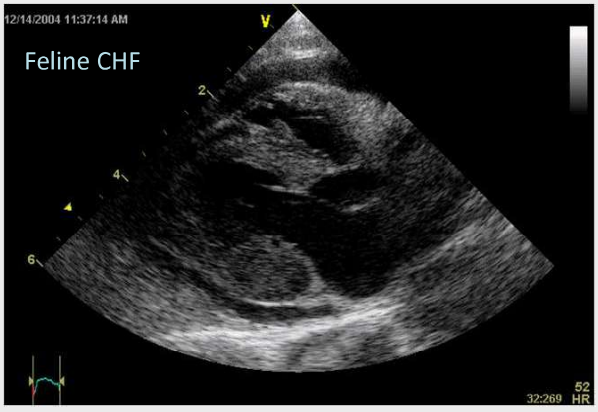
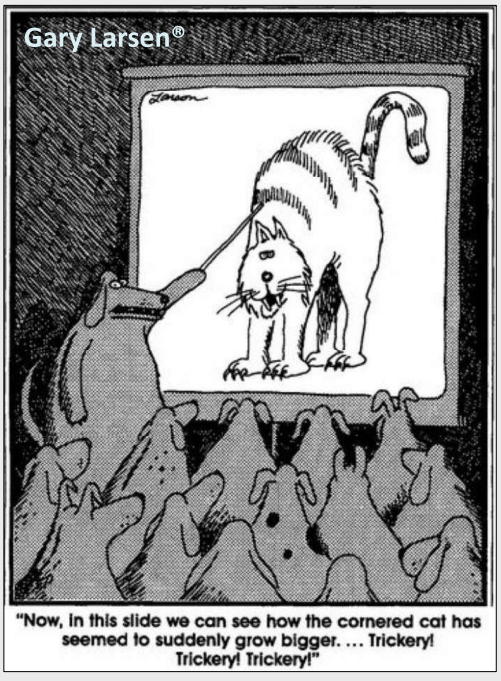
Pericardial Effusions in Cats





90

Pericardial Effusion in Cats

- CHF is the most common reason
  - Feline infectious peritonitis virus infection
  - Bacterial infections (e.g. Pasteurella spp)
  - LSA
  - Other
- Mechanisms? …speculation!
- When to consider pericardiocentesis?
- How to perform (sedation | site | catheters)

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Pericardial Diseases & Cardiac Tumors in Dogs

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Adjunct Professor – Cardiology, Colorado State University College of Veterinary Medicine
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Adjunct Professor of Cardiology, North Carolina State University College of Veterinary Medicine
jdbonagu@ncsu.edu

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VetRad

Is the heart sick?

Cardiac decompensation or other pulmonary patterns in dogs

Nele Eley

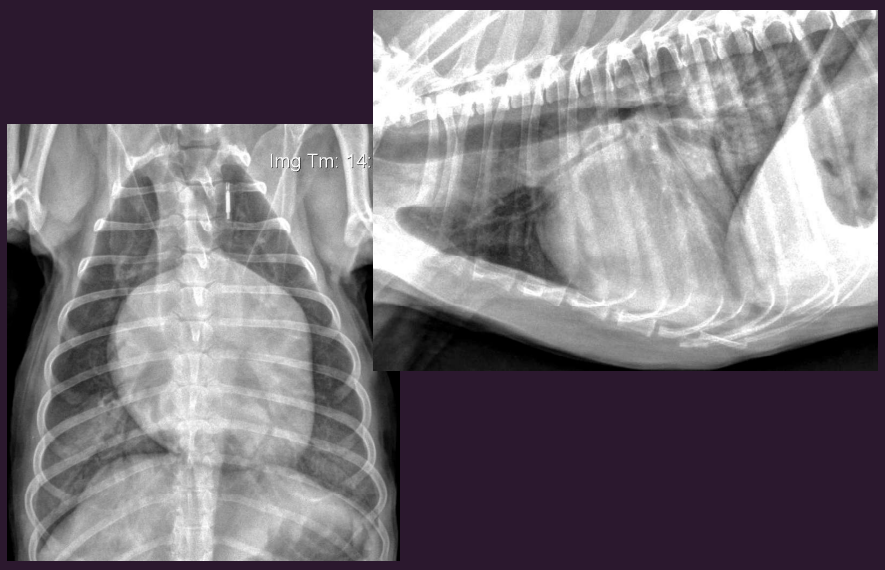
DVM
DECVDI
Specialist in Radiology

1

VetRad

Congestive Heart Failure on X-ray

1. Pulmonary infiltrates
2. Cardiac silhouette



2

Enlargement of the left atrium

VetRad

Increased pressure in the left atrium → Enlarged left atrium → Pulmonary venous congestion → Edema

3

Congestive heart failure on X-ray

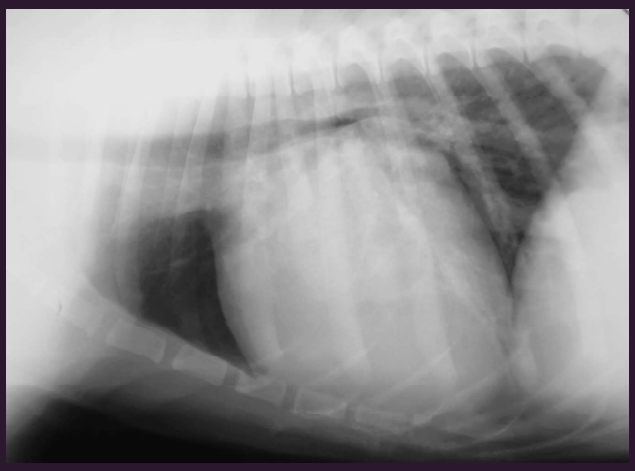
VetRad

- Interstitial/alveolar infiltrates
- Enlarged pulmonary veins
- Enlarged left atrium

4

Left ventricular enlargement on X-ray → ...

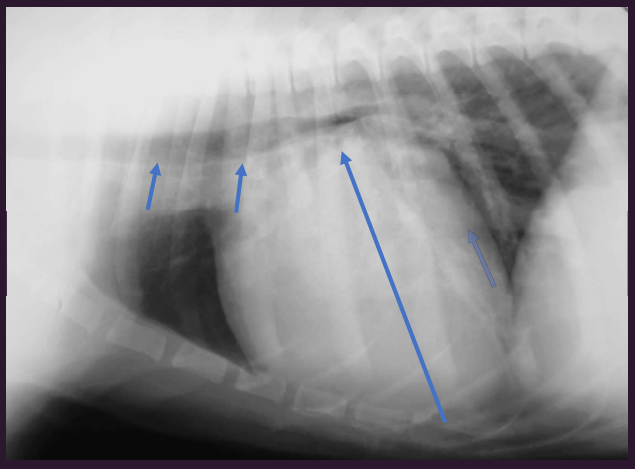
VetRad

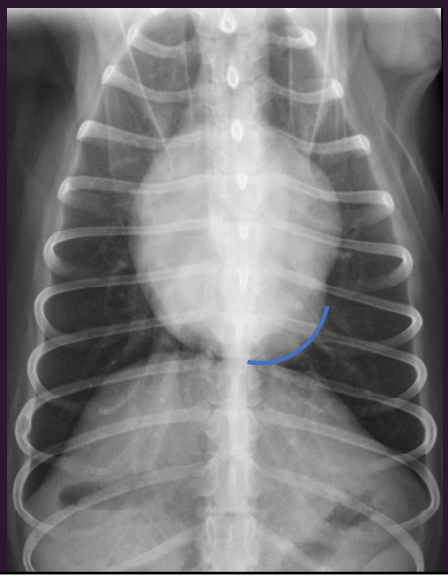


5

Left ventricle

VetRad





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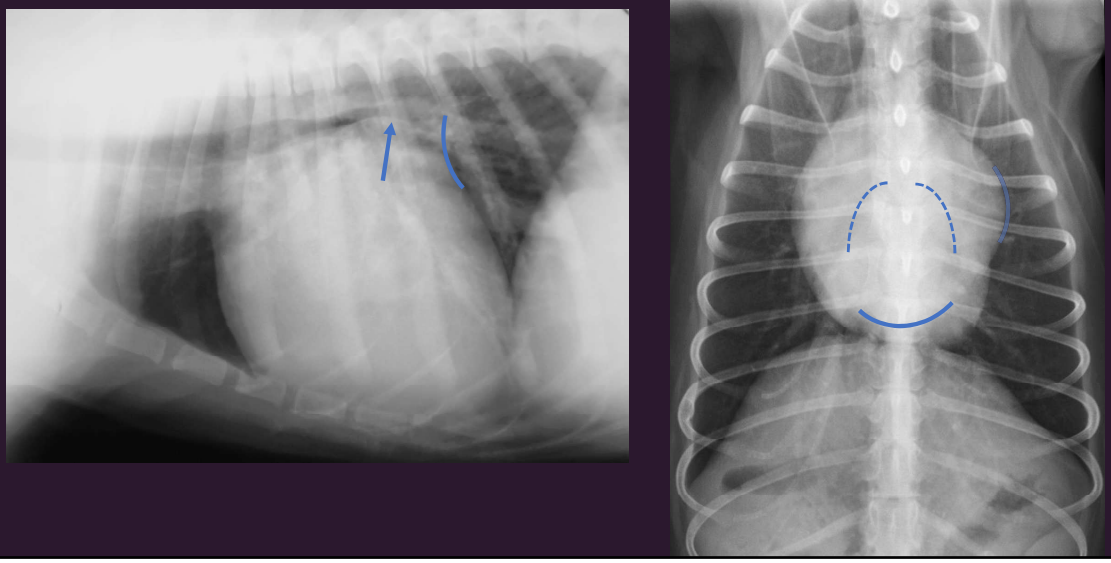
Left atrium

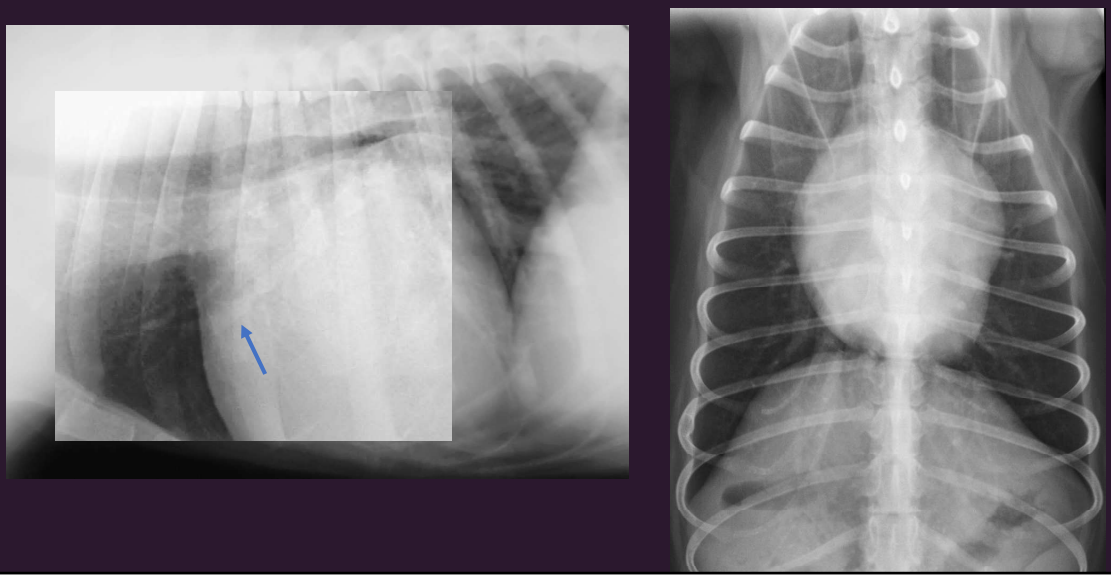
VetRad



7

Left atrium

VetRad



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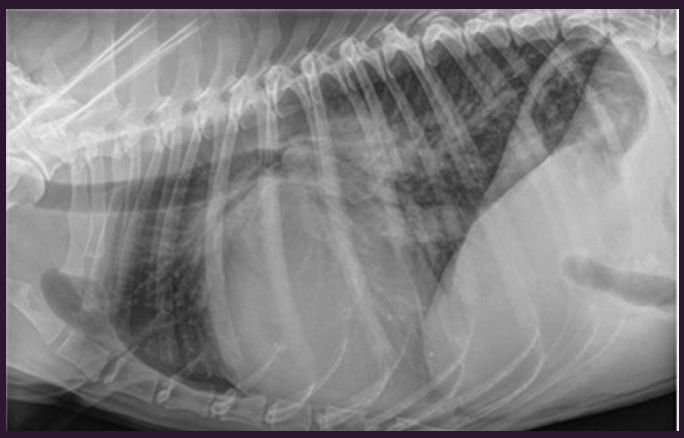
...Congestive heart failure

VetRad



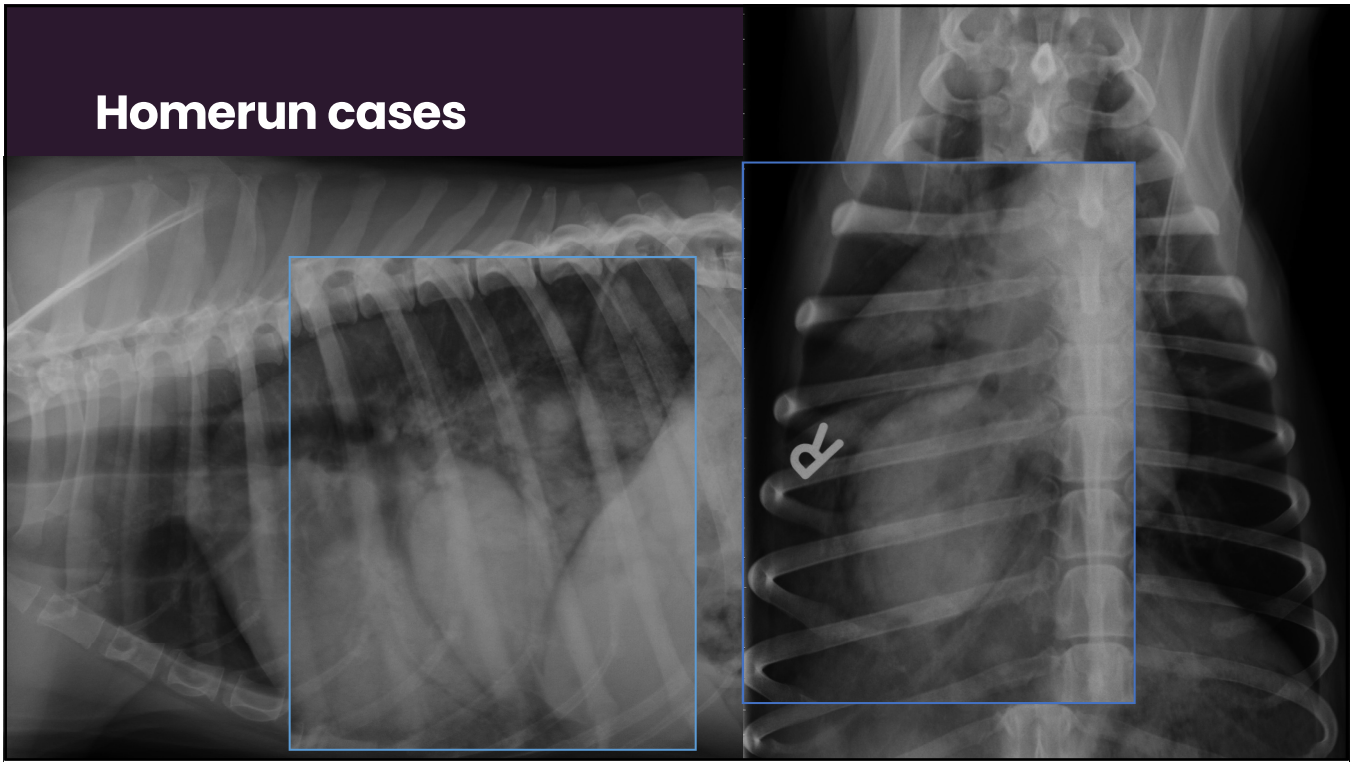
9

NOT congestive heart failure on X-ray

VetRad

- Lobar infiltrates
- Unilateral infiltrates
- Bronchial and nodular infiltrates
- No enlargement of the left atrium

10



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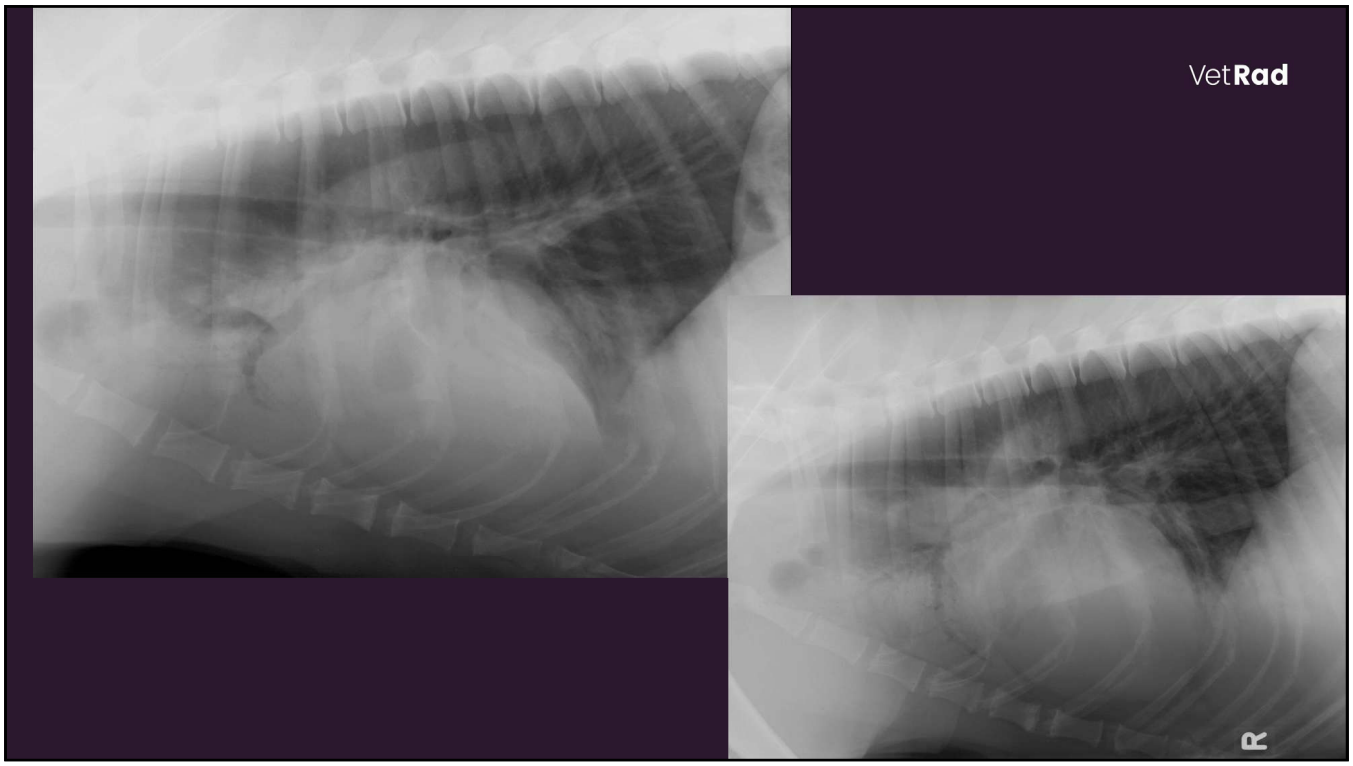

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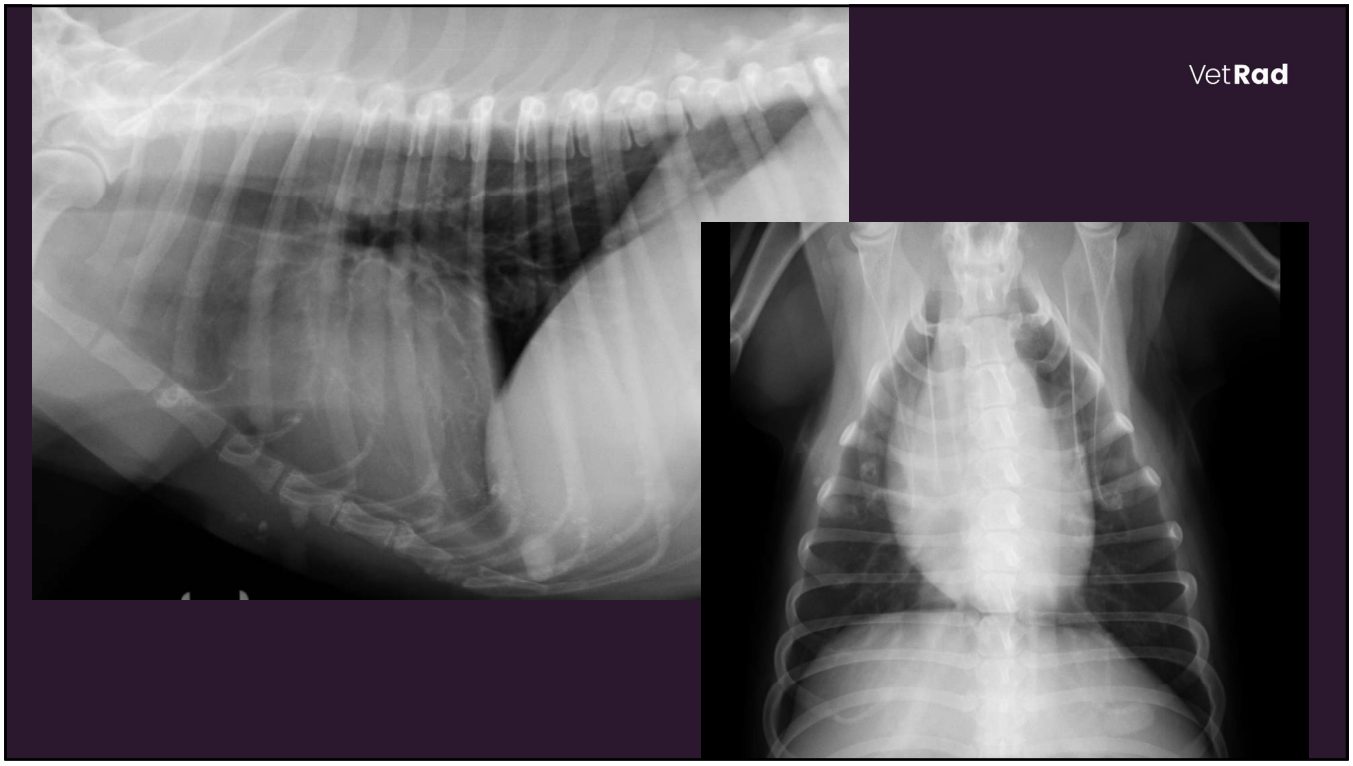

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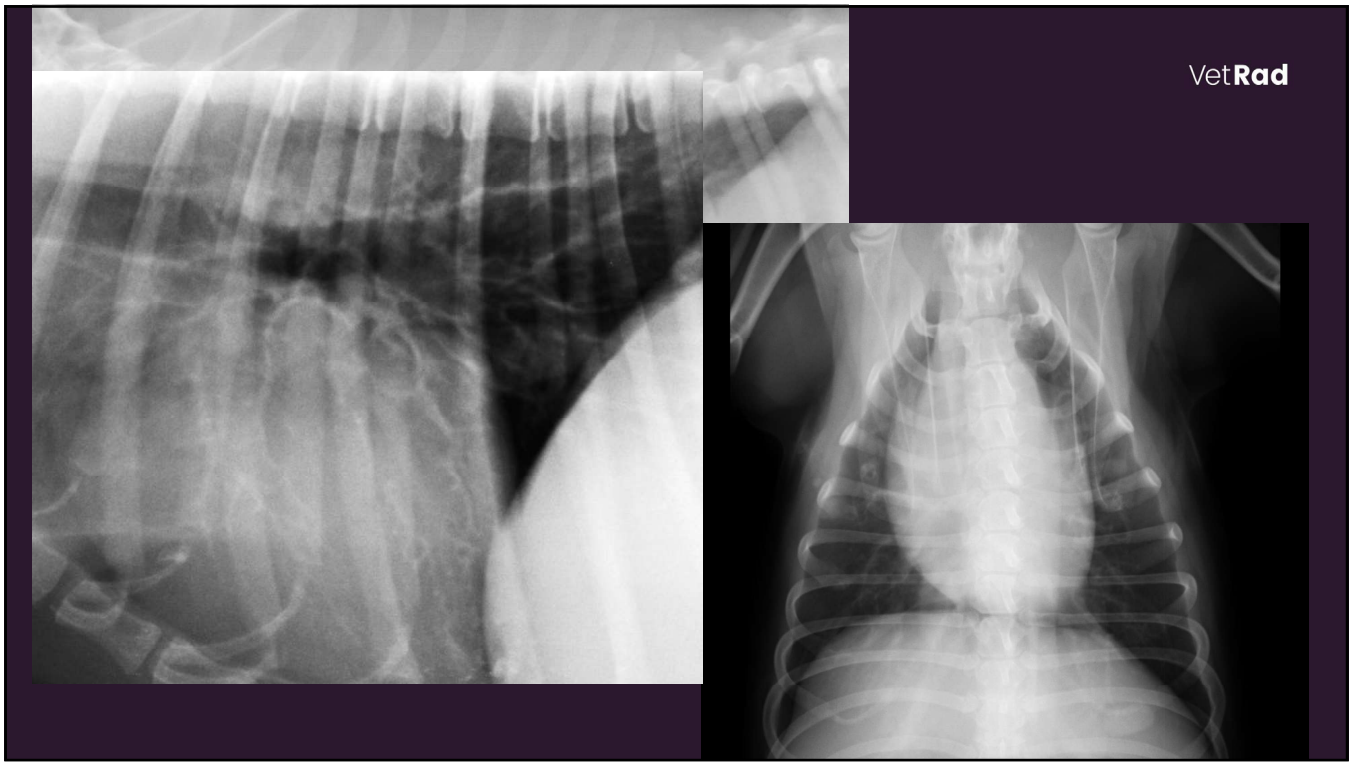


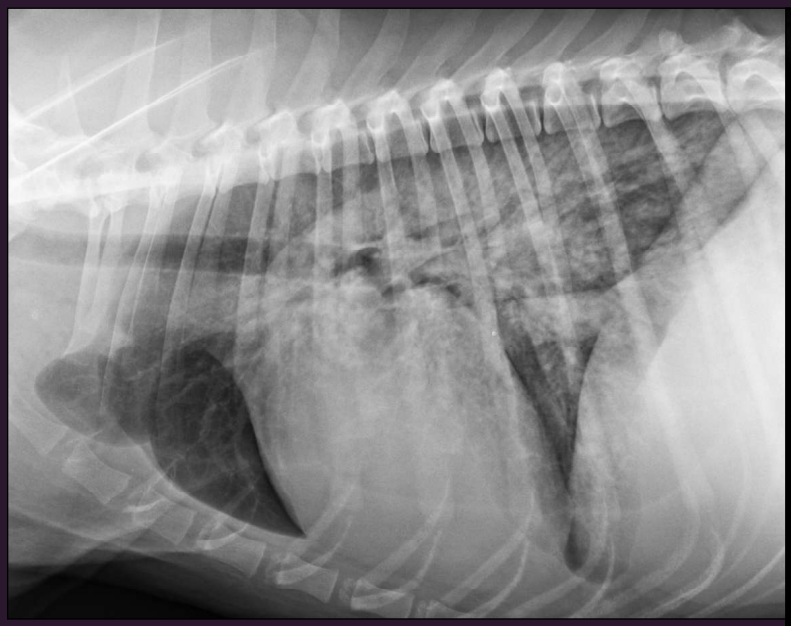
14

NOT congestive heart failure

VetRad

- A little trickier

15

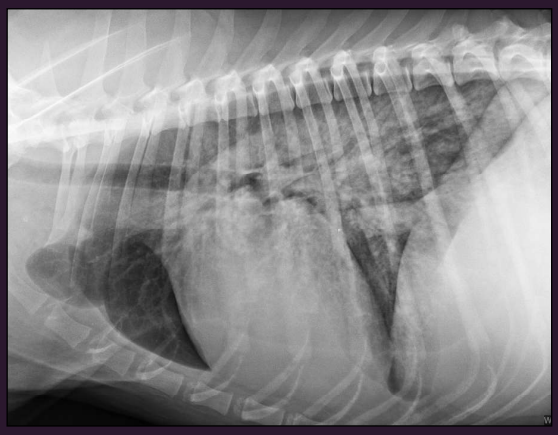


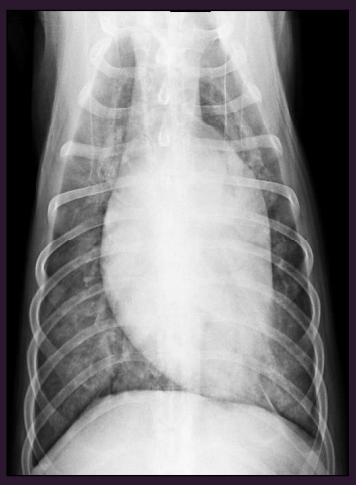
16

VetRad

Bella, Malinois, 8 years old, female

Dyspnea
Anemia, azotemia





17

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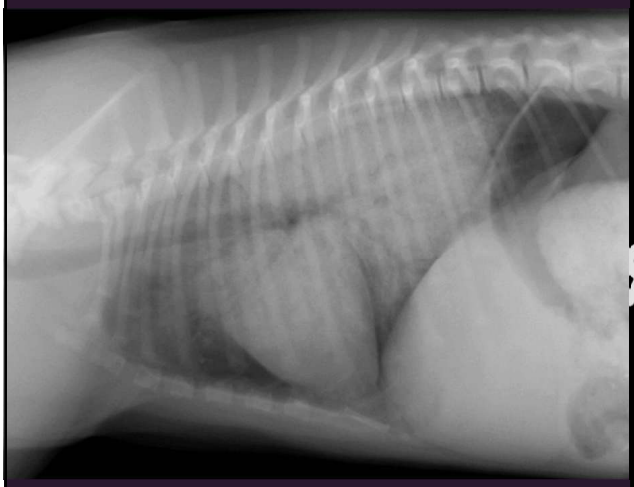
WHWT, 5 months, ARDS



18

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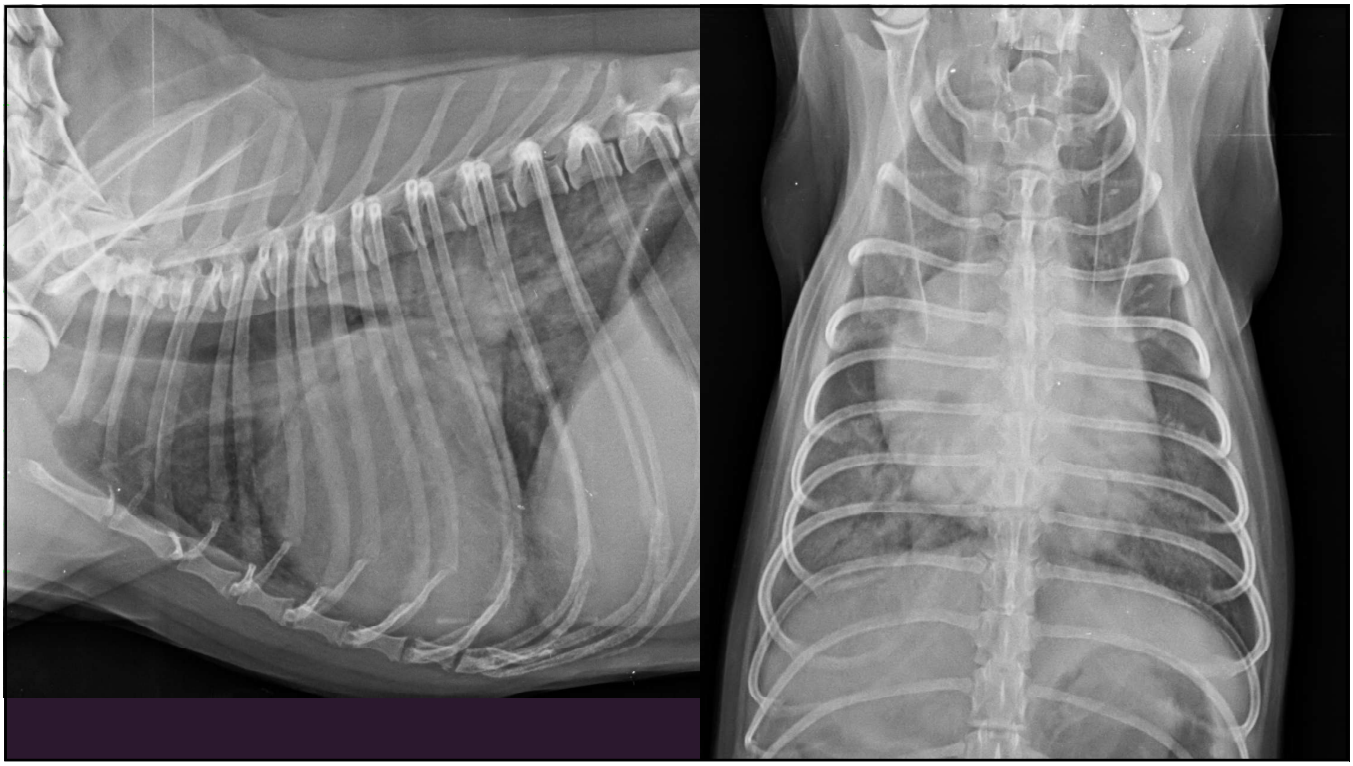
Pattern-based approach and Differentiation

- Alveolar, interstitial, ~~nodular, bronchial patterns~~
- Topographic distribution is key

- Cardiogenic pulmonary edema: Mostly **perihilar**?

19



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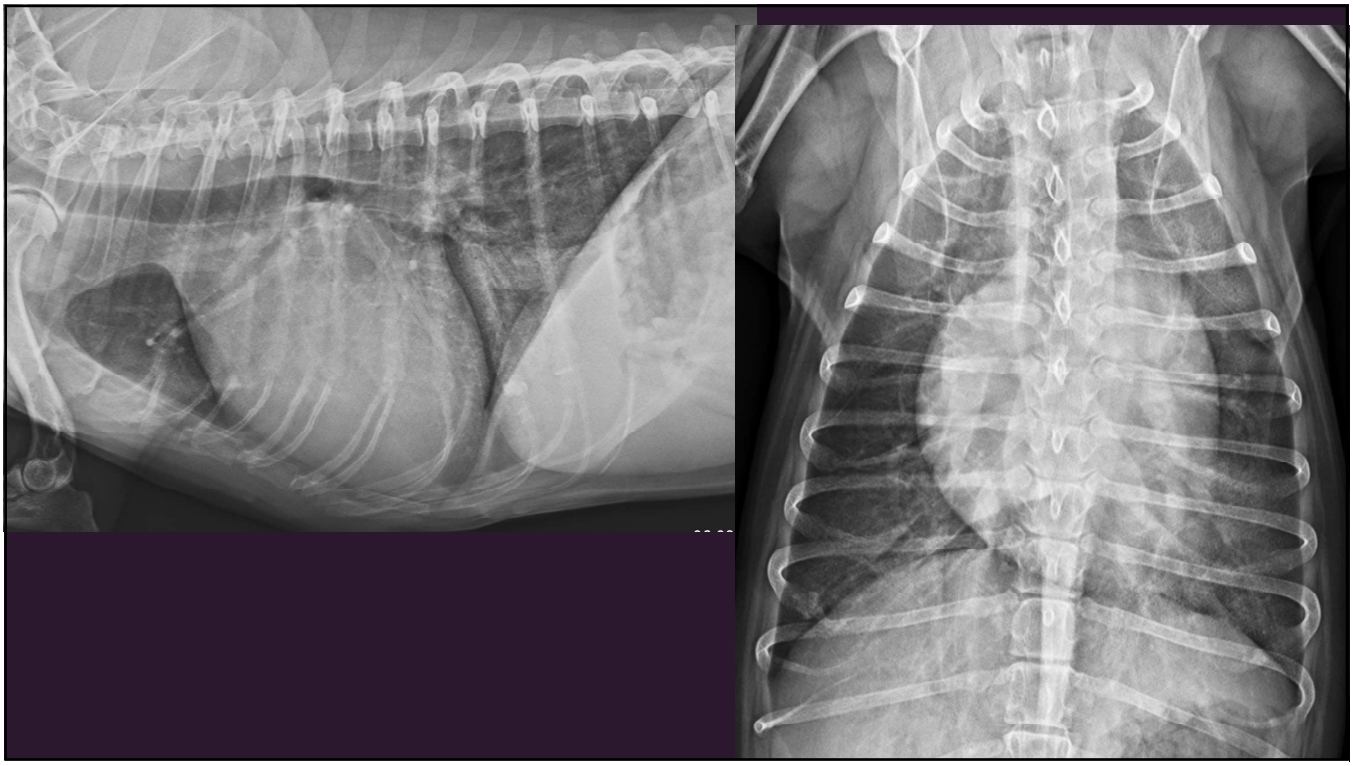

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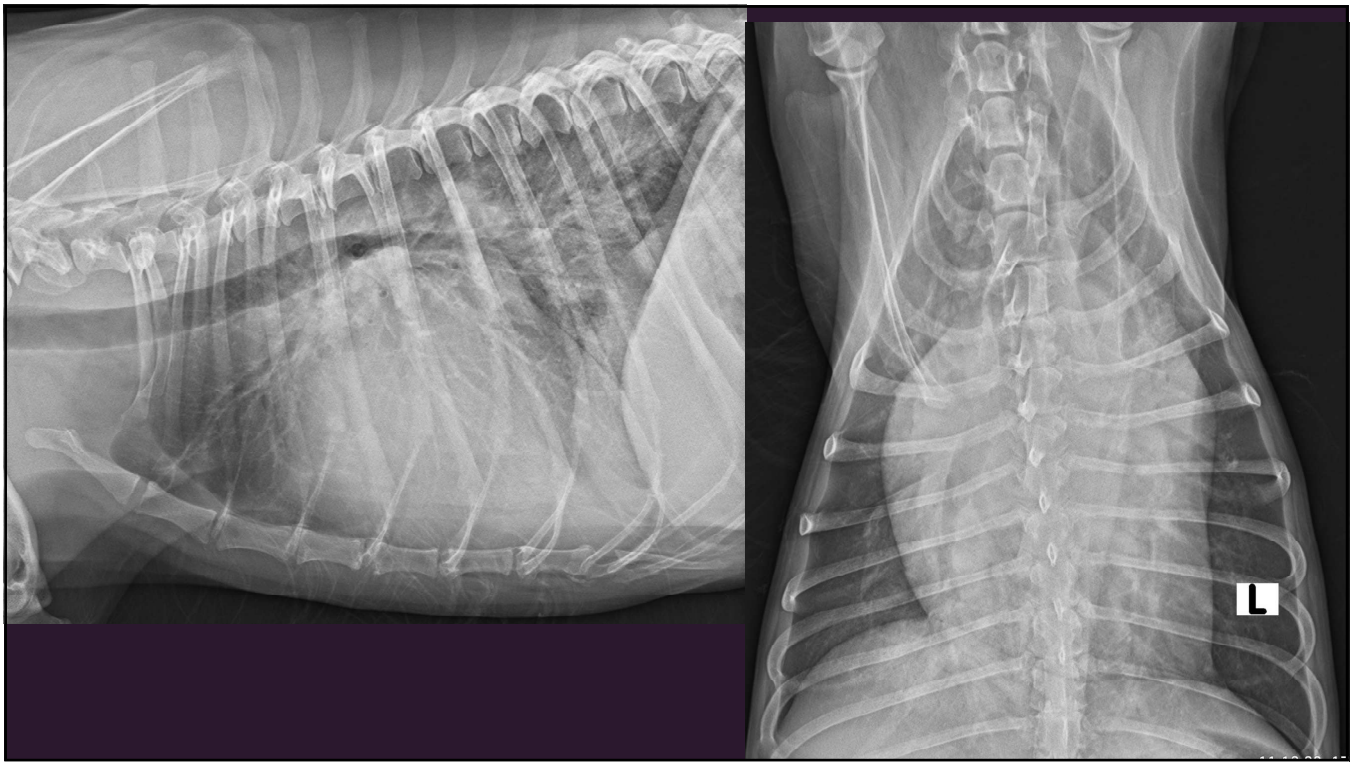

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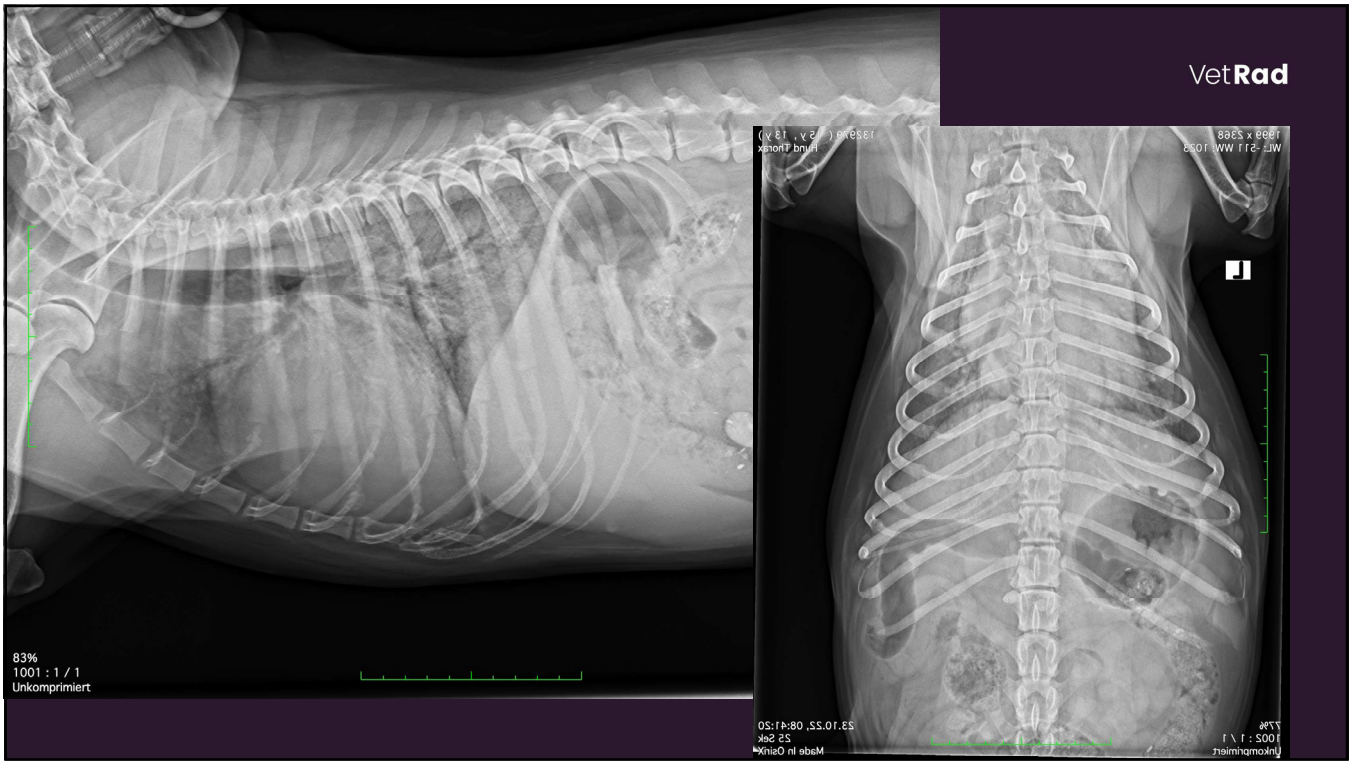

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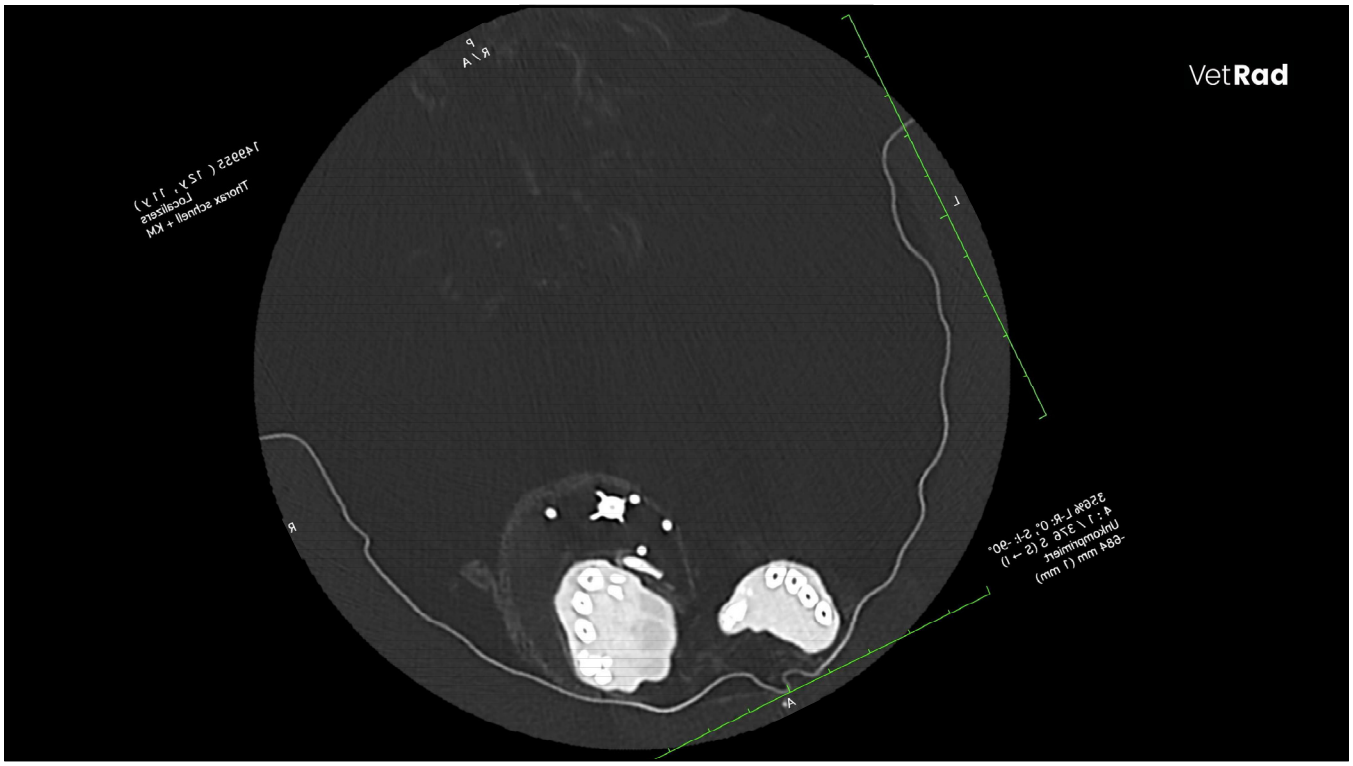

24

Radiographic findings

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- Cardiac enlargement (global or specific)
- Evidence of left atrial dilatation
- Vascular pattern: prominent pulmonary veins
- (pleural effusions)

25

Radiographic findings

VetRad

- Cardiac enlargement (global or specific)
- Evidence of **left atrial dilatation**

26

Is the heart too big?

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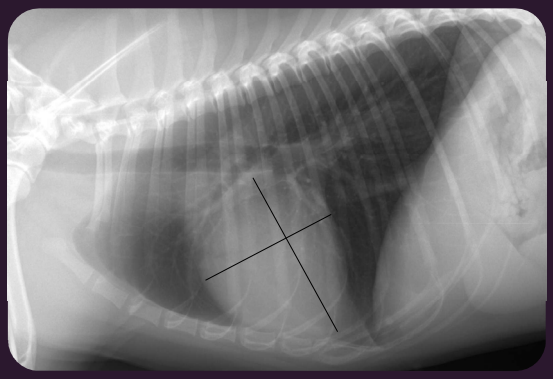
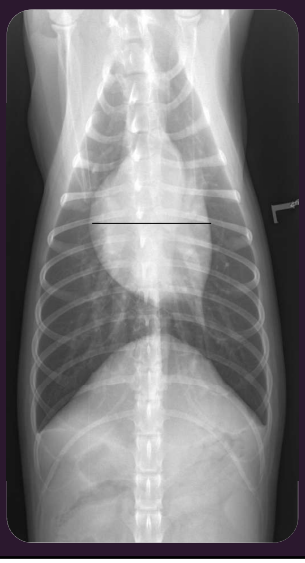


Dog: -3.5 IKR
70% H, 60–65% W

Cat: 2.5 IKR



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Assessment of (left atrial) enlargement

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- VHS (Vertebral Heart Scale):
  - Global heart size index
  - Well reproducible, but not chamber-specific
  - Dog: 8.4 to 10.5*

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Assessment of left atrial enlargement

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- VLAS (Vertebral Left Atrial Size):
  - Better correlation with echocardiographic LA enlargement
  - Specific: LA remodeling & volume overload
  - Informative for small dogs with MVDD
  - 1.8 to 2.3

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VHS

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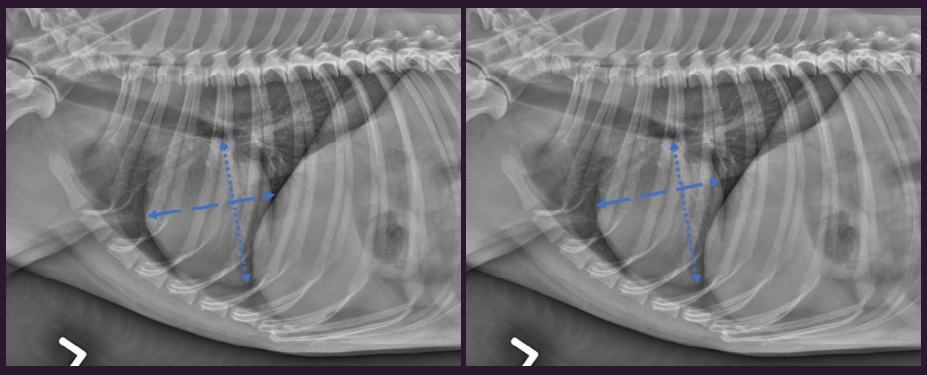

Buchanan JW, Bücheler J. Vertebral scale system to measure canine heart size in radiographs. *J Am Vet Med Assoc.* (1995)

Poad MH, Manzi TJ, Oyama MA, Gelzer ARU. Radiographic measurements to predict echocardiographic left heart enlargement in dogs with preclinical myxomatous mitral valve disease. *J Vet Intern Med.* (2020)

30

VHS – Significance

VetRad

- Mild systolic murmur (3/6 or higher)
- VHS ≥ 11.5:
  - MMVD B2 → ECHO or PIMO

ACVIM consensus guidelines for the diagnosis and treatment of myxomatous mitral valve disease in dogs **2019**

32

VLAS – Significance

VetRad

> J Am Vet Med Assoc. 2018 Oct 15;253(8):1038-1045. doi: 10.2460/javma.253.8.1038.

Diagnostic value of vertebral left atrial size as determined from thoracic radiographs for assessment of left atrial size in dogs with myxomatous mitral valve disease

Elizabeth L Malcolm, Lance C Visser, Kathryn L Phillips, Lynelle R Johnson

- VLAS is higher in B2, C, and D MMVD than in the control group and B1
- Moderate positive correlation between VLAS and LA:Ao
- VLAS ≥ 2.3 is a useful predictor of LA enlargement (AUC 0.85)
- Intraobserver and interobserver agreement for VLAS is high

- VLAS has reproducible predictive value for diagnosing LA enlargement in dogs with MMVD on radiographs = chamber-specific

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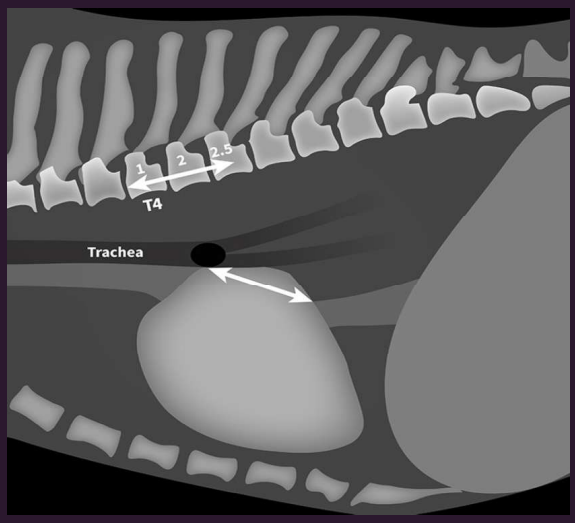
VLAS

- VLAS ≥ 2.3:
  - Enlargement of the left atrium
  - Hemodynamically significant MVDD
  - Stage B2



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VLAS – Significance

Variable	Control	Stage B1	Stage B2	Stage C-D
No. of dogs	15	40	26	22
Body weight (kg)	9.3 (5.4–27.2)	8.7 (5.7–27.3)	7.5 (5.4–13.2)	8.4 (4.8–10.9)
Age (y)	5.0 (2.4–11.0)	10.3 (8.5–13.3)*	11.1 (8.9–13.3)*	10.3 (7.7–11.8)*
No. (%) of females	9 (60)	20 (50)	14 (54)	13 (59)
Murmur grade (scale, 1–6)	2 (1–2)	3 (2–4)*	4 (3–4)*	4 (4–5)*†
LA:AoSx	1.3 (1.2–1.4)	1.4 (1.3–1.5)	2.0 (1.8–3.3)*†	2.6 (2.0–3.4)*†
LA:AoLx	2.3 (2.1–2.4)	2.5 (2.2–2.6)	3.3 (2.9–3.7)*†	4.1 (3.6–4.8)*†
VLAS (No. of vertebrae)	2.1 (1.8–2.3)	2.1 (2.0–2.4)	2.6 (2.3–2.9)*†	3.0 (2.7–3.6)*†

- Mild systolic murmur (3/6 or higher)
- VLAS ≥ 3:
  - MMVD B2 → ECHO or PIMO

ACVIM consensus guidelines for the diagnosis and treatment of myxomatous mitral valve disease in dogs **2019**

35

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J Vet Cardiol. 2022 Aug:42:23-33. doi: 10.1016/j.jvc.2022.05.003. Epub 2022 May 11.

Change of Vertebral Left Atrial Size in Dogs With Preclinical Myxomatous Mitral Valve Disease Prior to the Onset of Congestive Heart Failure

D Lee [1], T Yun [1], Y Koo [1], Y Chae [1], D Ku [1], D Chang [2], B-T Kang [1], M-P Yang [1], H Kim [3]

- VLAS higher in dogs with CHF (2.9 ± 0.4) vs. no CHF (2.6 ± 0.3), p = 0.028
- ΔVLAS/month: high diagnostic accuracy (AUC 0.91; p < 0.001) for predicting CHF within 180 days

→ VLAS and ΔVLAS/month can help identify dogs at risk for CHF early on.

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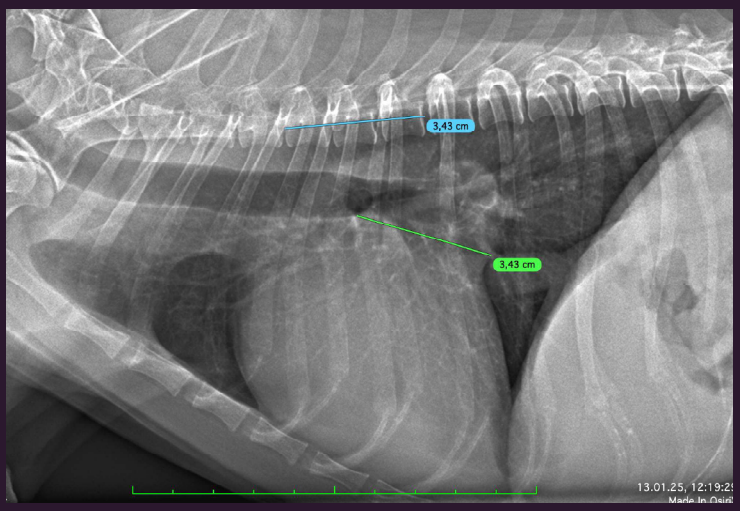
VLAS 3.0 – or: It's nice when the numbers prove us right!



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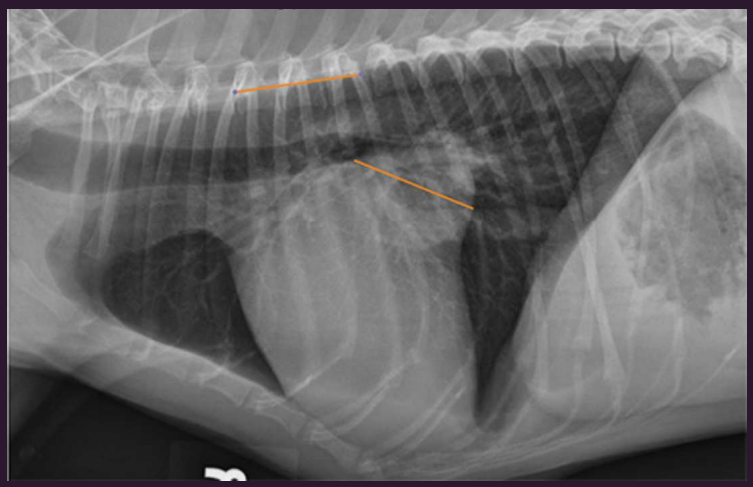
VLAS 2.8 – Wouldn't you want to treat it?



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Limitations

Sissi

- 8-year-old Labrador retriever
- Dyspnea following smoke inhalation

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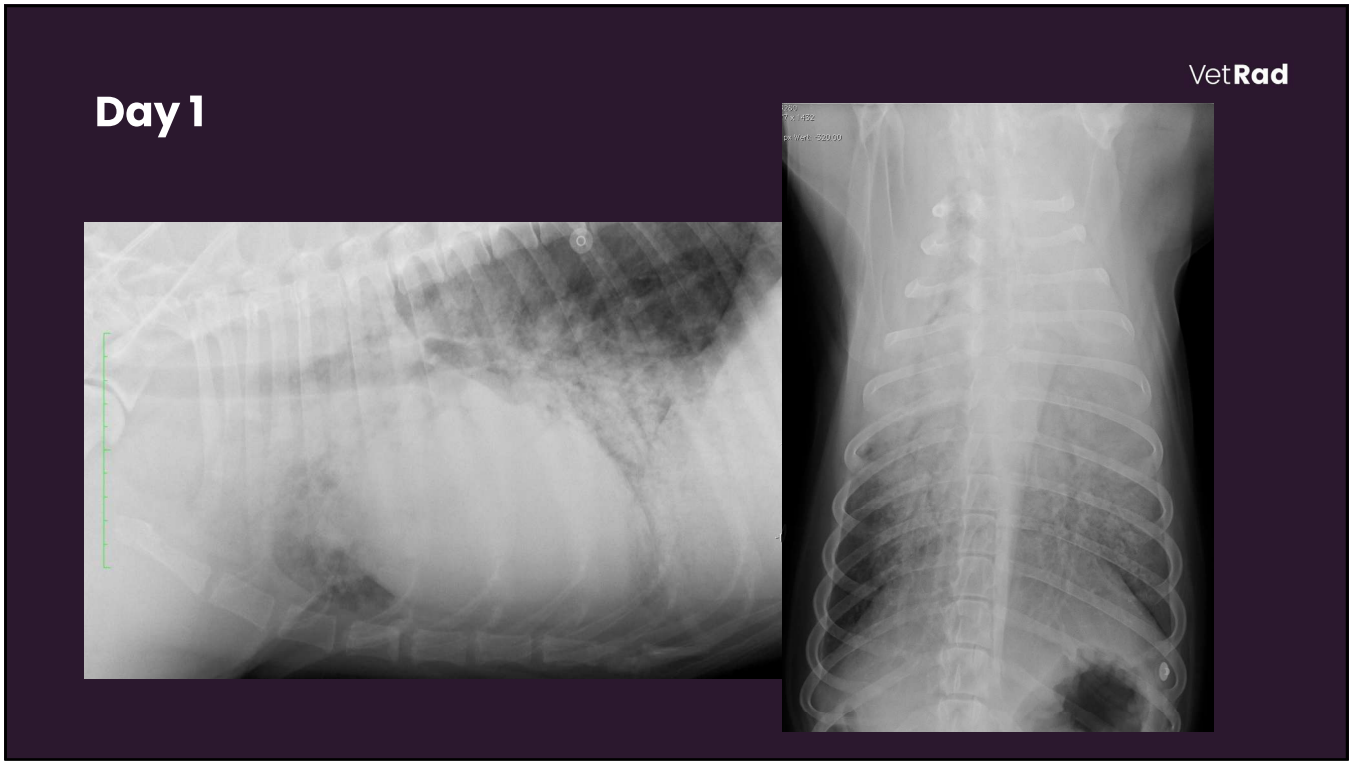

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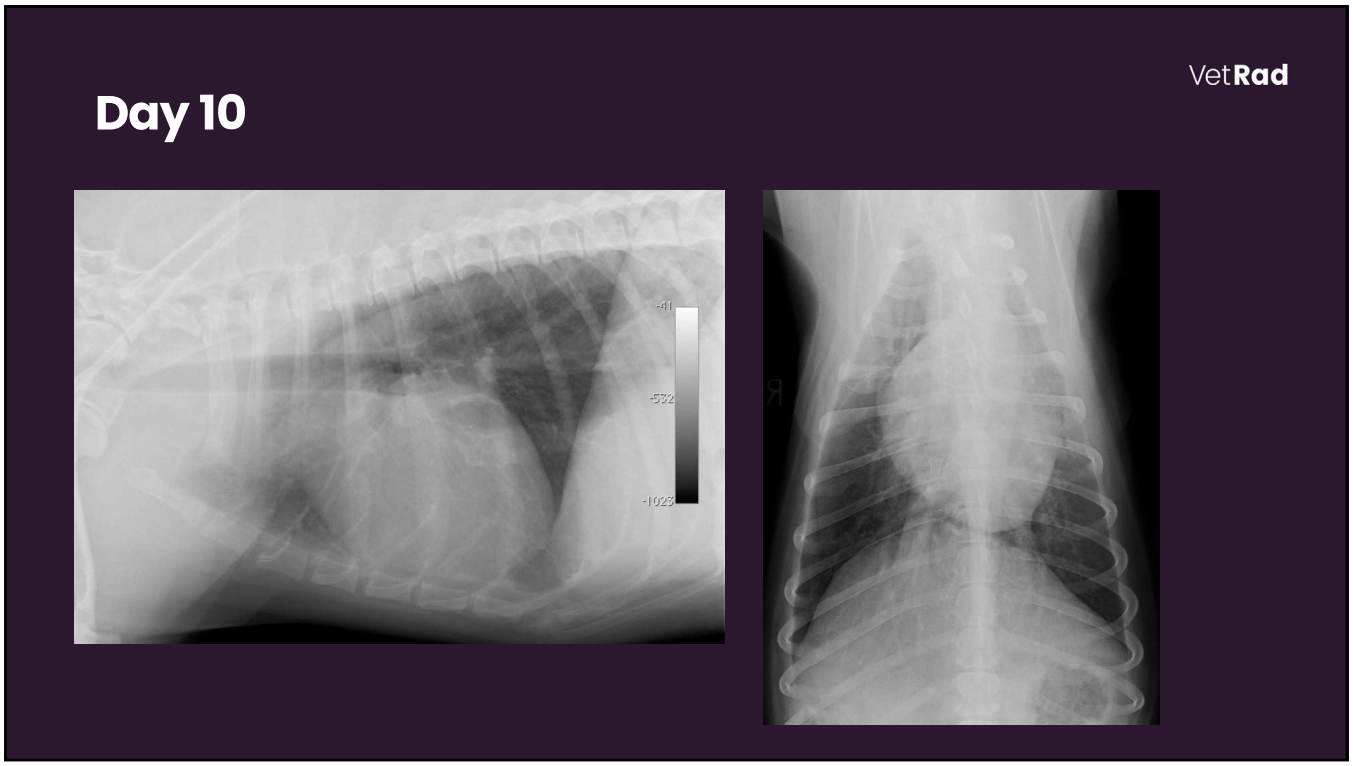

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Larger dogs?

J Vet Cardiol. 2022 Apr:40:126-141. doi: 10.1016/j.jvc.2021.07.003. Epub 2021 Aug 3.

Prediction of clinically important acquired cardiac disease without an echocardiogram in large breed dogs using a combination of clinical, radiographic and electrocardiographic variables

S Wesselowski [1], S G Gordon [2], N Meddaugh [2], A B Saunders [2], J Häggström [3], K Cusack [2], B W Janacek [2], D J Matthews [2]

- Accuracy of diagnosis of clinically relevant MVDD & DCM
  - VHS alone 0.861
  - VLAS alone 0.891
- Not suitable for diagnosing preclinical MVVD & DCM
- VHS/VLAS plus clinical findings & ECG: 0.978 (and 0.829 for preclinical DCM/MMVD)

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VHS & VLAS

- Summation, position-dependent,...
- VHS
  - Global
  - Better over time than a single measurement
  - Monitoring tool
- VLAS:
  - Ventricular-specific
  - Disease-specific (MMVD, DCM)
  - Accuracy in dogs weighing over 20 kg?

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Radiographic diagnosis of cardiomegaly in Dogs

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→ Combination of both values recommended

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Questions?

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Is the Cat's heart sick?

Cardiac decompensation or other pulmonary patterns

Nele Eley

DVM
DECVDI
Specialist in Radiology

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Introduction

- Abnormal radiographic findings in the lungs of cats = a challenge
- Cardiac decompensation is often nonspecific and variable
- Objective: typical/atypical patterns vs. differential diagnoses

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X-rays are essential

- Cat with respiratory symptoms
- -Cough
- Dyspnea / tachypnea / tachycardia
- Symptoms often nonspecific (lethargy, withdrawal, loss of appetite)
- May have no heart murmur (+/- 10%)

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An echocardiogram can do a lot

- **DOES** identify the underlying cardiac problem (structure & function)
- **DOES** identify prognostic indicators
- **DOES** help determine if CHF is a likely cause of pulmonary infiltrate
- **DOES** identify pericardial (& pleural) effusions
- **DOES** NOT usually diagnose pulmonary edema* *Ultrasound can generally help diagnose this (sometimes), but very limited assessment of DDx

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Cat infiltrates

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- Always with an interstitial component
- Often combined with alveolar infiltrates
- (Rarely a bronchial component)

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Problem: Topography of cardiac pulmonary edema

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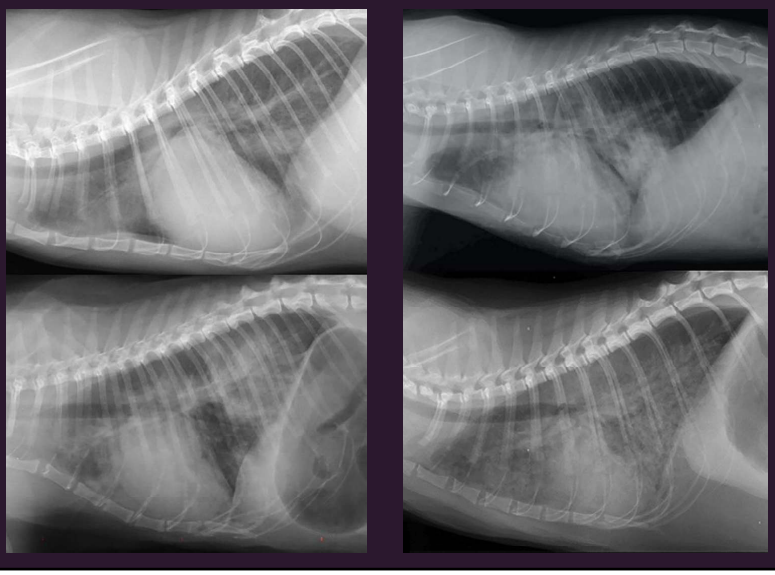
- Variable



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Radiological patterns of cardiac pulmonary edema

- Variable

→Concomitant findings are particularly important:
  - Cardiomegaly (LA)
  - Vessels
  - Pleural effusion particularly important

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Cardiomegaly

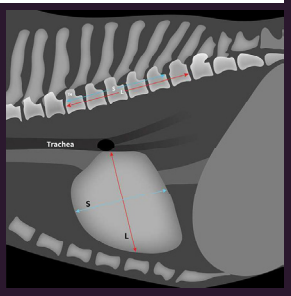
- VHS ≤ 7.9
- Overall Sensitivity 0.86
- Overall specificity 0.82

- Cardiomegaly in cats with left heart failure is reliably detectable on X-ray

J Feline Med Surg. 2014 Oct;16(10):812-25. doi: 10.1177/1098612X14522048. Epub 2014 Feb 11.

Diagnostic accuracy of the vertebral heart score and other radiographic indices in the detection of cardiac enlargement in cats with different cardiac disorders

Carlo Guglielmini [1], Marco Baron Toaldo [2], Helen Poser [3], Giulio Menciotti [3], Mario Cipone [2], Alessia Cordella [2], Barbara Contiero [3], Alessia Diana [2]



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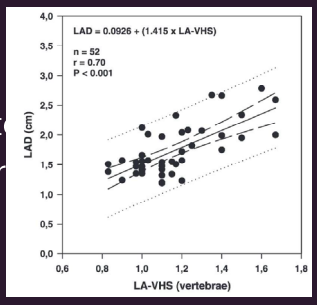
Left Atrium

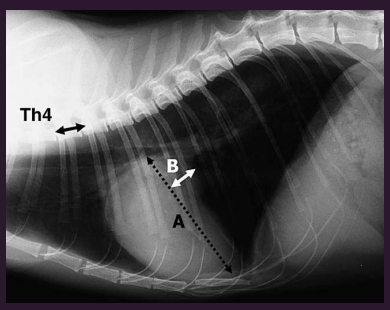
- LA-VHS 0.75–1.3
- LA enlarged from 1.3
- Sens 0.28 – 0.72
- Spec 0.74 – 0.95
- Sens subjectively bett
- Spec. subjectively wor

Comparative Study > J Vet Intern Med. 2007 Jul-Aug;21(4):709-18.
doi: 10.1892/0891-6640(2007)21[709:daoeat]2.0.co;2.

Diagnostic accuracy of electrocardiography and thoracic radiography in the assessment of left atrial size in cats: comparison with transthoracic 2-dimensional echocardiography

Karsten E Schober [1], Imke Maerz, Eberhard Ludwig, Joshua A Stern





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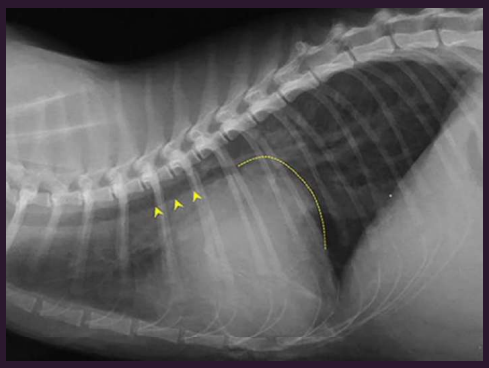
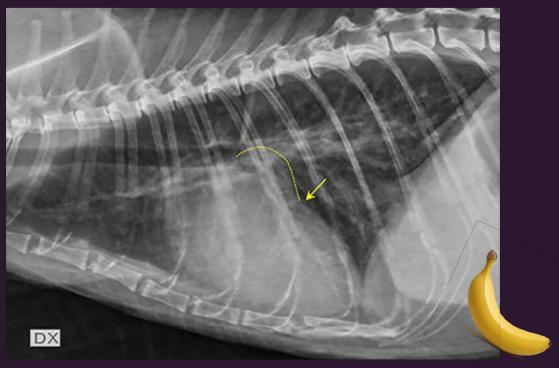
Left atrium

- Subjective enlargement in 80% of cats with left heart failure
  Mass effect on the left atrium or concave caudal cardiac contour





Diana et al, Radiographic features of cardiogenic pulmonary edema in cats with left-sided cardiac disease JFMS 2022

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Left atrium

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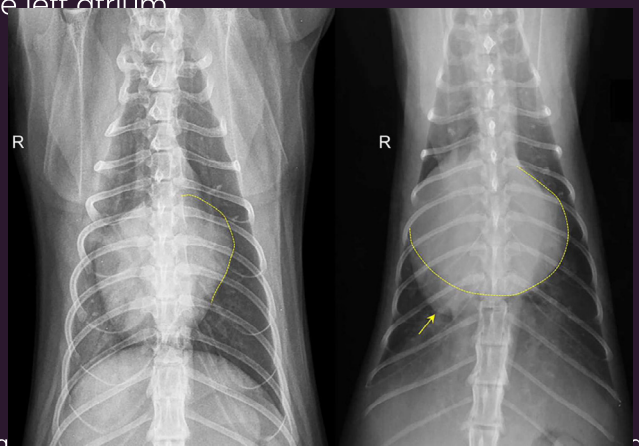
- Subjective enlargement in 80% of cats with left heart failure
  Mass effect on the left atrium



Diana et al, Radiographic features of cardiogenic pulmonary edema in cats with left-sided heart disease JFMS 2022

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Pulmonary vessels

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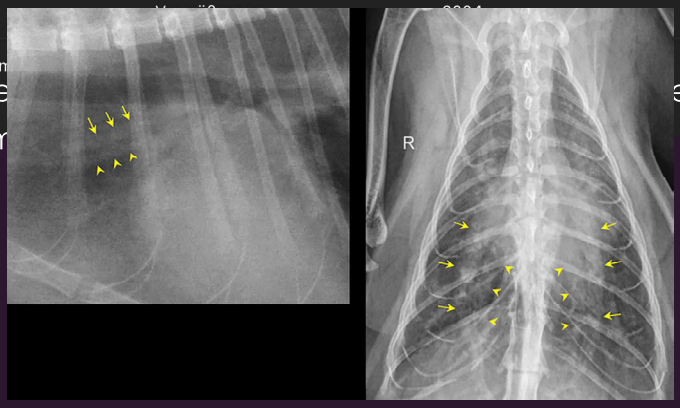
Cranial Pulmonalvene : 4. Rippe	Mittelwert ~0,54 (±0,13)	> ~0,7 → vergrößert (CHF)	Smith et al., AJVR 2023
Cranial Pulmonalarterie : 4. Rippe	Mittelwert ~0,70 (±0,13)	>1,0 → verdächtig auf	Sleeper et al., Vet Radiol Ultrasound
Caudale Pulmonalvene	< 5,3 mm		

- Dilated pulmonary vesse
- Significantly more comm
- Optimistic?



Diana et al, Radiographic features of cardiogenic pulmonary edema in cats with left-sided heart disease JFMS 2022

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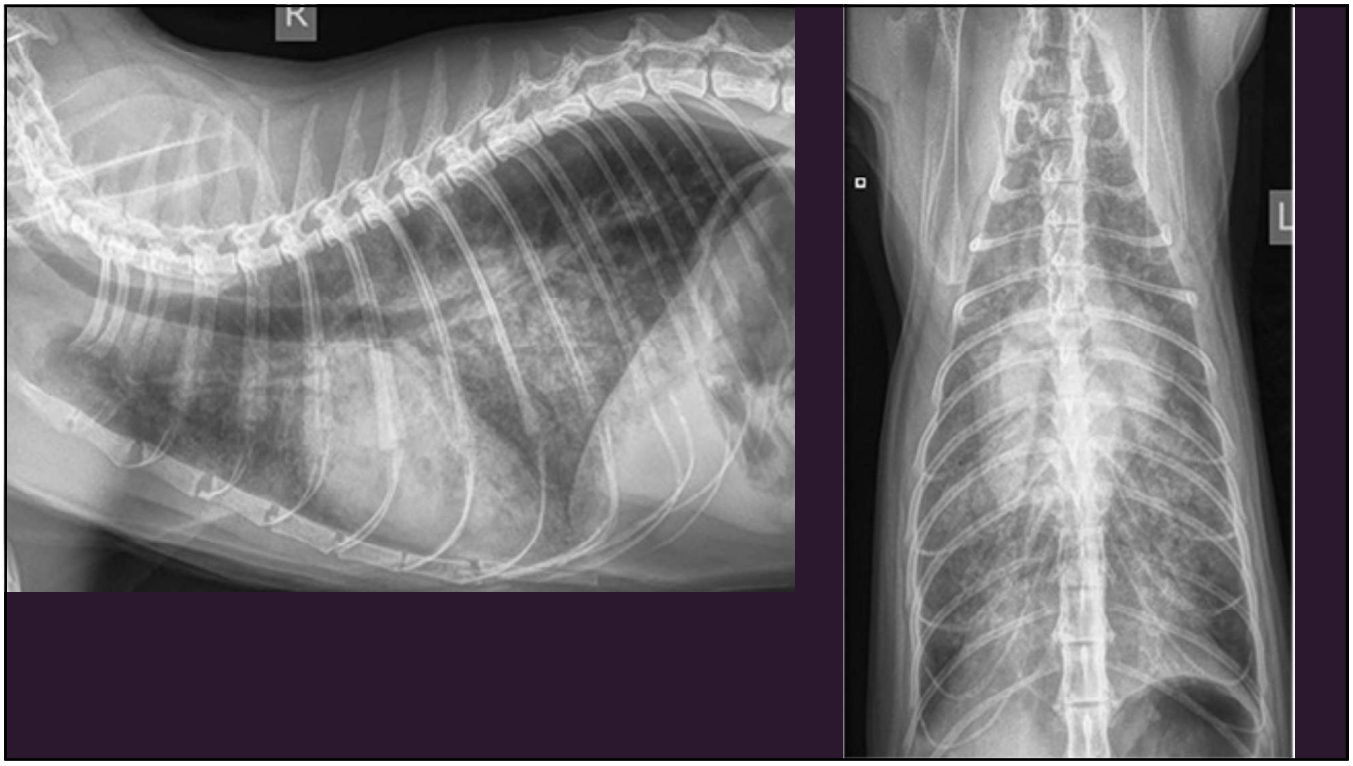

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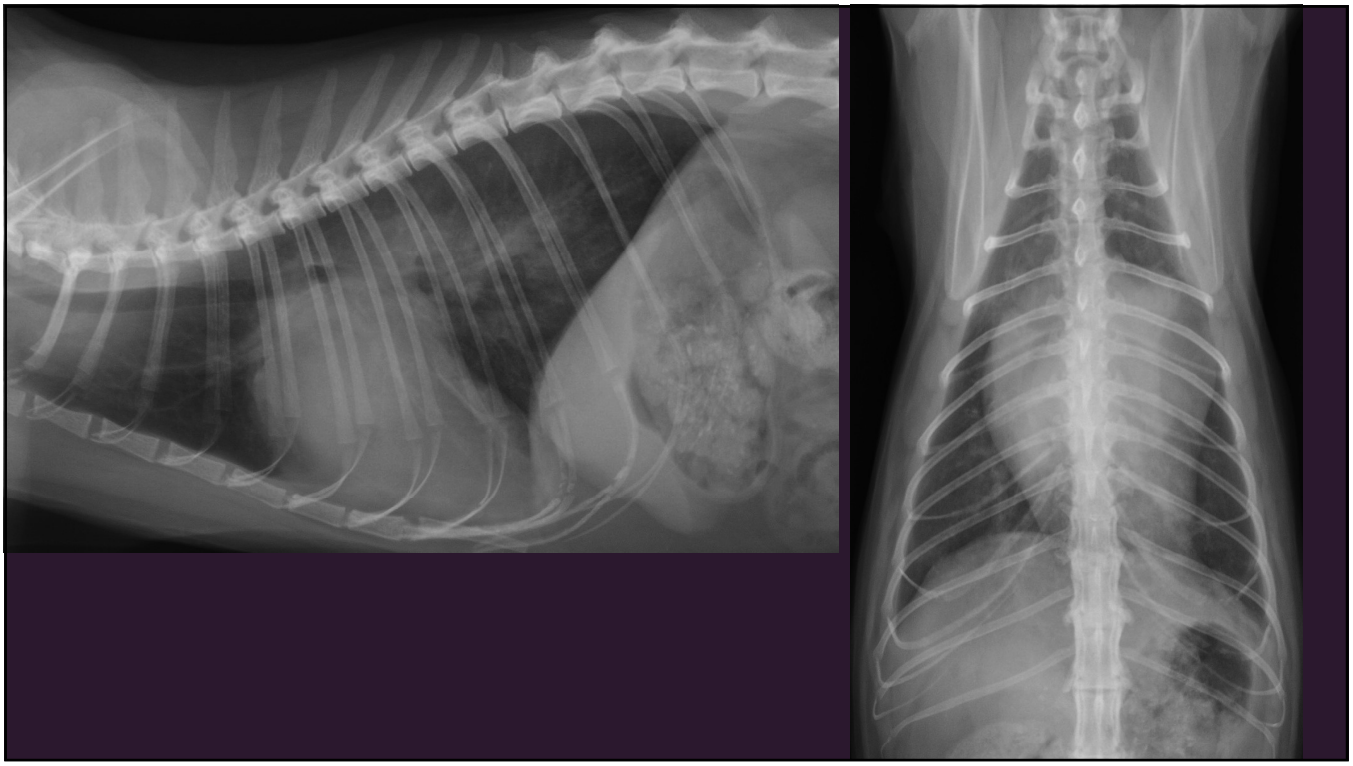

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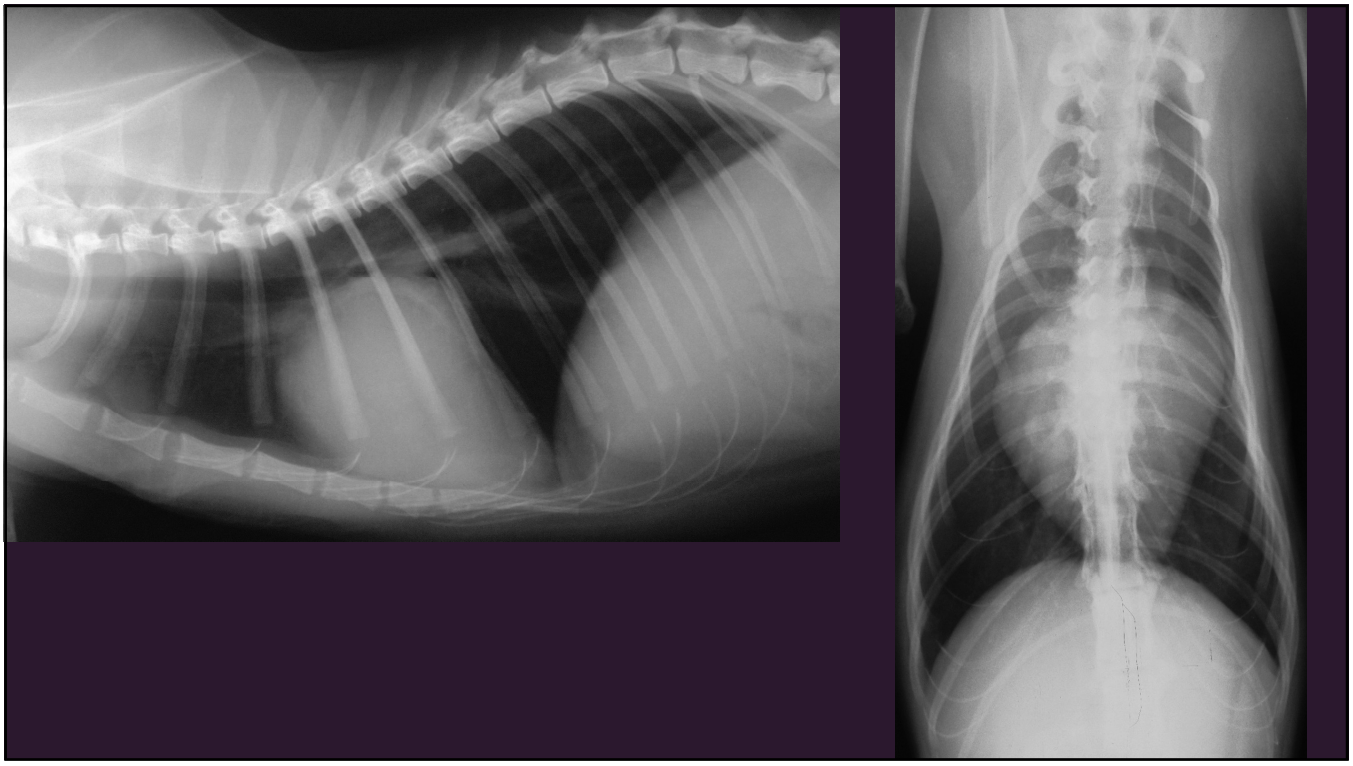

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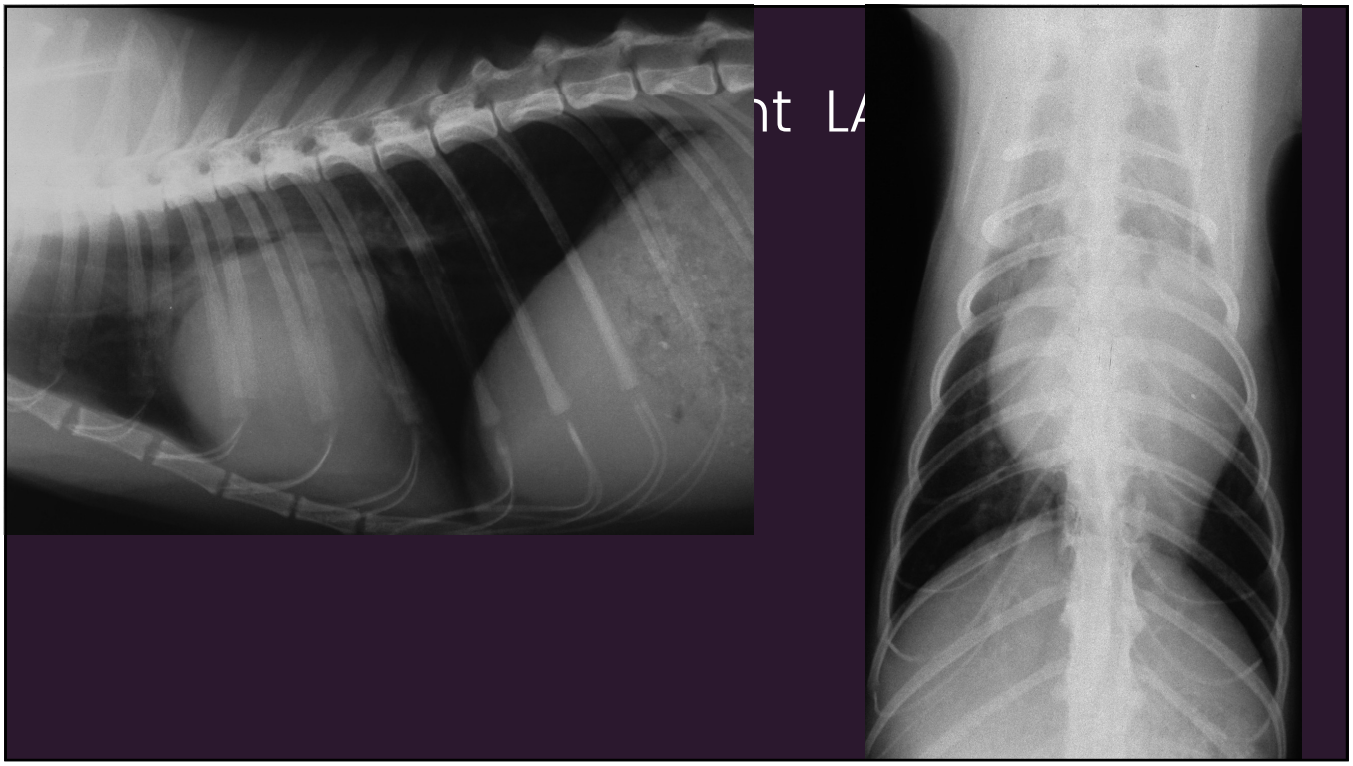

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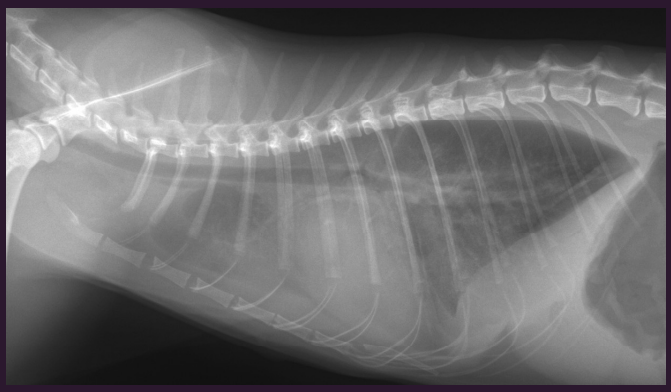
Pleural effusion



- Minor effusion > 50% of cats with left-sided heart failure

Diana et al, Radiographic features of cardiogenic pulmonary edema in cats with left-sided cardiac disease JFMS 2022

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Limitations of X-ray diagnostics

- Low sensitivity = false-negative findings
- Left heart failure in cats is possible without radiographically detectable LA enlargement
- Cardiomegaly & LA enlargement not 100% reliable, yet the most robust radiographic findings
- LA enlargement is radiographically detectable in up to 80% of cases

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Pitfalls

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- Subtle radiographic findings, possibly masked by effusions
- Taking only ONE view for the diagnosis of pulmonary edema and/or pleural effusion
  - Note: ONE X-ray is better than NONE
- Uncertainty in the assessment of pulmonary vessels
- Lack of reference to medical history and pulmonary embolism
- Lack of follow-up on treatment to be considered
  - RR ↓ and radiological improvement within 24 hours
- **Forgetting that cats can have left-sided CHF without cardiomegaly, especially without enlargement of the left atrium**

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Differential Diagnoses

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- Feline asthma (bronchial)
- Non-cardiogenic pulmonary edema
- Pneumonia (viral/bacterial)
- Neoplasia

66

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MOSHI CASE 1 – 11-year-old male European Shorthair

- Lethargy for 2 days, ↓ appetite today
- PB reports that the cat is "paranoid"

- HR 220 – Normal sinus rhythm; 2/6 parasternal heart murmur, systolic, strong synchronous pulses
- AF 50 ↑
- Increased respiratory sounds bilaterally, no crackles or rales

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MOSHI FALL 1 – 11J MK EKH

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MOSHI FALL 1 – 11J MK EKH

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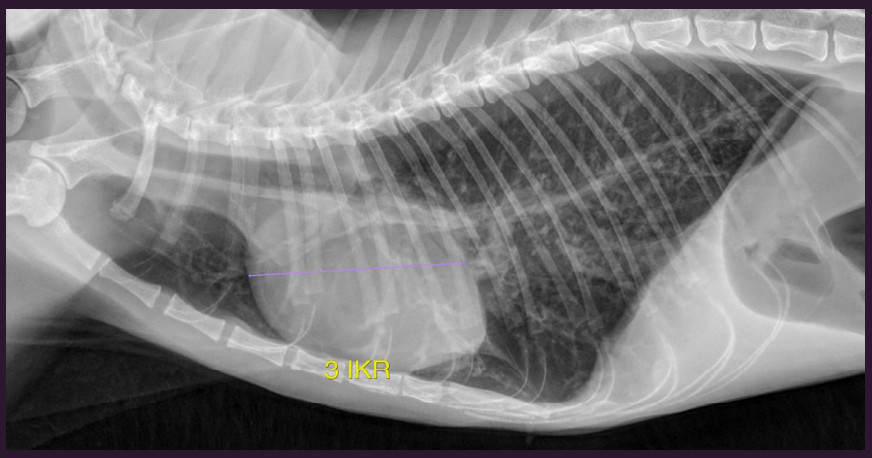

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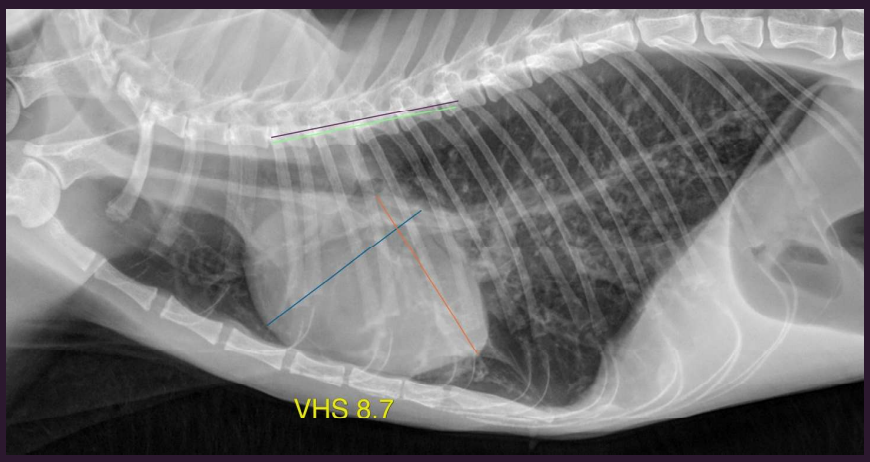
MOSHI FALL 1 – 11J MK EKH

VetRad



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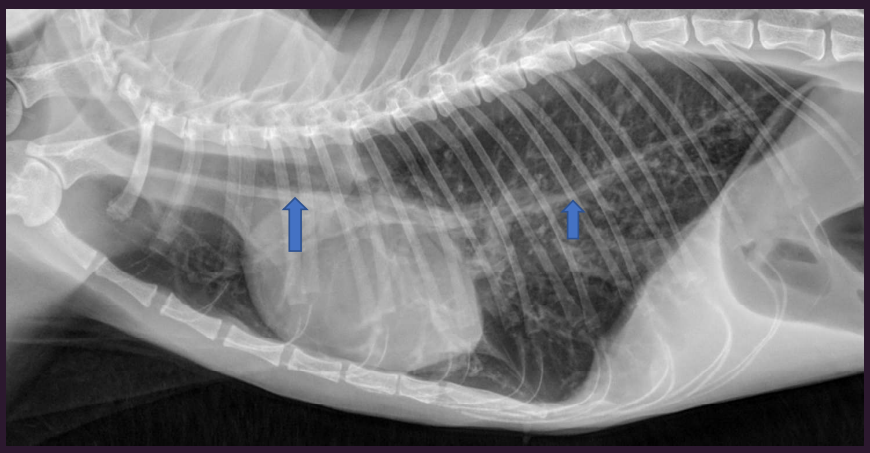
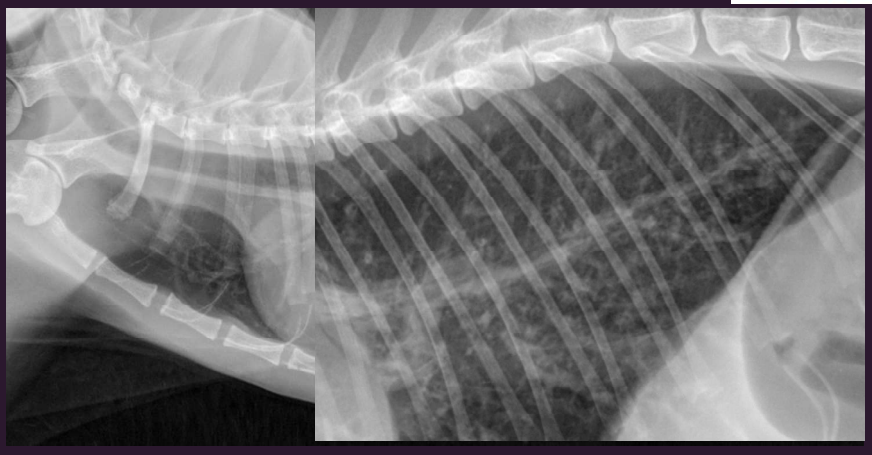


71

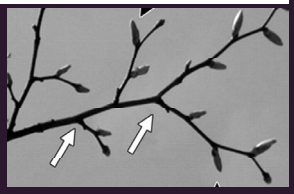
MOSHI FALL 1 – 11J MK EKH



Comparative Study > Vet Radiol Ultrasound. 2018 Jan;59(1):32-42.doi: 10.1111/vru.12564. Epub 2017 Oct 9.

The computed tomographic "tree-in-bud" pattern: Characterization and comparison with radiographic and clinical findings in 36 cats

Harriet Hahn [1], Swan Specchi [2], Isabelle Masseau [3], Carol Reinero [4], Ghita Benchekroun [5], Jaime Rechy [6], Gabriela Seiler [6], Pascaline Pey [1]



72

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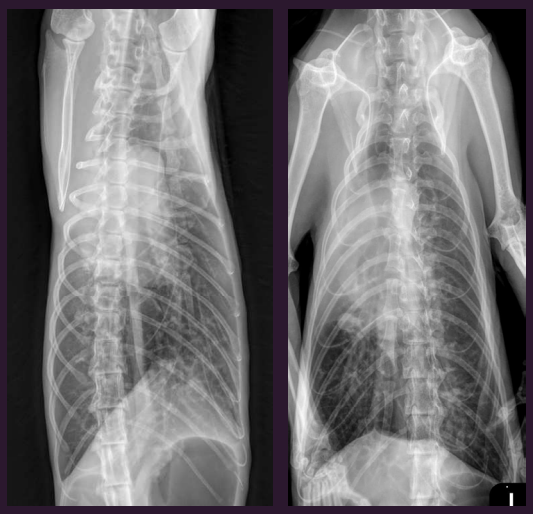
MOSHI FALL 1 – 11J MK EKH



73

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MOSHI CASE 1 – 11-YEAR-OLD MALE, CHILD

X-ray diagnosis

- Diffuse bronchial pattern
- “Air trapping”
- "Tree in bud"
- Hyperinflation
- + / - Cardiomegaly? Position-dependent / lobar atelectasis
- No evidence of left heart failure

74

VetRad

MOSHI CASE 1 – 11-YEAR-OLD MALE CAT

Key Points

- The bronchial pattern is atypical for pulmonary edema without a concurrent interstitial pattern.
- Is the heart murmur physiological? Temporary? Stress & high heart rate? What is its significance in the absence of cardiomegaly?
- Echocardiogram as baseline, to rule out cardiomyopathy
- *Steroids can lead to fluid overload, so use them systemically only with caution in pets with known heart disease.

75

VetRad

> J Feline Med Surg. 2022 Dec;24(12):e568-e579. doi: 10.1177/1098612X221121922. Epub 2022 Nov 9.

Radiographic features of cardiogenic pulmonary oedema in cats with left-sided cardiac disease: 71 cases

Alessia Diana [1], Simone Perfetti [1], Carlotta Valente [2], Marco Baron Toaldo [1 3], Pascaline Pey [1 4], Mario Cipone [1], Helen Poser [2], Carlo Guglielmini [2]

cats on right lateral and ventrodorsal or dorsoventral views, respectively. Interstitial (57.8%) and mixed interstitial-alveolar (38%) pattern, multifocal (84.5%) and symmetrical (75%) distribution with prevalent ventrocaudal (65.6% of cats) and ventrocranial (60.9% of cats) locations were most

> J Small Anim Pract. 2009 Jan;50(1):9-14. doi: 10.1111/j.1748-5827.2008.00655.x. Epub 2008 Aug 13.

Radiographic appearance of cardiogenic pulmonary oedema in 23 cats

L Benigni [1], N Morgan, C R Lamb

associated with a range of patterns and variable distribution. All cats had evidence of a reticular or granular interstitial pattern. This occurred in combination with alveolar pattern in 19 (83 per cent) cats, including six with air bronchograms, with increased diameter of pulmonary vessels in 16 (71 per cent) cats and with bronchial pattern in 14 (61 per cent) cats. The distribution of pulmonary

76

MAX CASE 2 – 6-year-old male, ECG

VetRad

- Presented with ↑ respiratory rate & labored breathing

- Abnormal breathing since this morning
- Progressed to ↑ malaise and lethargy over the course of the day
- Episode of vomiting 3 weeks ago
- Refused food today

77

MAX FALL 2–6J MK EKH

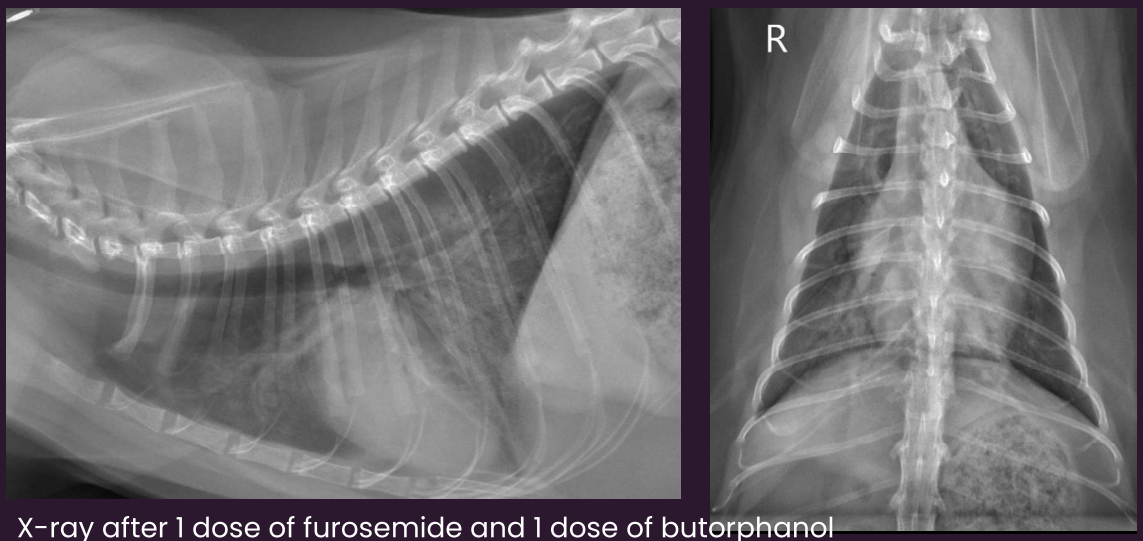
VetRad

- Klin US
- T – Standard
- P – 180
- AF – 150 bpm
- BCS 7/9
- HR < 2 sec.
- Regular rhythm with intermittent gallop; 3/6 left parasternal systolic murmur; strong synchronous pulses
- Tachypnea, dyspnea with an abdominal component

78

MAX CASE 2 – 6-year-old mc DSH

VetRad

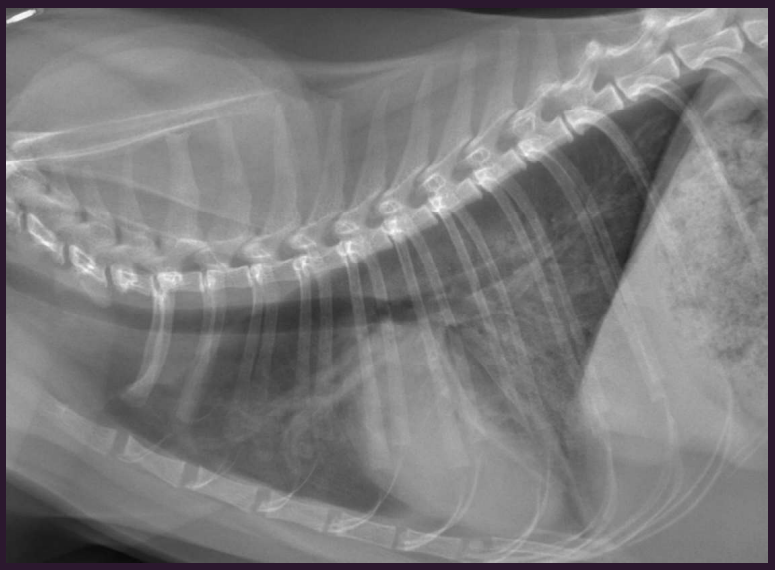


X-ray after 1 dose of furosemide and 1 dose of butorphanol

79

MAX CASE 2 – 6-year-old mc DSH

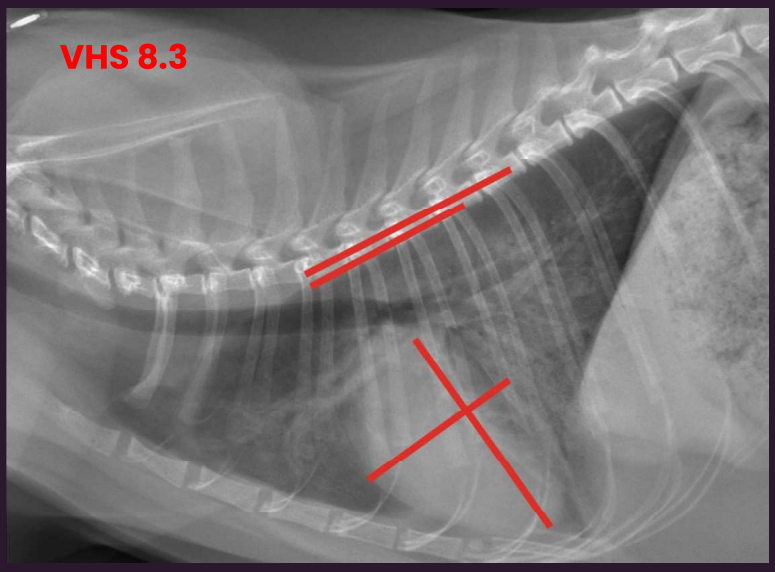
VetRad



80

MAX CASE 2 – 6-year-old mc DSH

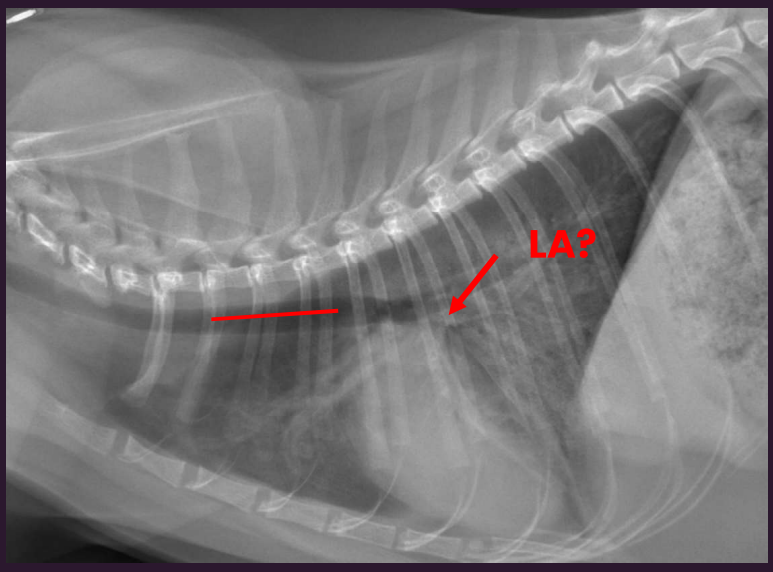
VetRad



81

MAX CASE 2 – 6-year-old mc DSH

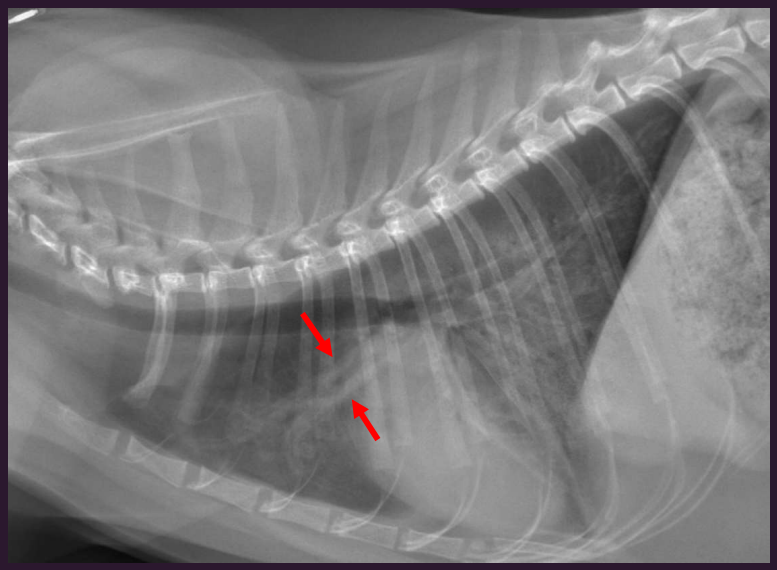
VetRad



82

MAX CASE 2 – 6-year-old mc DSH

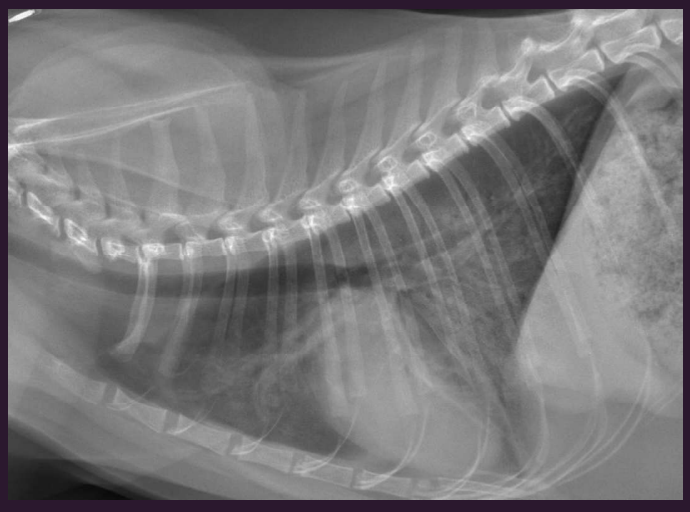
VetRad



83

MAX CASE 2 – 6-year-old mc DSH

VetRad



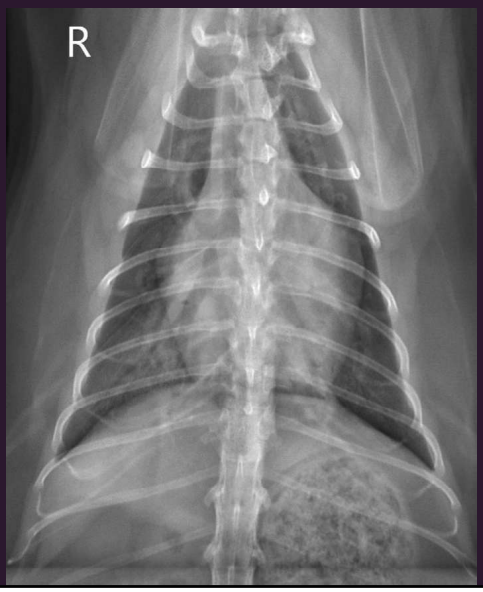
Interstitial infiltrates: diffuse, bilateral, accentuated in the ventral region

84

MAX CASE 2 – 6-year-old mc DSH

VetRad

- Significant effusion
- Caudal pulmonary vessels?

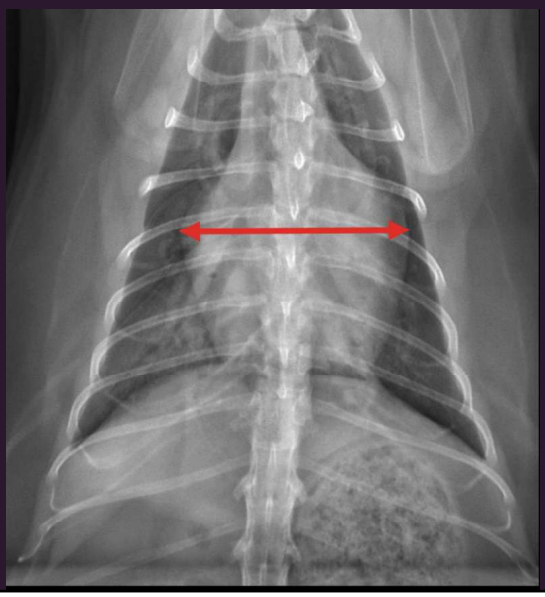


85

MAX CASE 2 – 6-year-old mc DSH

VetRad

- Generalized enlargement
- Valentine
- Biatrial??
- Double outline? Bold?



86

MAX CASE 2 – 6-year-old mc DSH

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Radiographic diagnoses

- Cardiomegaly with LV & LA or biatrial enlargement
- Diffuse, predominantly interstitial infiltrates
- Most likely cardiomyopathy with cardiogenic pulmonary edema
- Minor pleural effusion

Echo: HCM, mild PE

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MAX CASE 2 – 6-year-old mc DSH

VetRad

Takeaway

- Pulmonary vessels may be obscured by infiltrates and/or ↓ in size after diuretics
- DV projections particularly helpful
- Missing key component = tachycardia
- Cardiac arrhythmias? Irregular heart rate—early response to therapy vs. just before further decompensation..?
- Pericardial fat?

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MIMI CASE 3 – 8-year-old female European Shorthair

- Reason for presentation: Lethargy, anorexia, wheezing
- Loss of appetite
- Mucous nasal discharge
- Sneezing
- No improvement with antibiotics

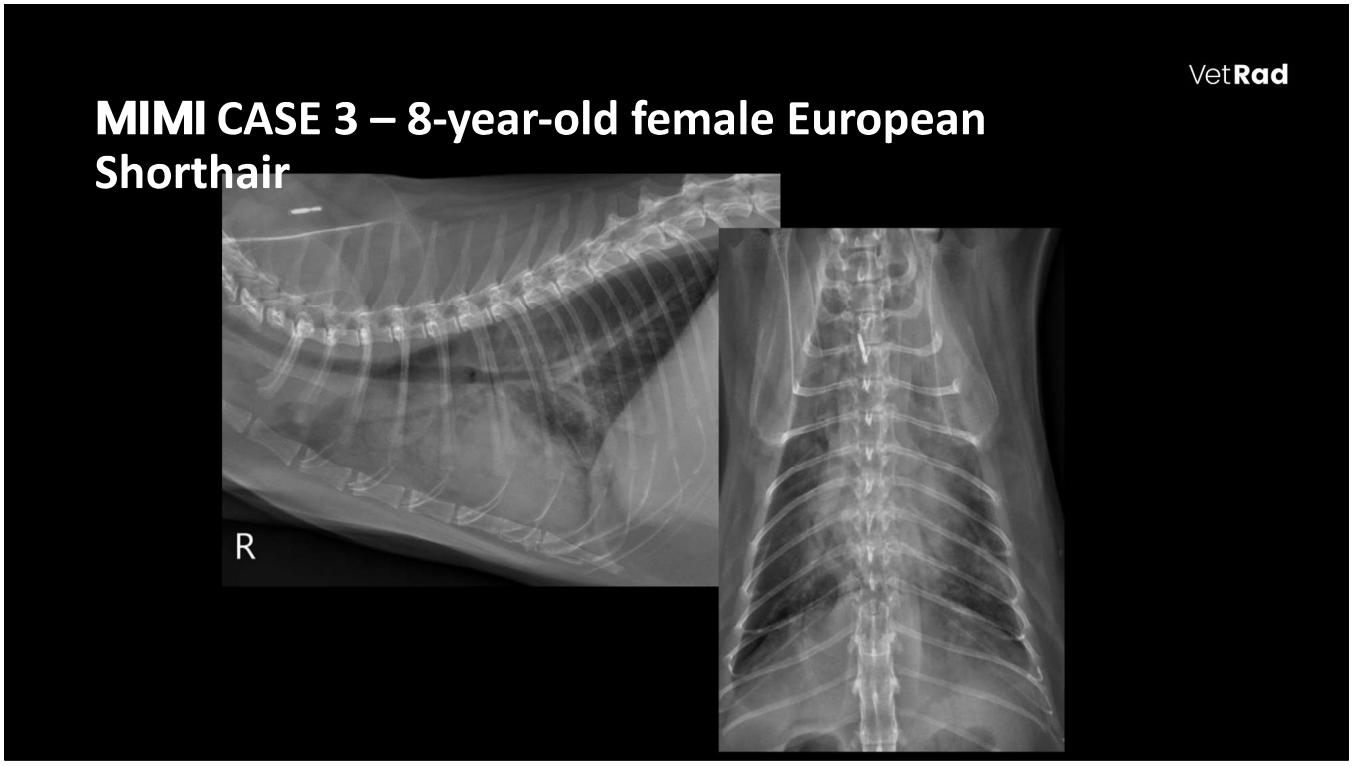
89

VetRad

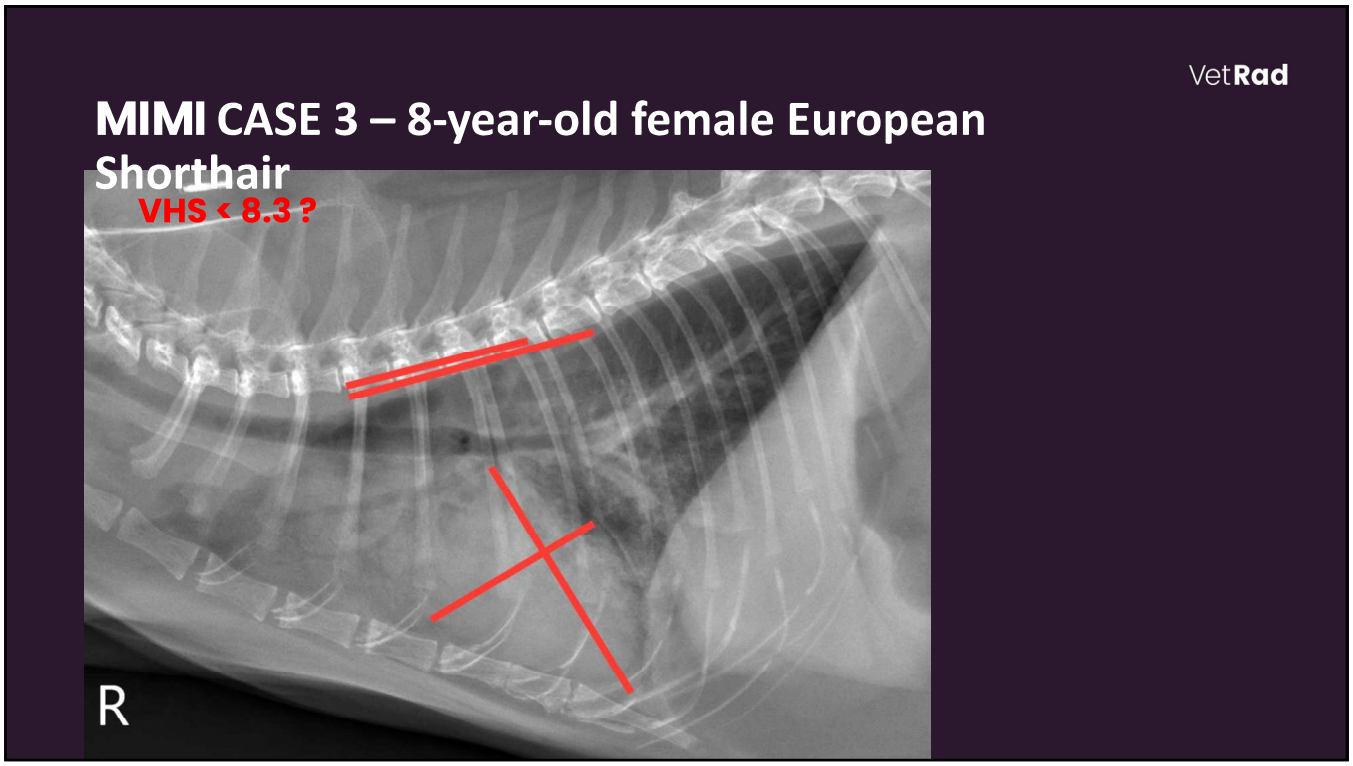
MIMI CASE 3 – 8-year-old female European Shorthair

- P – 160 bpm
- AF – 56 bpm
- BCS 6/9
- HR < 2 sec
- No heart murmur
- Dyspnea, crackles & rales bilaterally
- Lateral recumbent position

90


VetRad
MIMI CASE 3 – 8-year-old female European Shorthair
R

91


VetRad
MIMI CASE 3 – 8-year-old female European Shorthair
VHS < 8.3 ?
R

92

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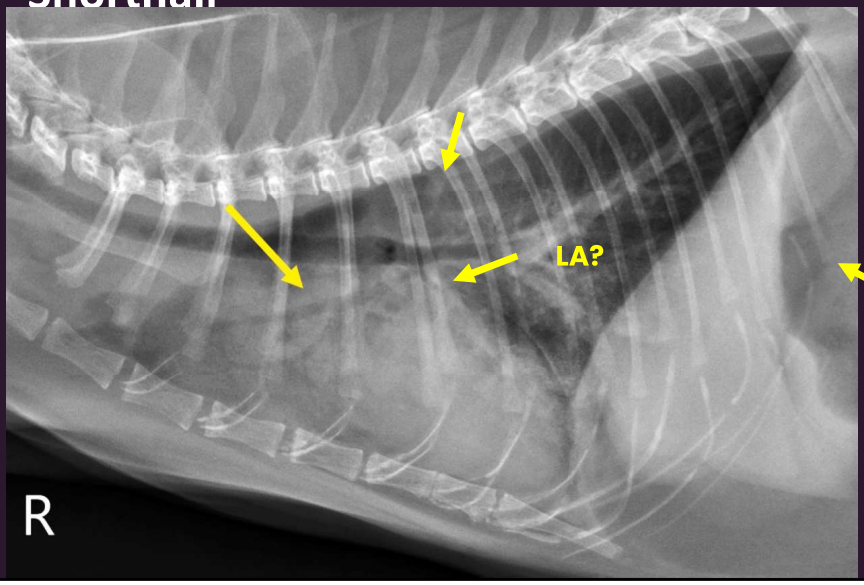
MIMI CASE 3 – 8-year-old female European Shorthair



Pulmonary vessels?
- Pleural effusion
- Trachea?

93

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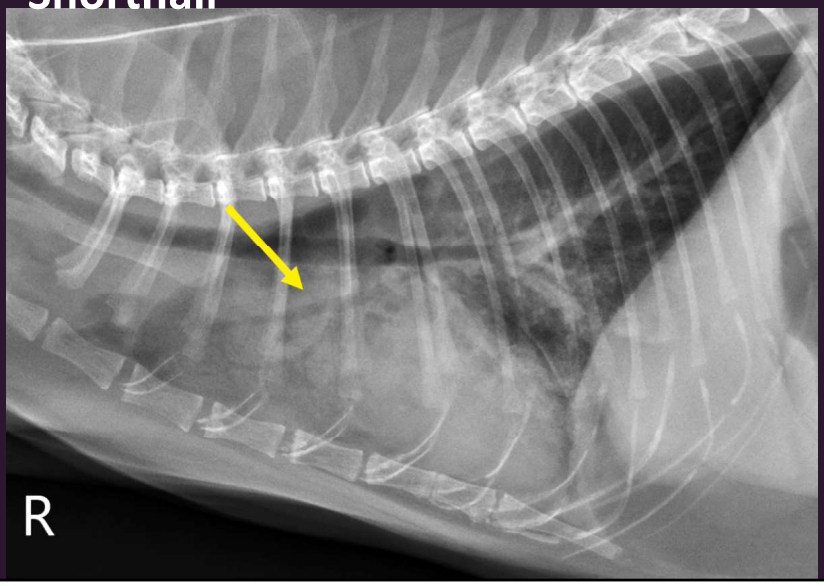
MIMI CASE 3 – 8-year-old female European Shorthair



- Mixed infiltrates
- Bronchograms

94

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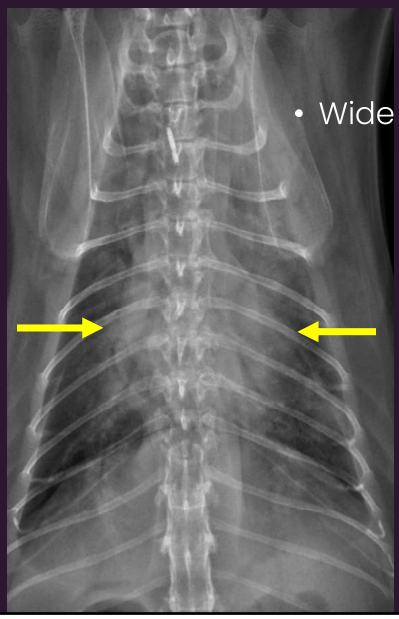
MIMI CASE 3 – 8-year-old female European Shorthair



- Wide heart-shaped silhouette
- difficult to define

95

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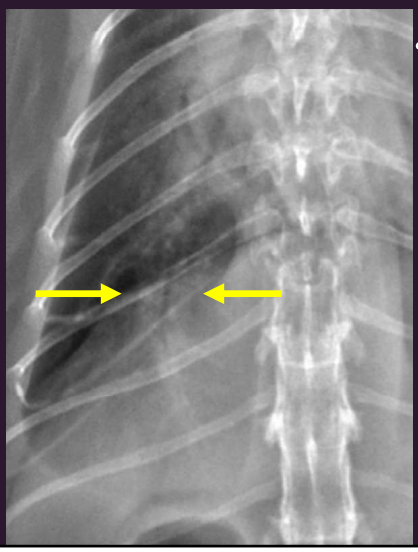
MIMI CASE 3 – 8-year-old female European Shorthair



- Dilated pulmonary vessels

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MIMI CASE 3 – 8-year-old female European Shorthair

X-ray diagnosis:

Primarily congestive heart failure with cardiogenic pulmonary edema and pleural effusion

No improvement with oxygen supplementation and repeated administration of furosemide (total 17.5 mg)

Echo: mild unclassified mitral valve disease – findings do not explain the pulmonary infiltrates

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MIMI CASE 3 – 8-year-old female European Shorthair

Takeaway

- A lack of response to diuretic therapy should lead to a broader differential diagnosis.
- *In this case, severe azotemia, hypokalemia → acute uremic pneumonitis?
- Other differential diagnoses: ARDS, infectious bronchopneumonia,...
- Cardiac arrest; unfortunately, no definitive diagnosis

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So what should you add to your cart?

VetRad

Minimum
- Medical history
- Physical examination
- X-ray
- Echocardiogram

99

What else can be added to the cart?

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- Point-of-Care Ultrasound
  - Ruling out pleural effusion & thoracentesis if necessary
- Stabilization of the patient
- Lung expansion → improves the diagnostic quality of X-rays

→ X-ray
→ Ultrasound

100

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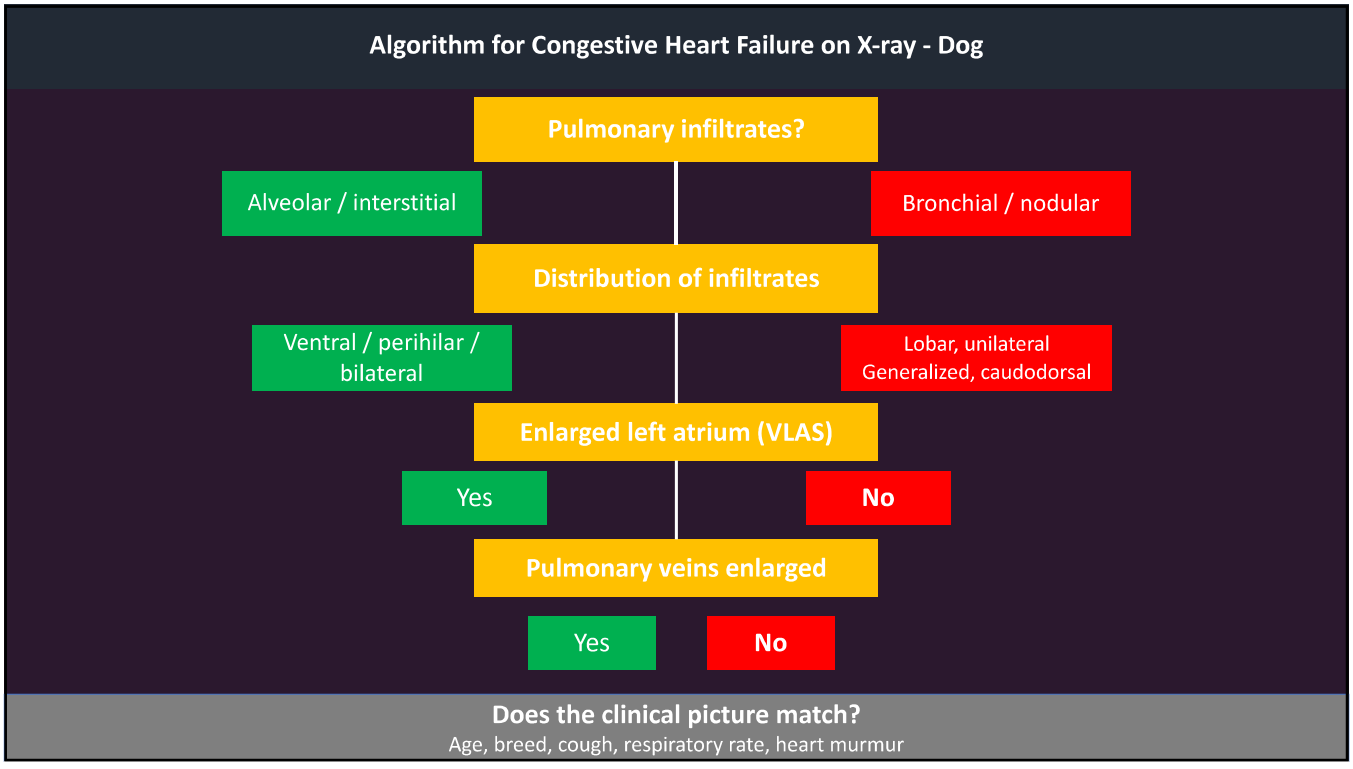
Conclusion

- Feline Heart Failure
- Context-based interpretation is necessary
- A structured approach and interdisciplinary collaboration are important

101



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- X-rays remain the screening method of choice for decompensation
- Assessment is highly dependent on positioning and image quality
- Echocardiography for definitive assessment

103

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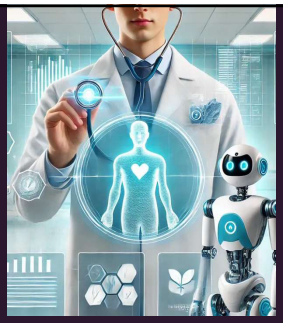
Can we refine it?

104

AI



> J Small Anim Pract. 2023 Dec;64(12):769-775. doi: 10.1111/jsap.13666. Epub 2023 Aug 25.

Diagnostic validation of vertebral heart score machine learning algorithm for canine lateral chest radiographs

J Solomon [1], S Bender [1], P Durgempudi [1], C Robar [1], M Cocchiaro [1], S Turner [1], C Watson [1], J Healy [1], A Spake [1], D Szlosek [1]

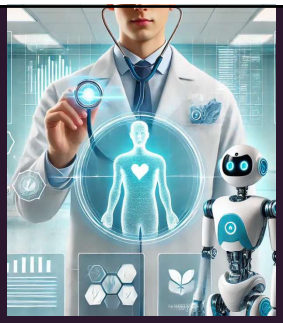
> Front Vet Sci. 2021 Dec 9:8:764570. doi: 10.3389/fvets.2021.764570. eCollection 2021.

Comparison of a Deep Learning Algorithm vs. Humans for Vertebral Heart Scale Measurements in Cats and Dogs Shows a High Degree of Agreement Among Readers

Emilie Boissady [1], Alois De La Comble [1], Xiajuan Zhu [2], Jonathan Abbott [3], Hespel Adrien-Maxence [3]

105

AI



Article | Open access | Published: 25 August 2022

An automated deep learning method and novel cardiac index to detect canine cardiomegaly from simple radiography

Yeojin Jeong & Joohon Sung

Scientific Reports **12**, Article number: 14494 (2022) | Cite this article

- Mixed results (AUC Stage B2 0.77)
- Validation still somewhat questionable

> Front Vet Sci. 2023 Sep 22;10:1227009. doi: 10.3389/fvets.2023.1227009

Development of an artificial intelligence-based method for the diagnosis of the severity of myxomatous mitral valve disease from canine chest radiographs

Carlotta Valente [1], Marek Wodzinski [2,3], Carlo Guglielmini [1], Helen Poser [1], David Chiavegato [4], Alessandro Zotti [1], Roberto Venturini [4], Tommaso Banzato [1,*]

106

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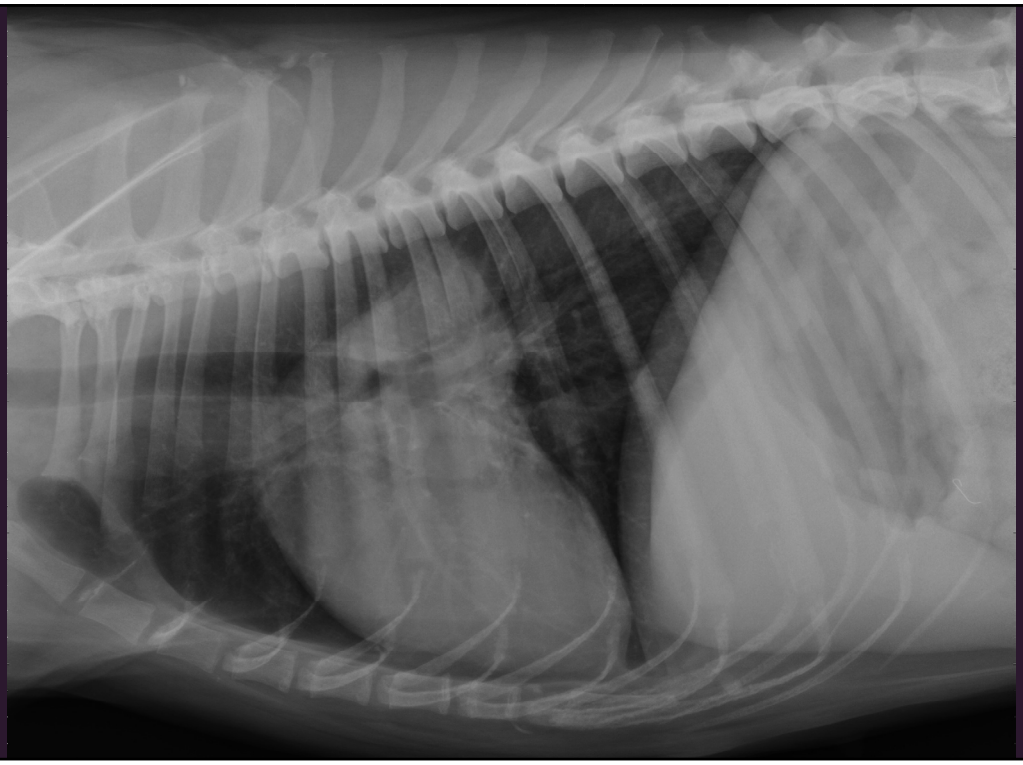
Amy

- 11-year-old mixed breed, female
- Lack of energy
- Coughing for 2–3 weeks
- Mammary tumors

107



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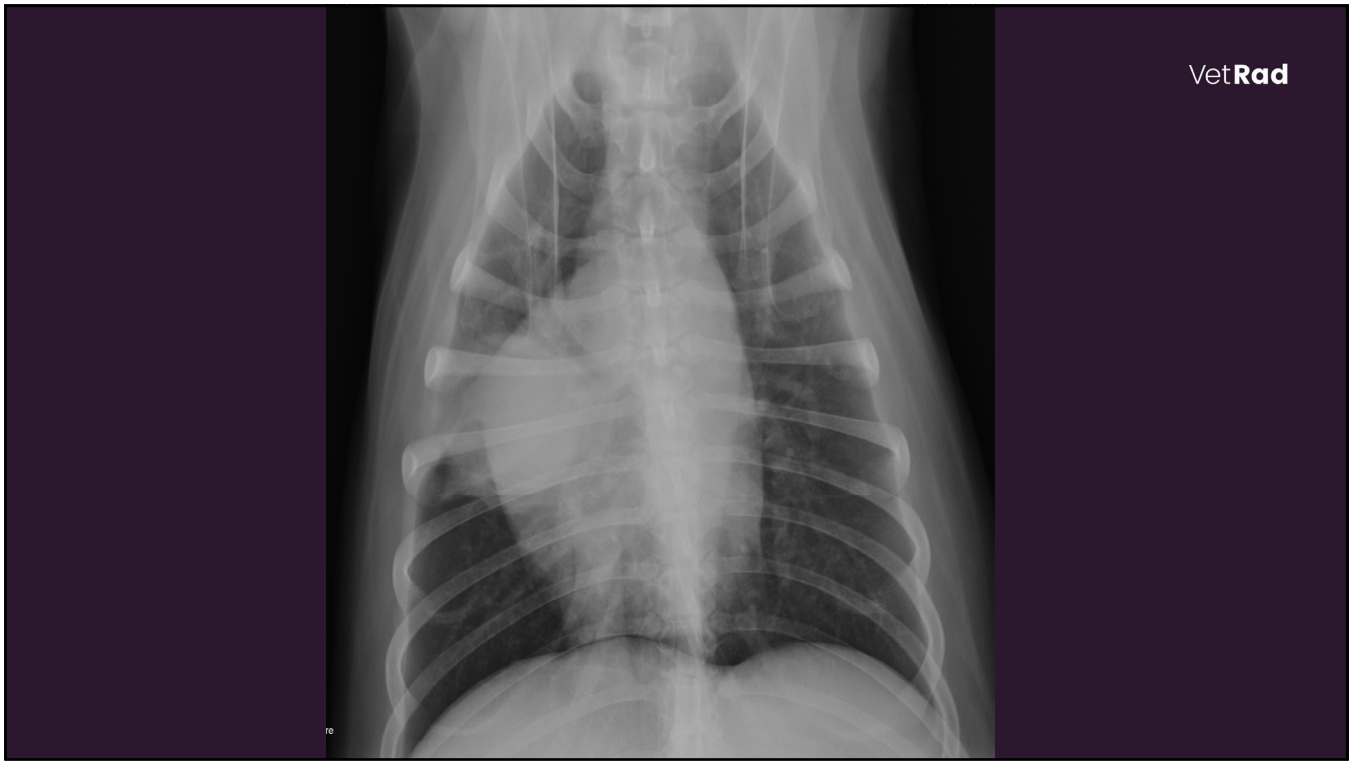

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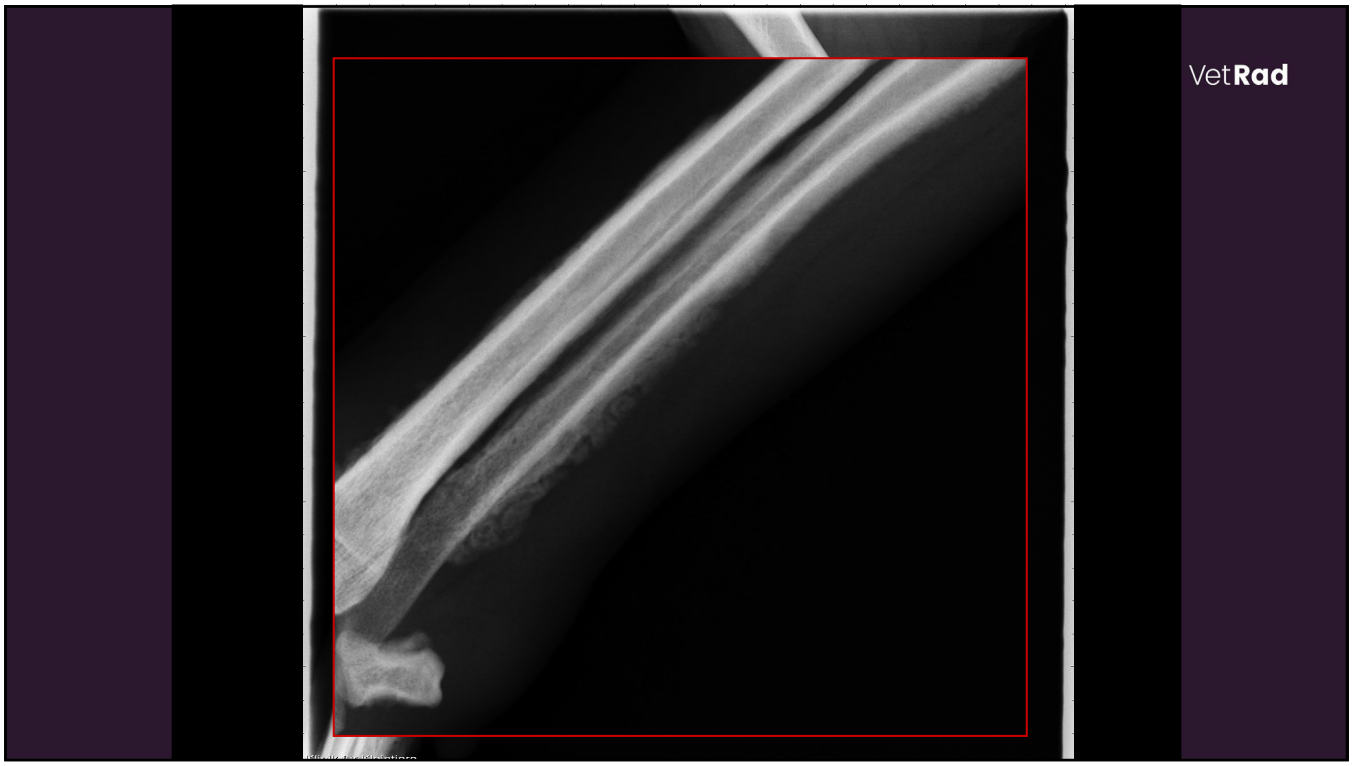

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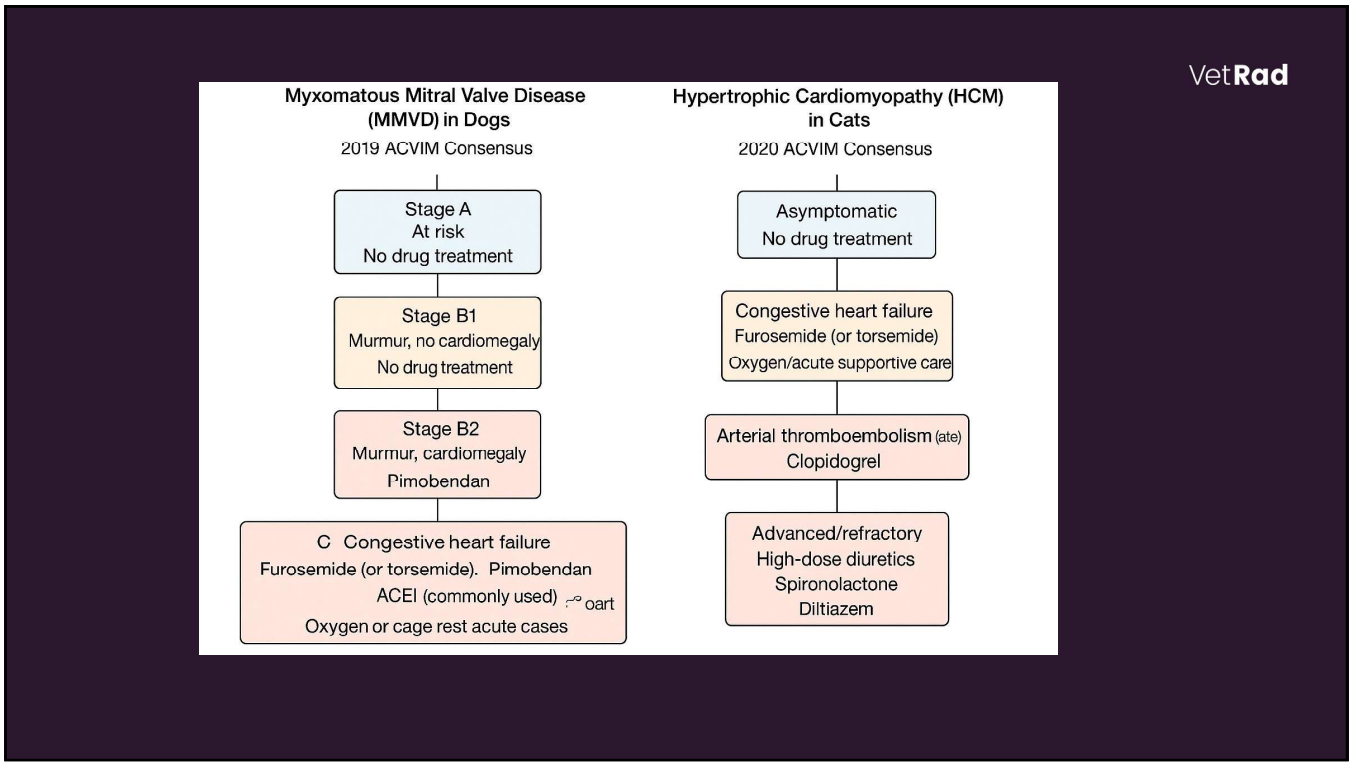
Vielen
Dank
VetRad

111


VetRad
Myxomatous Mitral Valve Disease (MMVD) in Dogs
2019 ACVIM Consensus
Stage A
At risk
No drug treatment
Stage B1
Murmur, no cardiomegaly
No drug treatment
Stage B2
Murmur, cardiomegaly
Pimobendan
C Congestive heart failure
Furosemide (or torsemide). Pimobendan
ACEI (commonly used)
Oxygen or cage rest acute cases
Hypertrophic Cardiomyopathy (HCM) in Cats
2020 ACVIM Consensus
Asymptomatic
No drug treatment
Congestive heart failure
Furosemide (or torsemide)
Oxygen/acute supportive care
Arterial thromboembolism (ate)
Clopidogrel
Advanced/refractory
High-dose diuretics
Spironolactone
Diltiazem

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Is the Canine Heart Sick? 2D & M-mode imaging of Cardiac Size and Function

John D Bonagura, DVM, DACVIM (Cardiology, Internal Medicine), FASE

Professor Emeritus, the Ohio State University College of Veterinary Medicine
Adjunct Professor – Cardiology, Colorado State University College of Veterinary Medicine & Biomedical Sciences
Adjunct Professor of Cardiology, North Carolina State University College of Veterinary Medicine

1

How are LA & LV size & Function Evaluated?

What are Measurement Principles & Pitfalls of the "Numbers"?

Relevancy:

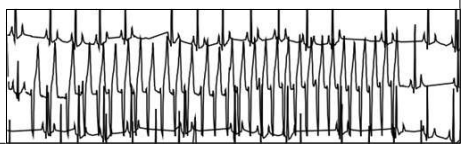
- Congenital heart diseases
  VSD, PDA
- Myxomatous mitral valve disease
- *Dilated cardiomyopathy* – especially preclinical (occult) DCM
- Other causes of left heart remodeling

2

2

What is your diagnostic goal or alternatively…
What *mistake* do you want to avoid?

- Cutoffs more *sensitive* for disease?
- Cutoffs more *specific* for disease?
- Both sensitivity + specificity (and the PPV) of Echo quantitation will increase with:
  - *Clinical signs* of heart failure
    - Ascites with jugular venous distension
    - Respiratory distress with a gallop sound
  - *High pre-test probability* of heart disease
    - Systolic murmur of MR in an old small-breed dog
    - Ventricular tachycardia in a Doberman pinscher



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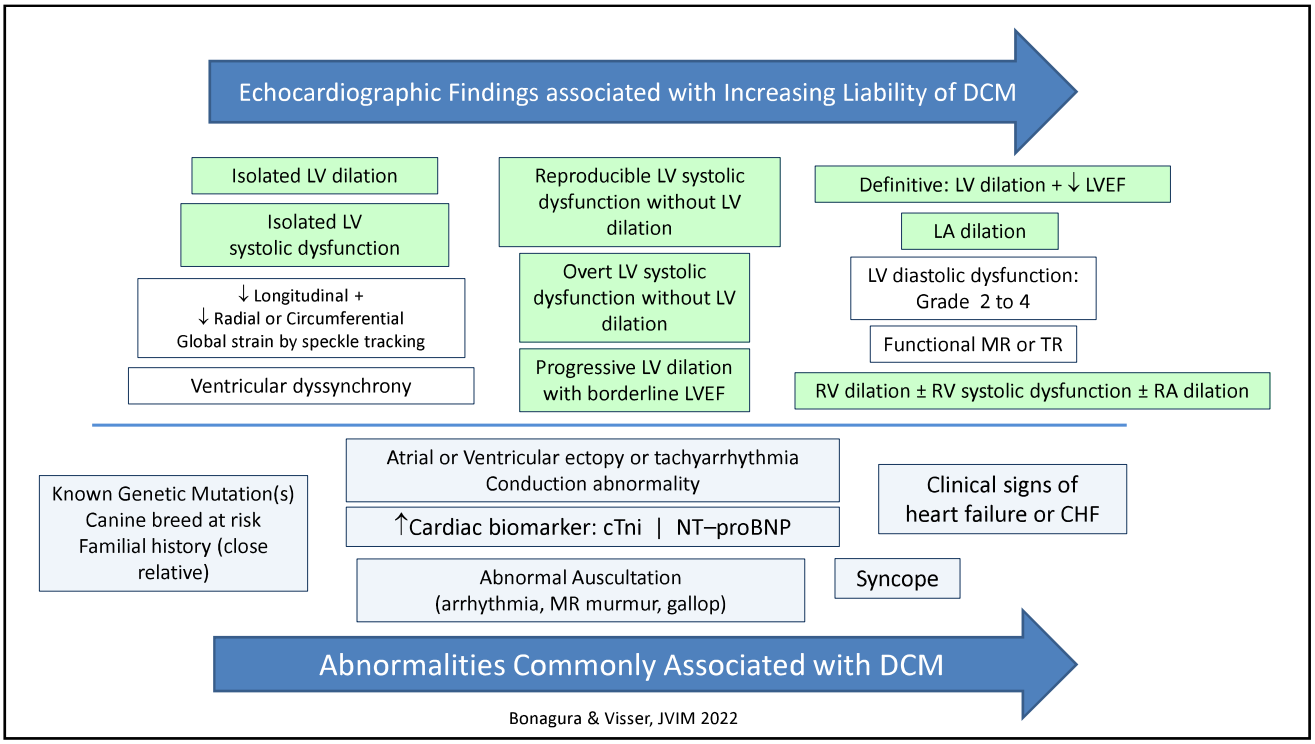
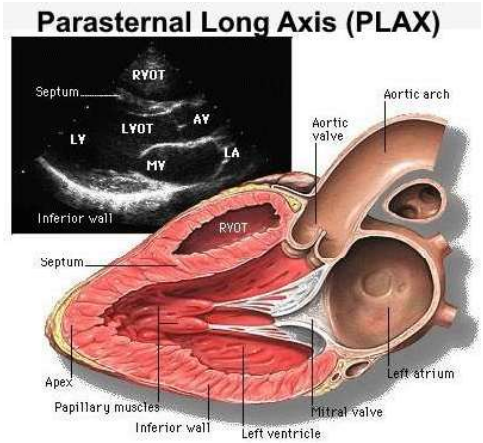
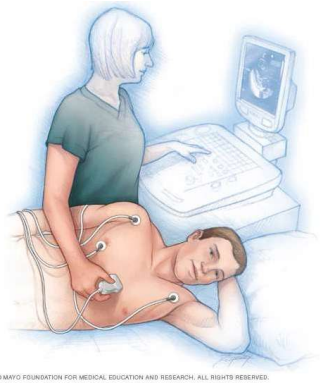


4

Imaging Quadrupeds vs. Humans

Planes are not identical – we do not actually follow ASE Standards

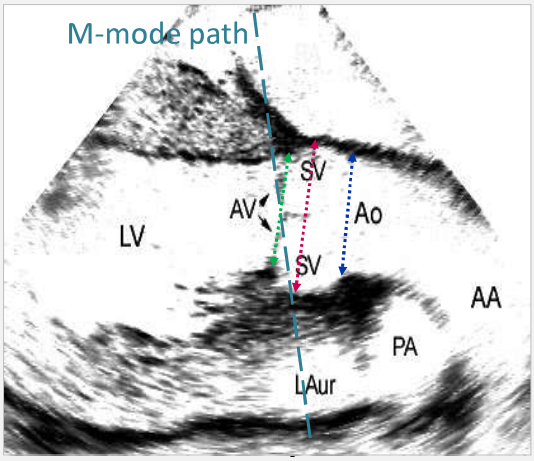




5

Quantitation of Cardiac Size: 2D Aortic Diameters

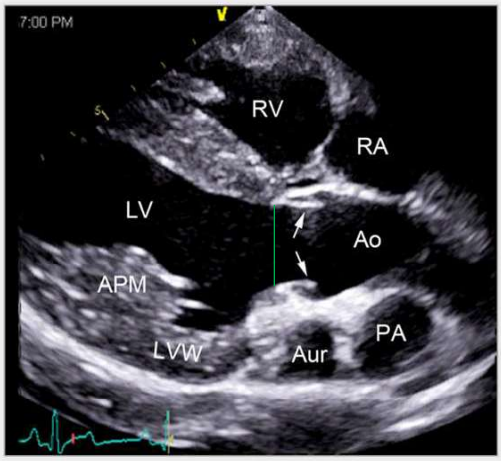
Used to Index LA & LV measurements



WHERE & WHEN you measure Aorta greatly affects measurements

Between **Hinge** points or opened **AV leaflets** (systole)

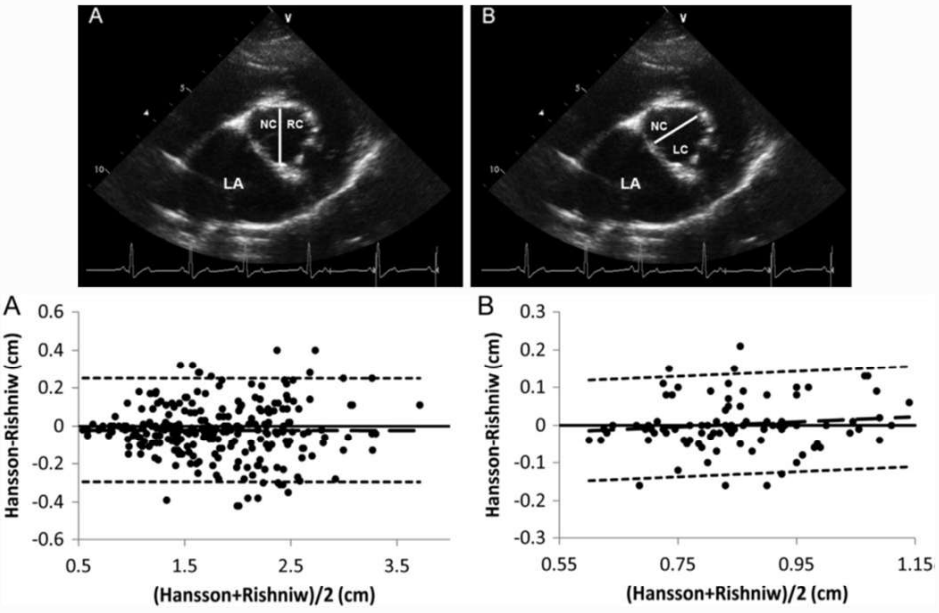
Hinge Points
Valve Sinuses
Sinotubular junction



6

6

Quantitation: Short-axis Aortic Measurements



Georgiev et al., Journal of Veterinary Cardiology (2013)

7

7

Reference: Predicting Ao size from BW

J Vet Intern Med. 2003 Sep-Oct;17(5):653-62.

M-mode echocardiographic ratio indices in normal dogs, cats, and horses: a novel quantitative method.

Brown DJ[1], Rush JE, MacGregor J, Koss JN Jr, Brewer B, Rand WM.

Bodyweight Predicted Aortic Size

AoD (wt based, mm)
$= (0.795 * BW^{0.33})$

Constants derived from M-mode studies – they also used these values for indexing LV size

1	8.0	21	21.9
2	10.0	22	22.3
3	11.5	23	22.6
4	12.6	24	22.9
5	13.6	25	23.2
6	14.4	26	23.6
7	15.2	27	23.9
8	15.9	28	24.1
9	16.5	29	24.4
10	17.1	30	24.7
11	17.7	31	25.0
12	18.2	32	25.2
13	18.7	33	25.5
14	19.2	34	25.8
15	19.6	35	26.0
16	20.0	36	26.3
17	20.4	37	26.5
18	20.8	38	26.7
19	21.2	39	27.0
20	21.6	40	27.2

8

8

Quantitation: Measuring & Assessing the Left Atrium

Left Atrial size is often predictive of severity in chronic diseases affecting the left side of the heart ⇒ Prognosis

- Subjective methods: "eyeballing" the 2D/M-mode images for enlargement of the atrium or appendage
  - Caveat: LA measurements relate to volume + remodeling
- M-mode methods – LA/Ao – only useful in cats
- 2D – LA diameters & areas – both short & long axis approaches
- 2D ratios of LA: Aorta – MANY!! and not interchangeable
- LA volumes – estimates from 2D calculations (infrequently 3DE)
- Notable Canine/Feline Differences

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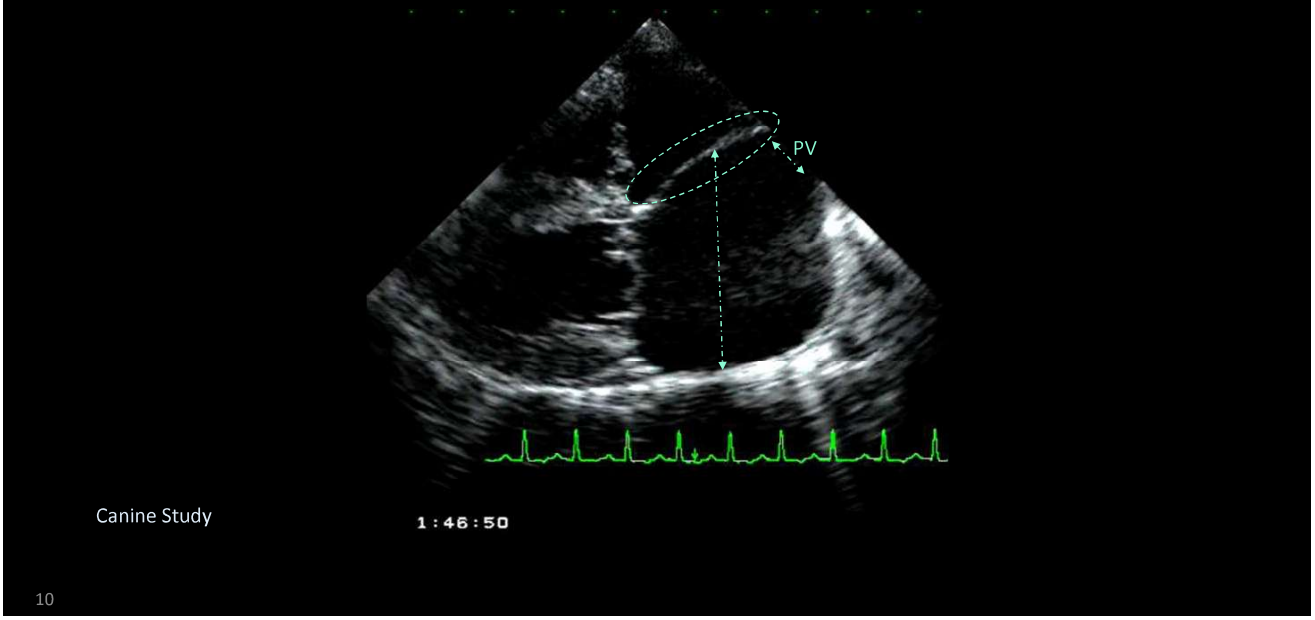
Subjective Assessment of LA Size



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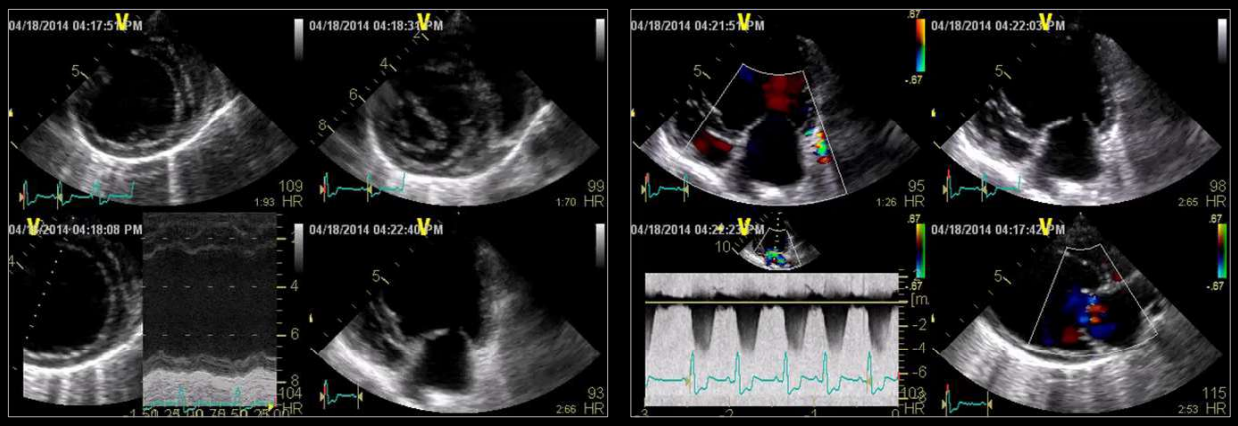
DCM: LA size often less prominent than for primary MR
"Functional" MR is commonly observed by Doppler



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Quantitation: Left Atrium – M-mode Cursor

Typical M-mode Cursor Path in Canine Studies

Canine ratio
<1.2 (LA/Ao)

A "tradition"

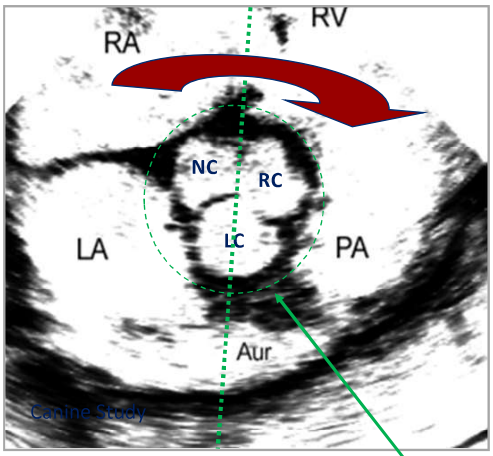

Image structures

How much fat do you want to measure?

12

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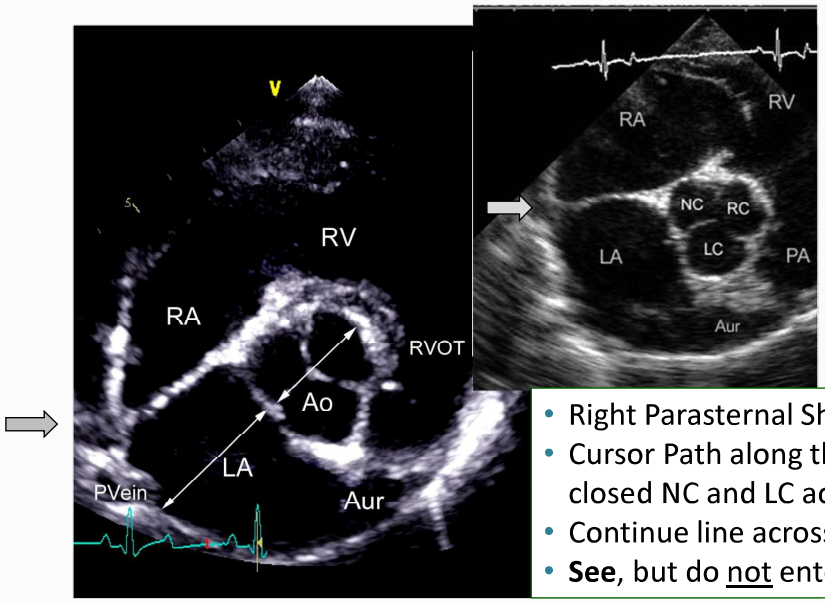
Quantitation: 2D Left Atrium to Aortic Ratio – "Swedish Method"



Upper Limit
LA/Ao ≈ 1.3???
Ratios >1.6 to 1.7
mild-mod dilatation

- Right Parasternal Short-axis
- Cursor Path along the commissure of closed NC and LC aortic valve cusps
- Continue line across LA
- **See**, but do not enter pulmonary vein

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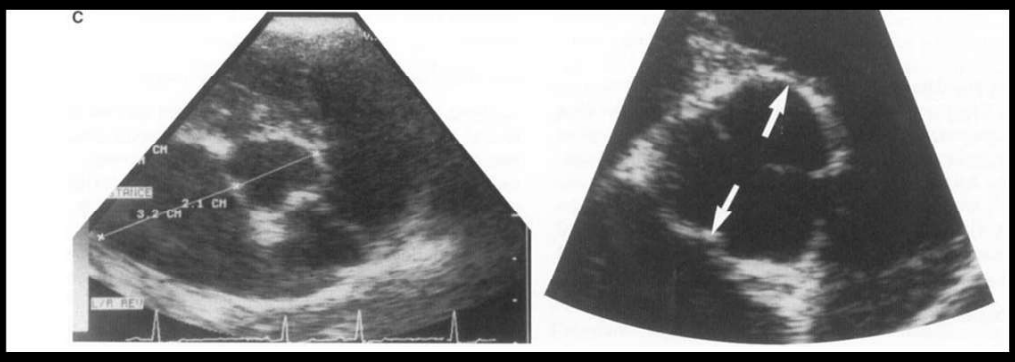
LEFT ATRIAL TO AORTIC ROOT INDICES USING TWO-DIMENSIONAL AND M-MODE ECHOCARDIOGRAPHY IN CAVALIER KING CHARLES SPANIELS WITH AND WITHOUT LEFT ATRIAL ENLARGEMENT

KERSTIN HANSSON, DVM, JENS HÄGGSTRÖM, DVM, PHD, CLARENCE KVART, DVM, PHD, PETER LORD, BVSC, FRCVS



Issues: 1) Image plane; 2) Timing; 3) Repeatability; 4) not maximal LA
Less concerns when there is moderate-severe LA dilation

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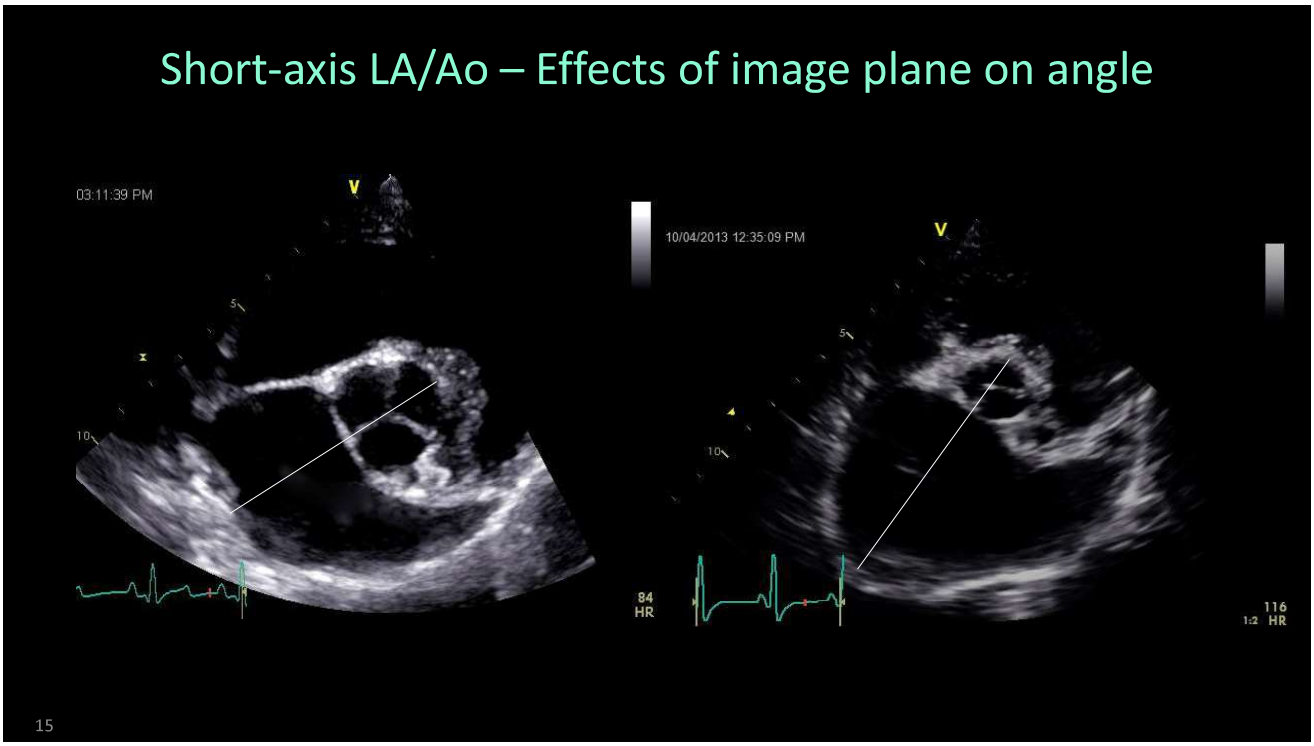
Short-axis LA/Ao – Effects of image plane on angle



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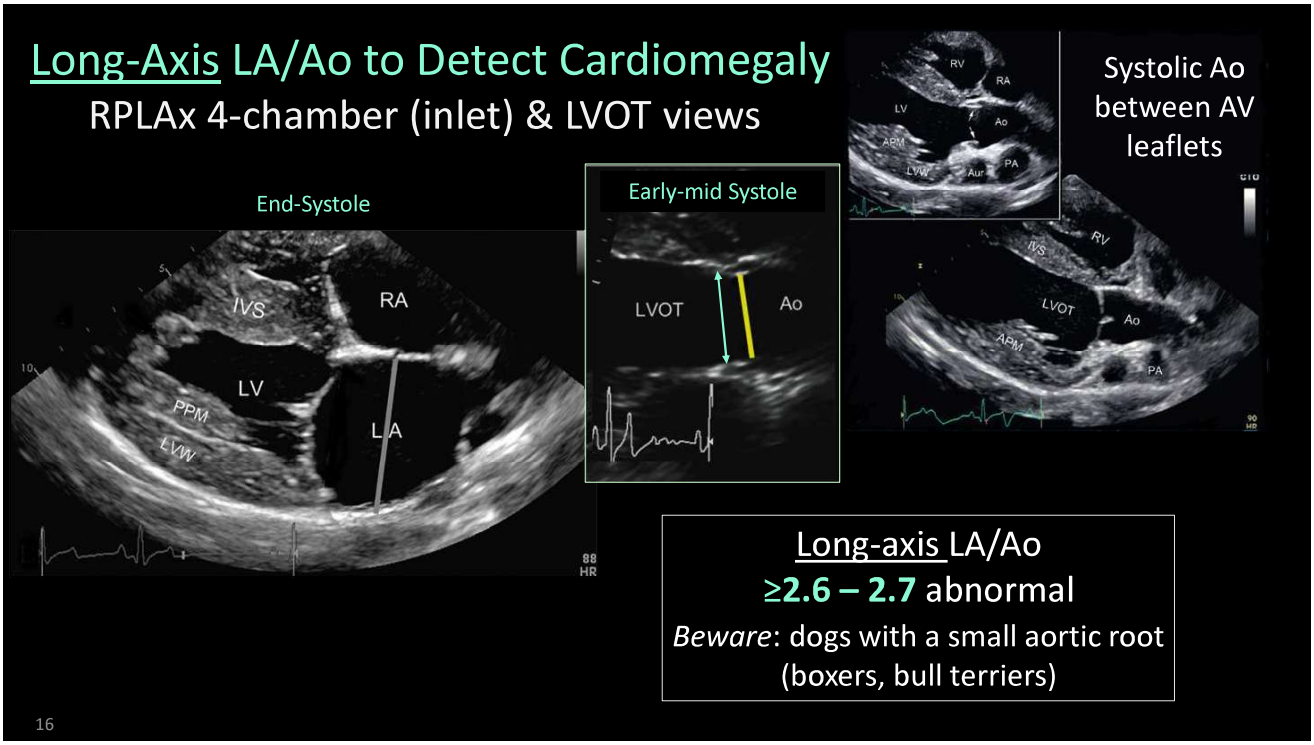
Long-Axis LA/Ao to Detect Cardiomegaly

RPLAx 4-chamber (inlet) & LVOT views



Long-axis LA/Ao
≥2.6 – 2.7 abnormal
Beware: dogs with a small aortic root (boxers, bull terriers)

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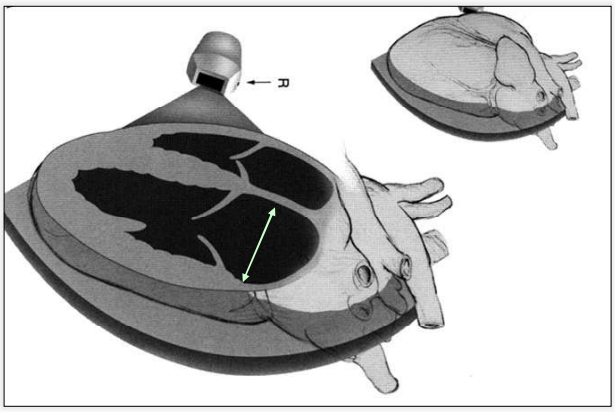
Bodyweight normalized Left Atrial Size from 2D

LAD normalized = LA (cm)/BW (kg)$^{0.31 \text{ to } .33}$

https://www.calculatorsoup.com/calculators/algebra/exponent.php



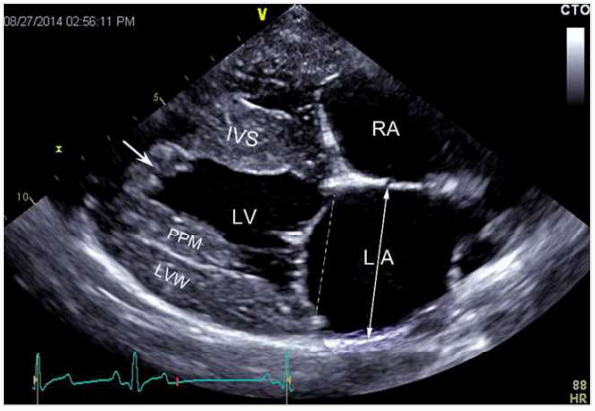


Illustration From: June A. Boon: **Manual of Veterinary Echocardiography,** Lippincott, Williams & Wilkins (1998)

Different exponents have been published; between **0.31 to 0.33**
Example: normalized LA Dimension: LAD = 3.6 cm; 10 kg dog
$LAD_n = 3.6/10^{.31} = 3.6/2.04 =$ **1.77** (normal <**1.7**)

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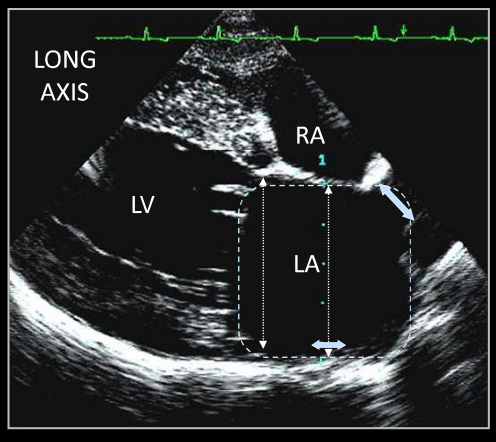
Reference: Steps for making 2D Left Atrial Measurements



Frozen 2D Image – end systole

Canine Study

1. Obtain *LV inlet image* (*Not aorta*!! Harder in cats)
2. Scroll to *end-systole* (however, the best image may be -1 or -2 frames)
3. *Imagine*: a ref line across annulus and overall LA area
4. *Bisect* LA area with a line ≈ parallel to reference
5. Ignore the Pulmonary Veins (dilated PV creates problem)
6. Compare dimension to a *reference or*
7. Compare to *AV (2D)*

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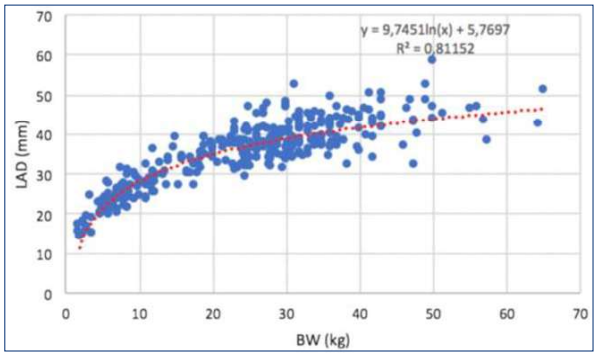
Normalized Long-axis, LAD: Reference Intervals in 330 Dogs

Data from Marchesotti, et al., 2019.

BW(kg)	LAD (mm)
2	13.1–19.7
3	15.0–22.4
4	16.4–24.6
5	17.7–26.5
6	18.7–28.1
7	19.7–29.5
8	20.6–30.8
9	21.4–32.0
10	22.1–33.1
15	25.2–37.8
20	27.7–41.5
25	29.8–44.6
30	31.6–47.3
35	33.2–49.7
40	34.7–51.9
50	37.3–55.8
60	39.5–59.2
70	41.6–62.3

Reference range for the normalized LAD in 330 healthy dogs in this study was approximately LADn 1.1 to **1.6**



Curvilinear relationship between linear measurements & weight (kg)

Scaling exponent is approximately 1/3 (0.**324**)

Allometric equation: Y = 10.49 to 15.72 × $M^{0.324}$

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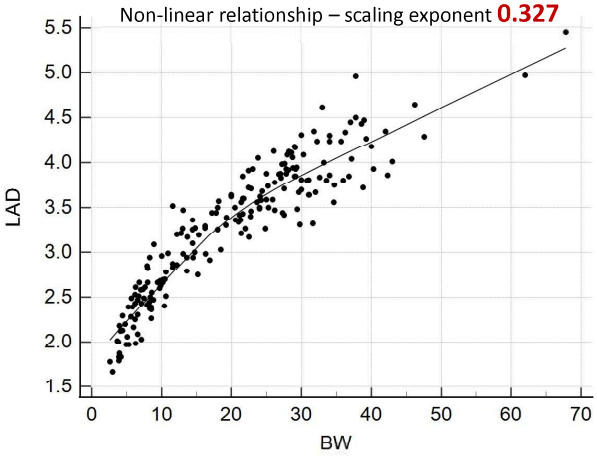
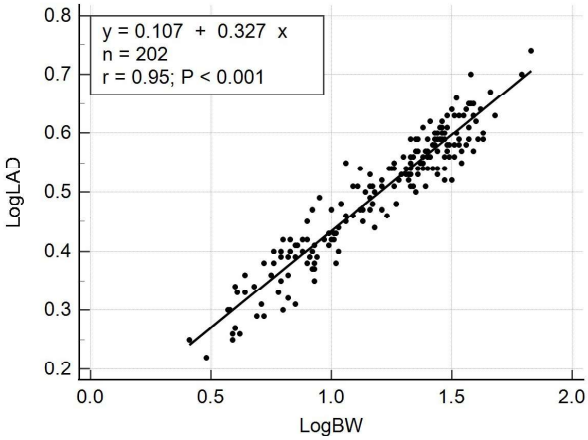
Reference: Right Parasternal Long-Axis, Left Atrial Dimension

(Measured at end-systole)

Non-linear relationship – scaling exponent **0.327**





Unpublished data from UC Davis & Ohio State University

Healthy dogs of various breeds including mixed breeds

From: Visser L, Strohm L, Chapel E & Bonagura J

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Reference: Multi-breed Studies of LA (and LV) in Healthy Dogs

Reference Intervals for LA size using different approaches

DOI: 10.1111/jvim.15562
STANDARD ARTICLE
Journal of Veterinary Internal Medicine ACVIM

Echocardiographic quantitation of left heart size and function in 122 healthy dogs: A prospective study proposing reference intervals and assessing repeatability

Lance C. Visser | Marisa M. Ciccozzi | Daniel J. Sintov | Ashley N. Sharpe

122 healthy dogs; LA scaling exponent 0.309
Median (95% CI) **1.38** (1.34 – 1.39)
RI (90% prediction CI): Lower: 1.19 (1.14, 1.21)
Upper 1.56 (1.49, **1.65**)
Suggested upper reference limit = **1.65 LADn**
Short-axis LA/Ao was median (range) **1.4 (.9 – 1.7)**
Short-axis LA/Ao prediction/RI: **0.9 to 1.7 (upper)**
Long-axis LA/Ao was median (range) **2.24 (1.6 – 2.6)**
Long-axis LA/Ao RI: **2.0 to 2.6 (upper) all values rounded up)**

The Journal of Veterinary Medical Science
FULL PAPER
Internal Medicine

Left atrial anteroposterior diameter in dogs: reference interval, allometric scaling, and agreement with the left atrial-to-aortic root ratio

Federica MARCHESOTTI[1], Tommaso VEZZOSI[1,2], Rosalba TOGNETTI[2]*, Francesca MARCHETTI[2], Valentina PATATA[1], Barbara CONTIERO[3], Eric ZINI[1,3,4] and Oriol DOMENECH[1]

330 healthy dogs; LA scaling exponent **0.324**
When *converted* from mm to cm measurements:
Median LAD(normalized) = 1.29 cm
RI Lower normalized LAD 1.05
RI Upper normalized 1.57
Suggested upper reference limit = **1.60 LADn**
Short-axis LA/Ao was median (range) **1.4 (.9 – 1.59)**
Short-axis LA/Ao upper limit in this study **1.6**

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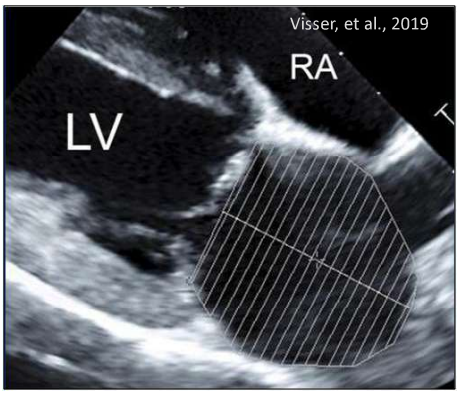
LA Volumes from Rt. Parasternal Images

Monoplane – Right parasternal long axis (LV inlet)

- LA end-systolic volume 2D (Long-axis)
- Median **1.09** ml/kg
- Upper limit ≈**1.65** ml/kg
- Higher than prior studies

Visser L: 122 healthy dogs (multiple breeds)



Advantages: 1-plane; right-sided; longest length
Disadvantages: 1-plane; veins; marked breed variation in other reports

See: **Höllmer M**, et al. Left atrial volume and phasic function in clinically healthy dogs of 12 different breeds. Vet J. 2013. 197(3):639-45; Comparison of four echocardiographic methods to determine left atrial size in dogs. J Vet Cardiol. 2016 18(2):137-45.

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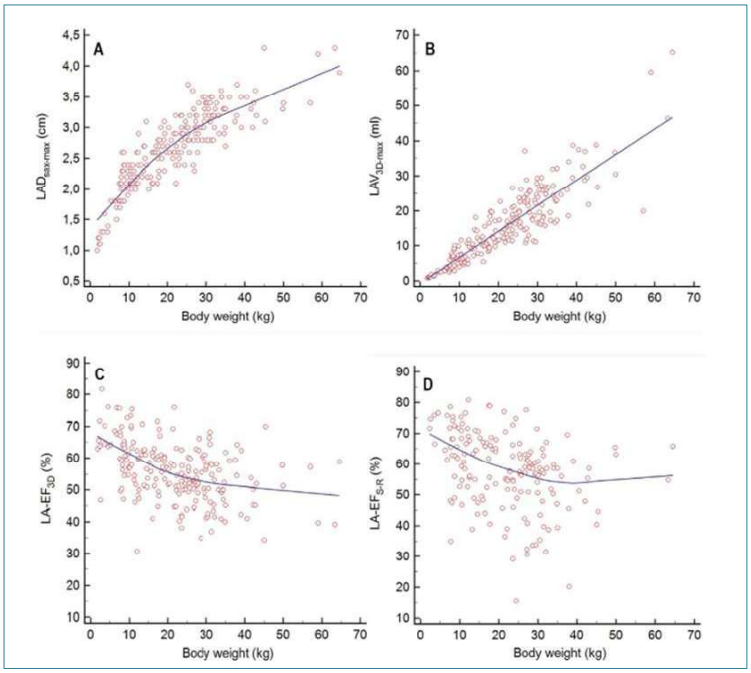
Canine LA size & Function

Journal of Veterinary Cardiology (2024) 52, 43–60
ELSEVIER
Journal of Veterinary Cardiology
www.elsevier.com/locate/jvc

Reference intervals for various measurements of canine left atrial size and function obtained using two-dimensional and three-dimensional echocardiography

J. Treibert [a], J. Friederich [a], S. Fischer [b], H. Küchenhoff [b], G. Wess [a,*]



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Summary – Quantitation: Left Atrium

- Obtain optimized **Long-axis** LV inlet view with MV
  - Atrial septum, RVP, RPA in plane; NO aorta
  - Measure: Mid LA at end-systole
  - Allometrically scale LA (optimal exponent: **0.31** to **0.33** for most dogs)
  - Also measure aorta LAx between opened leaflets or hinges in LVOT view
- Obtain optimized **Short-axis** view of aorta & LA with left auricle
  - Include appendage tip and caudal pulmonary veins in image
  - Measure Ao along the NC/LC commissural line – continue the line into LA
  - Timing should occur in “early” (proto)diastole (as the LA is emptying)

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Quantifying LV Size & Systolic Function in Dogs

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Reference: Recognizing LV Enlargement & Systolic Dysfunction

- Subjective – appearance
  - Spherical (long-axis), Squashed mushroom (short-axis)
- Linear measures (minor LV dimension)
  - M-mode measurements (septum → LV wall)
  - 2D short- or long-axis measurements (ideally: both!)
- LV Area + length measurements
  - Incorporated into volume calculations and functional indices
  - Measurements of the left ventricle over the cardiac cycle
  - Ejection fraction (EDV-ESV)/EDV and end-systolic volume index
- AI: Automated border detection | Strain | ? 3D volumes

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LV Systolic Function

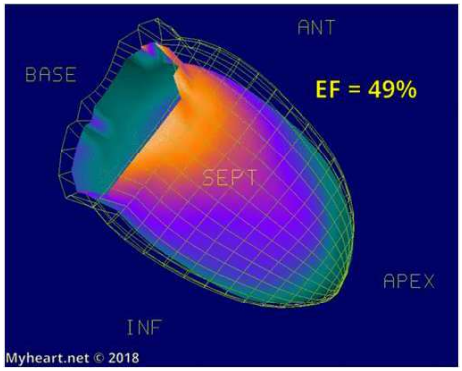
What is the *gold standard* of <u>global</u> LV systolic function??

LV ejection fraction =

LV stroke volume ÷ LV end-diastolic volume

LV stroke volume = EDV – ESV

$$EF = \frac{EDV - ESV}{EDV}$$



- **Subjective assessment**
- **Objective assessment**:
  - **Linear** (Fractional shortening & LVIDs),
  - **Area** (LV fractional area change)
  - **LV volumetric** estimates of EDV, ESV & EF
  - **AI approaches** – Strain & LV volumes

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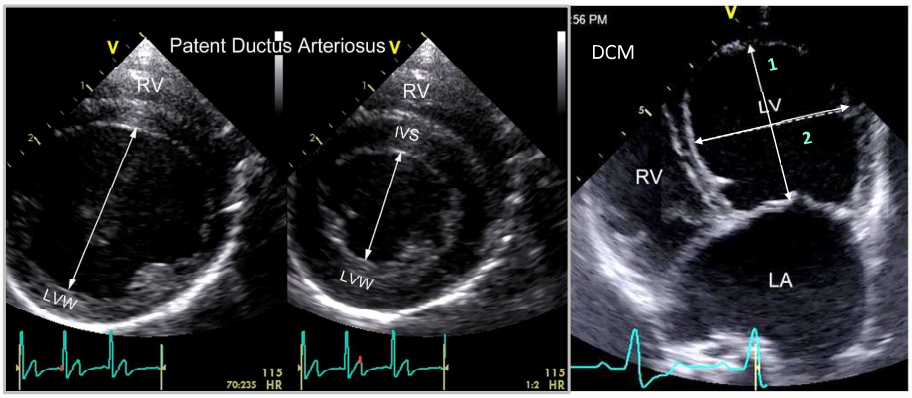
How do we determine if the Canine LV is "Enlarged"?



<u>Subjective Approach</u>: Good for Moderate to Severe LV↑

- Sometimes measurements do not change decision (CHF)
- In short-axis images ⇒ Look for a "squashed mushroom"
- Spherical appearance of LV (long-axis or apical views)

Sphericity index = d1/d2 (alt: d2/d1)

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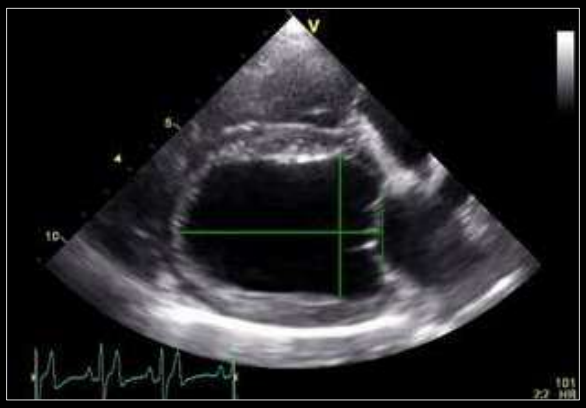
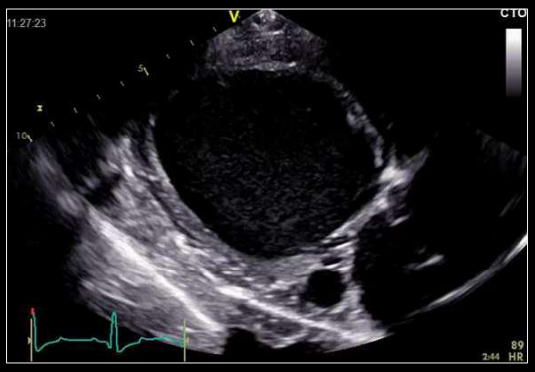
Sphericity Index: Major / Minor Dimensions





Holler & Wess, JVIM (2014)

Beware: off angle image planes

Sphericity index in Dob Pinscher of <1.65 (length/width) suggestive of DCM
Not necessarily transferrable to other breeds

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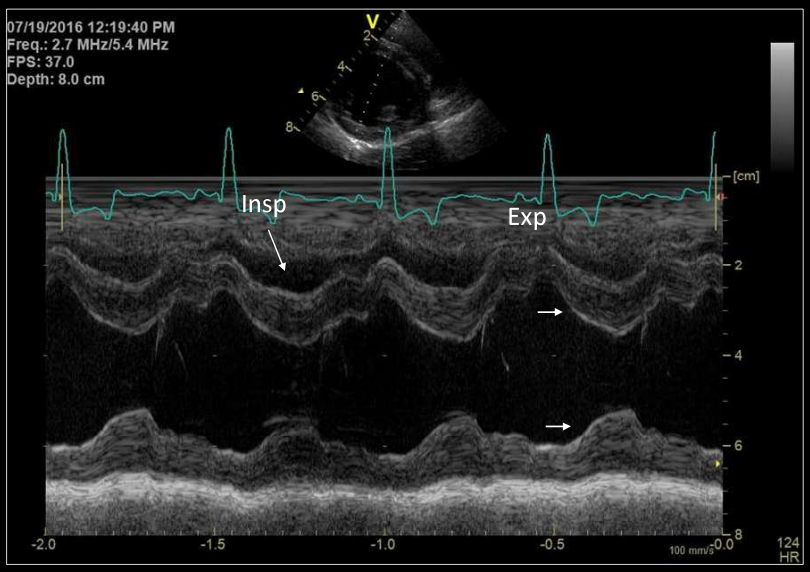
Subjective Appearance of LV Volume Overload

Mitral Regurgitation – Note Septal Excursion



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Measurements: LV Chamber is modeled using different approaches

Sphere, Truncated ellipsoid, Bullet, stacked Discs

Measurements create *estimates* of LV volumes or LV ventricular mass

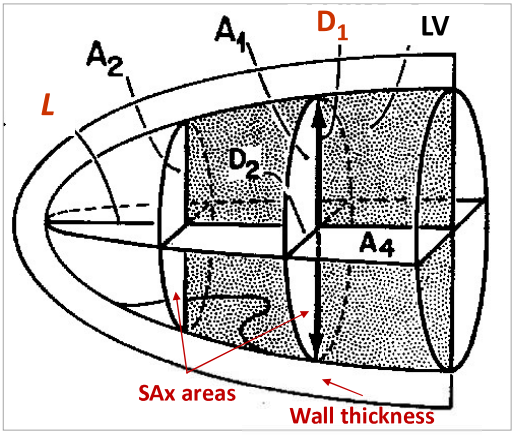
D1 = minor axis (**LVID**)
septal to LV wall

D2 = second minor axis of
short axis area A1

A1,2 = cross-sectional areas

- "Infinite" number
- **High Papillary** level used in dogs

L = **length** of the ventricle from
mitral annulus to apex



From **Weyman AE**: Echocardiography

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Reference: Some LV Models & Volume Calculations

A	B	C	D	E
Bi-plane ellipse	Bullet	3-axis measurement	Single plane long-axis ellipse	Bi-plane long-axis ellipse
$V = \frac{2}{3}AL$ (3)	$V = \frac{5}{6}AL$ (4)	$V = \frac{\pi}{6}D_1D_2L$ (5)	$V = \frac{8}{3\pi}\frac{A^2}{L}$ (6)	$V = \frac{8}{3\pi}\frac{A_1A_2}{L}$ (7)

O'Dell WG: J Am Heart Assoc. 2019;8:e009124. DOI: 10.1161/JAHA.118.009124

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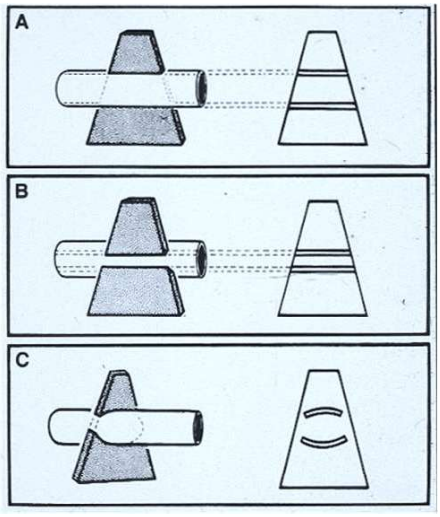
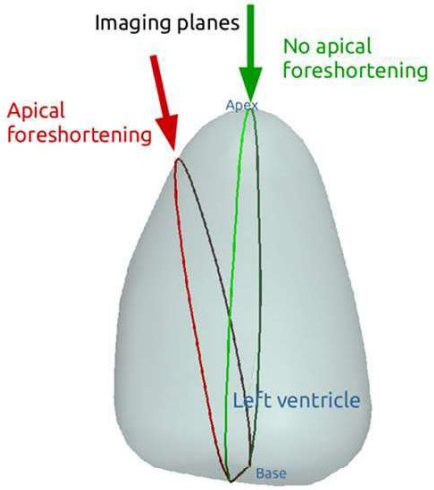
Pitfalls: Off-Angle imaging | Truncation | Foreshortening



Arthur Weyman, MD



Eric Smistad

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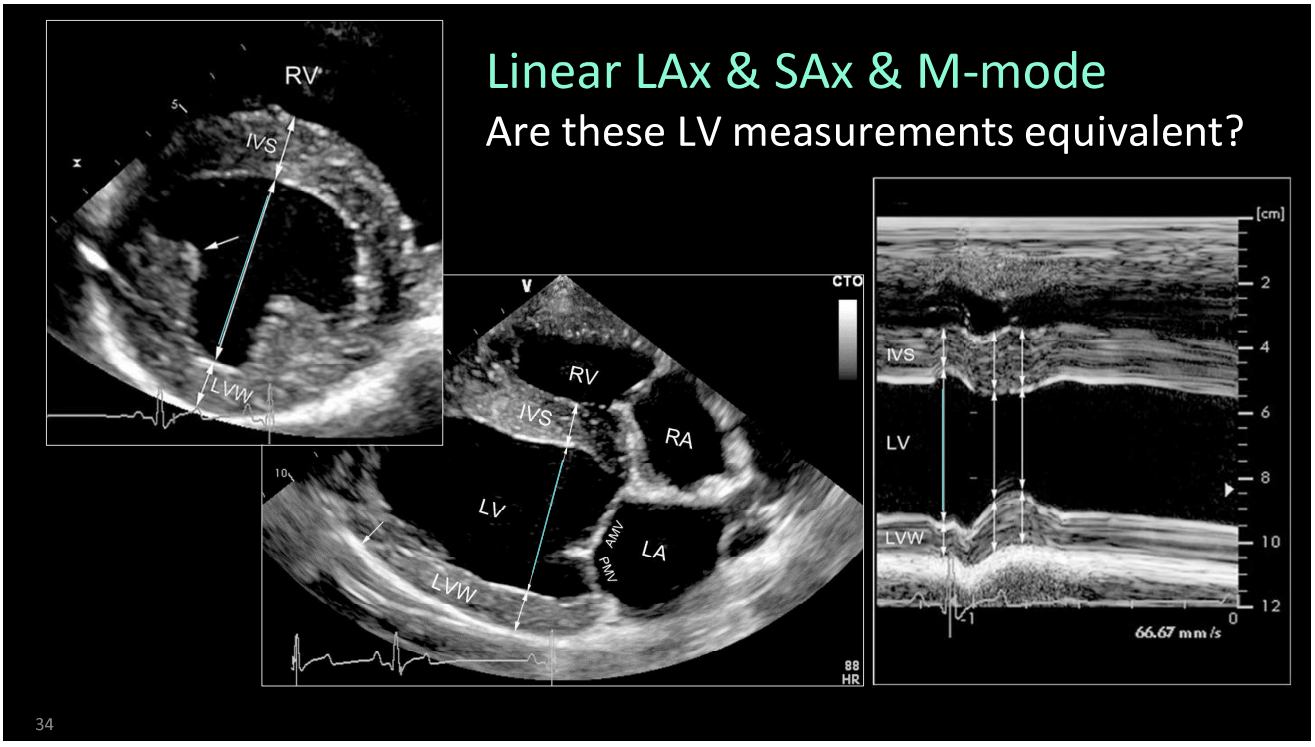

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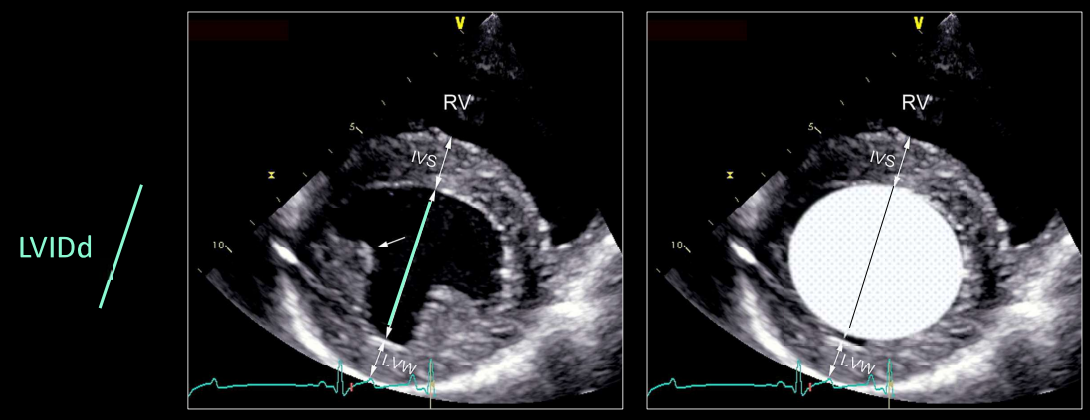
LV Measurements from 2D – Short-axis

Linear (volume est.) & Area (for function or FAC)



Canine

If you cannot align the M-mode cursor to bisect the LV, just measure with 2D

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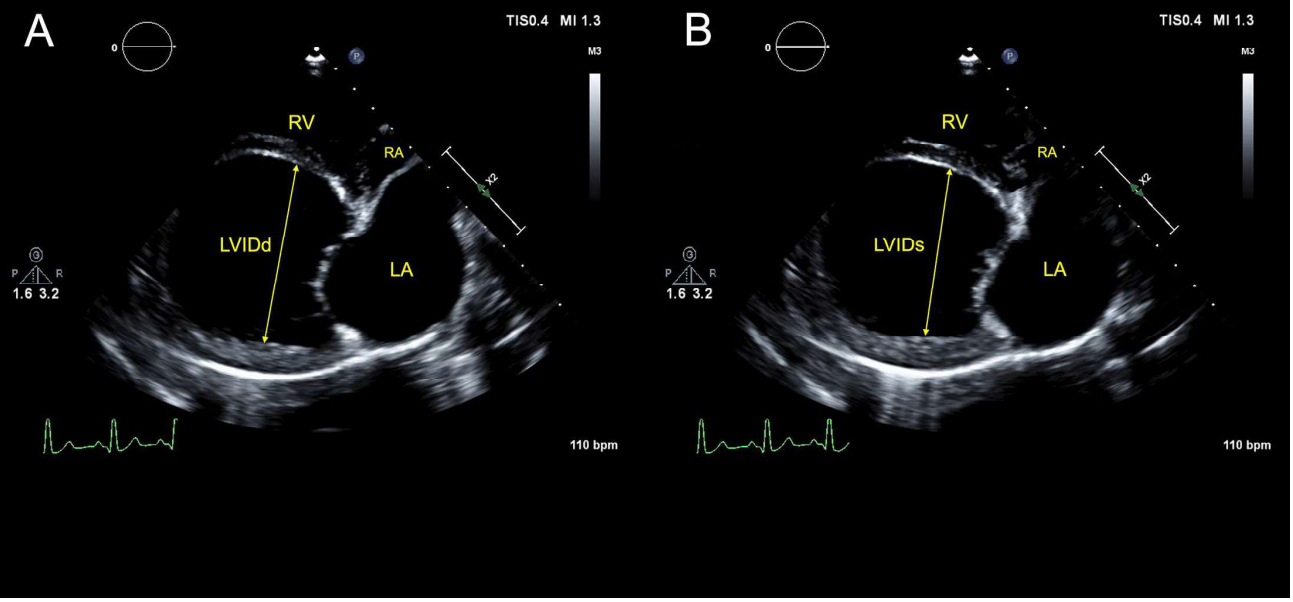
LV Minor Axis measurements from 2D images

Can be used as "reference check" to M-mode/Short-axis Measurements



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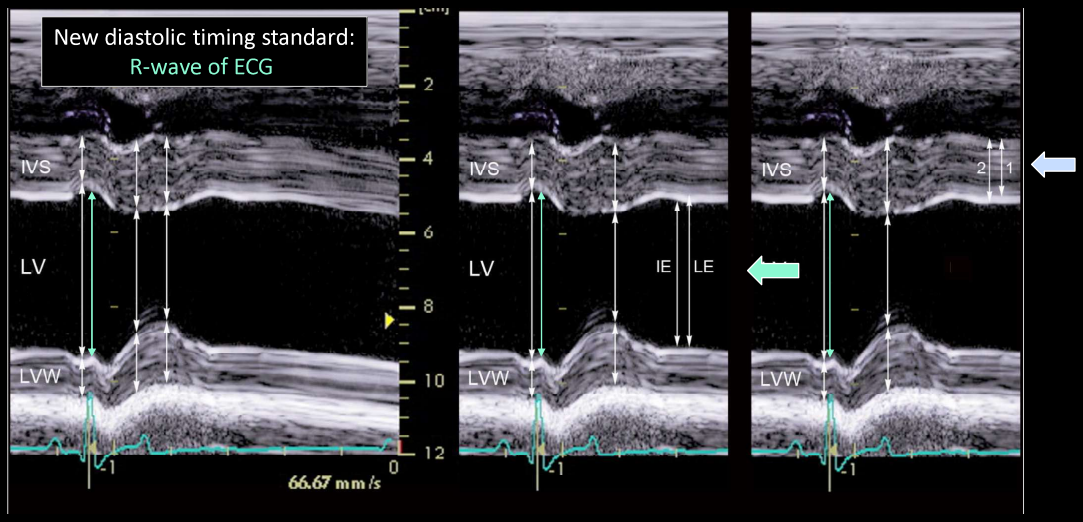
Measuring the LV Size & Function by M-mode Echo



Leading edge (ASE & most veterinary studies) vs. *Tissue/blood interface* vs. *TIL* (IVS: trailing, LV: inner, LVW: leading edges)

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Reference: How Does LV Size related to bodyweight?

Allometric Scaling: LVIDd vs. Body Size

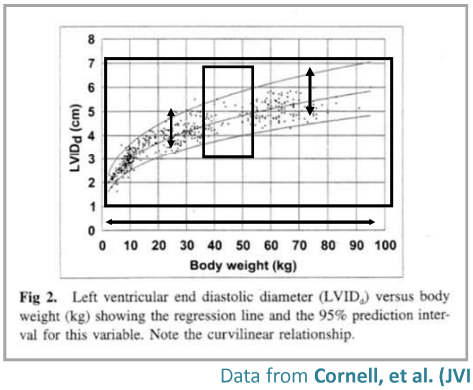

Fig 2. Left ventricular end diastolic diameter ($LVID_d$) versus body weight (kg) showing the regression line and the 95% prediction interval for this variable. Note the curvilinear relationship.

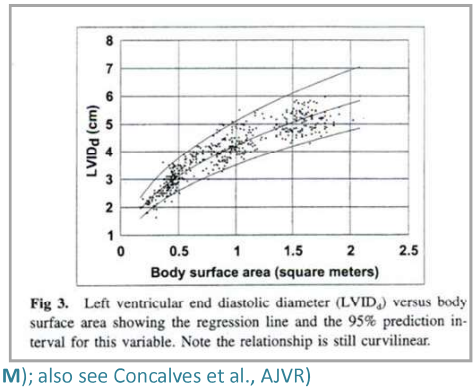

Fig 3. Left ventricular end diastolic diameter ($LVID_d$) versus body surface area showing the regression line and the 95% prediction interval for this variable. Note the relationship is still curvilinear.

Data from **Cornell, et al. (JVIM)**; also see Concalves et al., AJVR)

- These cut-offs are specific for LV dilation, but **insensitive** (too many sighthounds)
- Data gaps common – due to limited breeds represented
- ⇑Spread of data (to 20 mm for normal range) – wide but this is common
- Combining of breeds – influence of *somatotypes was unknown at the time*

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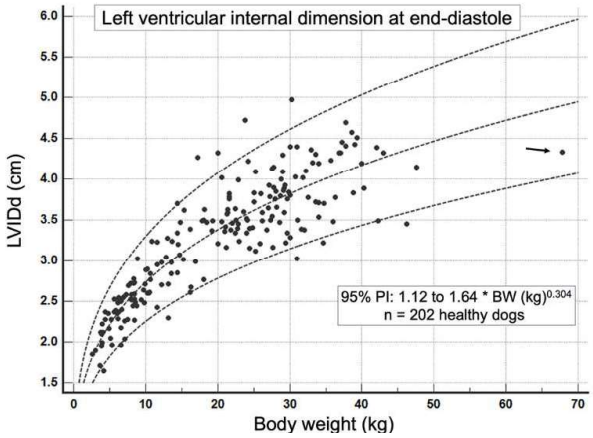
LVIDd vs. Bodyweight in Multiple-Breeds (Healthy Dogs)

Typical Scatter – Further skewed by certain breeds



(Multiple Breeds UCD + OSU data)

As shown by Cornell, et al. the LVID is best modeled using a nonlinear (allometric) approach to "normalize" the LV size to bodyweight (kg).

However, the *sample* used to generate the exponent affects the sensitivity / specificity of any cut-off. The Cornell sample was biased by preponderance of certain breeds and exponents from that study are not recommended for general use as the upper reference limit of 1.85 (LVEDDN), is too insensitive for most dogs.

The exception is for MMVD staging (see later)

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Calculating the Normalized LVIDd (multi-breed studies)

Example:

LVIDd is 4.1 cm
Bodyweight is 18 kg

$$x^n = 18^{0.315} = 2.4854832407891$$

LVIDd normalized = $4.1/18^{0.315}$
= 4.1/2.49
= **1.65**

Regarding the Cornell, et al. exponent 0.294
Use this exponent only for MR staging (B1/B2)
To identify cardiomegaly in most dogs, use larger exponents 0.31 - 0.33 as these are more sensitive

The LVIDd$^{0.32}$ Upper limits of normal (for all non-sighthound breeds) <**1.65**

We also need to look at other measures of LV and LA size or perform a repeated exam for borderline cases – especially if this "cut-off" will relate to therapy.

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Allometric Scaling in Multiple Breeds

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STANDARD ARTICLE

Journal of Veterinary Internal Medicine ACVIM Open Access American College of Veterinary Internal Medicine

Left ventricular M-mode prediction intervals in 7651 dogs: Population-wide and selected breed-specific values

Lilith Carla Esser[1] | Martin Borkovec[2] | Alexander Bauer[2] | Jens Häggström[3] | Gerhard Wess[1]

- Normalized LVID to bodyweight is allometrically scaled (as per LA) exponent = ^**.322**
- Their exponents differ between sighthounds & non-sighthounds
- Breed variation is likely an issue for "sensitivity" in all multi-breed studies
- Overall: slightly larger than Visser; smaller than ideal of ^**.33**

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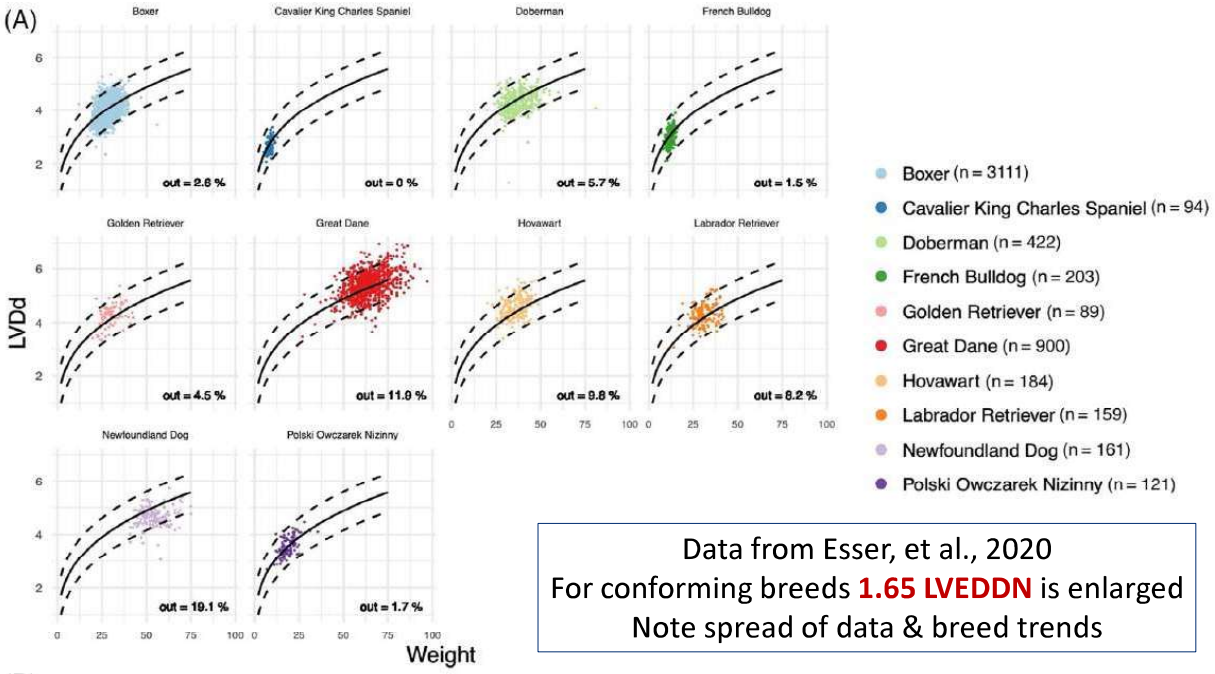

Data from Esser, et al., 2020
For conforming breeds **1.65 LVEDDN** is enlarged
Note spread of data & breed trends

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Reference: Data From Esser, et al. 2020

See: https://onlinelibrary.wiley.com/doi/full/10.1111/jvim.15914 (open access)

TABLE 3 Mean value and 95% prediction intervals (in centimeters) of the group *all nonsighthound dogs* (n = 6097)

BW (kg)	LVDd	LVDs	IVSd	IVSs	LVWd	LVWs
2	1.7 (1.5-2.0)	1.1 (0.9-1.4)	0.4 (0.3-0.6)	0.6 (0.5-0.8)	0.5 (0.4-0.6)	0.7 (0.5-0.9)
3.5	2.1 (1.7-2.4)	1.3 (1.1-1.7)	0.5 (0.4-0.7)	0.7 (0.5-1.0)	0.6 (0.4-0.7)	0.8 (0.6-1.1)
5	2.3 (2.0-2.7)	1.5 (1.2-1.9)	0.6 (0.4-0.8)	0.8 (0.6-1.1)	0.6 (0.4-0.8)	0.9 (0.7-1.2)
7.5	2.6 (2.2-3.1)	1.8 (1.4-2.2)	0.6 (0.5-0.9)	0.9 (0.7-1.2)	0.7 (0.5-0.9)	1.0 (0.8-1.3)
10	2.9 (2.4-3.4)	1.9 (1.5-2.4)	0.7 (0.5-1.0)	1.0 (0.7-1.3)	0.7 (0.5-1.0)	1.1 (0.8-1.4)
12.5	3.1 (2.6-3.7)	2.1 (1.7-2.6)	0.8 (0.6-1.0)	1.0 (0.8-1.4)	0.8 (0.6-1.0)	1.1 (0.9-1.5)
15	3.3 (2.8-3.9)	2.2 (1.8-2.8)	0.8 (0.6-1.1)	1.1 (0.8-1.4)	0.8 (0.6-1.1)	1.2 (0.9-1.5)
17.5	3.5 (2.9-4.1)	2.3 (1.9-2.9)	0.8 (0.6-1.1)	1.1 (0.8-1.5)	0.8 (0.6-1.1)	1.2 (0.9-1.6)
20	3.6 (3.1-4.3)	2.5 (2.0-3.1)	0.9 (0.6-1.2)	1.2 (0.9-1.6)	0.9 (0.6-1.2)	1.3 (1.0-1.6)
22.5	3.8 (3.2-4.4)	2.6 (2.0-3.2)	0.9 (0.7-1.2)	1.2 (0.9-1.6)	0.9 (0.7-1.2)	1.3 (1.0-1.7)
25	3.9 (3.3-4.6)	2.7 (2.1-3.3)	0.9 (0.7-1.2)	1.2 (0.9-1.7)	0.9 (0.7-1.2)	1.3 (1.0-1.7)
27.5	4.0 (3.4-4.7)	2.7 (2.2-3.4)	0.9 (0.7-1.3)	1.3 (0.9-1.7)	0.9 (0.7-1.3)	1.4 (1.0-1.8)
30	4.1 (3.5-4.9)	2.8 (2.3-3.5)	1.0 (0.7-1.3)	1.3 (1.0-1.7)	1.0 (0.7-1.3)	1.4 (1.1-1.8)
32.5	4.2 (3.6-5.0)	2.9 (2.3-3.6)	1.0 (0.7-1.3)	1.3 (1.0-1.8)	1.0 (0.7-1.3)	1.4 (1.1-1.8)
35	4.3 (3.7-5.1)	3.0 (2.4-3.7)	1.0 (0.7-1.4)	1.4 (1.0-1.8)	1.0 (0.7-1.4)	1.4 (1.1-1.9)
40	4.5 (3.8-5.3)	3.1 (2.5-3.9)	1.0 (0.8-1.4)	1.4 (1.0-1.9)	1.0 (0.8-1.4)	1.5 (1.1-1.9)
45	4.7 (4.0-5.6)	3.3 (2.6-4.1)	1.1 (0.8-1.5)	1.5 (1.1-2.0)	1.1 (0.8-1.4)	1.5 (1.2-2.0)
50	4.9 (4.1-5.7)	3.4 (2.7-4.2)	1.1 (0.8-1.5)	1.5 (1.1-2.0)	1.1 (0.8-1.5)	1.6 (1.2-2.0)
55	5.0 (4.2-5.9)	3.5 (2.8-4.4)	1.2 (0.8-1.6)	1.5 (1.1-2.1)	1.1 (0.8-1.5)	1.6 (1.2-2.1)
60	5.2 (4.4-6.1)	3.6 (2.9-4.5)	1.2 (0.9-1.6)	1.6 (1.1-2.1)	1.2 (0.9-1.6)	1.6 (1.3-2.1)
65	5.3 (4.5-6.3)	3.7 (3.0-4.6)	1.2 (0.9-1.6)	1.6 (1.2-2.2)	1.2 (0.9-1.6)	1.7 (1.3-2.2)
70	5.4 (4.6-6.4)	3.8 (3.0-4.7)	1.2 (0.9-1.7)	1.6 (1.2-2.2)	1.2 (0.9-1.6)	1.7 (1.3-2.2)
75	5.5 (4.7-6.5)	3.9 (3.1-4.9)	1.3 (0.9-1.7)	1.7 (1.2-2.3)	1.2 (0.9-1.7)	1.7 (1.3-2.3)

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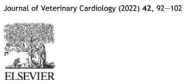
Journal of Veterinary Cardiology (2022) 42, 92–102



Journal of Veterinary Cardiology
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The ACVIM consensus statement definition of left ventricular enlargement in myxomatous mitral valve disease does not always represent left ventricular enlargement☆

M. Rishniw, BVSc, MS, PhD[a,*], D. Brown, DVM, PhD[b]

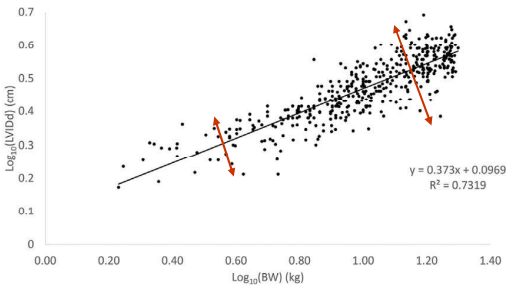

Fig. 2 Scatter plot and regression of the Log10-transformed left ventricular diastolic dimension (LVIDD) plotted against the Log10-transformed body-weight (BW) for 457 dogs <20 kg. The scaling exponent for this relationship is 0.373.

Key points: We need to identify "conforming" and "nonconforming" breeds (including sighthounds & some spaniels). Better to use scaling exponent close to ^0.32

- Note: r^2 = 0.732 (*73.2%* shared variability; wide SEE)
- Relatively *large* exponent for small breed dogs.
- Many dogs "*reused*" from prior studies.

200 IWs represent a potential sampling error.

Table 5 Proposed upper reference limits for normalized left ventricular diastolic dimensions for specific non-conforming breeds and for dogs that conform to the standard allometric model using a scaling exponent of 0.33.

Breed/group	n	Upper reference limit	90% Confidence interval
Conforming	878	1.61	1.58–1.63
Cavalier King Charles spaniel	59	1.69	1.62–1.71
English setter	101	1.79	1.74–1.81
English springer spaniel	41	1.96	1.79–1.97
Greyhound	32	1.70	1.64–1.77
Scottish deerhound	62	1.75	1.72–1.76
Whippet	70	1.84	1.76–1.97

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Example: Effects of different Scaling Factors

LVIDd (cm)	Weight (kg)	Exponent	Normalized BWt	LVEDDn
2.4	5	**.294**	1.61	1.49
2.4	5	**.333**	1.71	1.40
3.2	10	.294	1.97	1.62
3.2	10	.333	2.15	1.49
3.9	15	.294	2.22	**1.76**
3.9	15	.333	2.46	1.59

Do not normalize to ^.294 to diagnose "cardiomegaly" – Use .315 to .33 for reports
But do calculate LVEDDn (^.294) for MMVD (EPIC study)

DO NOT round up!!!

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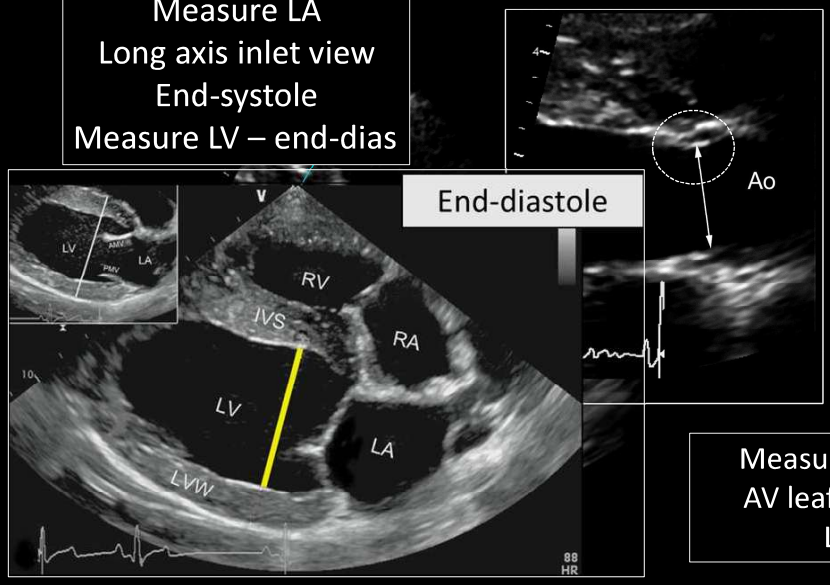
Another approach: LV/Ao (AV sys) ratio from Long Axis Images

Measure LA
Long axis inlet view
End-systole
Measure LV – end-dias



Long-axis
LV:Ao >2.6 is abnormal in most dogs
Beware: dogs with a small aortic root (boxers, bull terriers)

Measure AV between the opened AV leaflets or hinges; mid-systole
Long axis outlet view

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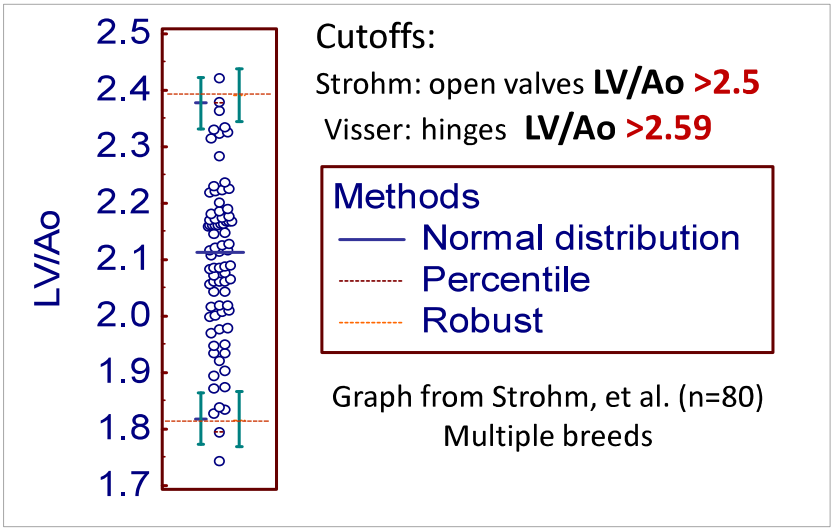
Reference: Identifying LV/Ao Dilation in the Dog

Ratio of Long Axis LV to Ao (AV) – Use Cutoff of **<2.6**



Cutoffs:

Strohm: open valves **LV/Ao >2.5**

Visser: hinges **LV/Ao >2.59**

Methods
- Normal distribution
- Percentile
- Robust

Graph from Strohm, et al. (n=80)
Multiple breeds

Should be similar if using 2D Short-axis or M-mode to measure the LV internal diameter

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Summary – Quantitation: LV Size (dilation) in Dogs

- Subjective assessment – rounding, sphericity index, EPSS
- Breed reference ranges – limited data [**mean * 1.17**] (see Mattoon textbook)
- Allometric scaling used to generate the "normalized" LVID (LVEDDn)
  - Verify LVIDd in orthogonal planes (short & long axis)…using exponent **^0.315** to **0.33**
  - **LVEDDN * 1.65 to 1.7** is useful for many breeds to identify LV dilation
- Ratio LVIDd/Ao in long-axis (assuming precise aortic measurement)
  - LV/Ao (long-axis) ≥ **2.6** useful across many breeds for detecting **mild LV dilation**
- LV volumes (Simpson's) – ideally compare Long-axis & Apical 4C volumes
  - Some specific breed & multi-breed studies have been completed
  - LV end-diastolic volume **>3.0 to 3.3 ml/kg** usually indicates LV dilation
- Currently there is no "best" system, but these are all useful
  - Beware: Sighthounds, some spaniel breeds, bulldogs!

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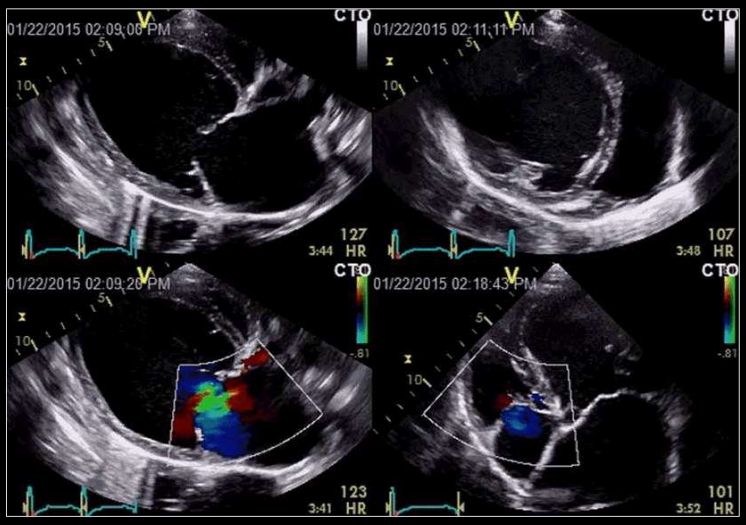
LV Systolic Function (Dysfunction)

It's safer to assess LV systolic function in the setting of congestive heart failure or with other signs of heart disease.

Be cautious in labeling an asymptomatic dog "DCM" for life



DCM (canine) with Functional MR and TR

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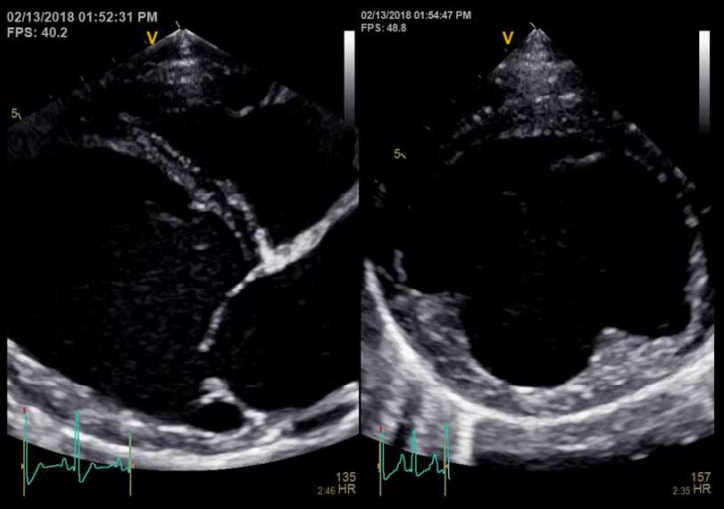
Subjective Approach: ↑LV Volume with ↓ Function

Sometimes "measurements" add little

Spherical, hypokinetic LV
+ LA Dilation



Canine Dilated Cardiomyopathy: LV dilation + ↓ LV Systolic Function

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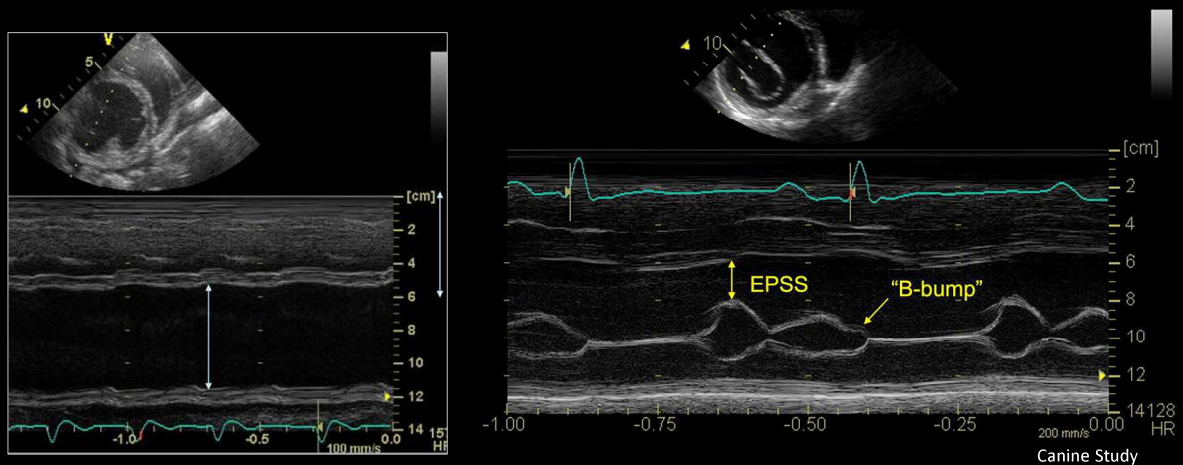
Subjective Assessment of Reduced LV Systolic Function

↓FS ↑EPSS (DDx: Off-angle image, MS, eccentric jet of AR)

B-bump (shoulder) = Typical of Congestive Heart Failure



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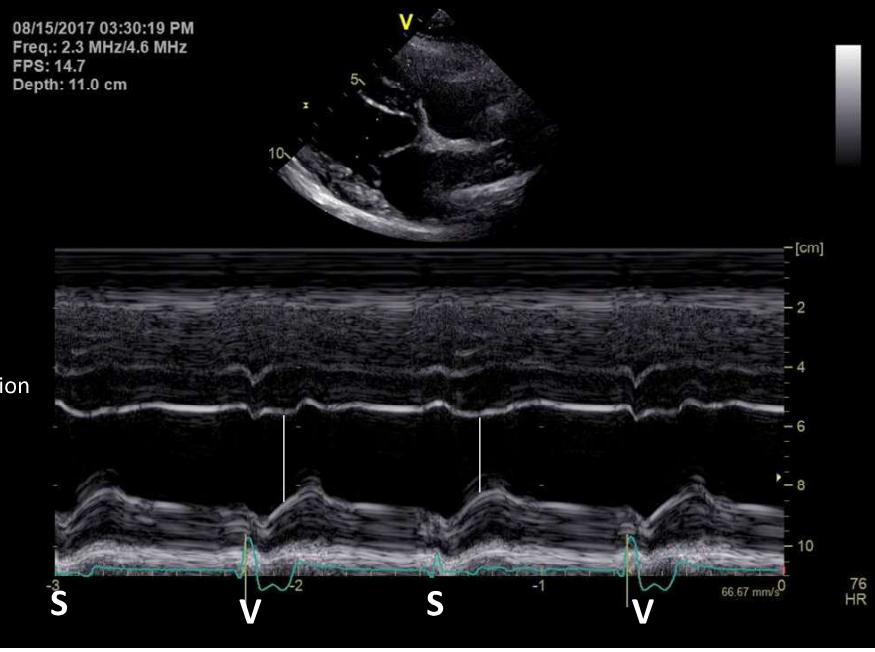
Effect of LV Dyssynchrony of LV Contraction (ventricular ectopics)



Note septal motion

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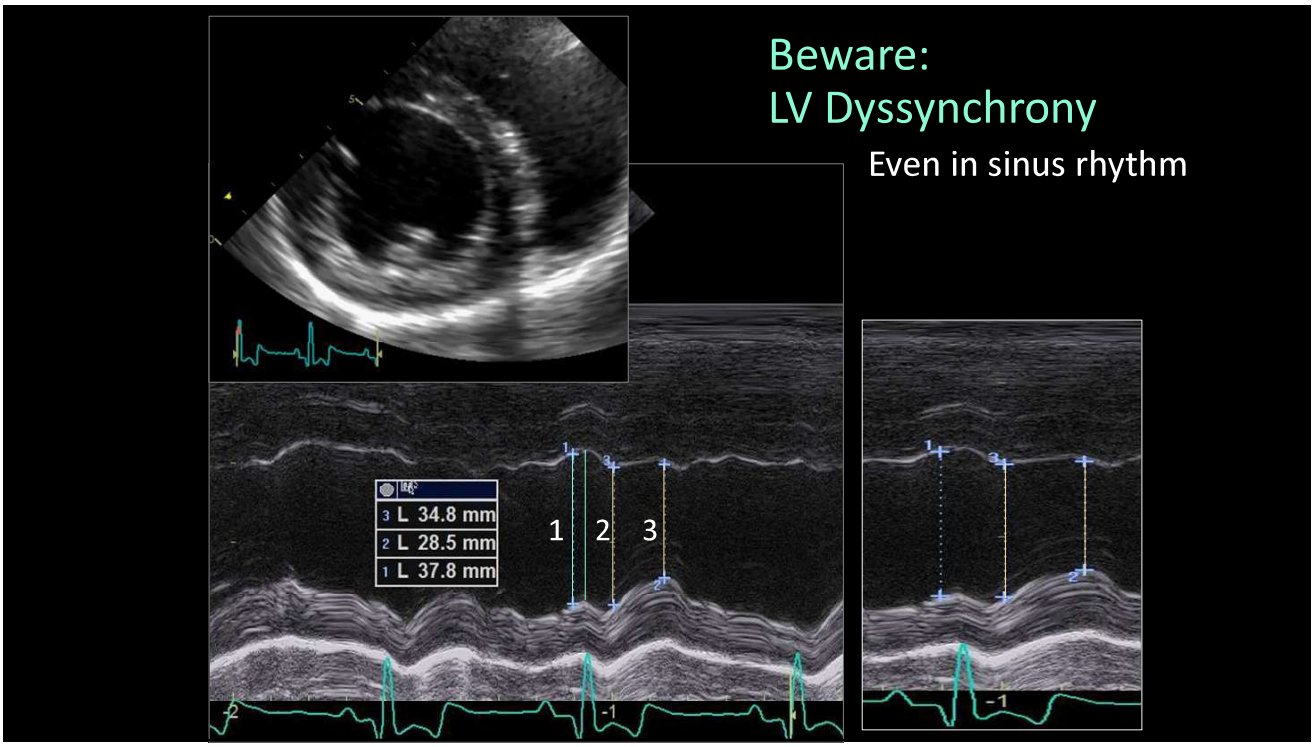
Beware:
LV Dyssynchrony
Even in sinus rhythm
3 L 34.8 mm
2 L 28.5 mm
1 L 37.8 mm
1
2
3

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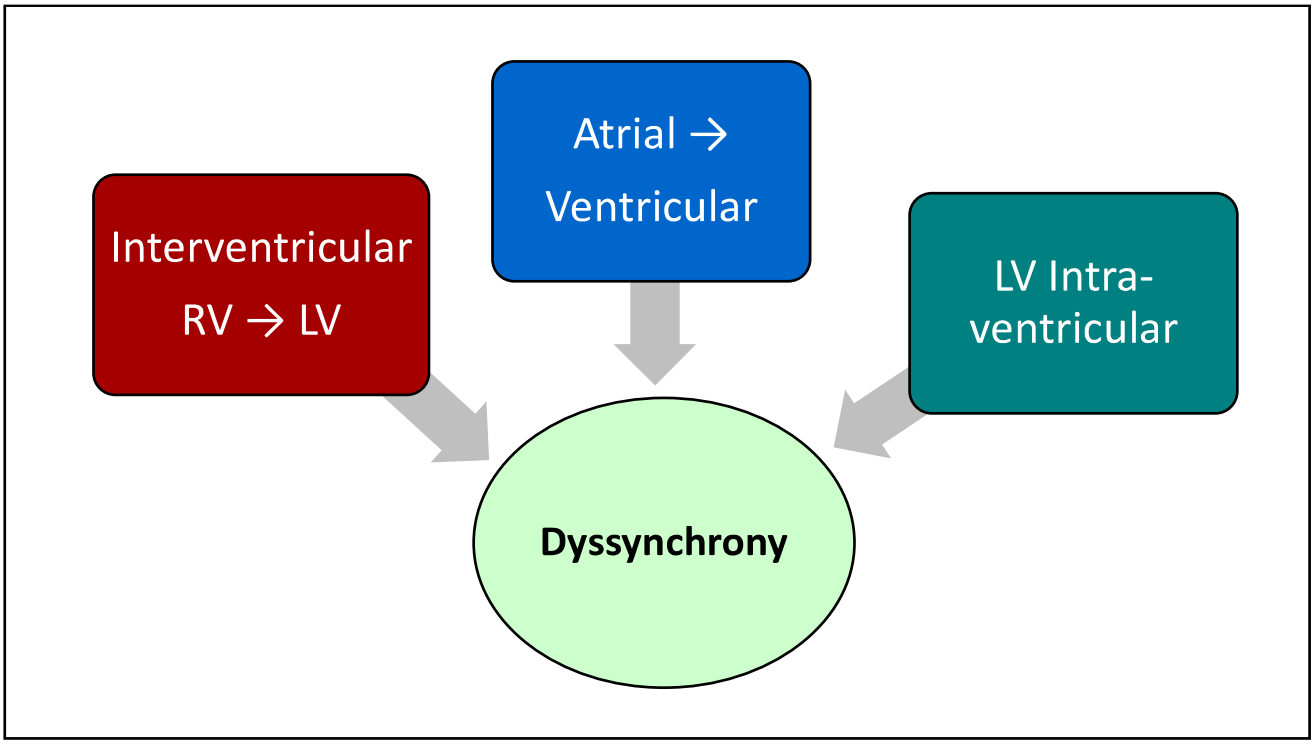
Atrial → Ventricular
Interventricular RV → LV
LV Intra-ventricular
Dyssynchrony

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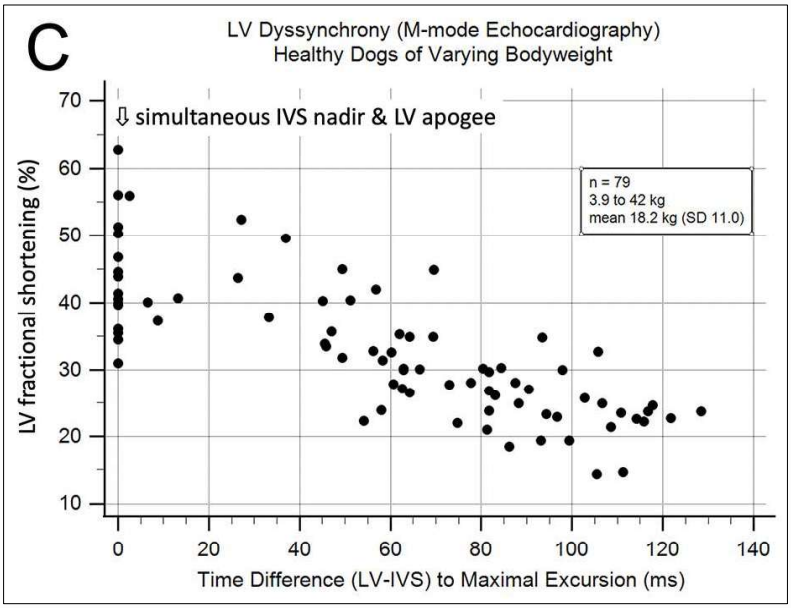
Effects of Dyssynchrony on LV Fractional Shortening



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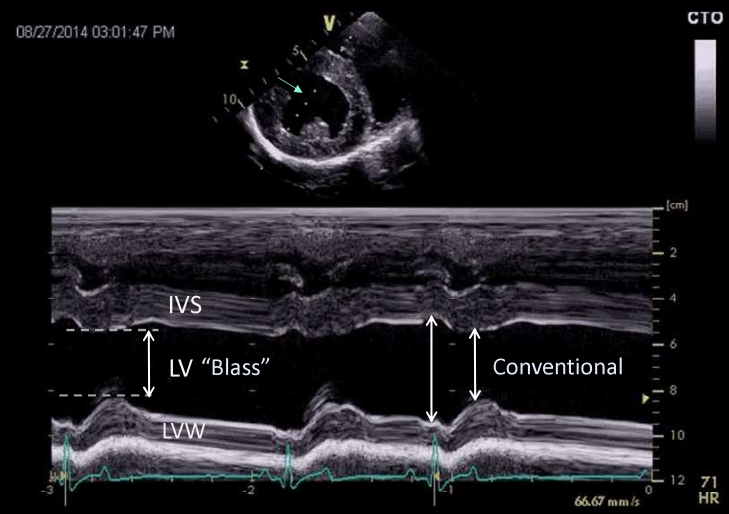
M-Mode Echo – Calculation of Fractional Shortening



Guide the M-line (cursor) to bisect the LV in short axis
In long axis cursor should be ventral to mitral valve, perpendicular to walls

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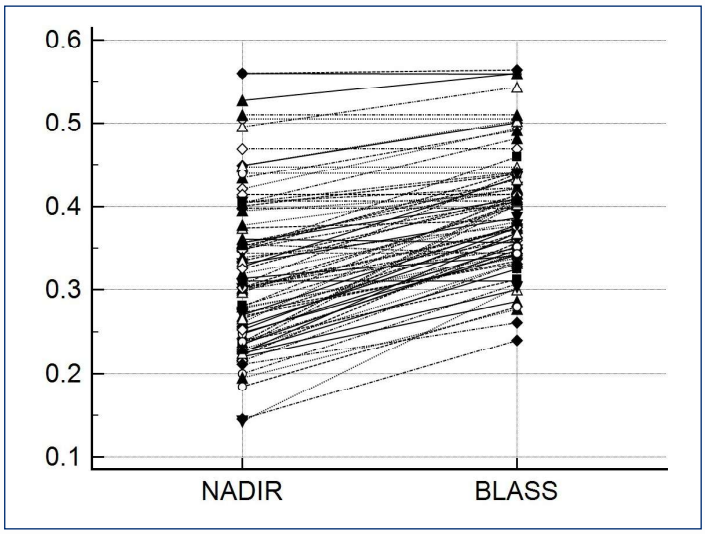
Comparison of LV Fractional Shortening



n = 79 healthy dogs – varying sizes & breeds

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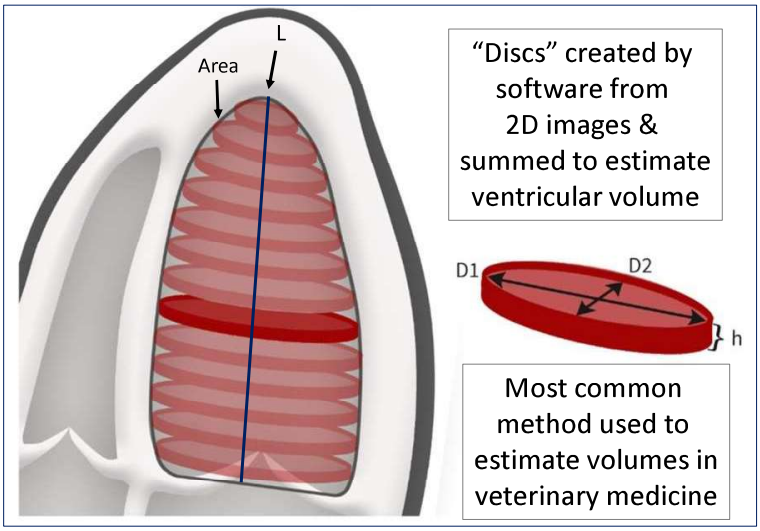
Estimating Volumes & Ejection Fraction
Area – Length & Simpson's Method of Discs

EF = (EDV – ESV) / EDV

EF = Stroke Volume / EDV



Modified from Cardioserv®

https://www.google.com/search?q=simpson+method+of+discs&rlz=1C1GGRV_enGB770US721&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiQ2tuPlv7cAhURIMKHRmOARcQ_AUICygC&biw=1229&bih=584#imgrc=jUezzq1m4QhzSM

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Guidelines Emphasize LV Volumes for Dx of Preclinical DCM

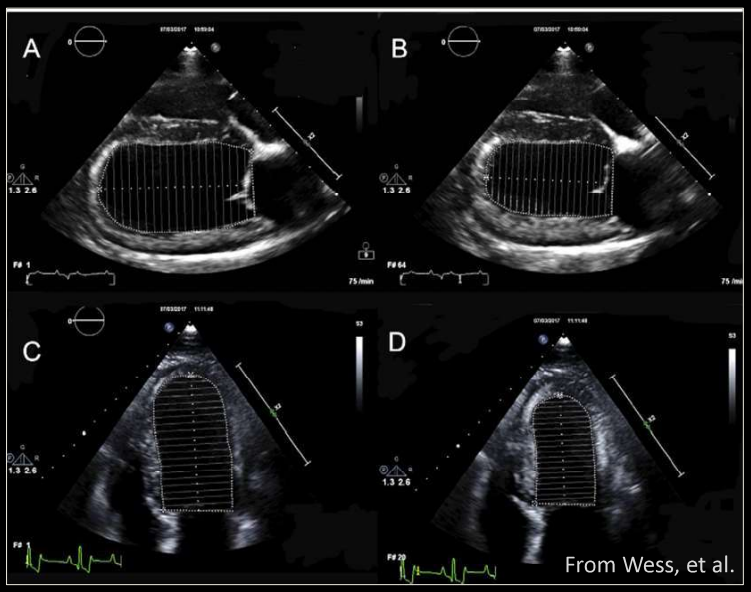
Note: This is not the human "bi-plane"

Approaches:

- Single plane
- Largest volume
- Average volume

Challenges

- Foreshortening
- Apex
- Endocardial resolution



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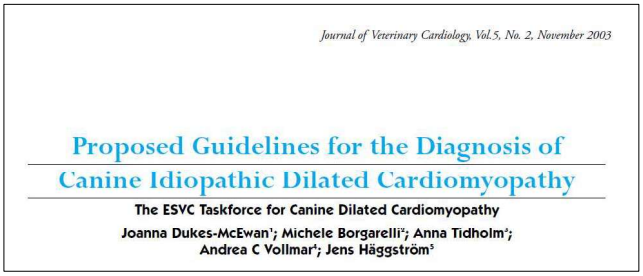
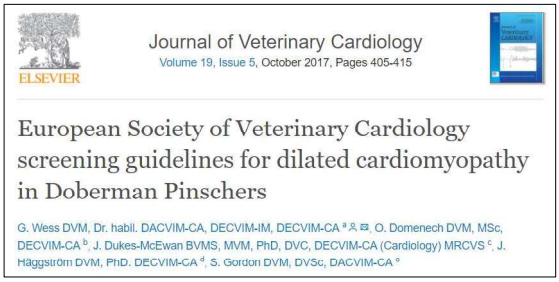
Reference: Guidelines & Reviews (J Vet Cardiology)


Journal of Veterinary Cardiology, Vol.5, No. 2, November 2003

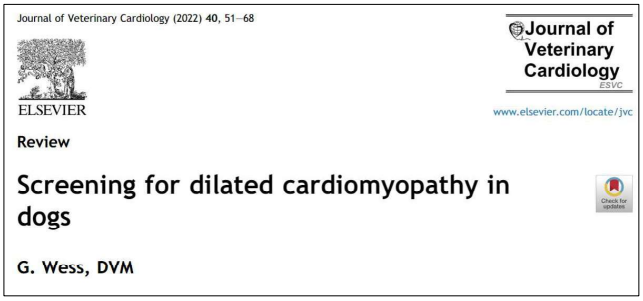
Proposed Guidelines for the Diagnosis of Canine Idiopathic Dilated Cardiomyopathy

The ESVC Taskforce for Canine Dilated Cardiomyopathy

Joanna Dukes-McEwan[1]; Michele Borgarelli[2]; Anna Tidholm[3]; Andrea C Vollmar[4]; Jens Häggström[5]


Journal of Veterinary Cardiology
Volume 19, Issue 5, October 2017, Pages 405-415

European Society of Veterinary Cardiology screening guidelines for dilated cardiomyopathy in Doberman Pinschers


Journal of Veterinary Cardiology (2022) 40, 51–68

Journal of Veterinary Cardiology

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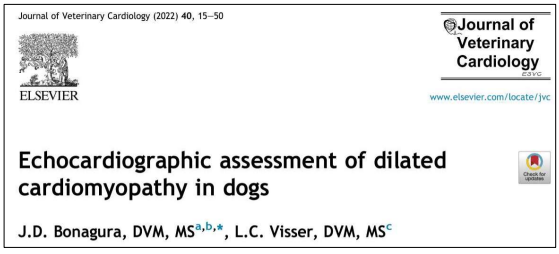
Review

Screening for dilated cardiomyopathy in dogs

G. Wess, DVM


Journal of Veterinary Cardiology (2022) 40, 15–50

Journal of Veterinary Cardiology

www.elsevier.com/locate/jvc

Echocardiographic assessment of dilated cardiomyopathy in dogs

J.D. Bonagura, DVM, MS[a,b,*], L.C. Visser, DVM, MS[c]

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Reference: LV Volumes using Method of Discs
Multi-breed study

Journal of Veterinary Internal Medicine
Open Access
ACVIM

STANDARD ARTICLE | Open Access

Echocardiographic reference intervals for volumetric measurements of the left ventricle using the Simpson's method of discs in 1331 dogs

Gerhard Wess, Alexander Bauer, Antonia Kopp

First published: 06 March 2021 | https://doi.org/10.1111/jvim.16089

Upper Reference limits in this study were ≈**3.3 ml/kg** end-diastole + **1.54 ml/kg** end-systole

Visser study: limits were ≈**3.0 ml/kg** end-diastole + **1.35 ml/kg** end-systole

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TABLE 2 Prediction intervals (PI) for non-sighthound breeds, estimated as 95% PIs for left ventricular end-diastolic and end-systolic volumes in milliliters, measured by Simpson method of discs

Body weight	Diastole Lower PI	Diastole Upper PI	Systole Lower PI	Systole Upper PI
1	1.4	4.7	0.4	1.5
2	2.8	7.2	0.9	2.3
3	4.0	10.1	1.4	3.5
4	5.4	13.3	1.9	4.8
5	6.8	16.8	2.5	6.2
6	8.1	20.1	3.1	7.6
7	9.3	23.1	3.6	9.0
8	10.4	25.8	4.1	10.1
9	11.4	28.2	4.4	11.0
10	12.4	30.8	4.8	11.8
11	13.6	33.8	5.2	13.0
12	15.0	37.3	5.8	14.4
13	16.6	41.2	6.5	16.2
14	18.4	45.5	7.3	18.2
15	20.2	50.1	8.2	20.3
16	22.0	54.6	9.1	22.5
17	23.8	59.0	9.9	24.7
18	25.6	63.4	10.8	26.9
19	27.3	67.6	11.7	29.1
20	29.0	71.8	12.5	31.2
22.5	32.9	81.4	14.4	35.8
25	36.2	89.6	16.0	39.7
27.5	38.8	96.1	17.3	42.9
30	41.1	101.6	18.4	45.6
32.5	43.3	107.1	19.5	48.2
35	45.5	112.6	20.5	50.8
37.5	47.8	118.3	21.5	53.3
40	50.1	124.0	22.5	56.0
42.5	52.4	129.9	23.6	58.7
45	54.8	135.8	24.8	61.5
47.5	57.3	142.0	26.0	64.5
50	59.9	148.5	27.2	67.8
52.5	62.7	155.4	28.6	71.3
55	65.6	162.8	30.1	75.0
57.5	68.7	170.7	31.6	79.0
60	72.1	179.0	33.3	83.3
62.5	75.6	187.9	35.1	87.8
65	79.3	197.4	37.0	92.7
67.5	83.3	207.4	39.0	98.0
70	87.4	218.1	41.1	103.6
72.5	91.7	229.4	43.2	109.7
75	96.1	241.6	45.4	116.3

Reference: Data from Wess, et al., 2021

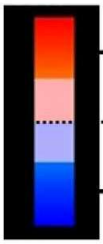
https://onlinelibrary.wiley.com/doi/epdf/10.1111/jvim.16089

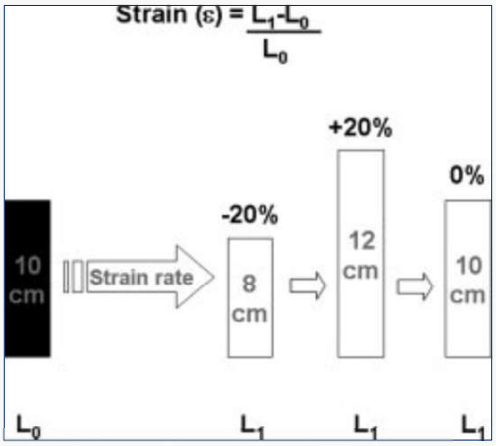
62

62

Tissue Deformation Imaging: Strain & Strain Rate

$$\text{Strain} = \frac{\Delta \text{ Length}}{\text{Length}_0}$$



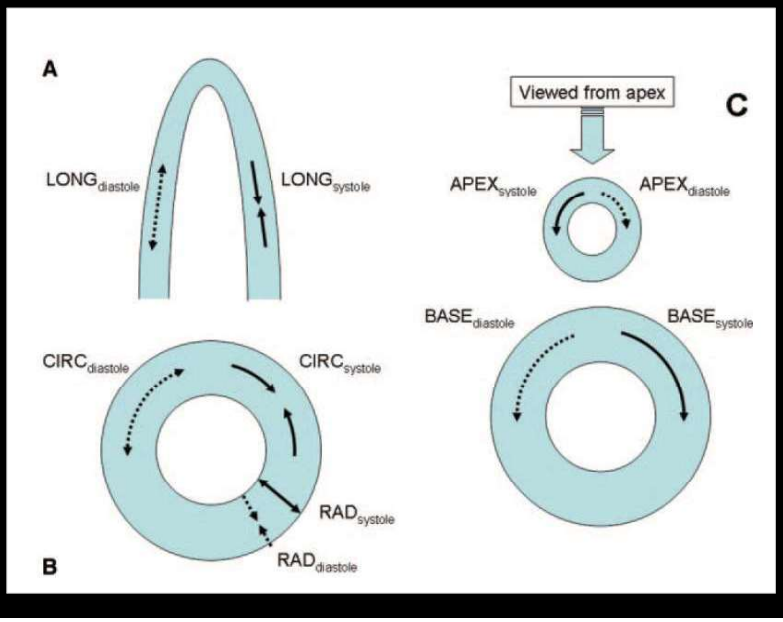


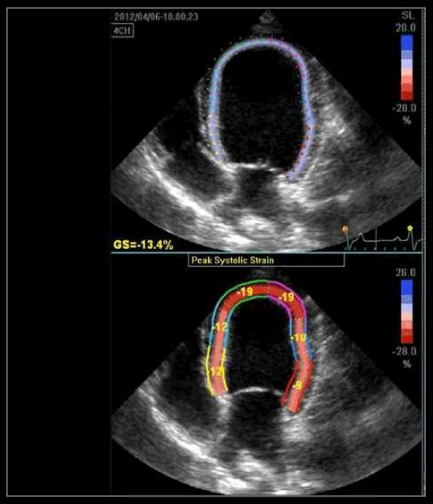
10cm 8cm 12cm 10cm

Strain is the fractional change in length of a segment of myocardium (relative to "resting" or baseline length)

63

Myocardial Deformations (types of strain)
Main value: Preclinical DCM or Doxorubicin CM

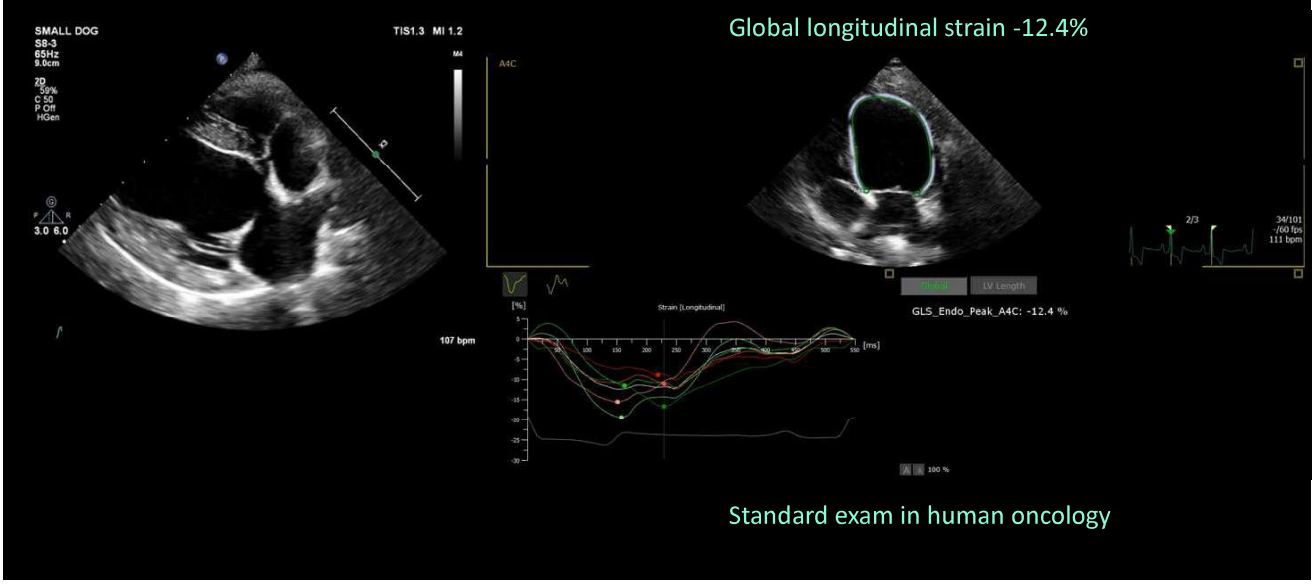




Preclinical DCM

64

Doxorubicin Cardiotoxicity



Global longitudinal strain -12.4%

Standard exam in human oncology

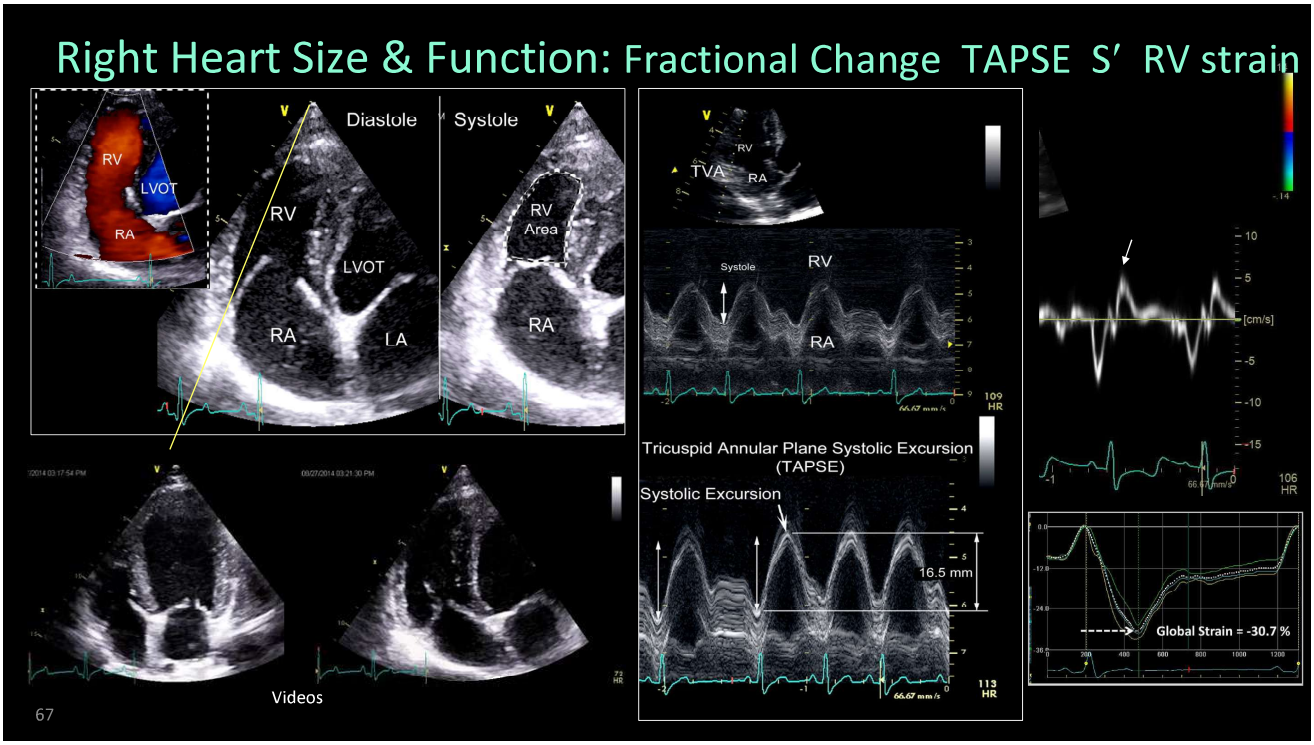
65

Summary – Quantitation: LV Systolic Function

- Only accept LVFS if "normal" or severely ↓
  - Must be congruous with clinical diagnosis
  - "All breed" normal ≥25%; FS values of 18 to 24% ⇒ more work is needed!
  - Remember the technical pitfalls
    - Cursor alignment to LV wall and IVS | Off-angle cursor | Dyssynchrony
  - Do not calculate volumes or end-systolic volume index from M-mode
- Subjectively evaluate fractional area change & MAPSE
- Quantify LV volumes using method of discs (breed differences)
  - In general, normal <3.0 – 3.3 ml/kg end-diastole; <1.35 – 1.54 ml/kg end-systole
  - Calculate **LV ejection fraction** (usually >42% to 45% using single plane
- Can use AI for ejection fraction if available & potentially strain imaging
  - Longitudinal Strain >15.5% (unitless) or < -15.5% is probably normal
- Use *serial evaluations* for healthy dogs with borderline systolic function

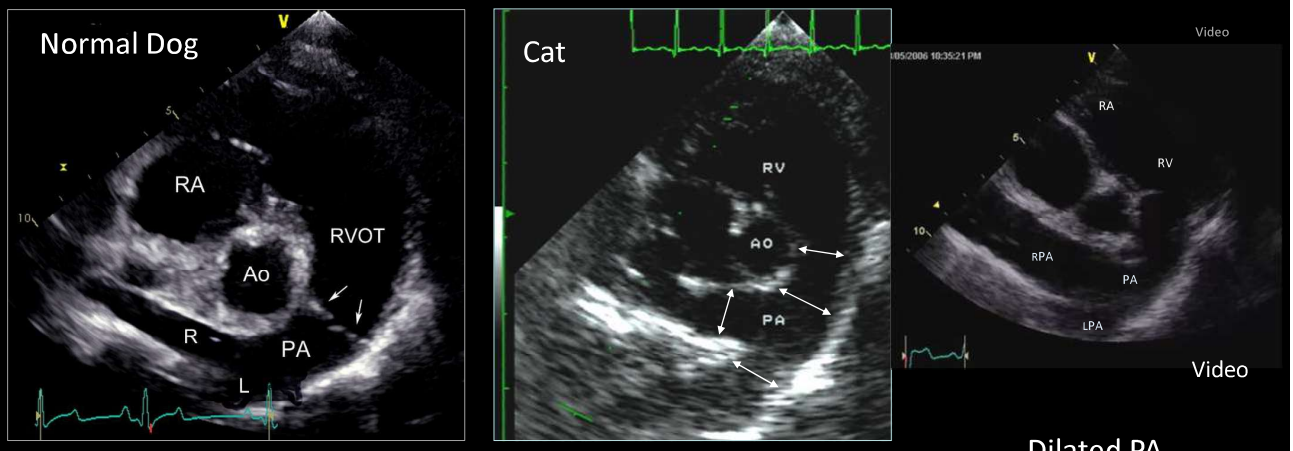
66

Right Heart Size & Function: Fractional Change TAPSE S' RV strain



67

Pulmonary Artery – Changes Associated with Pulmonary Hypertension
Right Parasternal Short Axis



Normal Branching of PA

PDA with PH

Dilated PA
HW Disease

PA Size: Where do changes Develop with PS – Shunts – PH?

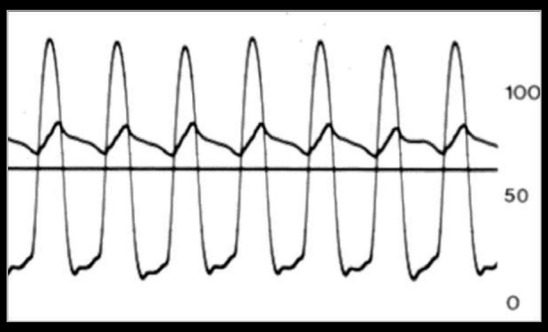
68

Valvular Heart Disease: Doppler Assessment

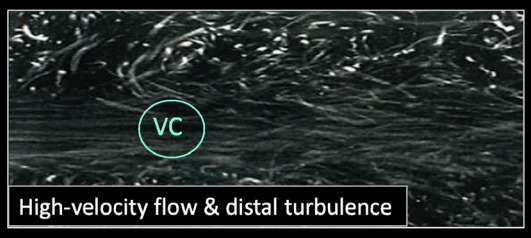
John D Bonagura, DVM, DACVIM (Cardiology, Interna! Medicine), FASE
Professor Emeritus, the Ohio State University, Dept. Veterinary Clinical Sciences, College of Veterinary Medicine
Adjunct Professor - Cardiology, Colorado State University College of Veterinary Medicine
Adjunct Professor of Cardiology, North Carolina State University College ofVeterinary Medicine

1

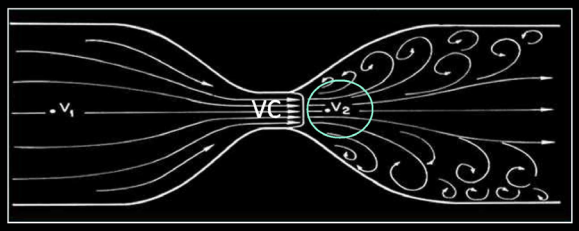
Flow Across a Stenotic (or restrictive) Orifice



Pressure gradient ΔP ⇒
Flow acceleration ⇒
Jet (high velocity flow)
- Vena contracta
- Distal flow disturbance



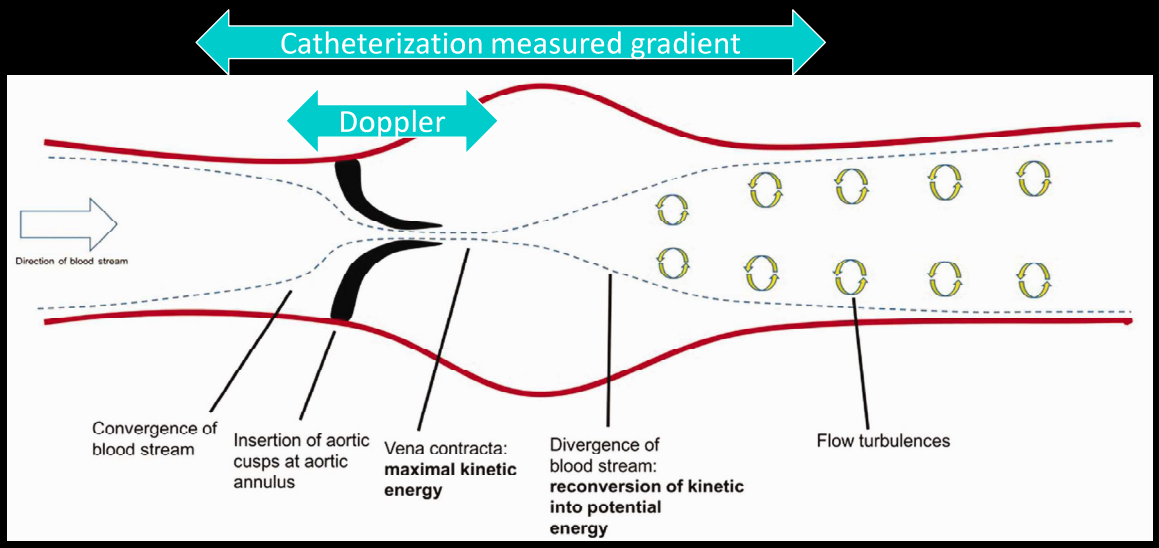
Simplified Bernoulli relationship: $\Delta P = 4V^2$



Continuity relationship: $CSA_1 * Vel_1 = CSA_2 * Vel_2$
Can Solve for CSA_2 (functional stenosis area)

2

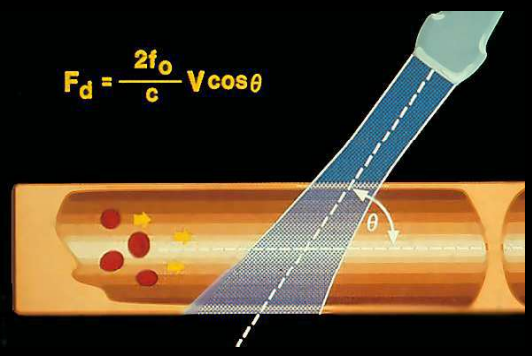
Pressure Recovery Across a Stenosis: Increases (Catheter-measured) Arterial Pressure



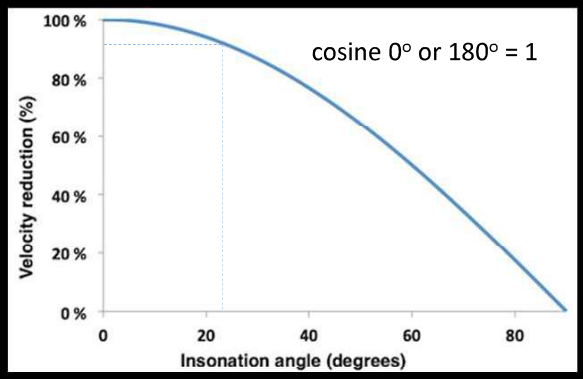
Sagmeister F, Herrmann S, Gassenmaier T, et al. Non-invasive determination of pressure recovery by cardiac MRI and echocardiography in patients with severe aortic stenosis: short and long-term outcome prediction. Journal of International Medical Research. 2020;48(10)

3

Velocity Estimates: Consider the Doppler Equation



From: J Kisslo, Adams & Belkin: Doppler Color Flow Imaging



https://folk.ntnu.no/stoylen/strainrate/Basic_Doppler_ultrasound

Maintain angle at < 22°

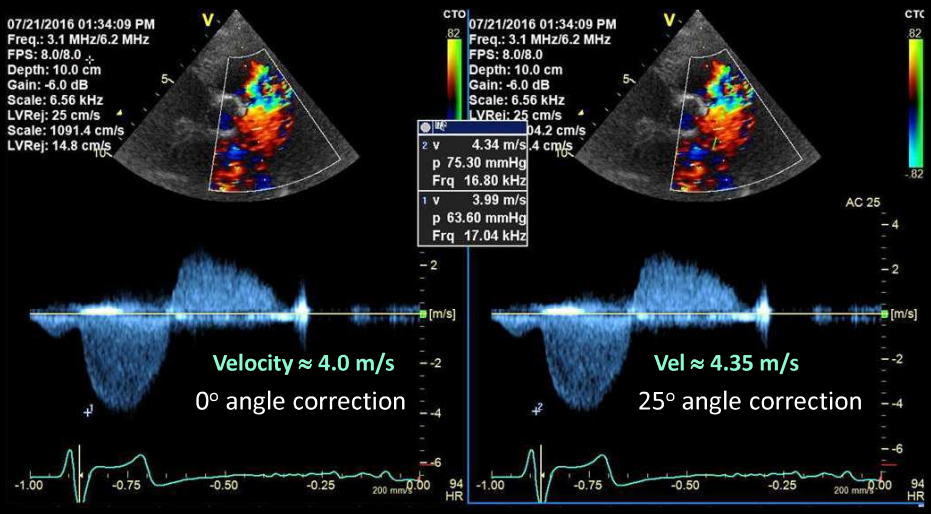
Angle is critical to cardiac imaging
If Θ = 0, then RBC Velocity ∝ Fd

4

4

Example: Angle Correction: Don't (!)

The third (elevational) plane cannot be determined from 2D imaging

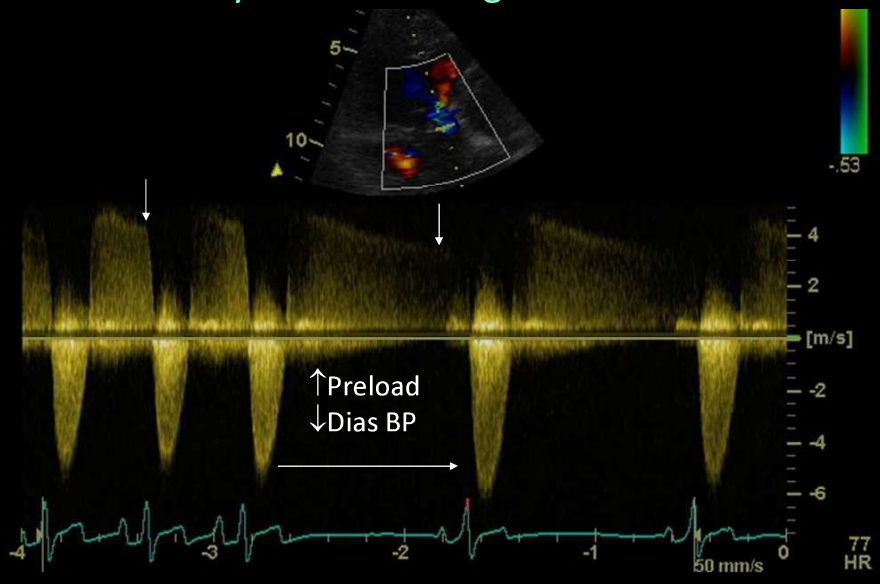


PS Gradient 64 mm Hg PS Gradient 75 mm Hg

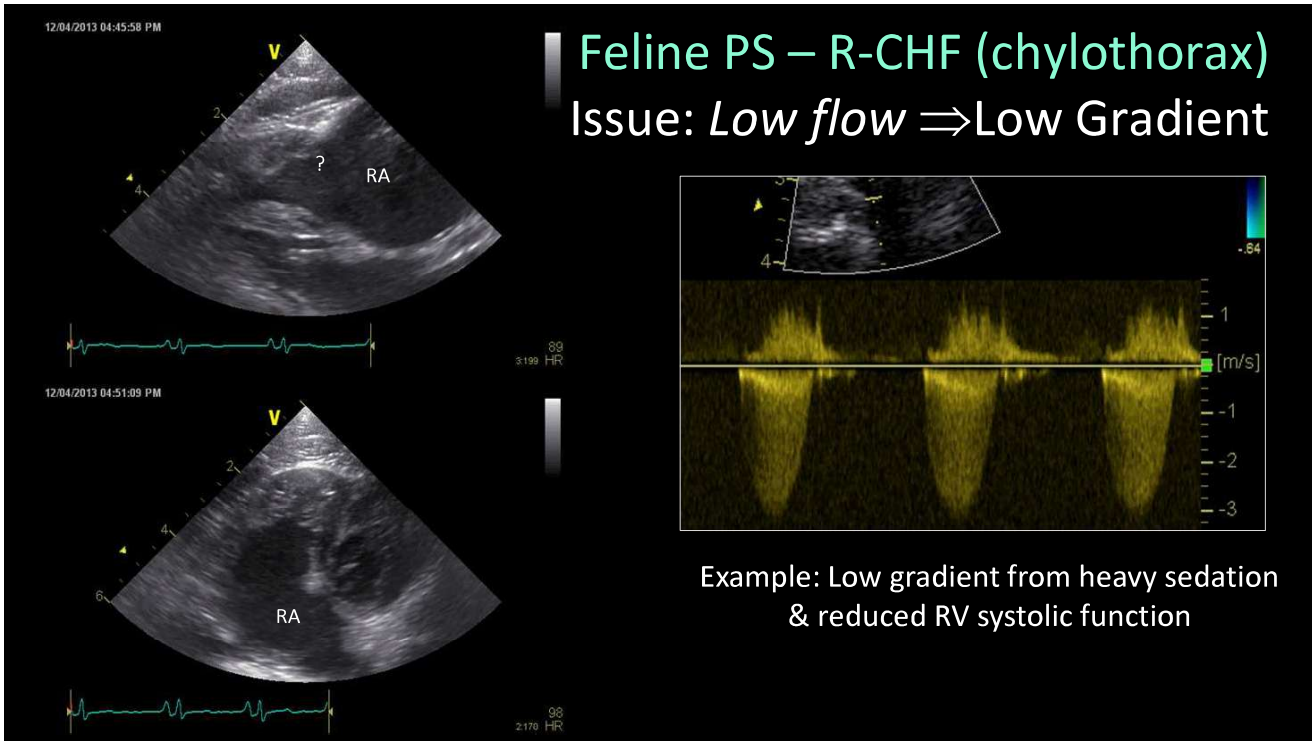
5

Appreciate: Effect of Stroke Volume on Pressure Gradients

Sinus Arrhythmia in a dog with subvalvular AS

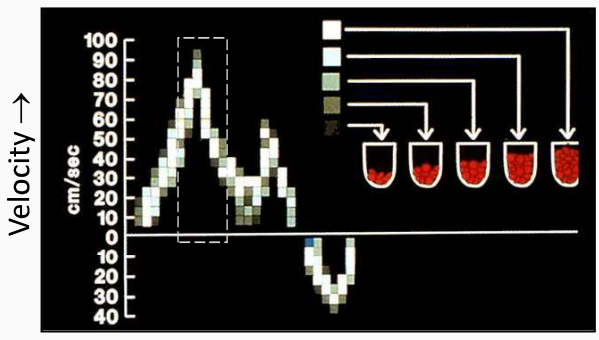


6



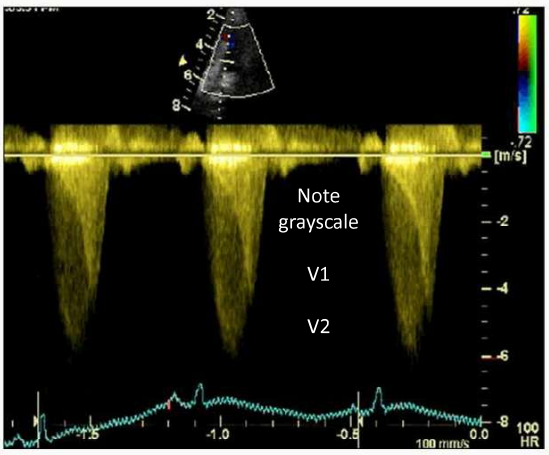
7

Ensure Grayscale in your Spectral Doppler Processing



Bin processing of grayscale affects the intensity of the velocity spectrum

From: J Kisslo, Adams & Belkin: Doppler Color Flow Imaging



Canine pulmonary stenosis

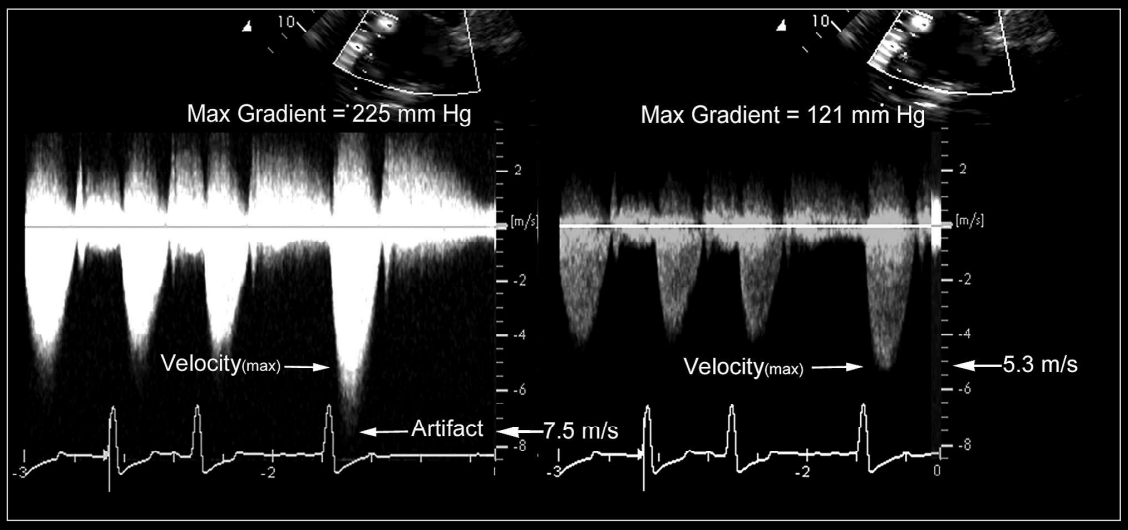
V1 - *Proximal* + *dynamic* RVOT obstruction

V2 - *Fixed* pulmonary valve obstruction

8

8

Pitfall – Over-Powered/Gained Spectra: Overestimate Gradients



Canine SAS

9

9

How to Achieve Spectral Grayscale?

Goals:

Clear velocity peak (no "whiskers") & spectral envelope

Grayscale in velocity spectrum

Adjustments:

↑Transmit Frequency or use a higher frequency TDx

↓ Transmit Power

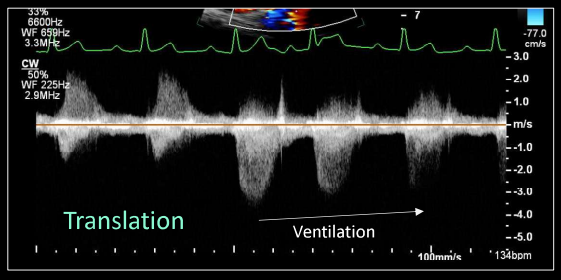
↓Gain

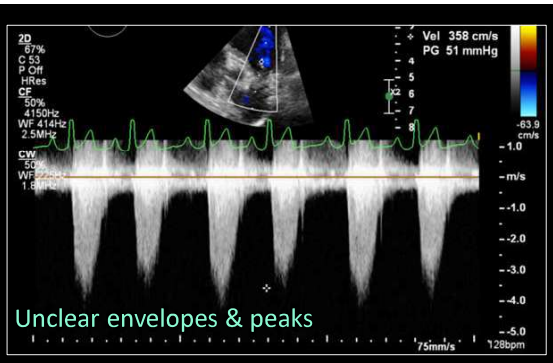
Compression – increase the *dynamic range* (more grays)

Reject adjust if available (rejects weakest returning signals)

10

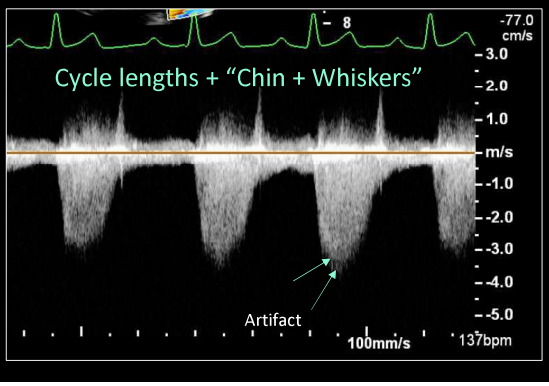
Other Doppler Pitfalls





~~Consecutive cycles~~

Pulmonary Stenosis CWD
Velocity Spectra



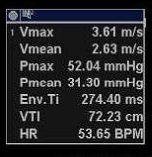
11

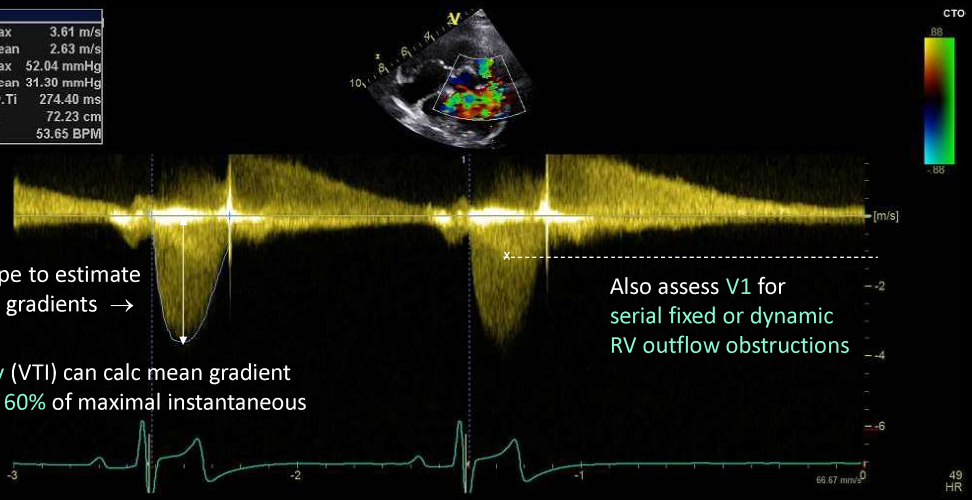
11

Doppler Quantitation – Estimating Pressure Gradients

Simplified Bernoulli relationship: $\Delta P = 4V^2$

Applies to Stenosis & Shunts





Tracing envelope to estimate
peak & mean gradients →

Also assess V1 for
serial fixed or dynamic
RV outflow obstructions

Mean velocity (VTI) can calc mean gradient
Mean ≈ 55 to 60% of maximal instantaneous

12

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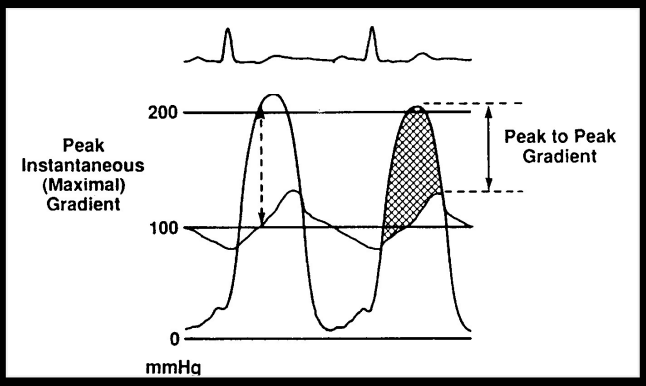
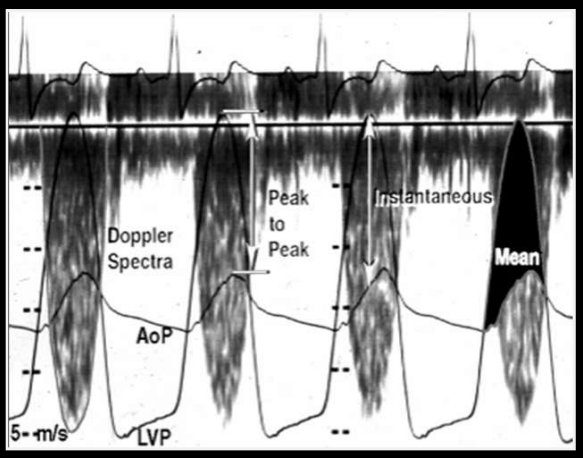
Pressure Gradients in Ventricular Outflow Stenosis



The pressure gradient is the most common Doppler method used to assess severity of obstruction



Canine Subvalvular Aortic Stenosis
Simultaneous CW Doppler & LV-Ao Pressures

13

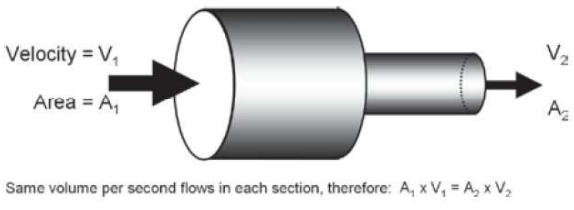
Received: 6 March 2018 | Revised: 20 April 2018 | Accepted: 22 May 2018
DOI: 10.1111/jvim.15244
Journal of Veterinary Internal Medicine ACVIM Open Access
STANDARD ARTICLE

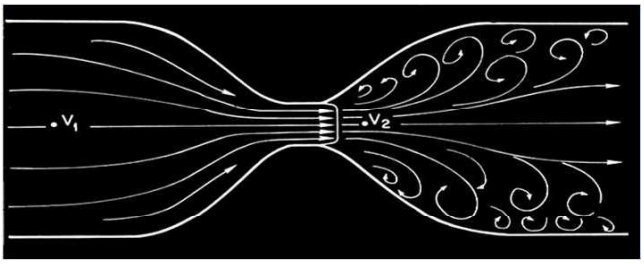
Echocardiographic evaluation of velocity ratio, velocity time integral ratio, and pulmonary valve area in dogs with pulmonary valve stenosis

Satoko Nishimura | Lance C. Visser | Catherine Bélanger | Maureen S. Oldach | Catherine T. Gunther-Harrington | Joshua A. Stern

$$PV_{CSA} = \frac{AV_{CSA} * AV_{VTI}}{PV_{VTI}}$$

Stroke volume dependence: VTI ratios (PA/Ao) & indexed valve CSA (Continuity)



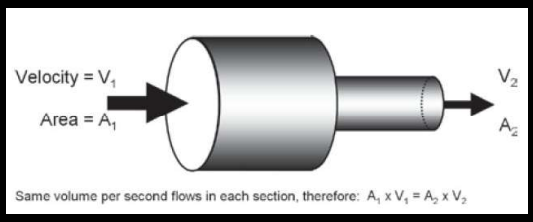


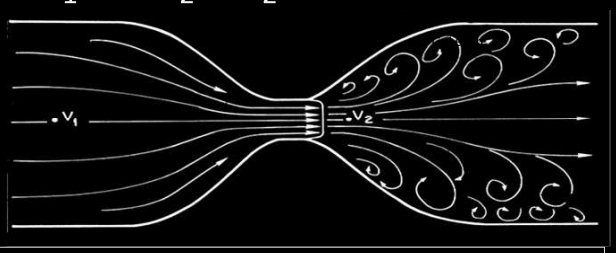
14

14

Reference: Valve CSA & Adjusting for Stroke Volume

Continuity Relationship: $V_1 * A_1 = V_2 * A_2$ & VTI ratios





Before the stenosis or at the other (*normal*) outflow tract:

A1 *Measure* diameter to calculate cross-sectional area at proximal site

V1 *Measure* mean velocity (VTI) at same location (PWD) & prior R-R interval

Across the stenosis:

V2 Measure mean velocity (VTI) at obstruction (CWD) – at similar prior R-R interval

A2 Solve for effective CSA at the stenosis

Calculate VTI ratio: $VTI_{stenosis} \div VTI_{reference}$ Example: $VTI_{PS} \div VTI_{Aortic}$

15

15

Reference: How can we account for Influence of Stroke Volume in Assessing PS?

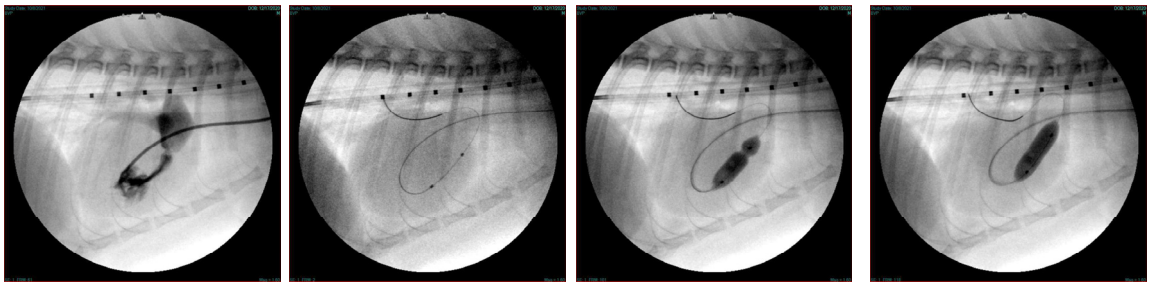
- Gorlin equation relates flow, systolic time & gradients to calculation of CSA, but it's complicated and not validated
- Suggested approaches: VTI ratios and calculation of CSA
- Presume no substantial shunt: stroke volume across AV & PV is not different over an average of cycles (match R-R)
- VTI ratios are simplest PV_{VTI}/AV_{VTI}
- Continuity equation should also be considered

$$PV_{CSA} = \frac{AV_{CSA} * AV_{VTI}}{PV_{VTI}}$$

16

Case Example – Cat with PS

Macallan (8-month-old Ragdoll Mix, Wt: 5.3 kg)



Pre-balloon:

maximal PG: **125** mmHg

PV/AV VTI ratio: **9.1** (VTI PV: 76.2; VTI AV: 8.3)

Cross sectional Area: **0.1** cm^2/m^2

Post-balloon:

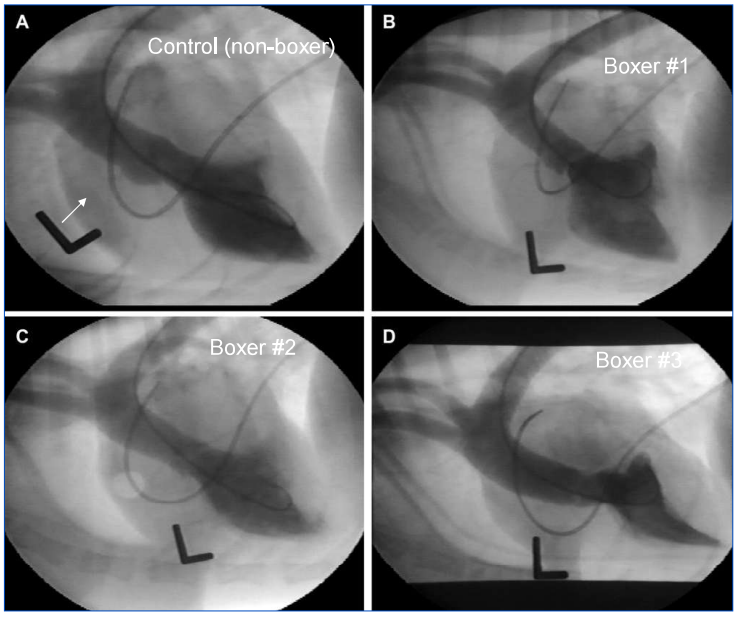
Maximal PG: **68** mmHg

PV/AV VTI ratio: **4.5** (VTI AV: 8.7; VTI PV: 40)

Cross sectional area: **0.3** cm^2/m^2

17

What constitutes the definitive diagnosis of Aortic Stenosis?



Koplitz S, Bonagura JD, Meurs K
Unpublished data

18

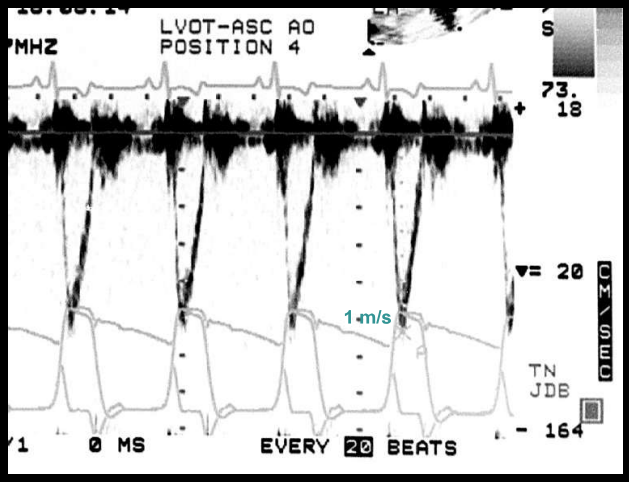
PW & CW Doppler – What are normal LVOT Gradients?
What is the velocity that "diagnoses" AS?

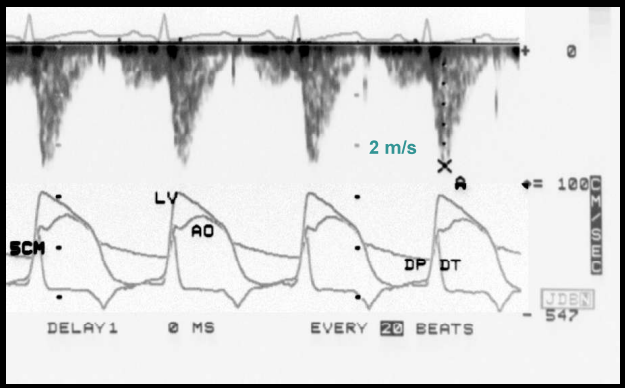
Subcostal, properly "gained", and not after a long cycle:
2.2 to 2.4 m/s likely has an increased liability for AS. Most dogs are <2 m/s

However, we do not have a definite "cut-off" for SAS based on pathology

19

Impulse Gradients



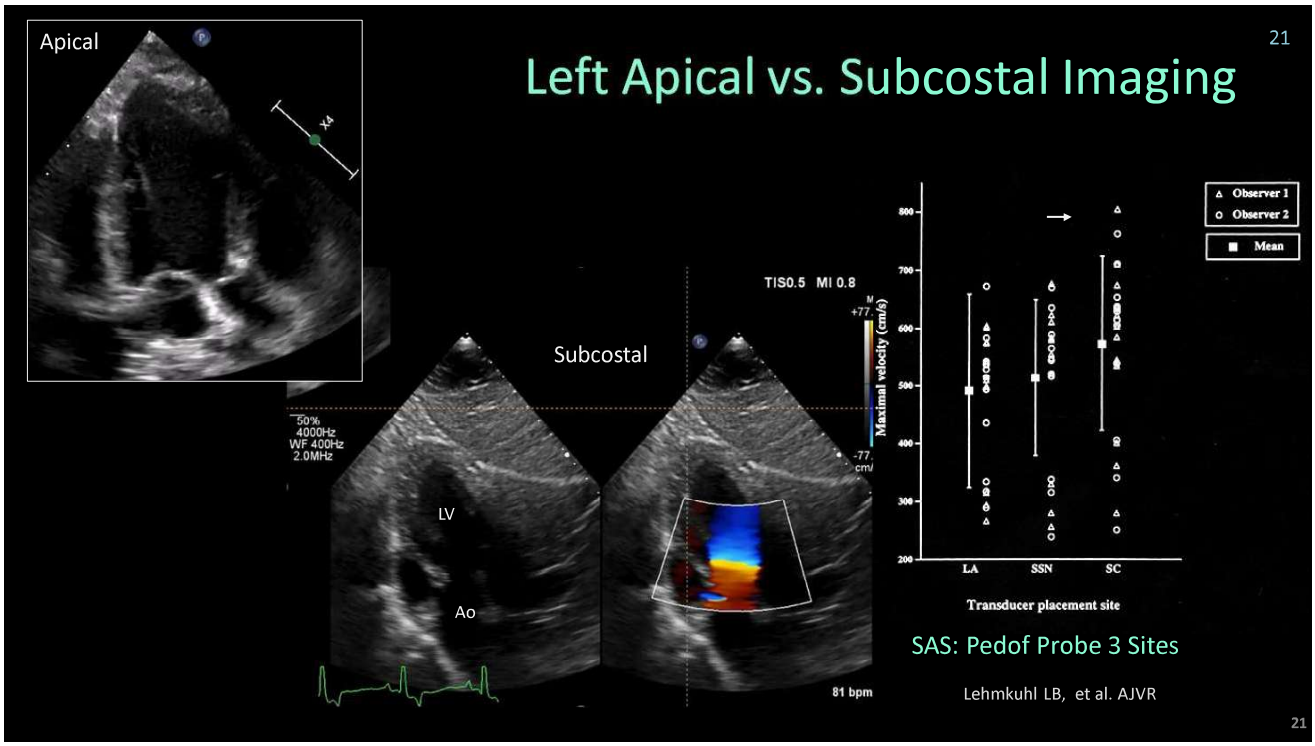


Normal Dog – Isoproterenol Stimulation

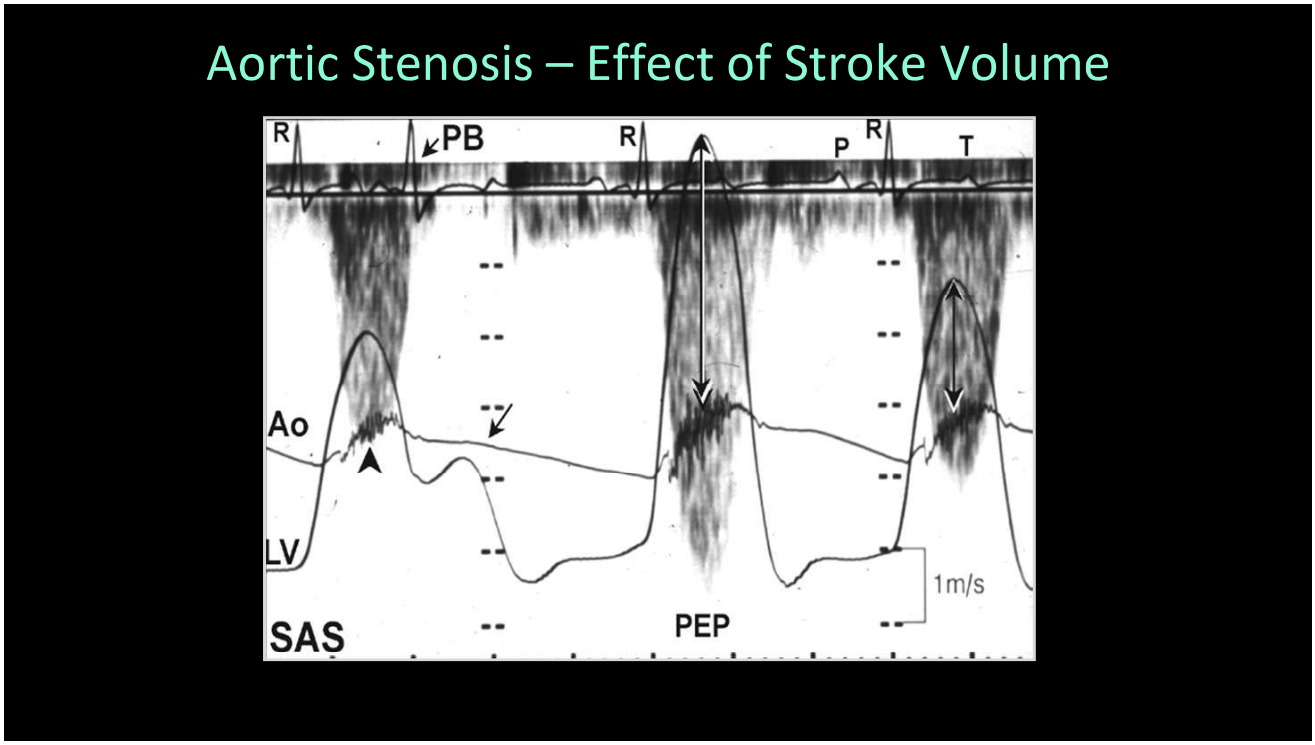
Unpublished data: Drs. T. Nakade & JD Bonagura

20

20


21
Left Apical vs. Subcostal Imaging
Apical
Subcostal
LV
Ao
TIS0.5 MI 0.8
81 bpm
Maximal velocity (cm/s)
Observer 1
Observer 2
Mean
LA
SSN
SC
Transducer placement site
SAS: Pedof Probe 3 Sites
Lehmkuhl LB, et al. AJVR
21

21

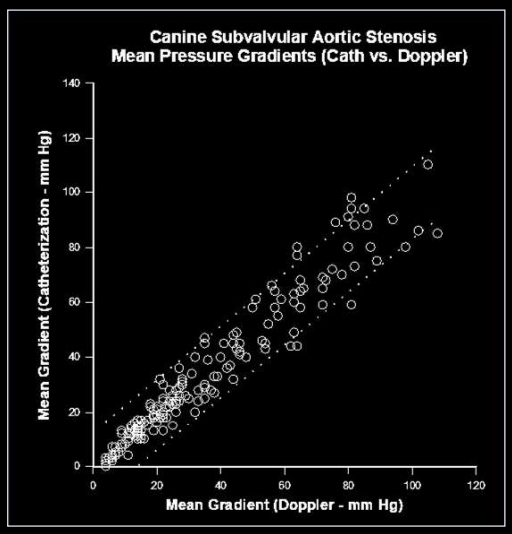

Aortic Stenosis – Effect of Stroke Volume
R
PB
R
P
R
T
Ao
LV
SAS
PEP
1m/s

22

Canine SAS
Doppler vs. Cath Gradients

CW Doppler shows strong correlation with invasive catheterization measures of PG in canine subaortic stenosis

Study at right shows *simultaneous* catheter & Doppler mean gradients

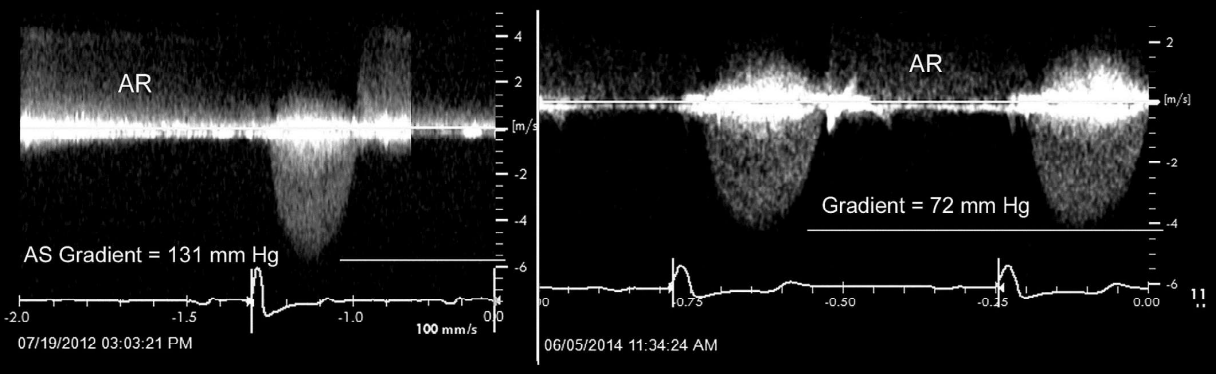


Lehmkuhl, Bonagura, Stepien et al., J Am Soc Echocardiography 1988

The **Mean** Pressure Gradient is typically 55-60% of the maximal instantaneous gradient in moderate to severe SAS

23

Chronic SAS – Secondary Cardiomyopathy of Pressure Overload: Effects of ↓Stoke volume

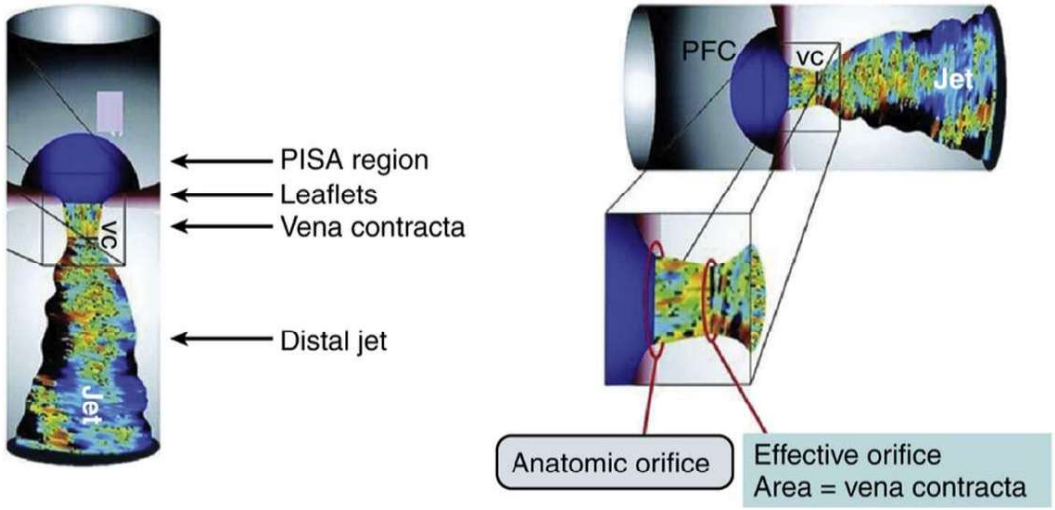


Baseline (2 years prior)

Follow up examination (Echo showed ↓LVEF)
Reduced stroke volume = ↓ pressure gradient

24

Flow Across Regurgitant Orifice



(Figure Courtesy of Catherine Otto, MD & American Society of Echocardiography)

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Reference slide: Color Doppler Analysis of AV Valve Regurgitation

Initially:

- Identify abnormal color flow signal ⇒ atrium (3+ planes)
- Slow motion replay!
- Quantify the duration (color M-mode | Spectral Doppler)
- Qualify Jets: single or multiple; central or eccentric

Potential Evaluations or Measurements:

- Receiving chamber analysis: jet area & length relative to atrial area
  - Commonly used – many pitfalls – overemphasized
- Orthogonal jet width at the vena contracta → Most useful method
- Flow convergence: Proximal isovelocity surface area (PISA)
  - Can calculate flow rates and effective regurgitant orifice – challenging

26

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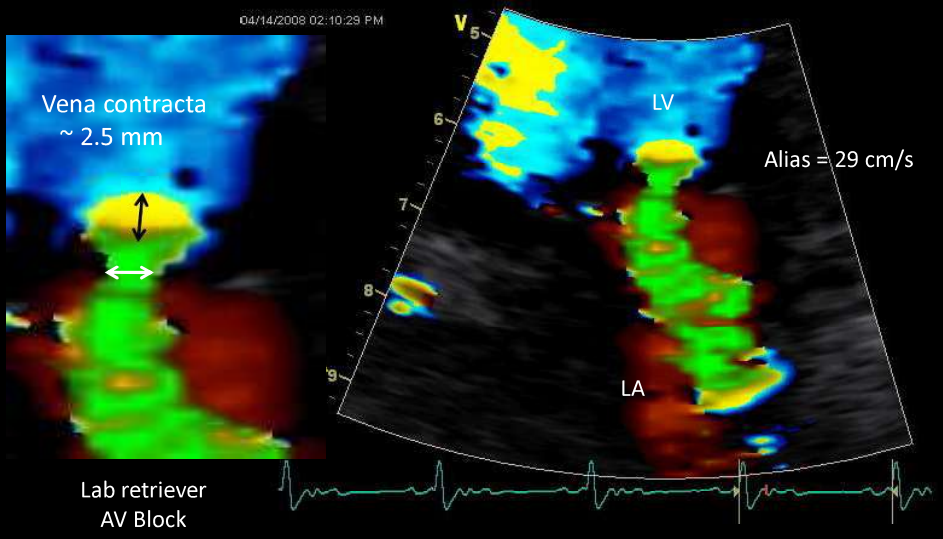
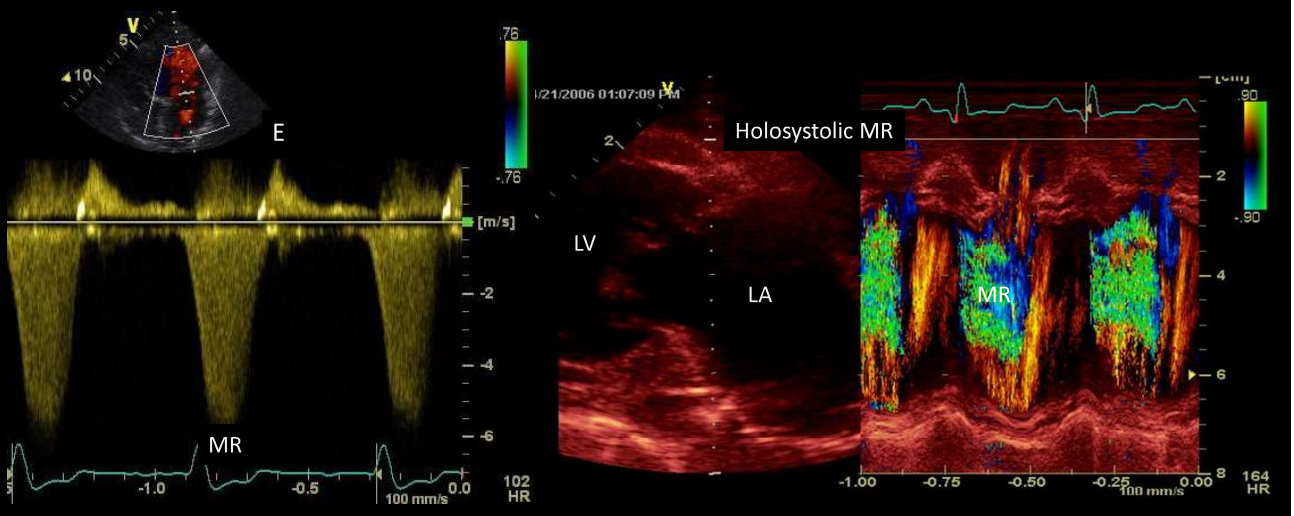
Mitral Regurgitation: Proximal Flow Convergence (PISA) → Vena Contracta → Jet



Values must be related to the size of the dog!

27

Time the Flow Disturbance: Spectral Doppler or Color M-mode



Temporal resolution: High frame rate 2D-CDI, C-MM, PWD/CWD

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Vena Contracta in MR: Narrow vs. Wide

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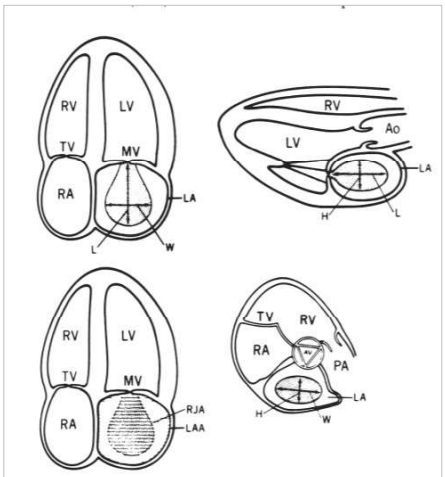
Why do we think single-plane "Jet" area / LA area is sufficient?

DIAGNOSTIC METHODS
MITRAL REGURGITATION

Circulation, Volume 75:185, 1987

Color Doppler assessment of mitral regurgitation with orthogonal planes

FREDERICK HELMCKE, M.D., NAVIN C. NANDA, M.D., MING C. HSIUNG, M.D., BENIGNO SOTO, M.D., CHRISTOPHER K. ADEY, M.D., RAJENDRA G. GOYAL, M.D., AND ROBERT P. GATEWOOD, JR., M.D.



"Neither the dimensions nor area of the RJ (regurgitant jet) assessed **in any single plane** correlated well with angiographic severity of mitral regurgitation"

"Experience has shown that attention to ….three components of the regurgitation lesion by color Doppler – **as opposed to the traditional regurgitant jet area alone** – significantly improves the overall accuracy of estimation & quantitation of the severity." *(ASE Guidelines)*

30

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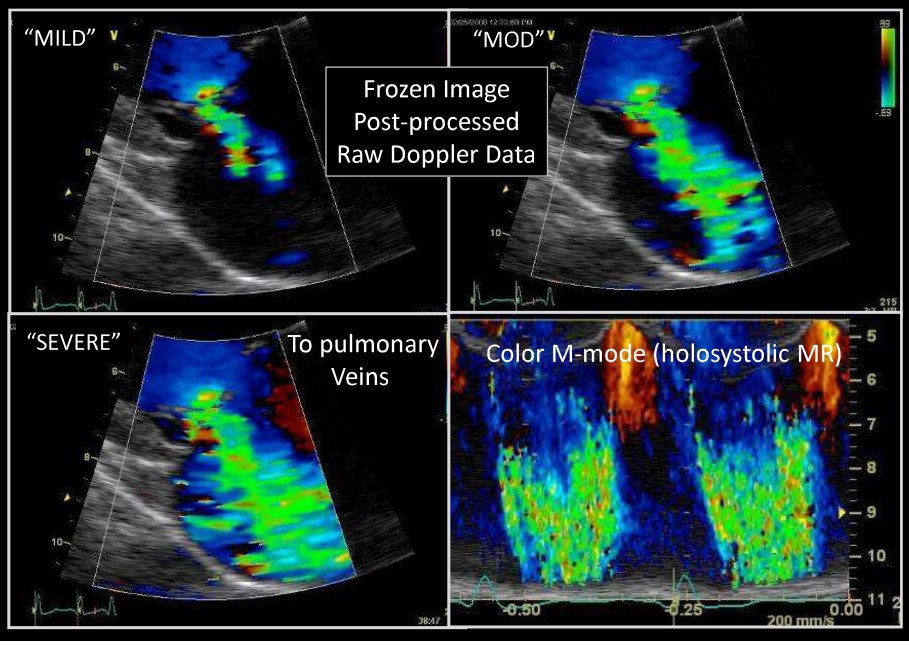
Receiving Chamber Analysis: Effects of Gain on Jet Area – "*Dial-a-Jet*"



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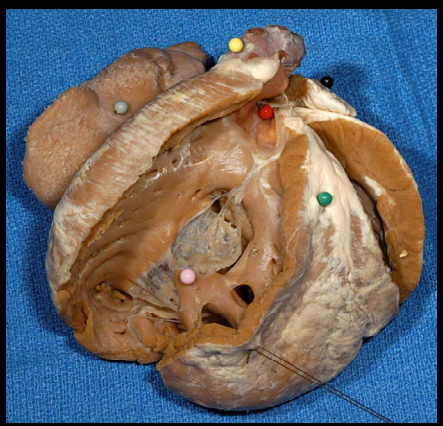
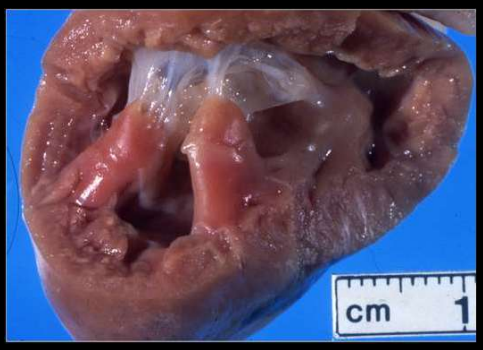
Tricuspid Valve Dysplasia (Malformation)



Dog: Tricuspid Dysplasia

Cat: Tricuspid Stenosis
AV stenosis is relatively rare



Dog: Tricuspid Dysplasia
Courtesy Dr. Matt Miller, DACVIM

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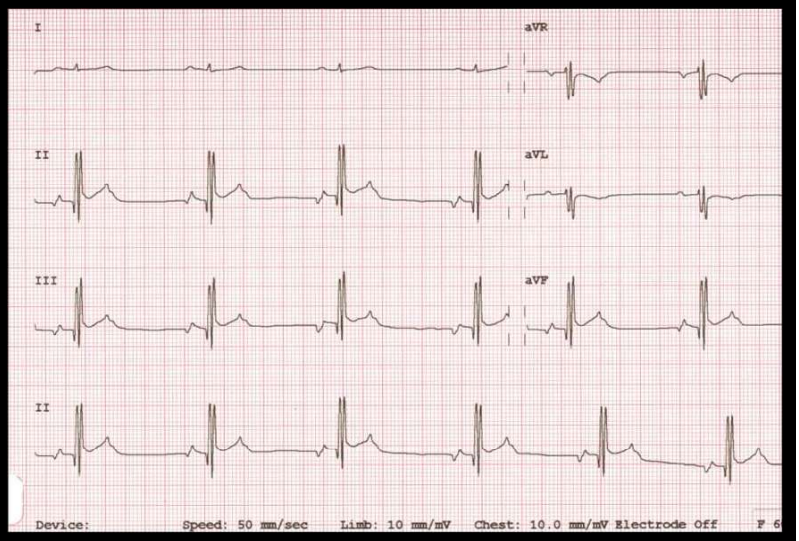
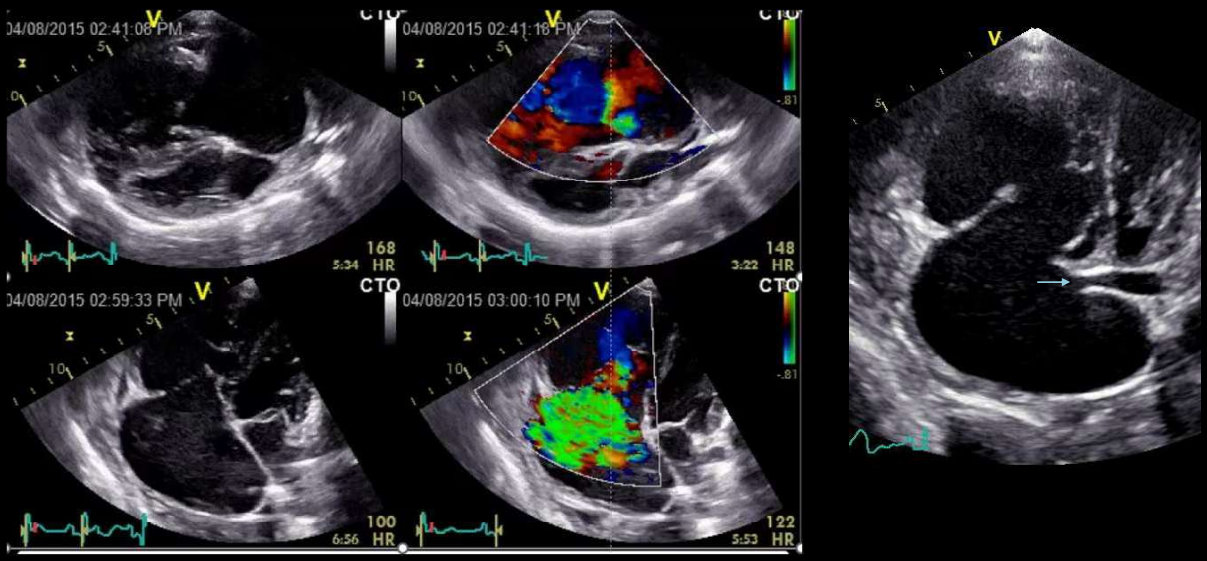
Reference: Clinical Findings

- Typical breeds – Labs
- Systolic right-sided murmur
- Puppies: Often soft
- Often severe cardiomegaly
- ECG: IVCS, “splintered” QRS
- Abnormal P-waves
- Atrial arrhythmias



33

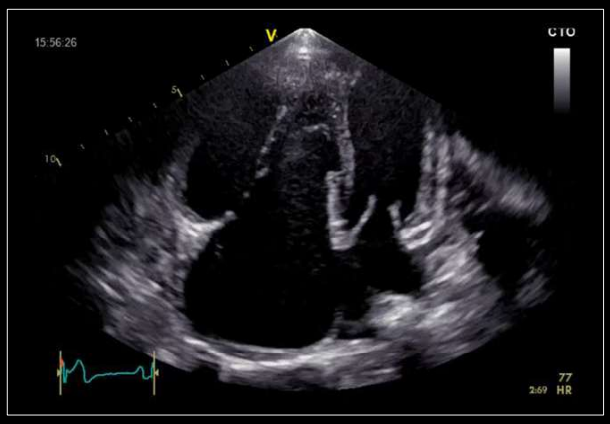
TV Dysplasia

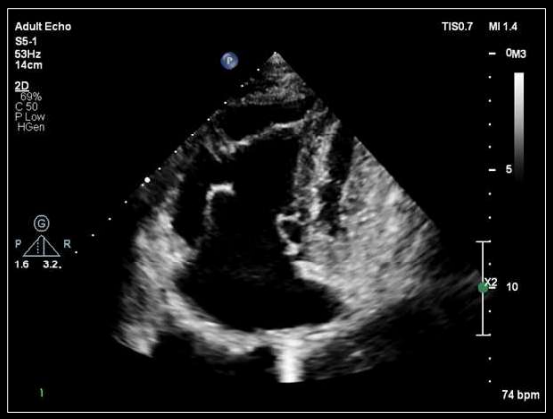


34

TV Dysplasia (vs. Ebstein's Anomaly)

CDI shows Severe TR (Apically Displaced Regurgitant Orifice)



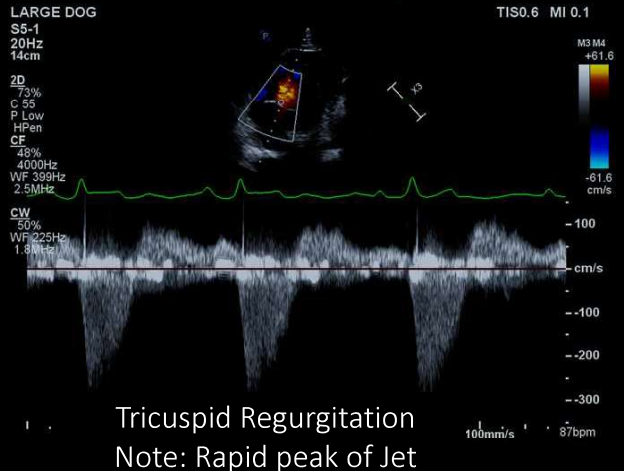


Is the TV annulus displaced apically?

35

TVD – Tricuspid Regurgitation (severe – 2 dogs)

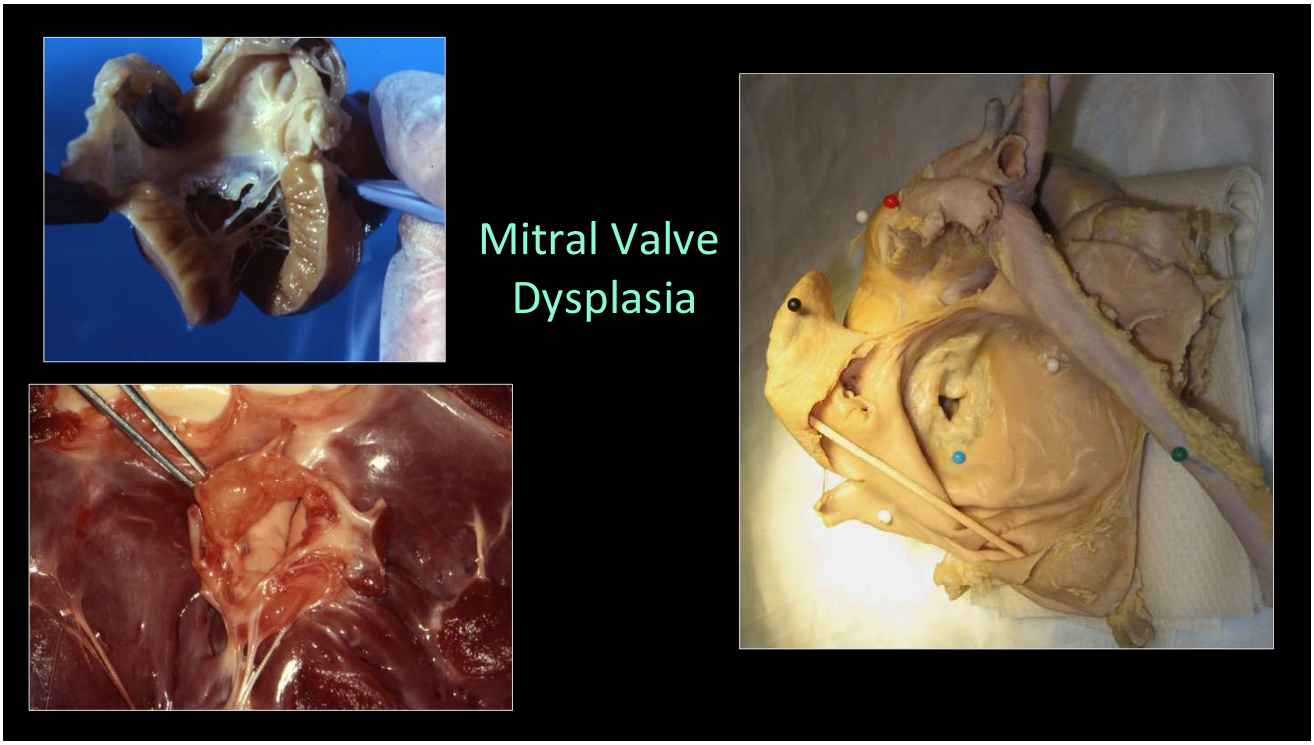
Note wide vena contracta



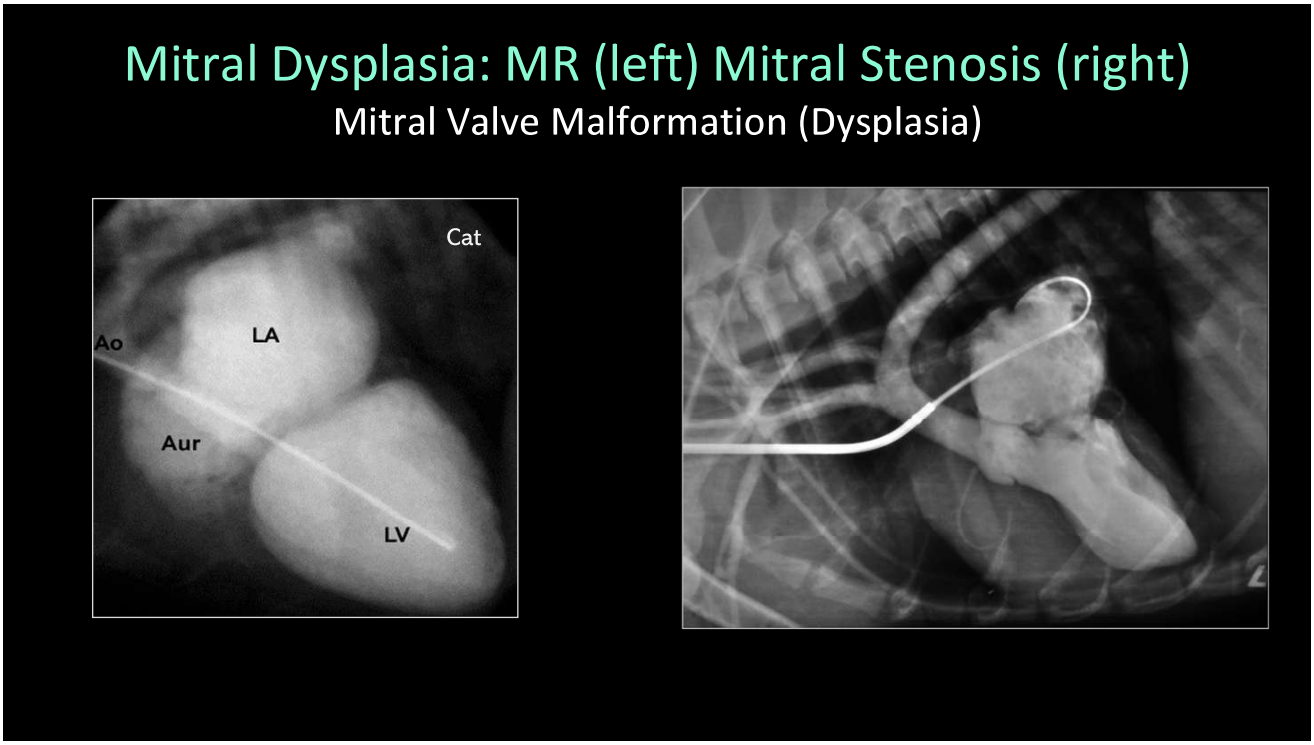
Tricuspid Regurgitation
Note: Rapid peak of Jet

Dogs with Severe PS might require medical therapy for CHF or AF
Surgery is performed at a small number of centers (open-heart)

36

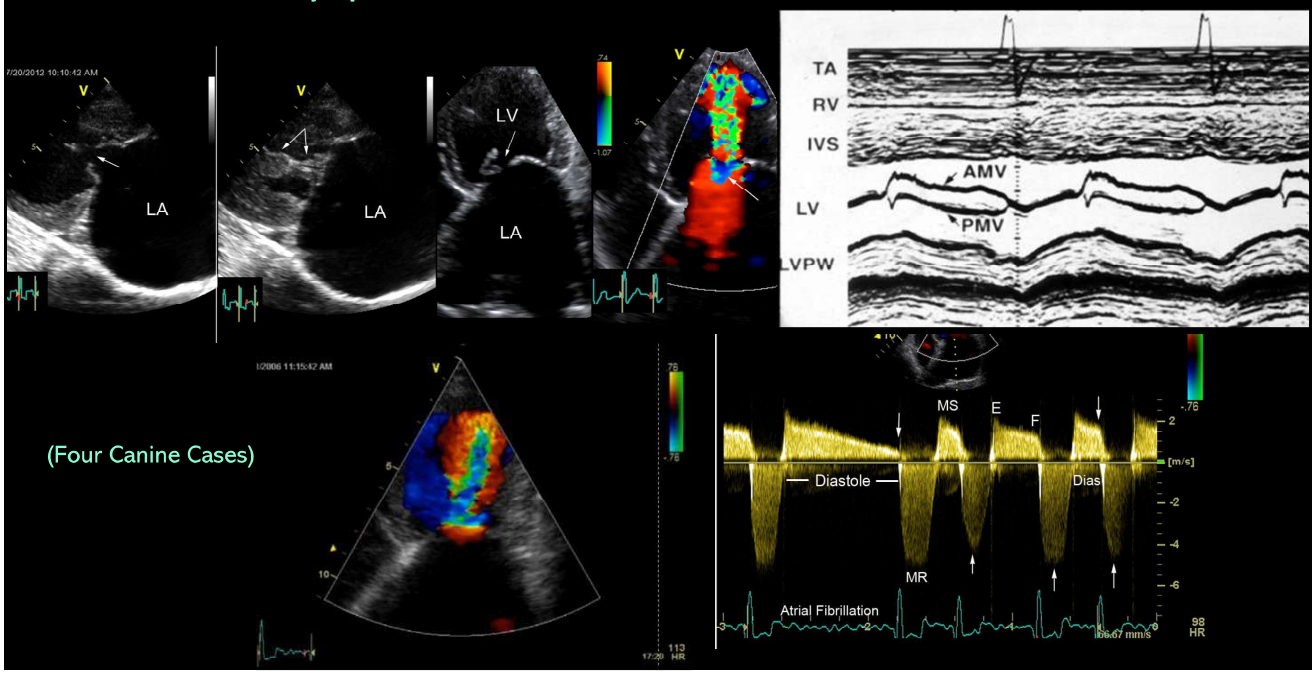

Mitral Valve
Dysplasia

37


Mitral Dysplasia: MR (left) Mitral Stenosis (right)
Mitral Valve Malformation (Dysplasia)
Cat
Ao
LA
Aur
LV

38

Mitral Valve Dysplasia: Mitral Stenosis & MR



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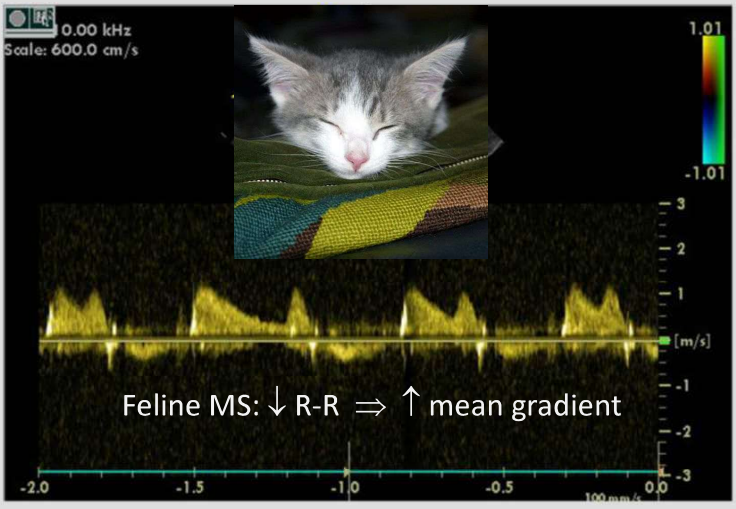
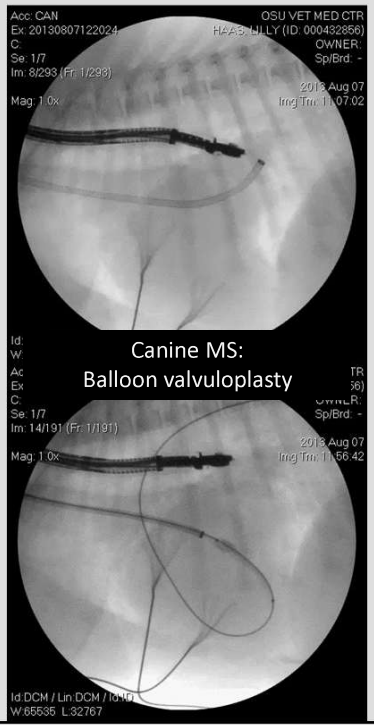
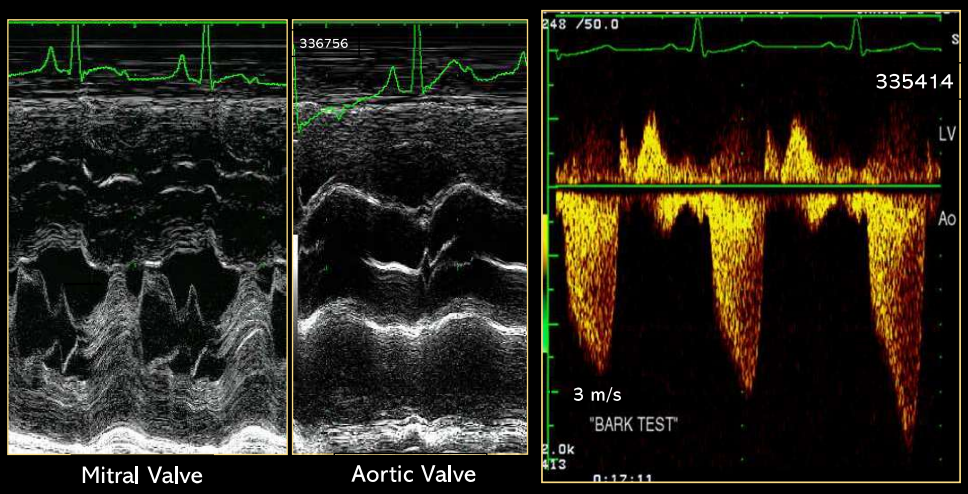
Mitral Stenosis





40

Dynamic LV Outflow Tract Obstruction (MV dysplasia)



Mitral Valve | Aortic Valve | LVOT – CW Doppler

Clinical Significance: May improve with β-blocker

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Valvular Heart Disease: Doppler Assessment

John D Bonagura, DVM, DACVIM (Cardiology, Internal Medicine), FASE
Professor Emeritus, the Ohio State University, Dept. Veterinary Clinical Sciences, College of Veterinary Medicine
Adjunct Professor – Cardiology, Colorado State University College of Veterinary Medicine
Adjunct Professor of Cardiology, North Carolina State University College of Veterinary Medicine

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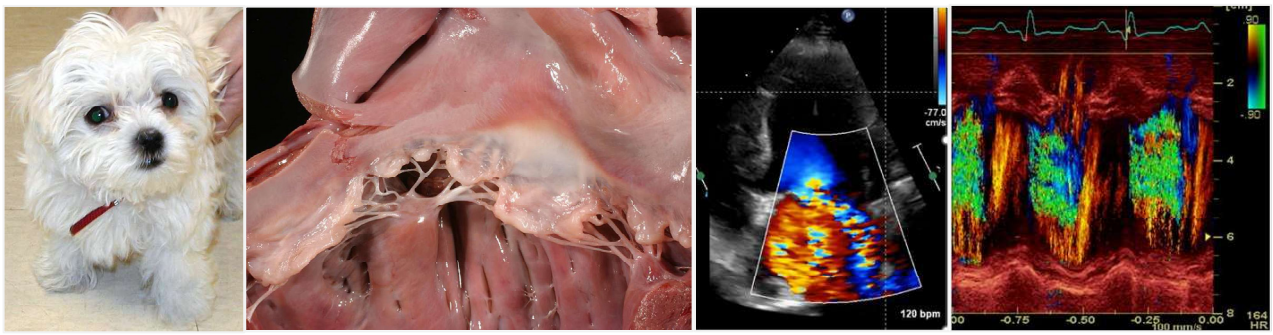
Myxomatous Mitral Valve Disease:
Imaging examples and Therapeutic Implications

John D Bonagura, DVM, DACVIM (Cardiology, Internal Medicine), FASE



1

Speaker Information & Conflict of Interest Disclosures

- Professor Emeritus – Veterinary Clinical Sciences
  Ohio State University, College of Veterinary Medicine
- Adjunct Professor – Cardiology – Colorado State University
  College of Veterinary Medicine & Biomedical Sciences
- Adjunct Professor of Cardiology – North Carolina State University
  College of Veterinary Medicine
- Associate Editor, *Journal of Veterinary Cardiology*
- Member, *Cardiac Education Group.org* [https://cardiaceducationgroup.org]

Conflicts of Interest related to this topic

EPIC study: Co-investigator – uncompensated, contributed cases & to manuscript review

Lifelearn® (BI-Vetmedica Speakers Bureau) – compensated for lectures on this subject

2

2

A Note about "Reference Slides"

- Numerous "supplementary" reference slides have been inserted in the notes
- Placed in the order of the topic under discussion
- These expand on the lecture slides / subject
  - Many of these topics would merit stand-alone presentations
- Reference slides are not discussed during lecture
- If you have any questions about these please email me or see me during the breaks

3

3

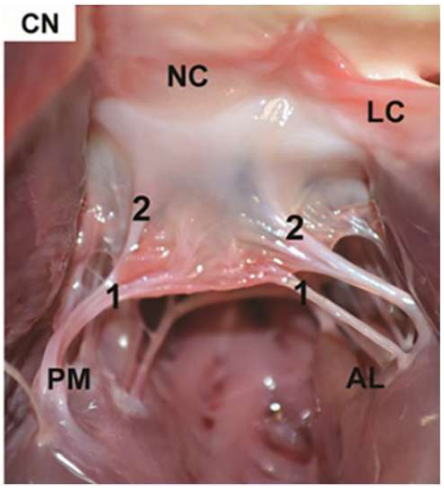
Presentation Topics

1. Transthoracic echocardiographic evaluation of the mitral valve
   - General "imaging targets" in MMVD
   - TTE imaging planes for assessment of the canine mitral valve
   - Assessment of valve morphology & motion
   - Mitral valve measurements
   - Principles of Doppler assessment in mitral regurgitation – *Review of key points*
2. Other Imaging considerations
   - Left Ventricle: Remodeling, Systolic function – *Review of key points*
   - Left Atrium: Remodeling, tear(s) – *Review of key points*
   - Right heart: TR & Pulmonary hypertension
3. Principles of Staging & Therapy
   - ACVIM Staging of MMVD
   - Treatment by stages: Preclinical → Acute pulmonary edema → Chronic therapy

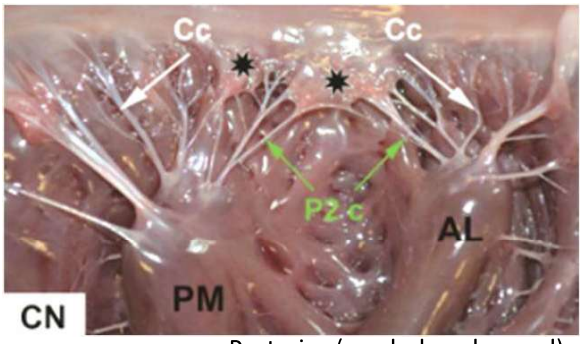
4

4

Causes & Mechanisms of Mitral Regurgitation



Anterior (cranioventral, aortic)



Posterior (caudodorsal, mural)

Alexis, M, Laurence, F, Marie-Aude, G, Christian, L., Nicolas, B *Embryologia*, 2023 Vol 52, 927–935.

Mitral Regurgitation: Etiology

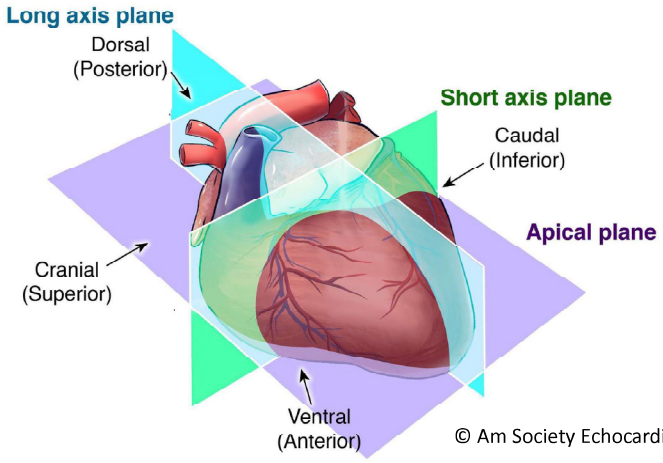
- Primary valve disease (congenital, degenerative, infective)
- Functional valve regurgitation
- LA dilation | LV Dilation or hypertrophy

Mitral Regurgitation: Valvular Motion (Carpentier)

- Normal (I)| Excessive (II): Prolapse | Flail | Restricted (III)

5

2D Imaging: Directional Nomenclature is Complicated!



© Am Society Echocardiography – *not for reproduction*

Often veterinary anatomic orientation is a "combination" of human directionality
Example: "human anterior" ≈ veterinary cranioventral

6

6

Reference Slide: Directional Nomenclature

Canine (quadruped)	Human (biped)
Cranial	Superior
Caudal	Inferior
Dorsal	Posterior
Ventral	Anterior
Medial/Lateral	Medial/Lateral

Often described best by a “combination” term such as *cranioventral*

7

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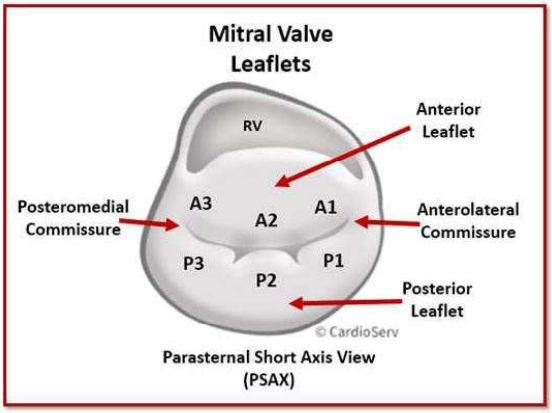
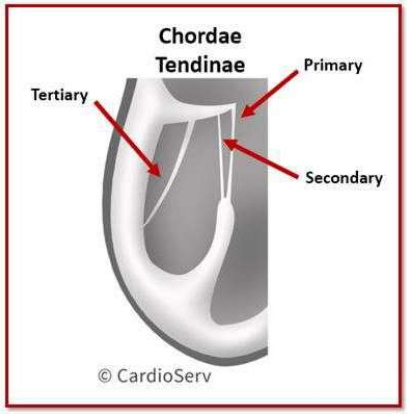
Mitral Valve: Segmental Anatomy & Chords

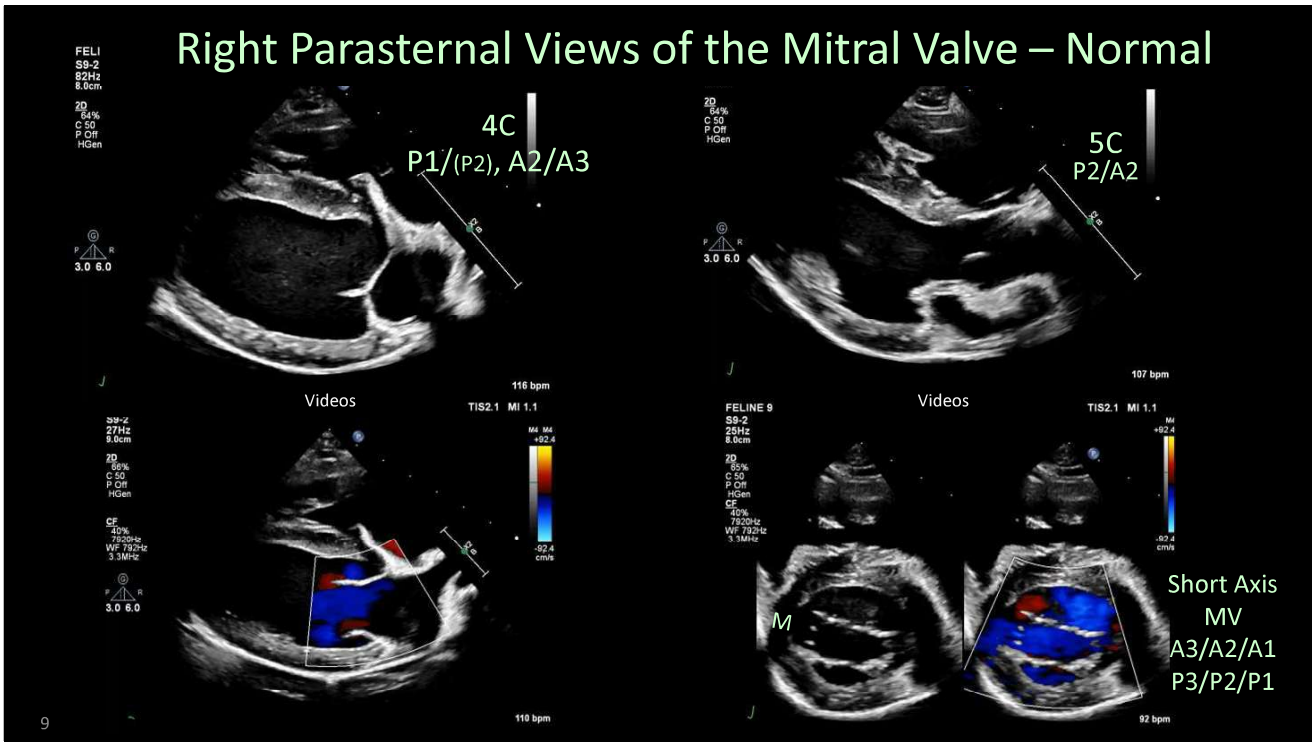


Canine

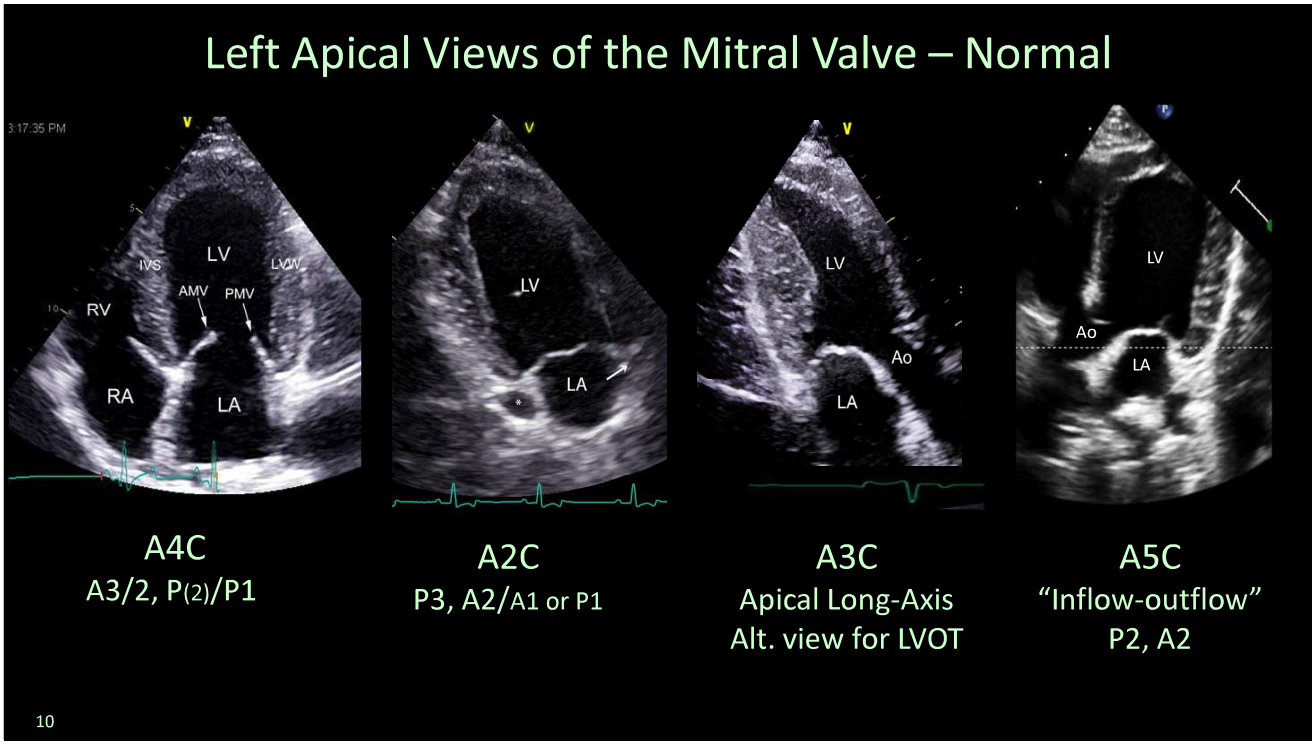


Illustrations from **CardioServ®**
https://www.cardioserv.net/mitral-valve-anatomy/

8

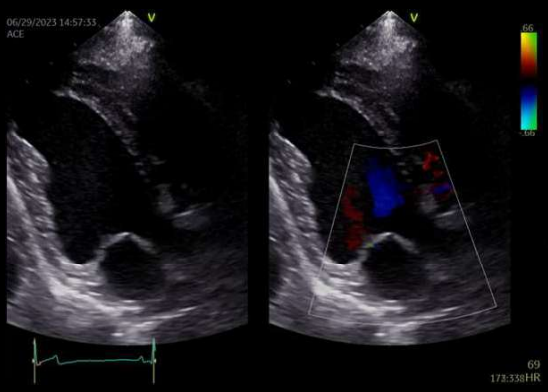

Right Parasternal Views of the Mitral Valve – Normal
4C
P1/(P2), A2/A3
5C
P2/A2
Videos
Videos
Short Axis
MV
A3/A2/A1
P3/P2/P1
M
9

9


Left Apical Views of the Mitral Valve – Normal
LV
IVS
LVW
AMV
PMV
RV
RA
LA
A4C
A3/2, P(2)/P1
LV
LA
A2C
P3, A2/A1 or P1
LV
Ao
LA
A3C
Apical Long-Axis
Alt. view for LVOT
LV
Ao
LA
A5C
"Inflow-outflow"
P2, A2
10

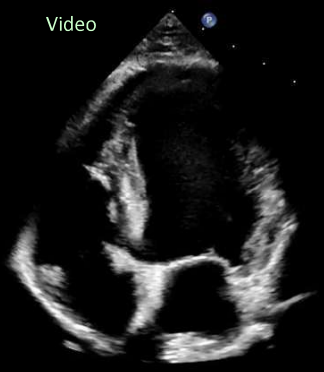
10

Left Apical Views of the Mitral Valve - Normal

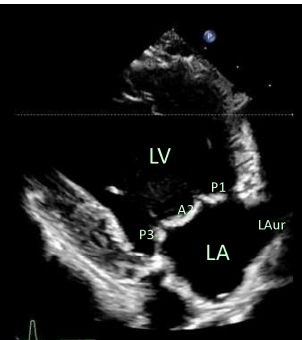


"Tipped" or Angled LV inflow-outflow
Obtained from ventral right parasternal

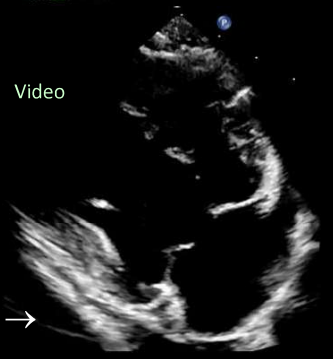
Video



Left A4C
A3/2, P(2)/P1



Video



Modified A2C "commissural view" →
P3, A2 ("floating"), P1

11

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Reference: 2D Views Typically used for MMVD Assessment

Right Parasternal Views

- **4-chamber** (LV inlet)
- **5-chamber** (LV inflow-outflow)
- **Angled** ("tipped") **4C & 5C**
- Dorsally placed 4C view (**RA/TV**)
- Short-axis **mitral**
- Short-axis **papillary/chordal**
  (for assessing LV minor dimensions)
- Short-axis **aortic/left atrial**
  (for assessing LA size)

Left Apical Views

- **4-chamber** (LV inlet)
- **5-chamber** (LV inflow-outflow)
- **2-chamber** (LA → LV)
- 2C "**commissural**" view (tilted 2C)
- **3-chamber** (LA → LV → **LVOT**)
- Optimized apical **RV** (inlet)
- **RV inflow-outflow** (also from RPSAx)

Subcostal: **LVOT** & CdVC + Hepatic vv.

12

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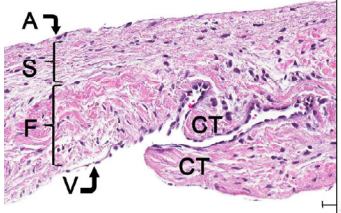
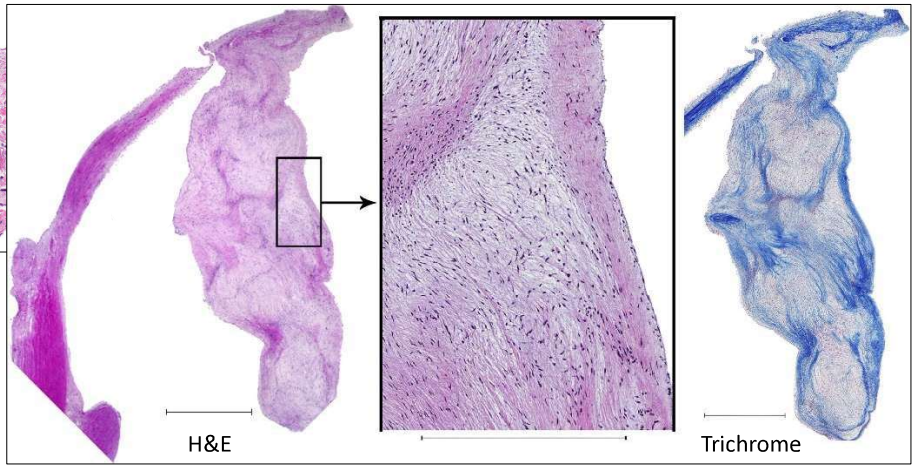
Histopathology of Myxomatous Mitral Valve Disease
Valve Thickening & Expansion/Disruption of Central Layers





Normal Mitral Layers:
Atrialis
Spongiosa
Fibrosis
Ventricularis
CT = chordae tendineae

Images courtesy of **Philip R. Fox**, DVM, DACVIM (Cardiology)
Fox PR: *J Veterinary Cardiology*, Vol 14, 2012

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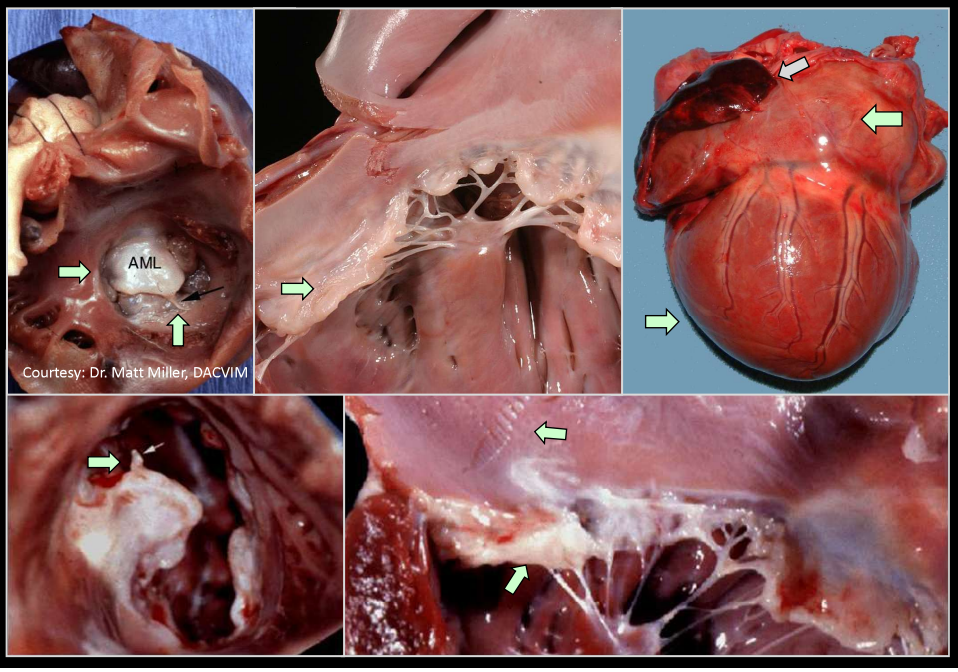
Echocardiography: Myxomatous Mitral Valve Disease – *Imaging Targets*

- *Mitral valve*
  - Morphology
  - Motion
  - Chords
  - Measurements
- *LA & LV*
  - Size
  - Shape
  - Function (??)
  - IAS: d/ tears
- *Right heart*
  - RA, RV, CdVC
  - Tricuspid valve
  - PA pressures



14

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Reference: Pathophysiologic Factors in MR: Echo Correlates

Progressive MR ⇒
↑↑↑LAP ⇒ LA dilation +
↑V-wave: ↑E-wave
(compliance ≈ LA size)
↑LV Diastolic Pressure ⇒
LV remodeling

↑↑↑ LV Filling ⇒ Frank Starling ⇒
↑*Total* LV stroke volume
(↑LVEDV & EF by MOD)
Altered LV Loading
(↑LVEF & LVFS + ↑TDI e')

MR

↓Forward Stroke Volume
↓ Aortic VTI
↑LA + venous pressure ⇒ PHT
↑TR vel ↑PA
Lung congestion/edema ↑E-wave

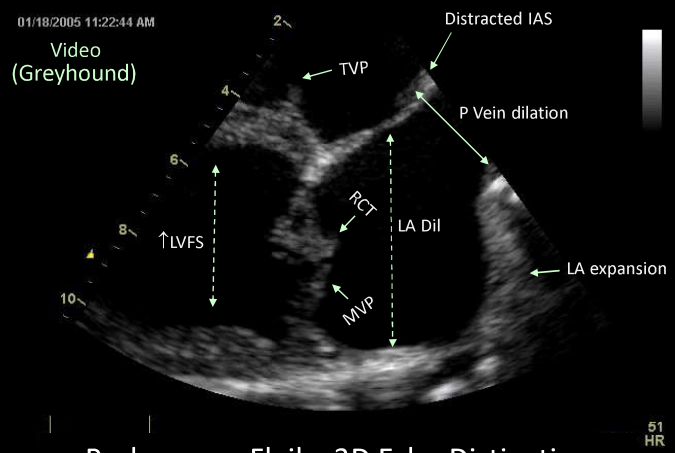
↑↑↑Regurgitant Fraction ⇒ ↓CO
↓Exercise capacity (HF)
↑SNS (vasoconstriction + HR reserve)
± RAAS + AVP activation
± Renal Na^+ retention

15

Reference Slides are supplementary – not presented during the lecture presentation

15

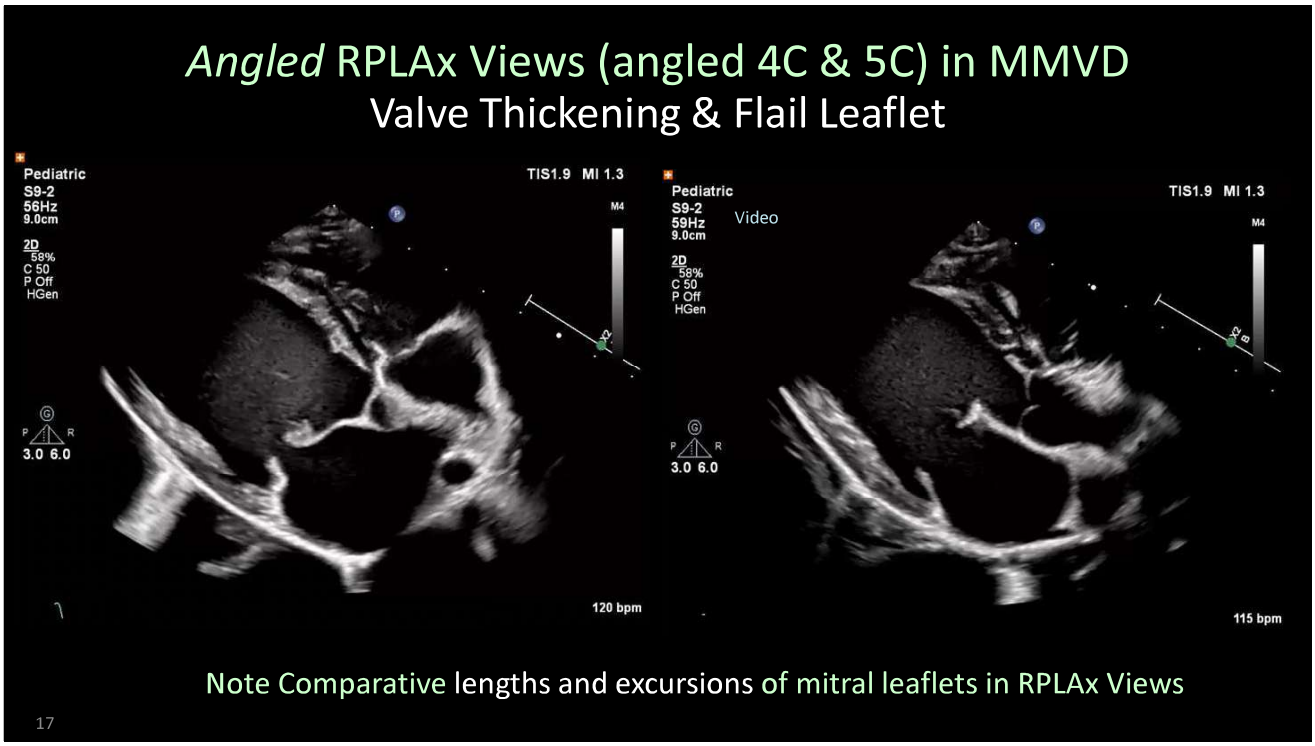
2D Imaging: Myxomatous AV Valve Disease
Valve thickening, Prolapse & Flail



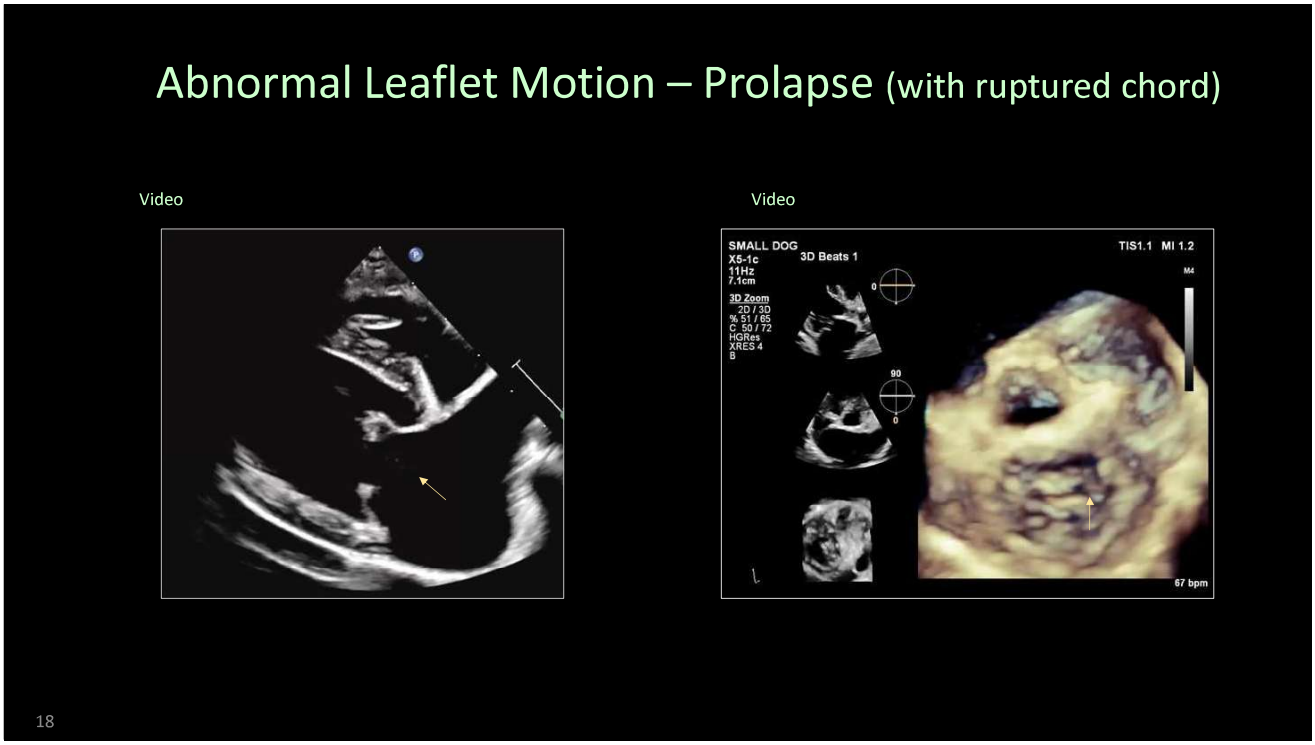
Prolapse vs. Flail – 2D Echo Distinction
Can both indicate ruptured chords?

16

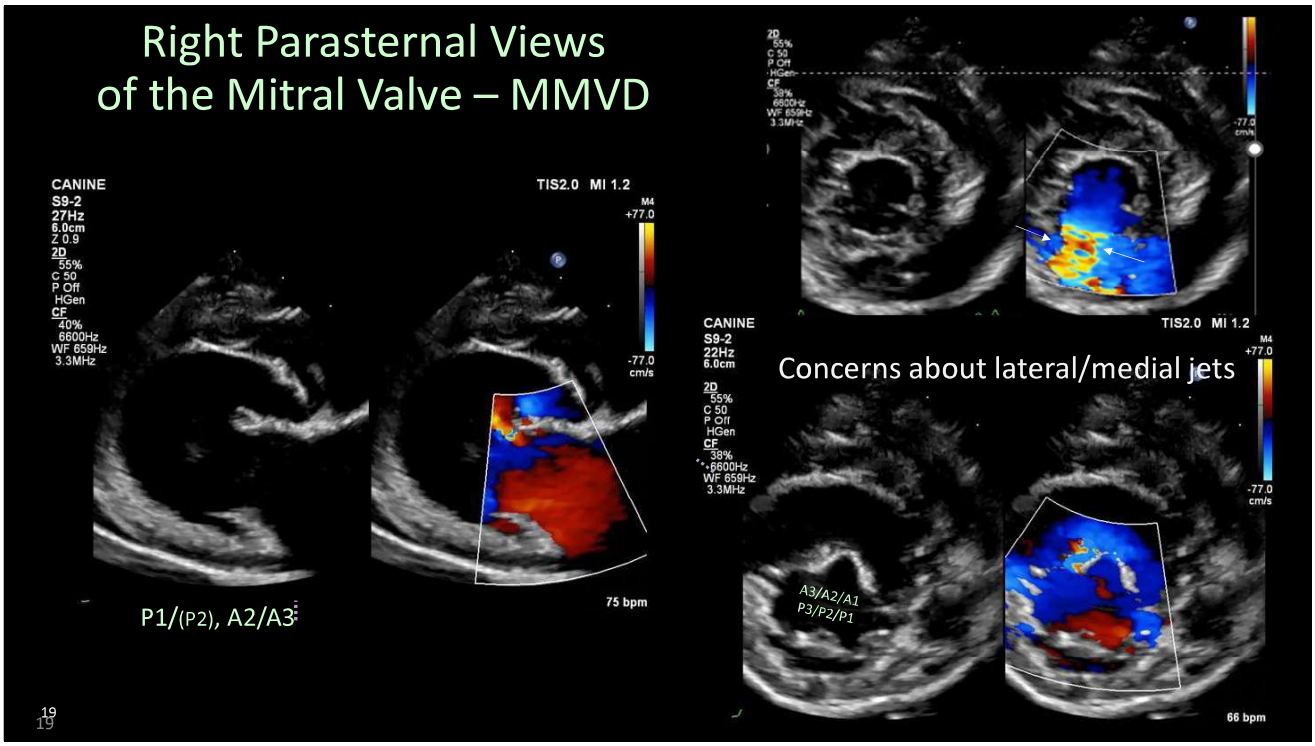
16


Angled RPLAx Views (angled 4C & 5C) in MMVD
Valve Thickening & Flail Leaflet
Pediatric
S9-2
56Hz
9.0cm
2D
58%
C 50
P Off
HGen
TIS1.9 MI 1.3
M4
3.0 6.0
120 bpm
Video
Pediatric
S9-2
59Hz
9.0cm
2D
58%
C 50
P Off
HGen
TIS1.9 MI 1.3
M4
3.0 6.0
115 bpm
Note Comparative lengths and excursions of mitral leaflets in RPLAx Views
17

17


Abnormal Leaflet Motion – Prolapse (with ruptured chord)
Video
Video
SMALL DOG
X5-1c
11Hz
7.1cm
3D Beats 1
3D Zoom
2D / 3D
% 51 / 65
C 50 / 72
HGRes
XRES 4
8
TIS1.1 MI 1.2
M4
67 bpm
18

18


Right Parasternal Views
of the Mitral Valve – MMVD
CANINE
S9-2
27Hz
6.0cm
TIS2.0 MI 1.2
75 bpm
P1/(P2), A2/A3
CANINE
S9-2
22Hz
6.0cm
TIS2.0 MI 1.2
Concerns about lateral/medial jets
A3/A2/A1
P3/P2/P1
66 bpm
19

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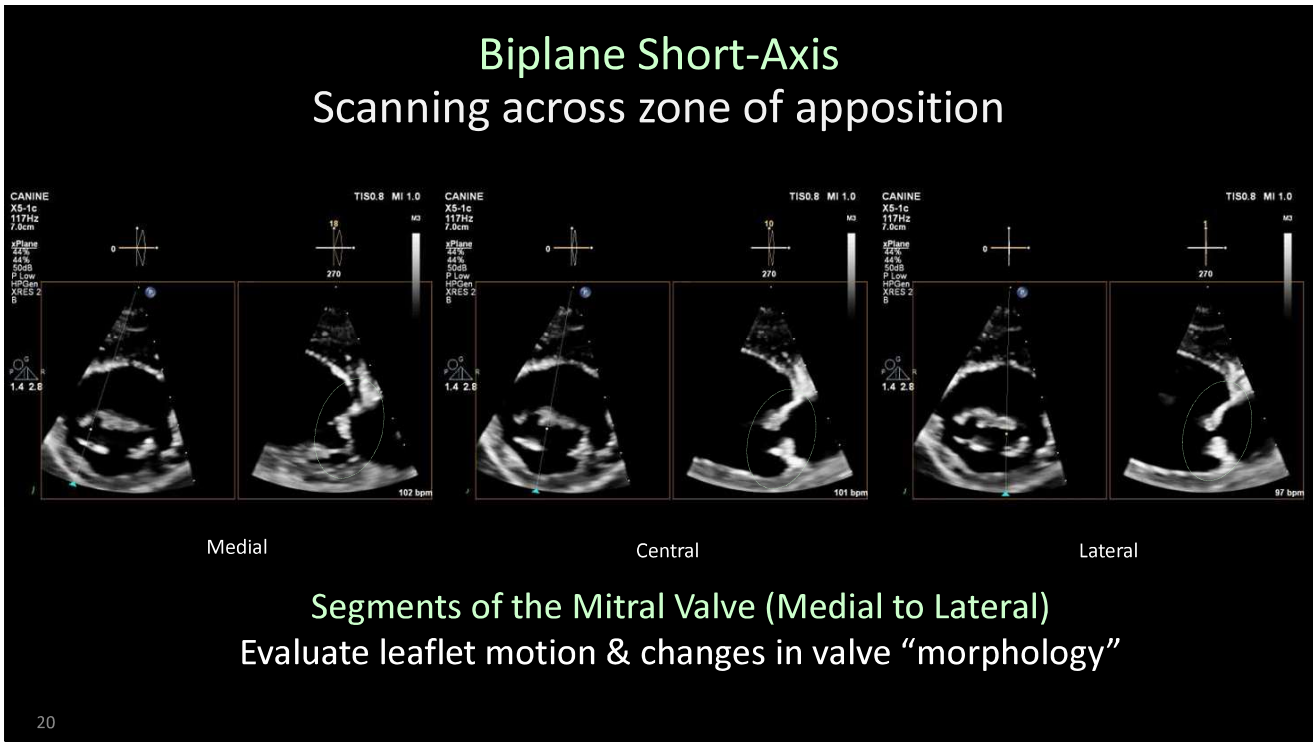
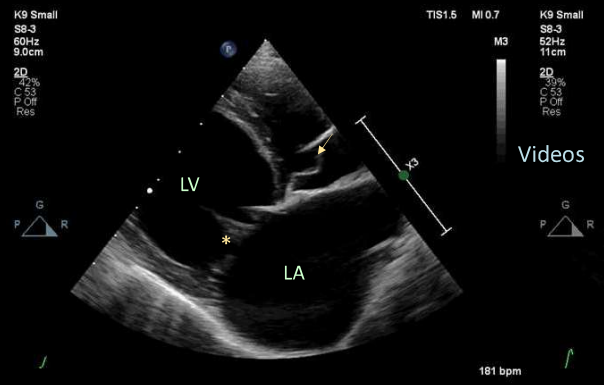

Biplane Short-Axis
Scanning across zone of apposition
Medial
Central
Lateral
Segments of the Mitral Valve (Medial to Lateral)
Evaluate leaflet motion & changes in valve "morphology"
20

20

Mitral Valve Thickening, Prolapse & Annular Dilation

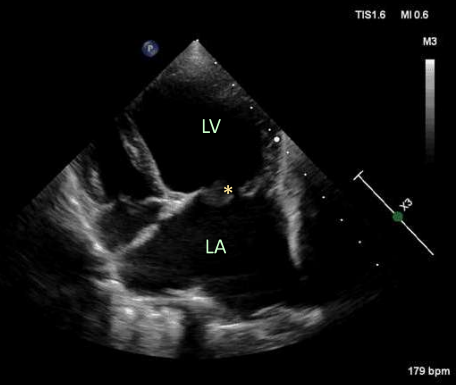
Left Heart Remodeling – Potential for additional Functional/Atrial MR
Wide horizontal coaptation gap

Right parasternal image plane



Videos

Left apical image plane

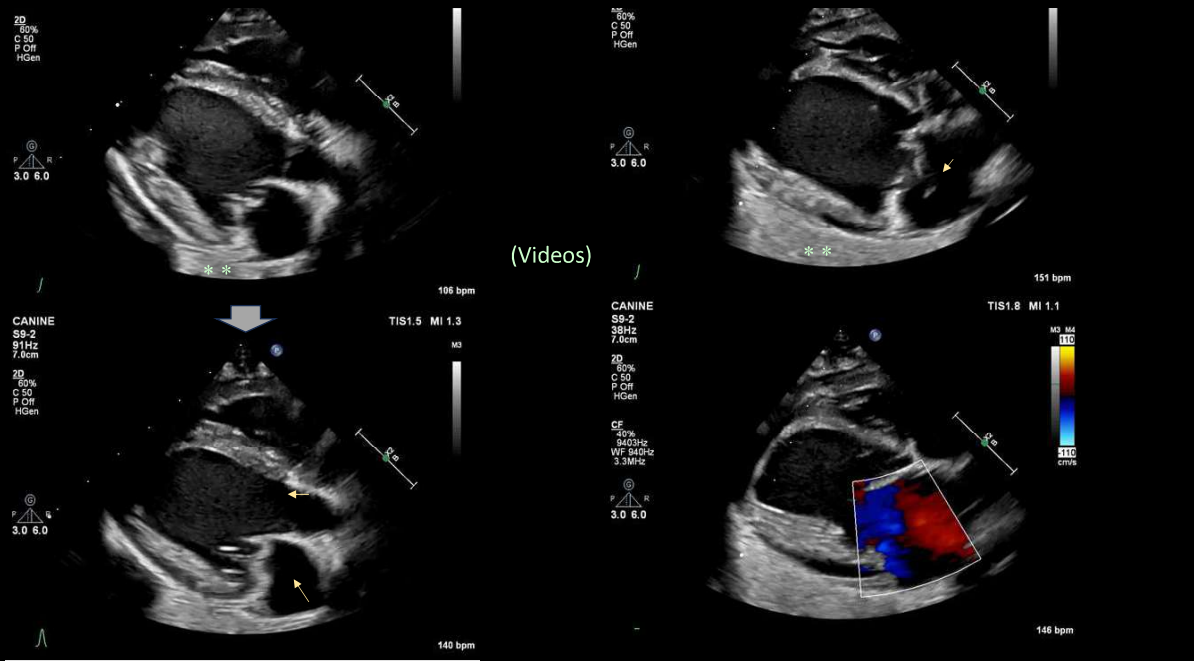


* Mitral valve orifice – Horizontal Coaptation Gap
Arrow: Tricuspid valve prolapse

21

21

Flail AMV Leaflet + “Cardiac window” * B-lines *

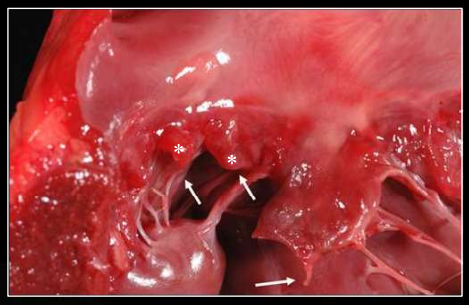


22

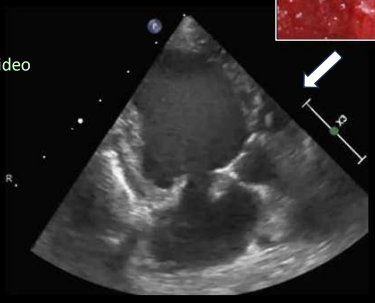
22

Left: MMVD with Flail Right: Flail ± restricted PML motion

Nodular thickening of leaflets *
Ruptured Chord (lower arrow)



Video



Note Leaflet Eversion Towards LVOT
APC → A2C View

Slow Motion loop: RCT + ?Restricted PMVL

23

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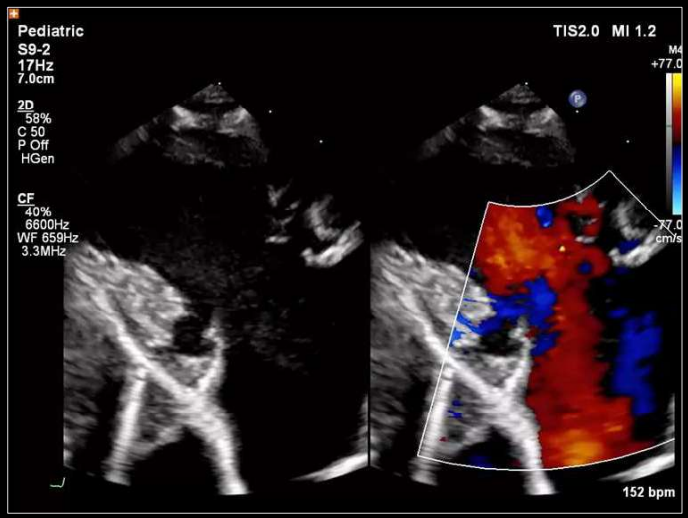
Left Apical Views of the Mitral Valve



Modified A2C "commissural view"
P3, A2 ("floating"), P1

24

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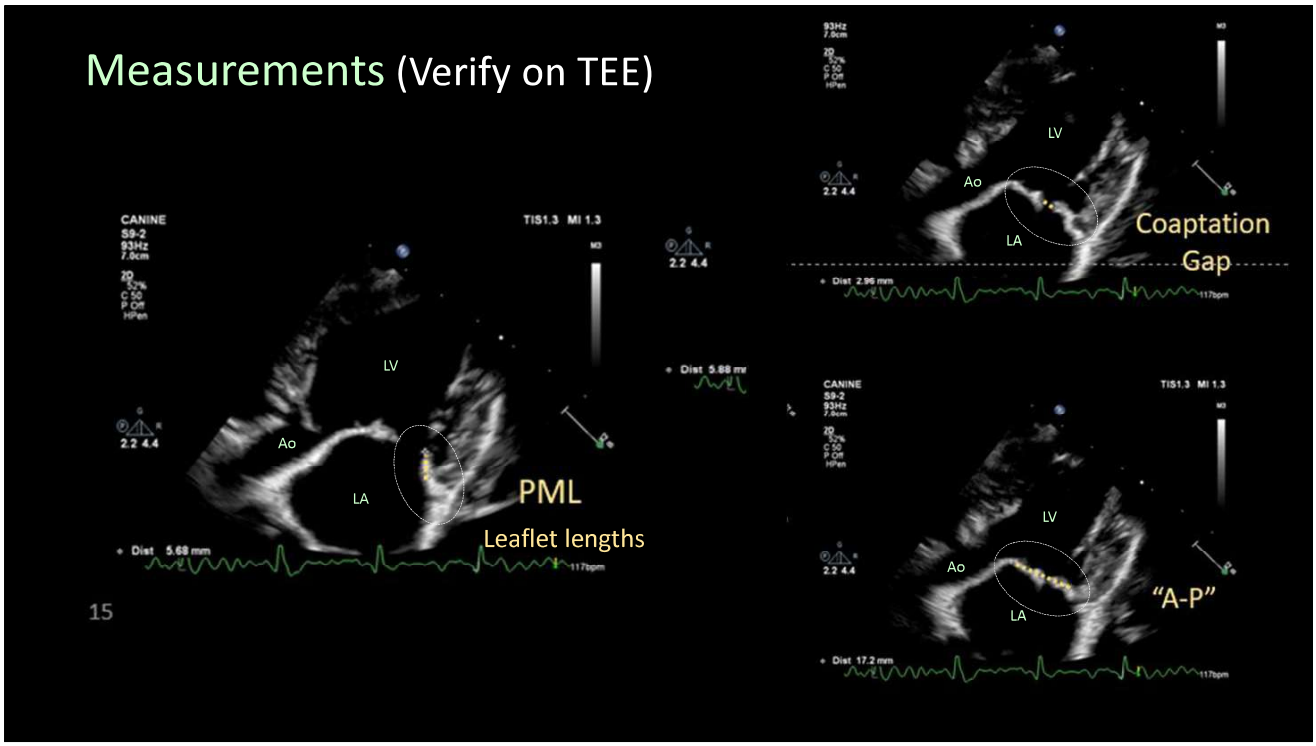
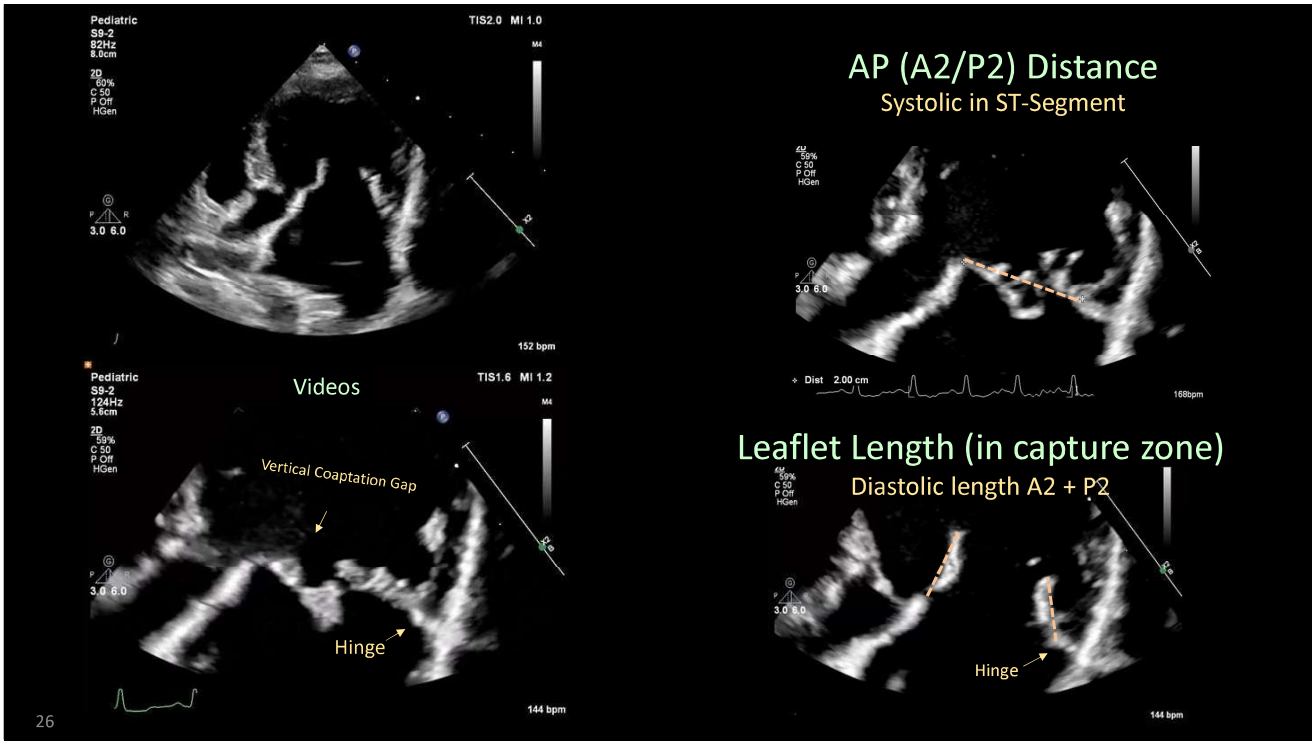

Measurements (Verify on TEE)
LV
Ao
LA
PML
Leaflet lengths
Coaptation Gap
"A-P"
15

25


AP (A2/P2) Distance
Systolic in ST-Segment
Videos
Vertical Coaptation Gap
Hinge
Leaflet Length (in capture zone)
Diastolic length A2 + P2
Hinge
26

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Reference slide: MR – Color Doppler Analysis: *Principles*

Initially:

1. Identify abnormal color flow signal ⇒ LA (3+ planes)
2. Slow motion replay!
3. Quantify the duration of MR (color M-mode or CW Doppler)
4. Qualify Jets: single or multiple; central or eccentric

Potential Evaluations or Measurements:

1. Receiving chamber analysis: jet area & length relative to LA area
2. Orthogonal Jet width at the vena contracta → Most useful method (green or yellow encoding; but also try with variance "off")
3. Flow convergence: Proximal isovelocity area (PISA) to calculate flow rates and effective regurgitant orifice – challenging

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Review: Flow Across Regurgitant Orifice

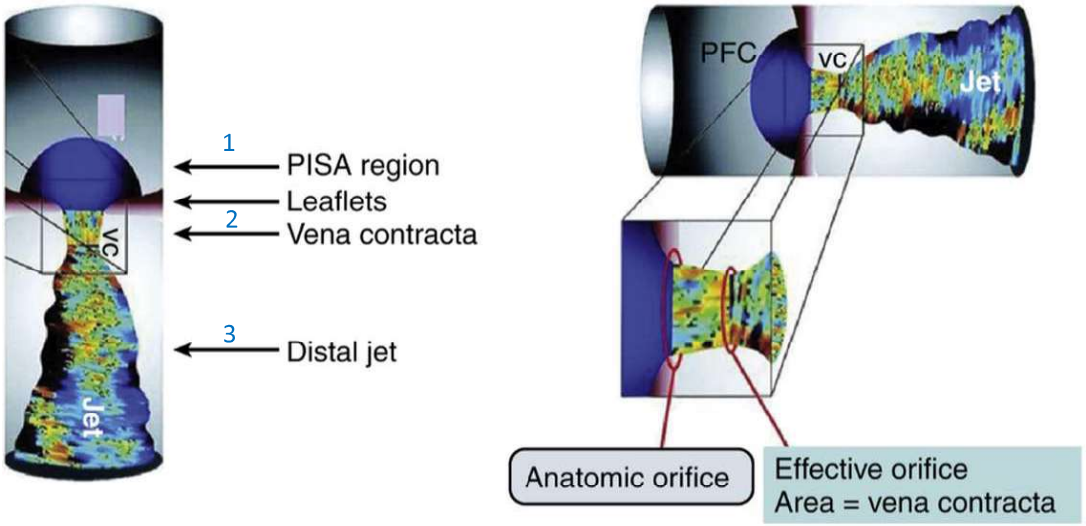

Figure: Catherine Otto, MD, FASE Am Soc Echo

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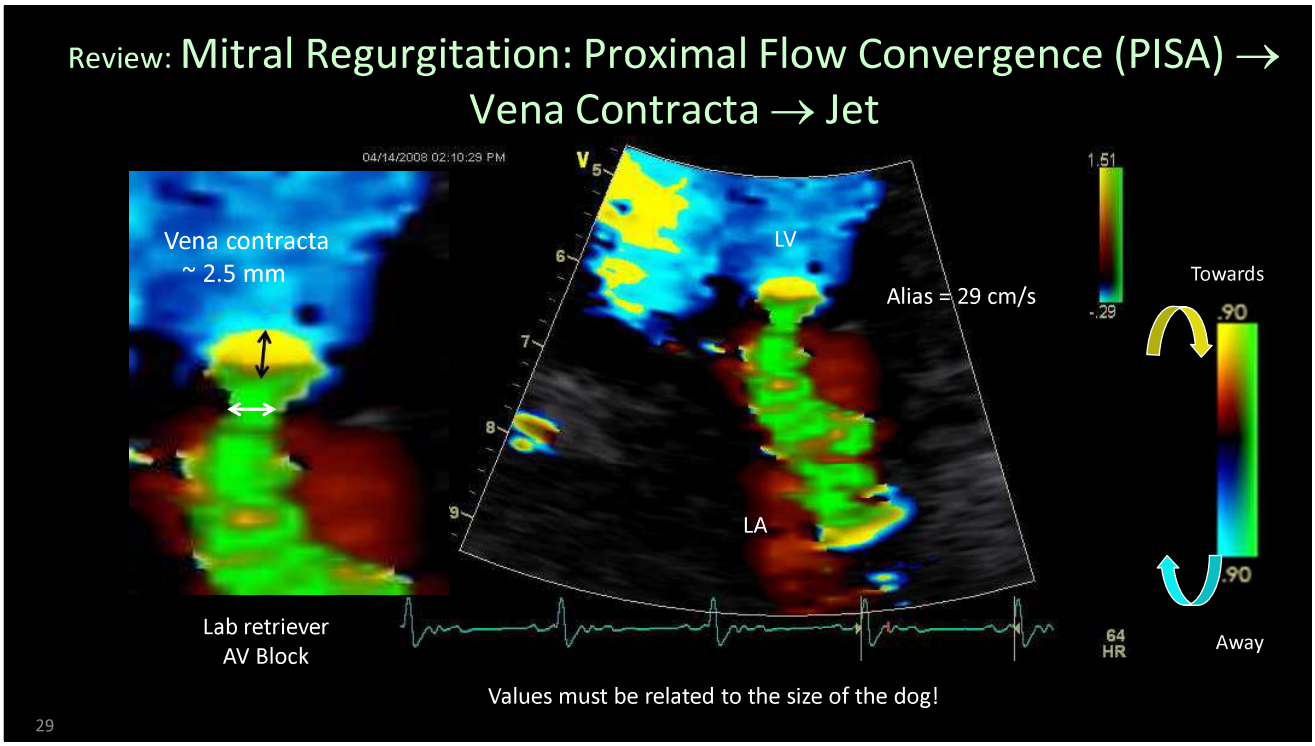
Review: Mitral Regurgitation: Proximal Flow Convergence (PISA) → Vena Contracta → Jet
04/14/2008 02:10:29 PM
Vena contracta
~ 2.5 mm
LV
LA
Alias = 29 cm/s
1.51
-.29
Towards
.90
.90
Away
64
HR
Lab retriever
AV Block
Values must be related to the size of the dog!
29

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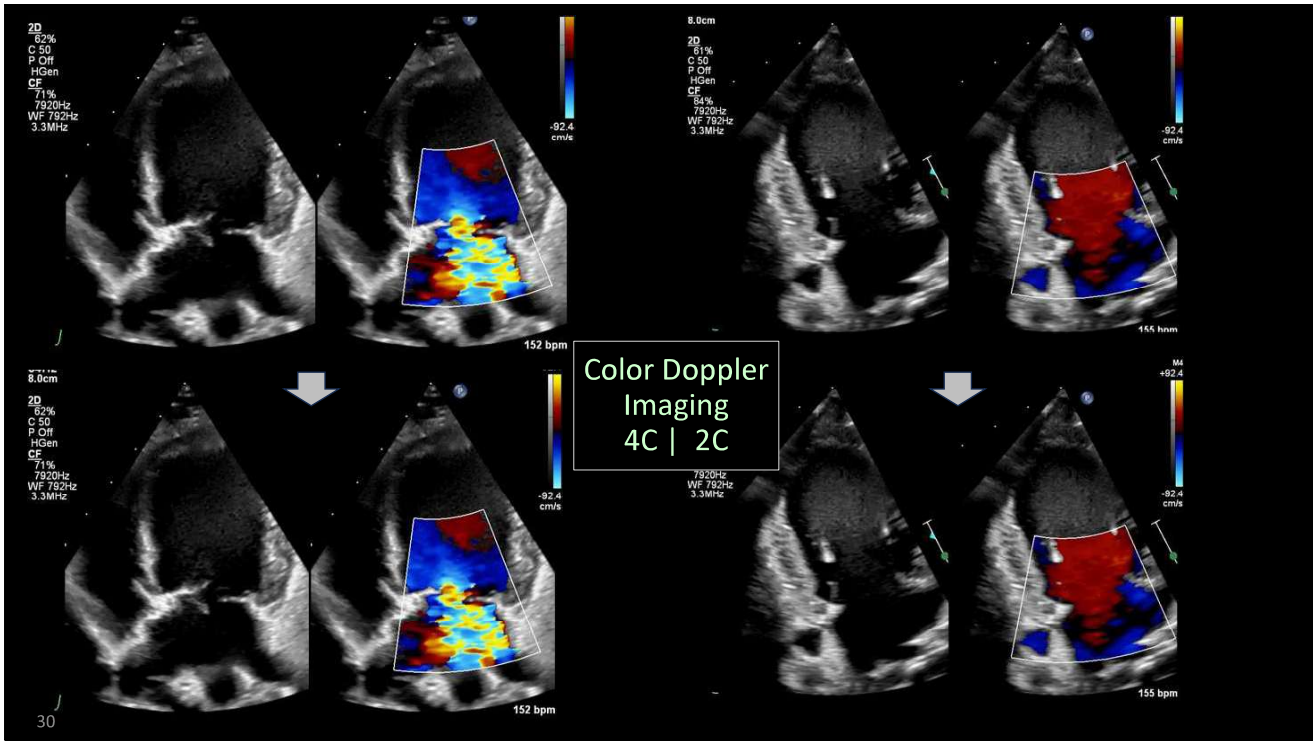
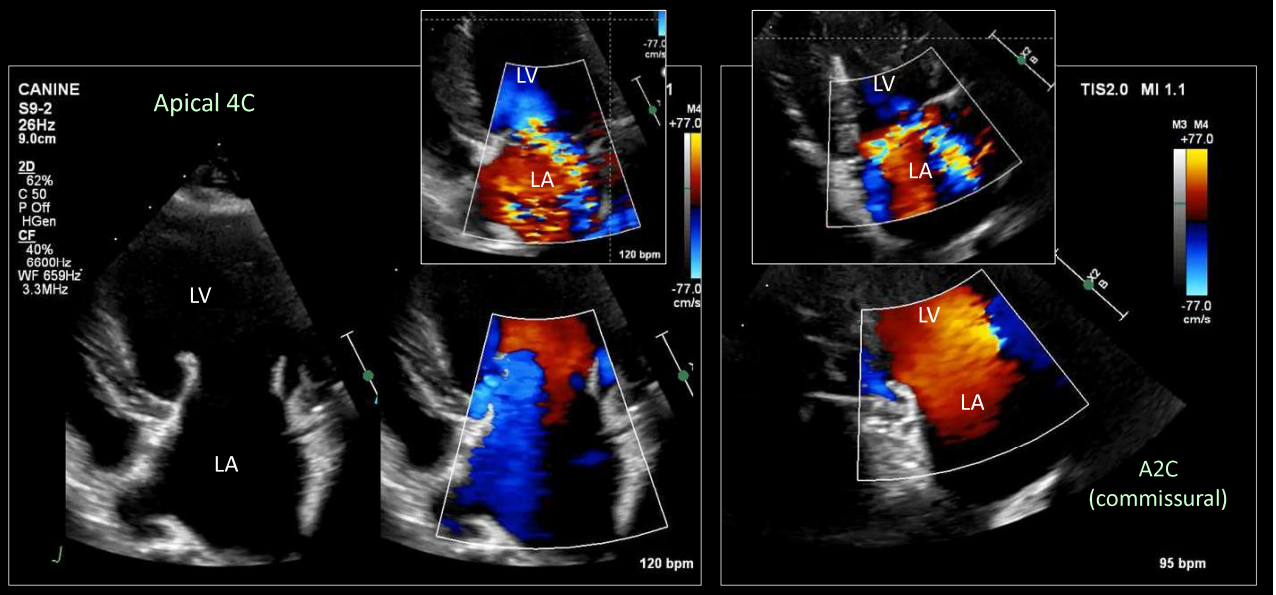

Color Doppler
Imaging
4C | 2C
152 bpm
155 bpm
30

30

MR: Receiving Chamber – Typical Eccentric Jet(s)



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Limitations of Receiving Chamber Analysis

Doppler *velocity* is <u>not</u> “flow” volume

Hose: Courtesy of Dr. Virginia Luis Fuentes, DACVIM, ECVIM

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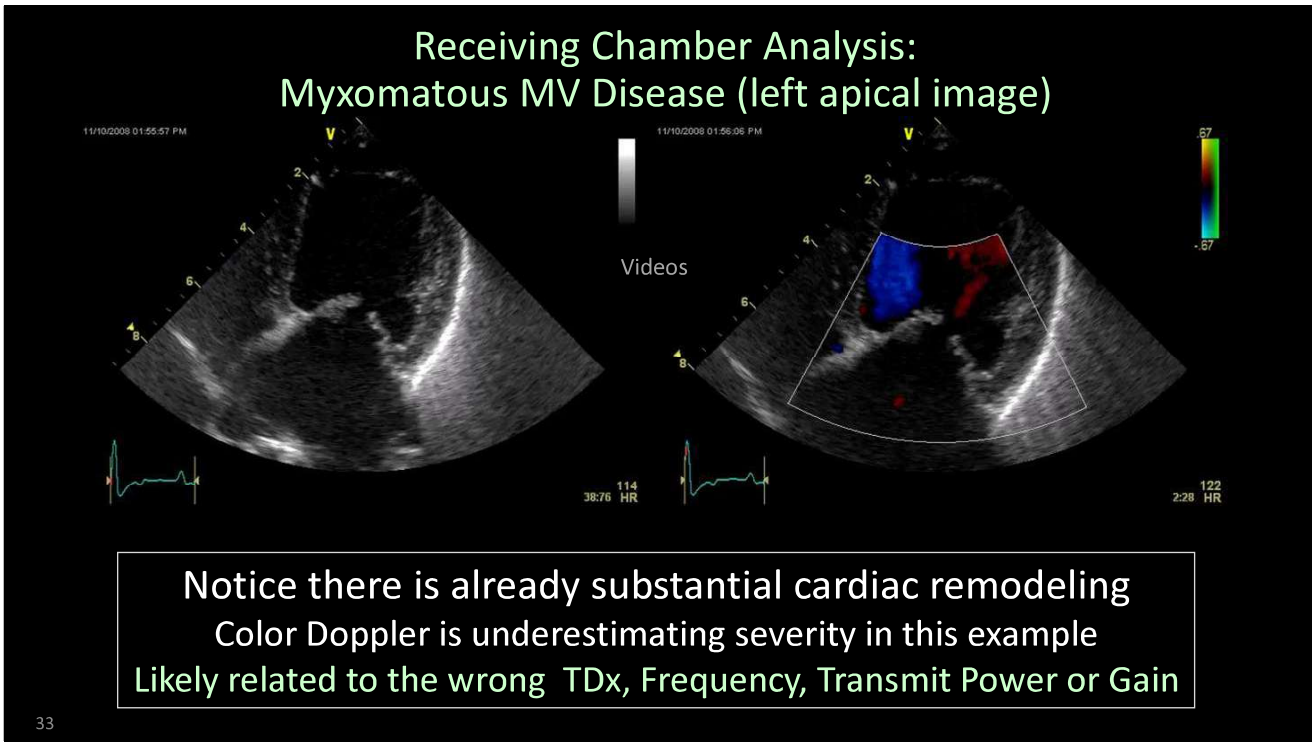
Receiving Chamber Analysis:
Myxomatous MV Disease (left apical image)
Videos
Notice there is already substantial cardiac remodeling
Color Doppler is underestimating severity in this example
Likely related to the wrong TDx, Frequency, Transmit Power or Gain
33

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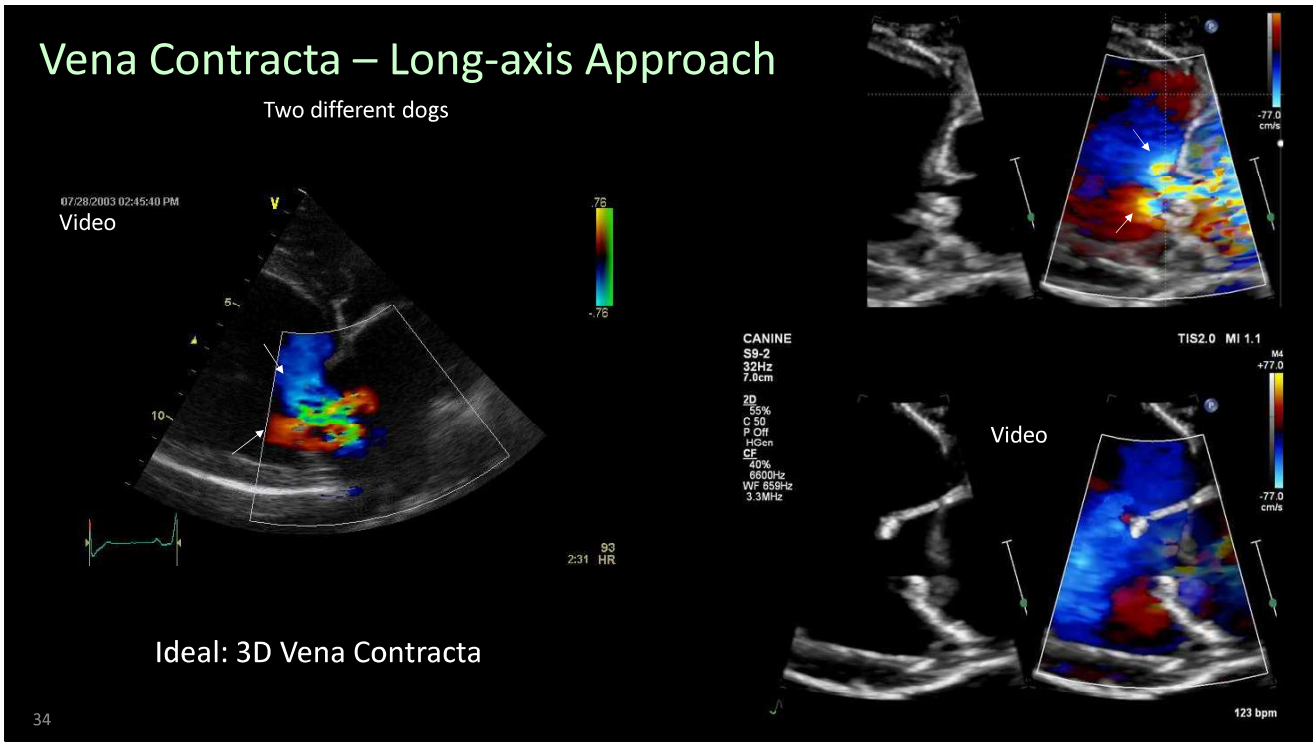
Vena Contracta – Long-axis Approach
Two different dogs
Video
Video
Ideal: 3D Vena Contracta
34

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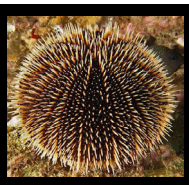
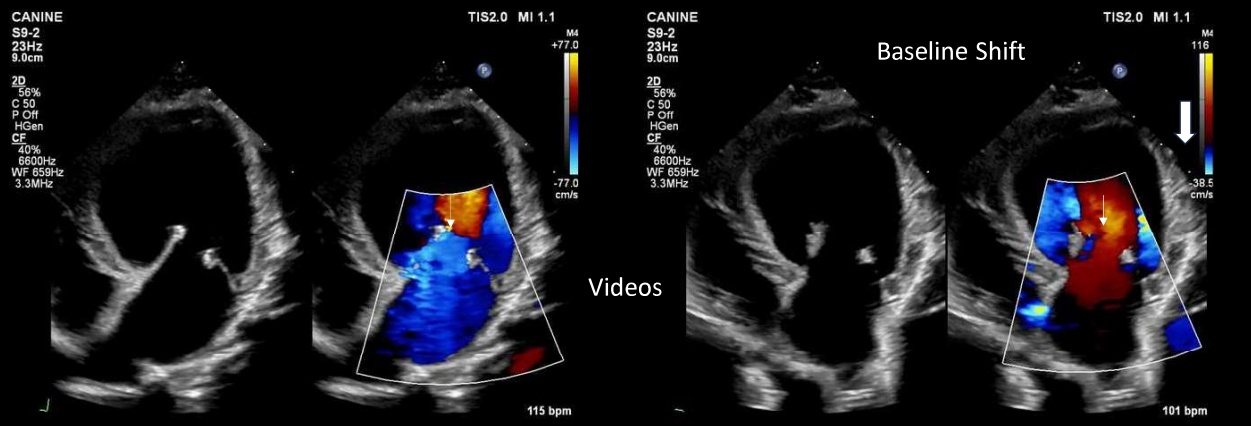
Color Doppler – PISA
Proximal Isovelocity Surface Area

***Moraldo M**, et al. Evidence-based recommendations for PISA measurements in mitral regurgitation: systematic review, clinical and in-vitro study. Int J Cardiol. 2013*



The PISA shape is often urchinoid



35

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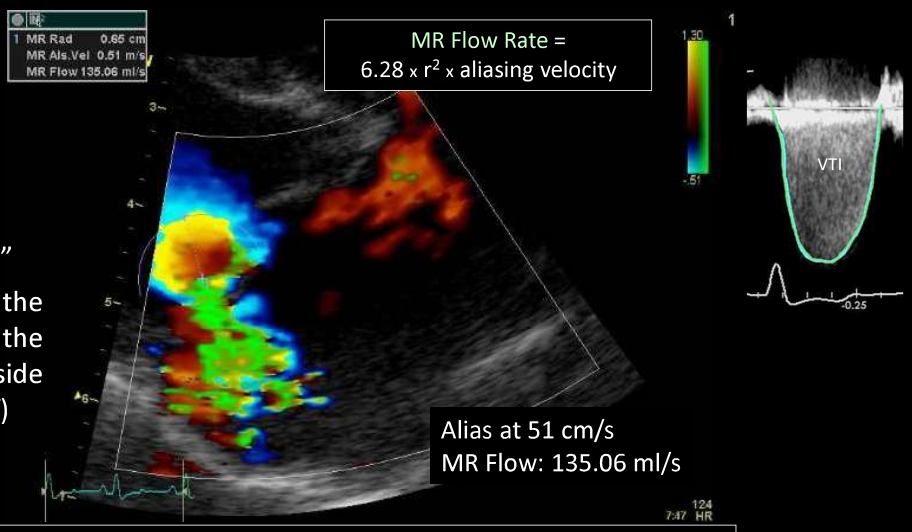
Reference: Proximal Isovelocity Surface Area (PISA) Method (example)

Reference Slide

<u>Key steps</u>

1. Set Aliasing Velocity 25 to 55 cm/s
2. Find :hemisphere: or urchinoid or a "ball on a jet"
3. Outline PISA & draw the radius (distance) from the signal alias to ventricular side of valve (turn color on + off)

   Average at least 3 beats
4. Trace MR VTI
5. Perform calcs



ERO* = <u>MR flow rate</u> / MR max velocity (by CW)

Regurg Vol = ERO x VTI (MR)

* Would need to be indexed to body size in dogs to provide meaningful figure

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J Vet Intern Med 2014;28:1206–1213

Assessment of Mitral Regurgitation Severity by Doppler Color Flow Mapping of the Vena Contracta in Dogs

M. Di Marcello, E. Terzo, C. Locatelli, V. Palermo, E. Sala, E. Dall'Aglio, C.M. Bussadori, I. Spalla, and P.G. Brambilla

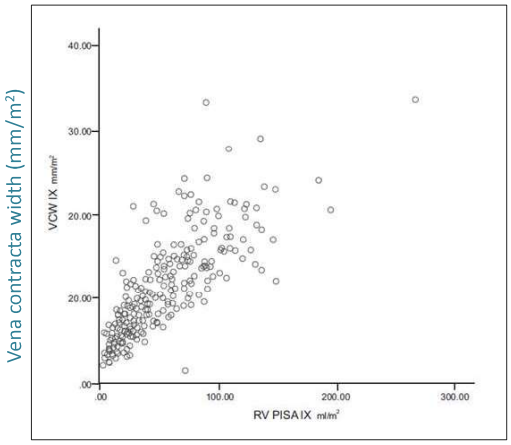
Reference Slide

Mean age 11.4
Mean weight 11.7

The median values of Vena contracta width:

2.9 mm (IQR 3.4–2.5) or 4.4 mm/m2 (IQR = 5.5–4.2)
mild to moderate by PISA

4.6 mm (IQR 5.4–4.1) or 10.8 mm/m2 (IQR = 12.8–9.4)
moderate to severe by MR by PISA



Regurgitant Volume estimate (ml/m²)

Is there a "practical" way to use this information?

My experience: in small dogs with MR a VC >3mm is clinically important VC >5 usually severe
For PISA – setting aliasing velocity at about 40 cm/s: a radius > 5 mm is usually mod-severe MR

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Review of Comparative Methods for MR Quantitation

Journal of Veterinary Cardiology (2025) **58**, 38–46

ELSEVIER

Journal of Veterinary Cardiology
ESVC

www.elsevier.com/locate/jvc

Quantitative methods for evaluation of mitral regurgitation severity in canine degenerative mitral valve disease☆

B. Del Nero, B.M. Potter*, L.C. Visser, B.A. Scansen, E.C. Orton

Department of Clinical Sciences, Colorado State University, Campus Delivery 1678, Fort Collins, CO 80523-1678, USA

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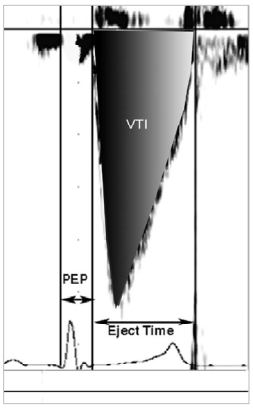
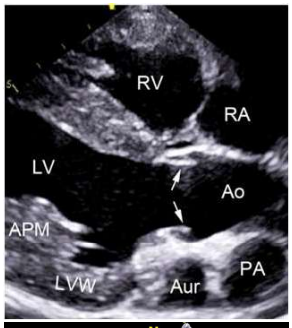
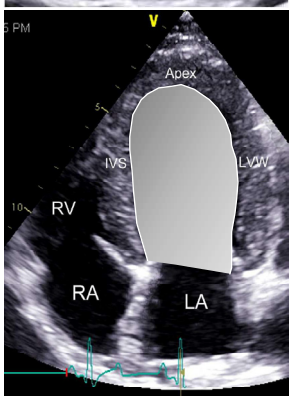
Reference Slide: Combining Spectral Doppler + 2D Imaging to Assess MR







[Calculate forward stroke volume](#) (ml/beat)

- Record aortic valve Doppler
- Measure aortic VTI (cm)
- Measure aortic diameter (cm) at same site
- Valve CSA (cm^2) = $\{d^2 * 0.7854\}$

[Calculate total LV stroke volume (SV)](#) (ml/beat)

- Determine end-diastolic & end-systolic volumes (recommendation: from 2D Simpson's MOD)
- Total LV stroke volume = (EDV – ESV)

[Calculate regurgitant volume](#) = (Total SV – Forward SV)

[Calculate regurgitant fraction](#) = (Vol_{regurg} ÷ total LV stroke vol)

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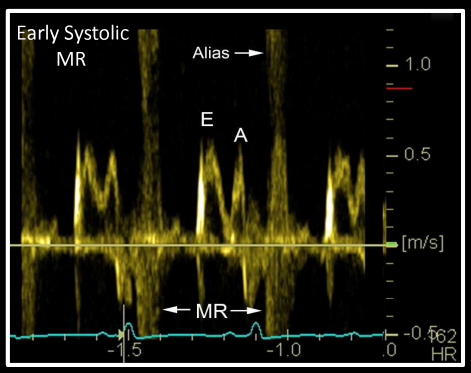
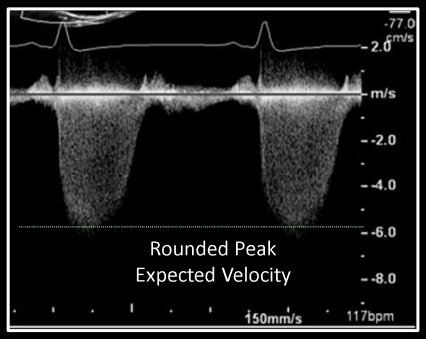
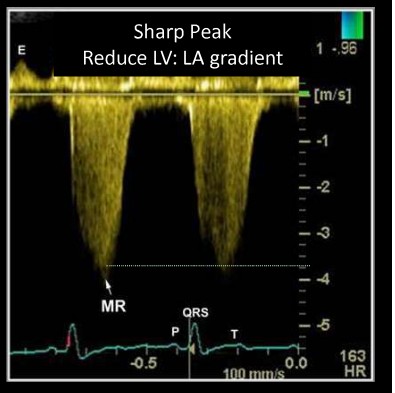
Spectral Doppler Echo: Assessing Severity







- Signal strength (at constant settings relates somewhat to MR severity)
- Timing – less than holosystolic is "better" (left panel)
- Peak Velocity (with proper alignment and BP) – indicates LV to LA pressure Δ
- Contour of MR profile (rounded vs. peaked ⇒ severe with high V-wave ⇒ E-wave

40

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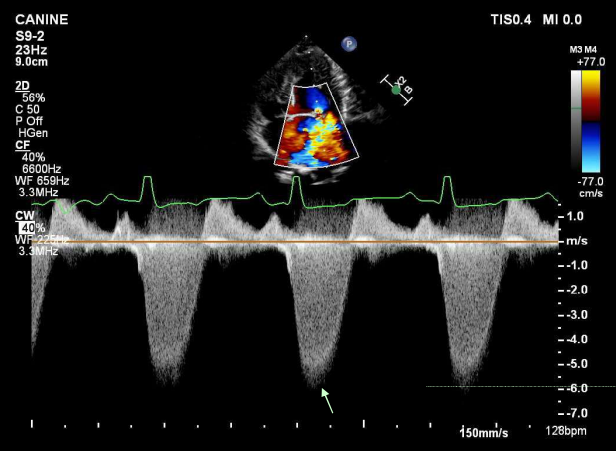
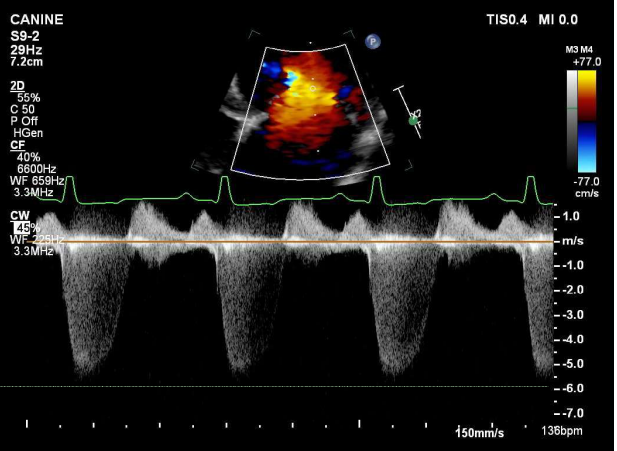
Spectral Doppler Instrumentation





Fixes: Use a Higher Frequency Transducer or Output Frequency for that transducer
Reduce Transmit Power (output) + Reduce Gain (Receive) & Process Grayscale / Compression

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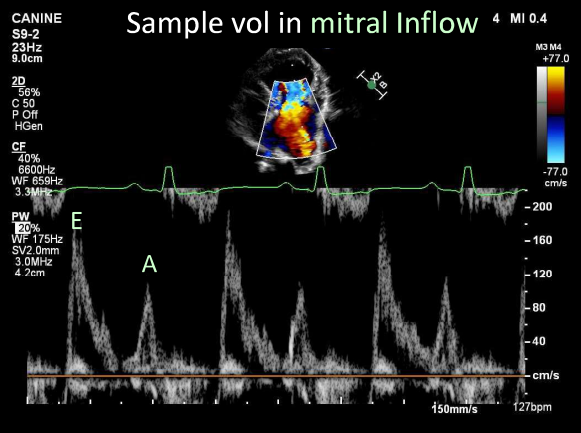
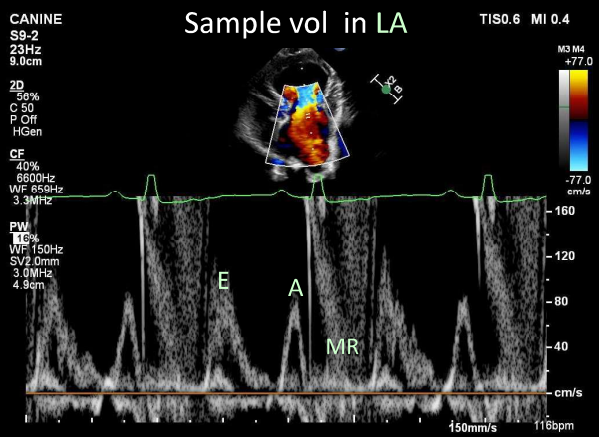
Spectral Doppler Instrumentation: Mitral E/A Waves
Impact of Sample Volume Placement





For PW Doppler reduce dispersion with a smaller sample volume (1.5 to 2 mm)
Also use properly instrumented CW Doppler to record maximal E-wave

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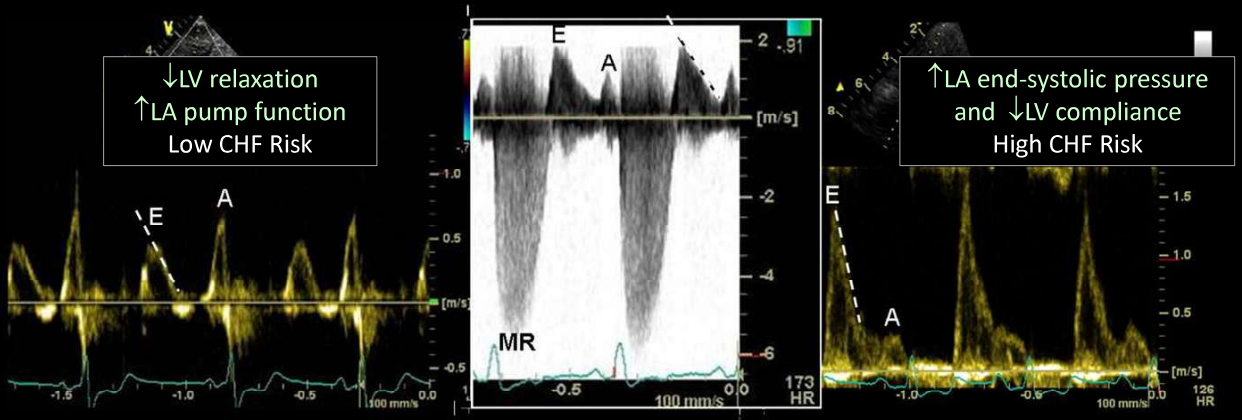
Diastolic Function & LV Filling in Advanced MMVD

Large V-waves inflate End-Systolic LAP ⇒ ↑E-wave (V ≠ Mean LAP)



Large V-wave + ↑LAP ⇒ ↑E

"Diagnosis" of CHF: Requires very high ratios of E/e' ≅ 15 or greater

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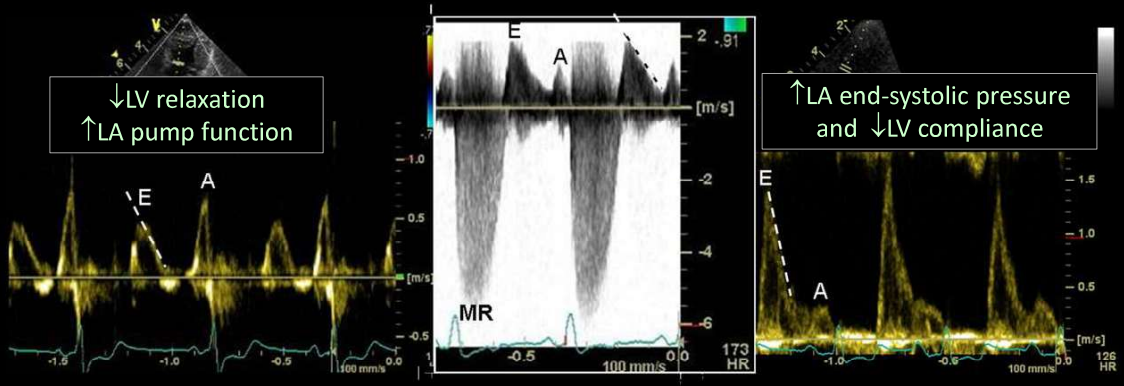
Reference : Diastolic Function & LV Filling in Advanced MMVD



E-waves, Mitral DT & IVRT represent complicated interplay among:

- Normal *aging* & hypertrophy that reduces diastolic function – relaxation & compliance
- Severity of MR + *V-waves* in the LA ↑ end-systolic LA pressure & mitral E-wave
- Fluid retention + venous pressures ↑mean LA pressure
- LA stiffness (compliance) as MR & venous return are received ⇒ LA pressure
- HR & autonomic influences

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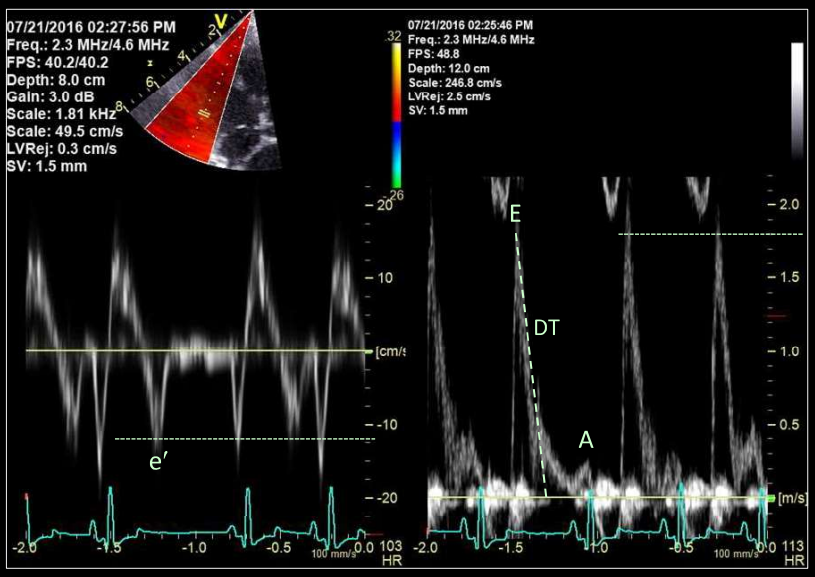
Restrictive Filling – Canine MR with CHF

High Velocity Transmitral E-wave – Short Decel Time with ↑↑↑E/e′



Transmitral flow:

E/A ≈ 165 cm/s ÷ 20 cm/s

= ↑8.5 E/A

Tissue Doppler:

E/e′ ≈ 165 cm/s ÷ 11 cm/s

= 15 E/e′

Low baseline filtering allows visualization of Mitral A-wave

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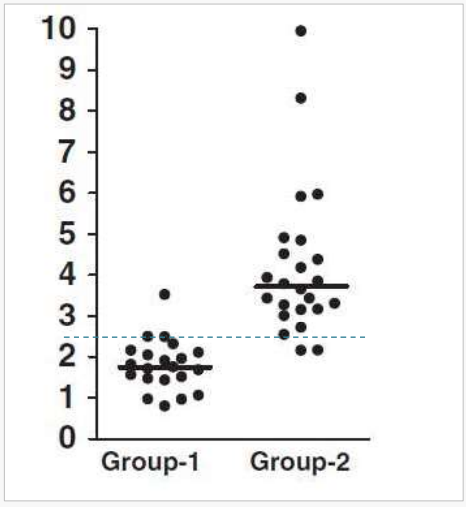
Reference: E-wave : Isovolumetric relaxation time

Alternative for "normalizing" diastolic E-velocity for the enhanced tissue annular motion

J Vet Intern Med 2010;24:1358–1368

Detection of Congestive Heart Failure in Dogs by Doppler Echocardiography

K.E. Schober, T.M. Hart, J.A. Stern, X. Li, V.F. Samii, L.J. Zekas, B.A. Scansen, and J.D. Bonagura



CHF prediction by Doppler:

E/IVRT >2.5 (AUC=0.97; lower $CI_{.95}$ 0.92)

92% sensitivity; 96% specificity

Small study, mixed DCM + MR cases

Data are not yet replicated

Concept: with CHF + ↑ LAP

E-wave ↑↑↑↑ IVRT ↓↓↓↓

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Reference: Can TDI Predict Elevated Filling Pressures in Dogs with Primary MR?

- High E-wave (>1.3 m/s) in dogs *risk* factor for L-CHF (multiple papers)
- Humans: E/e' *unreliable* in *primary* MR & likely so in dogs

Usefulness of Tissue Doppler Imaging for Estimation of Filling Pressures in Patients With Primary or Secondary Pure Mitral Regurgitation

Christian Bruch, MD, Jörg Stypmann, MD, Rainer Gradaus, MD, Günter Breithardt, MD, and Thomas Wichter, MD

Am J Cardiology 2014

- Spontaneous MR: ↑e' in advanced MR relates to increased tissue recoil & transmitral flow (↑preload)
- In K9 *models* & natural MR E/e' correlates to filling pressures but high ratios (>14 or 15:1) needed

(Oyama et al. & Schober, et al., Others)

J Vet Intern Med 2012;26:1309–1319

JVIM 2012

Radial and Longitudinal Strain and Strain Rate Assessed by Speckle-Tracking Echocardiography in Dogs with Myxomatous Mitral Valve Disease

N.E. Zois, A. Tidholm, K.M. Nägga, S.G. Moesgaard, C.E. Rasmussen, T. Falk, J. Häggström, H.D. Pedersen, B. Åblad, H.Y. Nilsen, and L.H. Olsen

- "Normalizing" E:to IVRT might be useful

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Presentation Topics

1. Transthoracic echocardiographic evaluation of the mitral valve
   - General "imaging targets" in MMVD
   - TTE imaging planes for assessment of the canine mitral valve
   - Assessment of valve morphology & motion
   - Mitral valve measurements
   - Principles of Doppler assessment in mitral regurgitation – Review of key points
2. Other Imaging considerations
   - Left Ventricle: Remodeling – Review of key points | Systolic & Diastolic function
   - Left Atrium: Remodeling, tear(s)
   - Right heart: TR & Pulmonary hypertension – "post-capillary" ± "precapillary"
3. Principles of Staging & Therapy
   - ACVIM Staging of MMVD
   - Treatment by stages: Preclinical → Acute pulmonary edema → Chronic therapy

48

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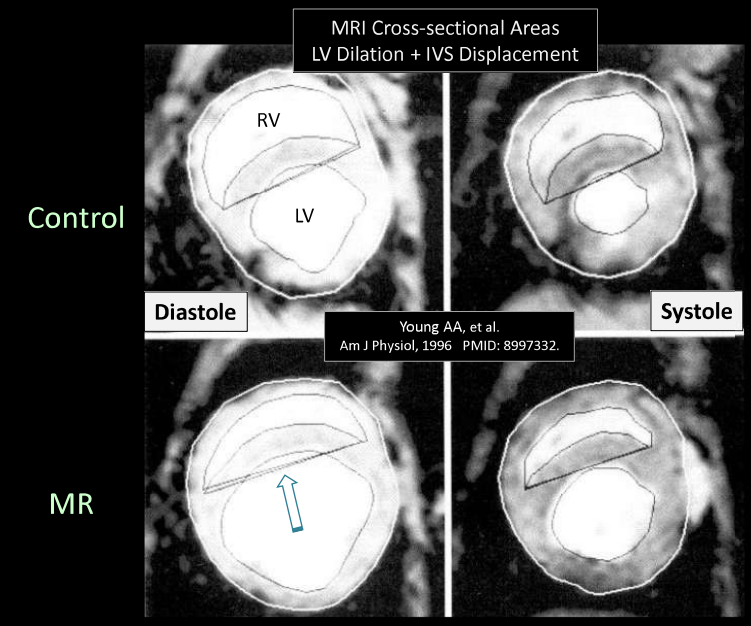
LV Remodeling in Canine Mitral Regurgitation



Hyperdynamic LV

49

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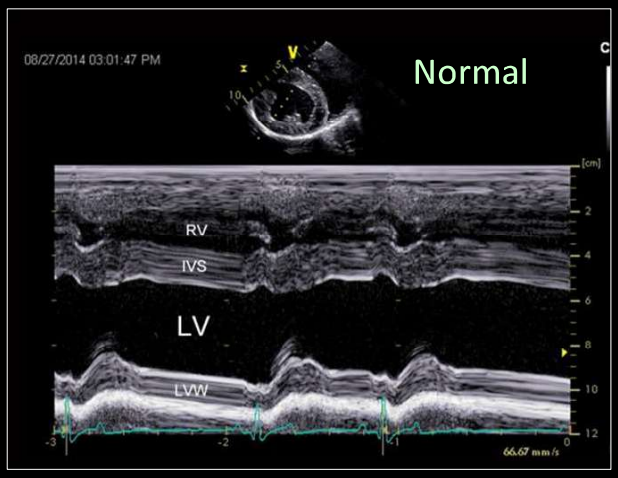
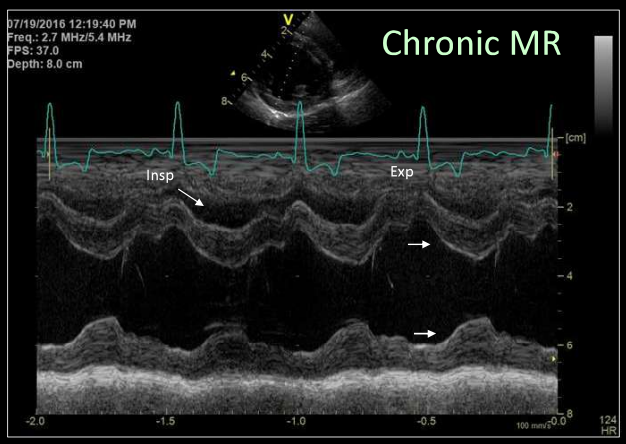
Appearance of LV Volume Overload (right)

Mitral Regurgitation – Note exuberant IVS excursion





Normalize LVIDd to weight (kg) – Do NOT calculate volumes from M-mode

Double-check short-axis LVIDd with a Long-axis measurement

Time diastolic measurement to R-wave | Measure in Expiration

50

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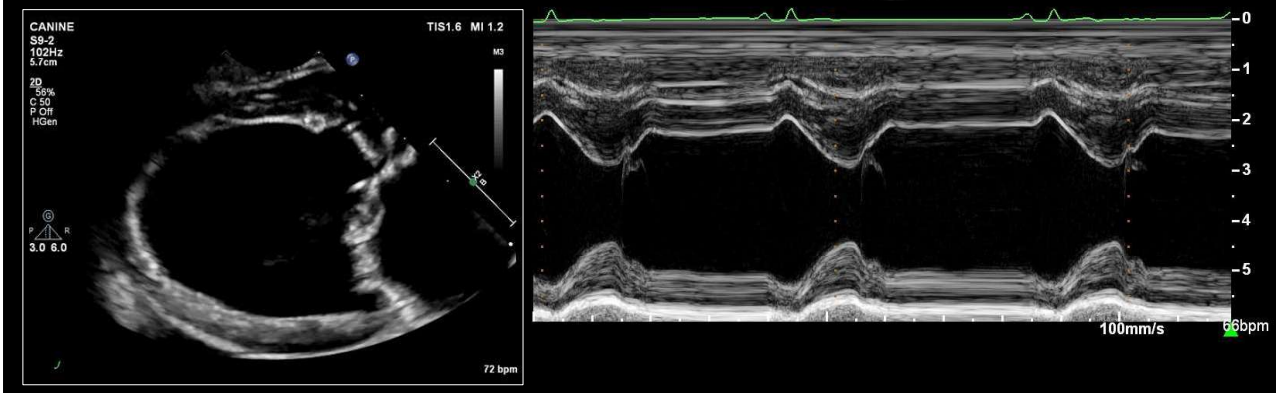
Progressive LV Chamber Dilation is Best Predictor of Severity
Systolic Function typically *hyperdynamic* in primary MR



Video

51

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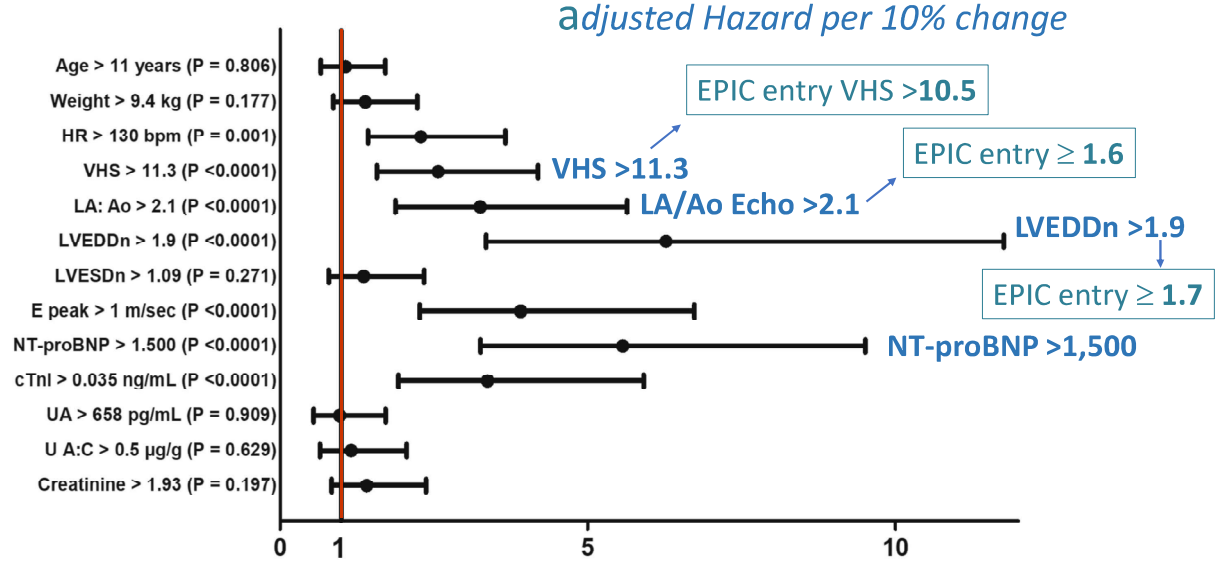
Prognosis: Predictors of Stage B2 Cardiac Events in DELAY*



*Borgarelli, et al. JVC, 2021 *DELay of Appearance of sYmptoms of canine degenerative mitral valve disease treated with spironolactone and benazepril – **Same ENTRY criteria as EPIC**

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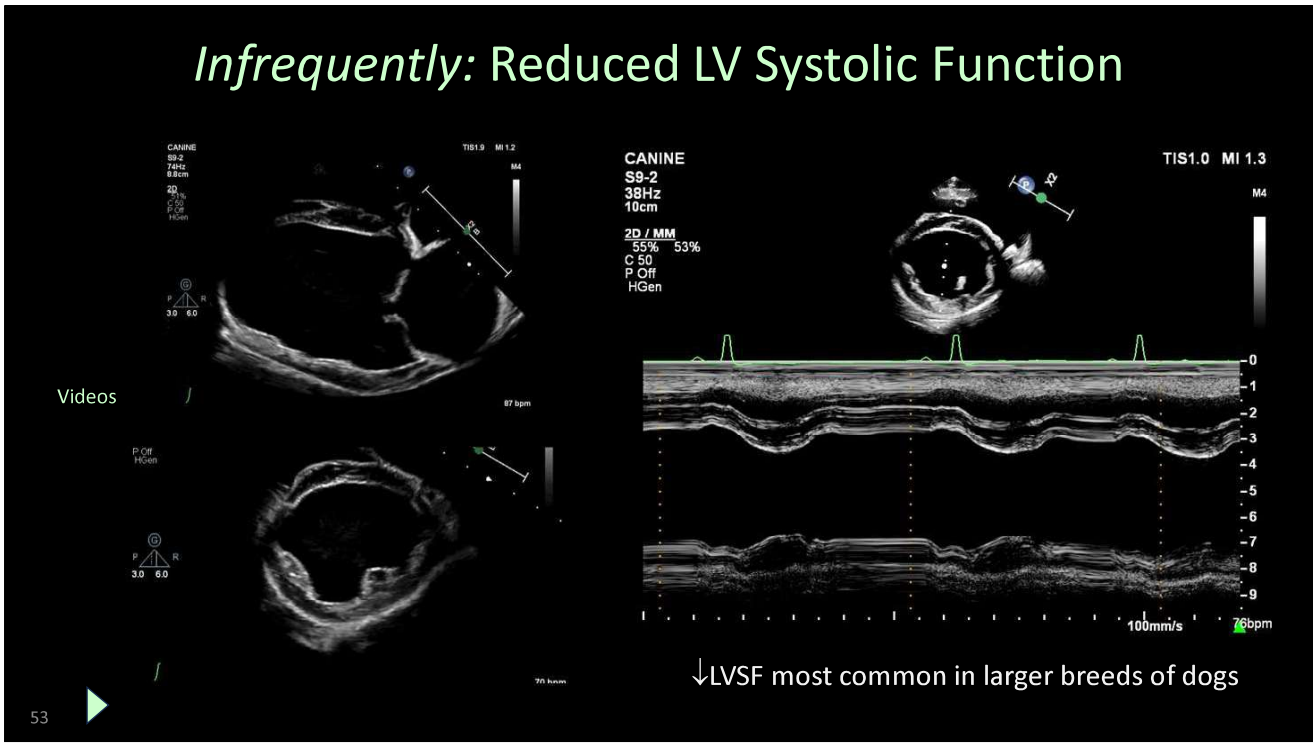
Infrequently: Reduced LV Systolic Function
Videos
CANINE
S9-2
38Hz
10cm
2D / MM
55% 53%
C 50
P Off
HGen
TIS1.0 MI 1.3
M4
100mm/s
76bpm
↓LVSF most common in larger breeds of dogs
53

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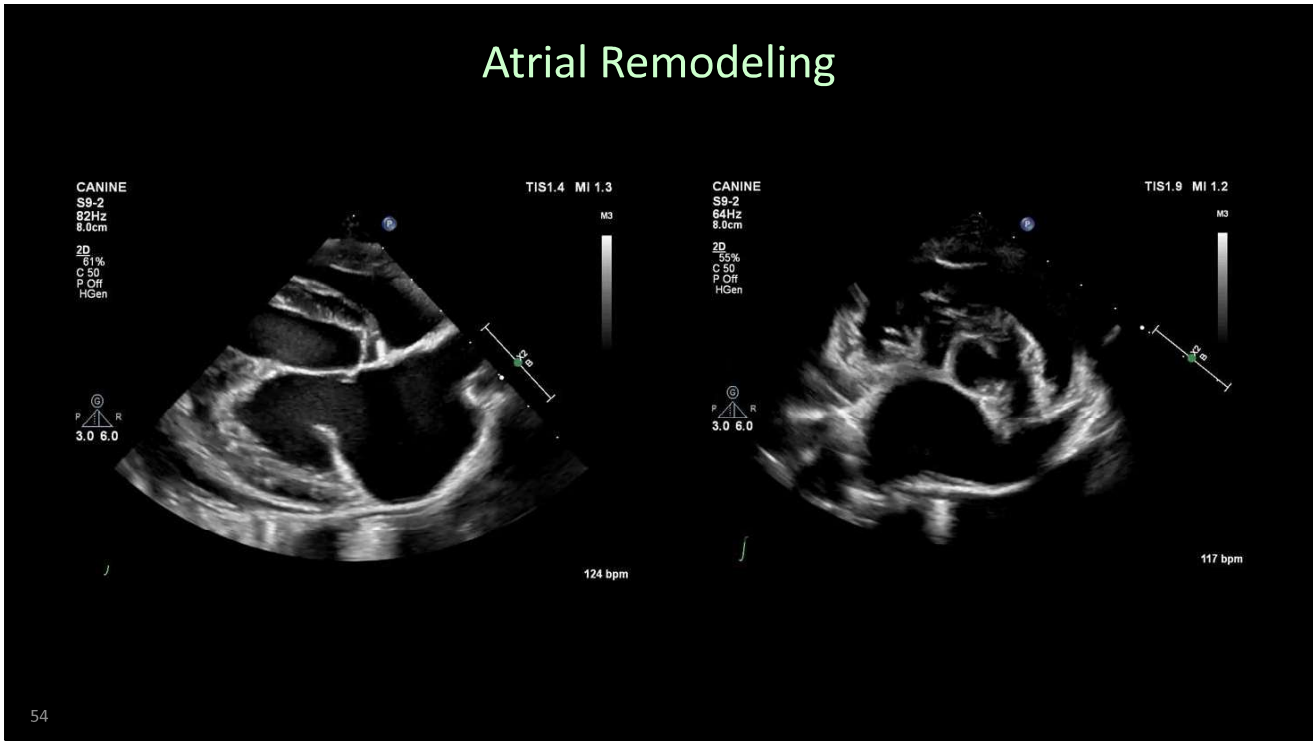
Atrial Remodeling
CANINE
S9-2
82Hz
8.0cm
2D
61%
C 50
P Off
HGen
TIS1.4 MI 1.3
M3
124 bpm
CANINE
S9-2
64Hz
8.0cm
2D
55%
C 50
P Off
HGen
TIS1.9 MI 1.2
M3
117 bpm
54

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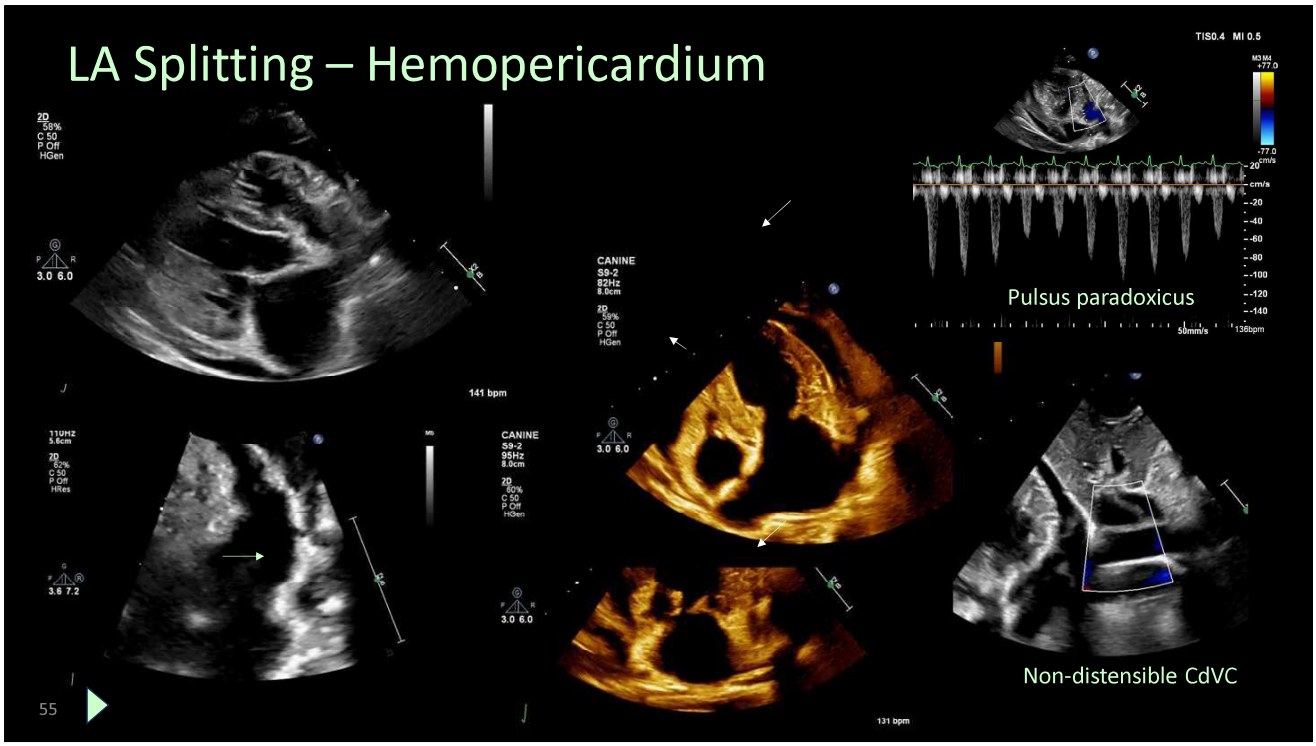
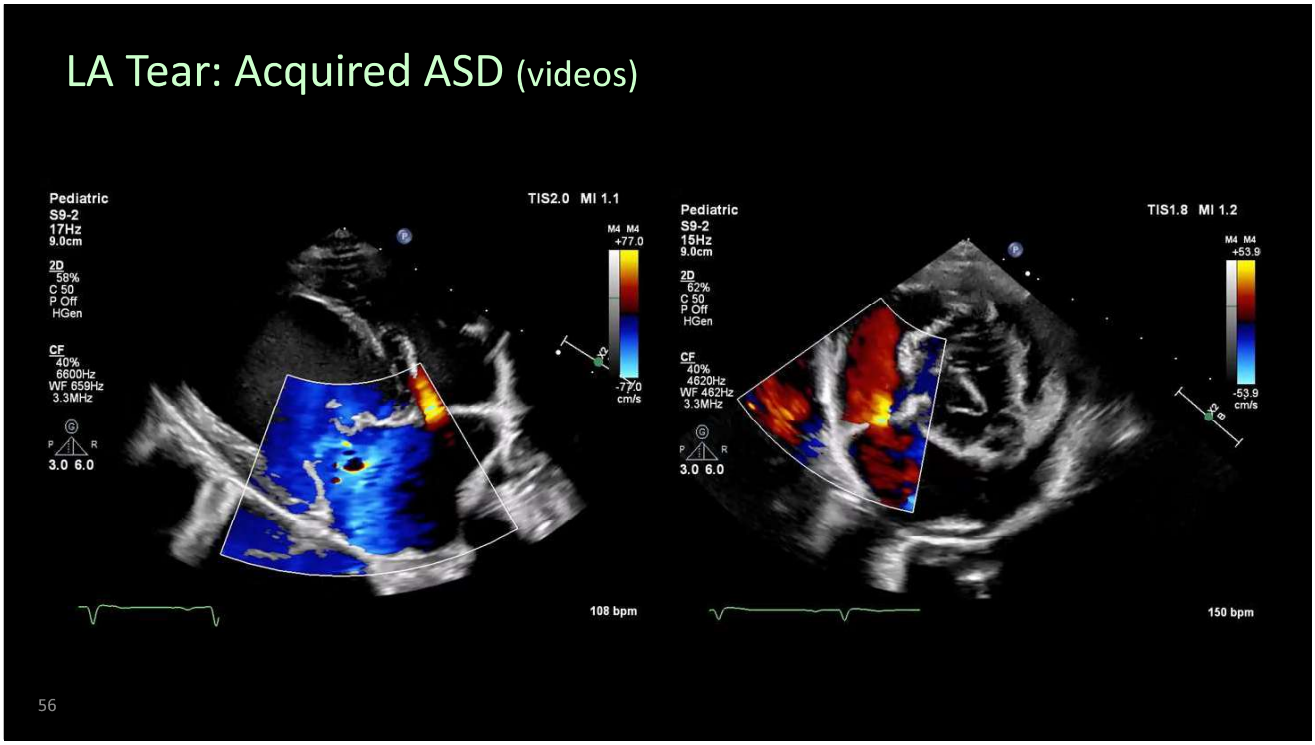

LA Splitting – Hemopericardium
Pulsus paradoxicus
Non-distensible CdVC
55

55


LA Tear: Acquired ASD (videos)
Pediatric
S9-2
17Hz
9.0cm
TIS2.0 MI 1.1
108 bpm
Pediatric
S9-2
15Hz
9.0cm
TIS1.8 MI 1.2
150 bpm
56

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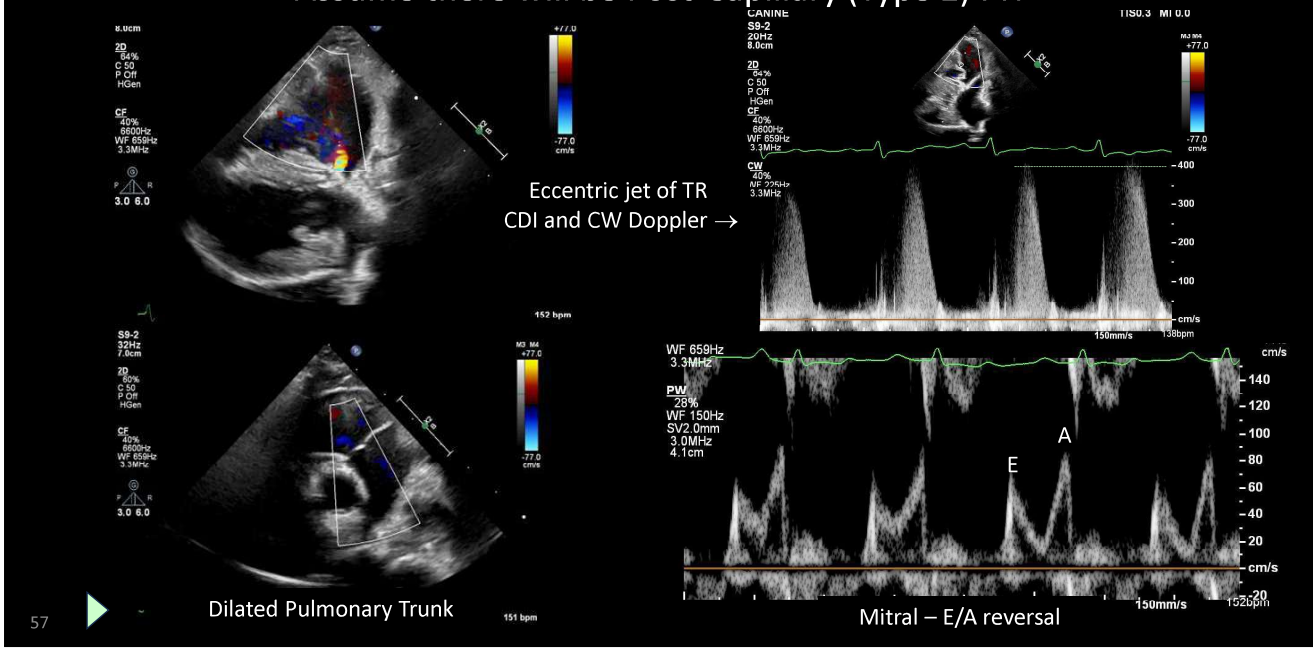
MMVD with Pulmonary Arterial Hypertension ("pre-capillary")

Assume there will be Post-Capillary (Type 2) PH



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Reference: Summary: Echo Evaluation of MMVD

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- **Valvular morphology & valve motion** – consider Differential diagnosis for MR
- **Assessment of MR & TR** – Timing & Duration of MR in cardiac cycle
- **Doppler Evaluation** of MR & TR severity
  - Color Doppler – Flow convergence (PISA) ⇒ vena contracta ⇒ Jet area & projection
  - Spectral Doppler – MR / TR jets & transmitral inflow
- **Cardiac remodeling** – LV and LA diameters or volumes
  - Dimensions – LVID (*normalized*), ±Volumes (from Simpson's not from M-mode)
- **LV Systolic Function** – challenges in primary MR – hyperdynamic in most MMVD patients
  - End systolic volume (index) | Global systolic function – typically normal to ↑
  - LV dp/dt by CW Doppler – impractical and too sensitive to cursor placement
  - Tissue Doppler & Strain (TDI methods & speckle based) – also hyperdynamic!
- **LV Diastolic Function –** challenges in primary MR – hyperdynamic in most MMVD patients
  - Estimation of LV filling pressures – less useful than for DCM ↑↑E-wave ↑↑↑ E/e'
- **Other complications** – Atrial tears (effusion), Acquired atrial septal defect
- **Pulmonary hypertension** – common…first treat Left-CHF then reassess for "precapillary" PAH

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Presentation Topics

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   - Assessment of valve morphology & motion
   - Mitral valve measurements
   - Principles of Doppler assessment in mitral regurgitation – Review of key points
2. Other Imaging considerations
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   - Left Atrium: Remodeling, tear(s)
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3. **Principles of Staging & Therapy**
   - ACVIM Staging of MMVD
   - Treatment by stages: Preclinical → Acute pulmonary edema → Chronic therapy

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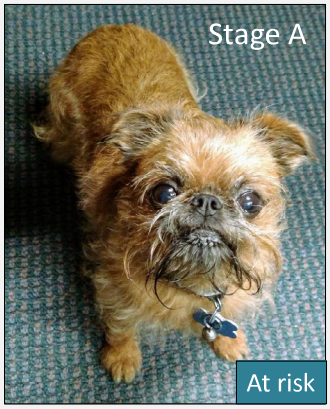
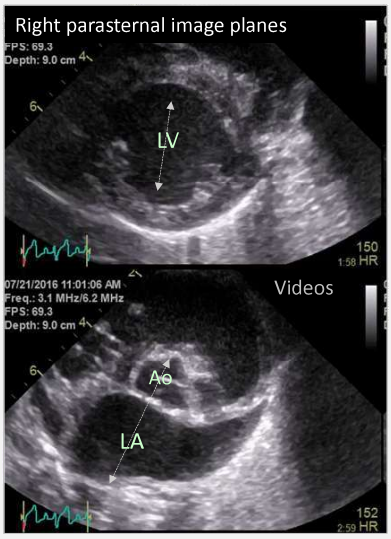
ACVIM – Four Stages of Myxomatous Mitral Valve Disease

Preclinical Stages: A = "at risk" B1 = MMVD (LA + LV size WNL to mild ↑ No Rx)
Stage B2 (LA + LV remodeling *sufficient to treat*) Stages C & D = **CHF**





Staging of B2 is based mainly on *clinical findings* & 2D (M-mode) Echo
Grade 3/6 murmur or louder | LVEDDn ≥1.7 LA/Ao≥1.6, 1.8 (if no LV)
In a compatible patient at risk for MMVD

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Reference:

ACVIM – Stages of MMVD

CONSENSUS STATEMENT

Journal of Veterinary Internal Medicine ACVIM

ACVIM consensus guidelines for the diagnosis and treatment of myxomatous mitral valve disease in dogs

Bruce W. Keene[1] | Clarke E. Atkins[1] | John D. Bonagura[1,2] | Philip R. Fox[3] | Jens Häggström[4] | Virginia Luis Fuentes[5] | Mark A. Oyama[6] | John E. Rush[7] | Rebecca Stepien[8] | Masami Uechi[9]

- **Stage A** – dogs at risk
- **Stage B** – objective evidence of heart disease (murmur) but no signs of heart failure
  - B1 – Heart size is normal or there is **insufficient remodeling** to justify therapy based on clinical trial evidence
  - B2 – Evidence of remodeling (cardiomegaly) **sufficient to treat** based on clinical trial evidence – **pimobendan** ± other treatments
- **Stage C** – Dog currently in or previously experienced **CHF** (on therapy)
- **Stage D – Refractory CHF** – **unresponsive** to "standard" therapy & doses

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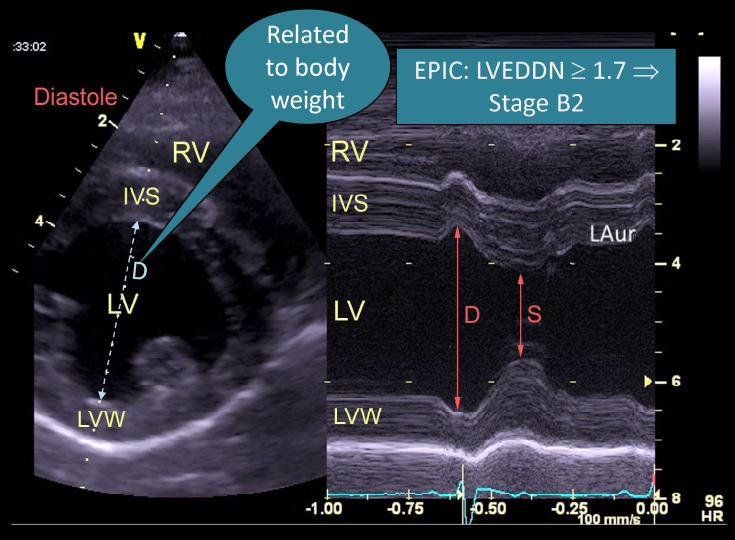
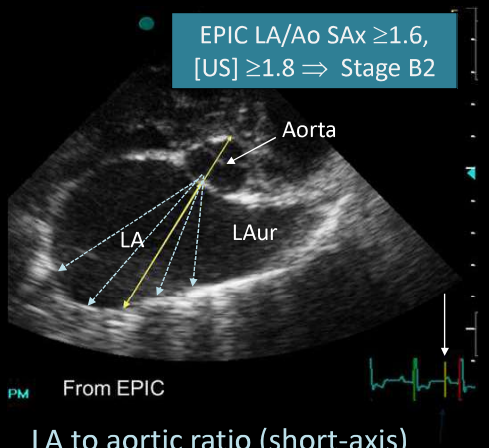
Staging By Echo: LV & LA size increase with progressive MR





Normalized LV: LVEDDN = LVIDd (cm)/Wt (kg)$^{0.294}$

LA to aortic ratio (short-axis)
Challenges: early diastolic timing & direction of the cursor across LA

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Reference: Current Staging of "B2" is based on the EPIC or EPOCHAL study criteria for initiation of Pimobendan

Journal of Veterinary Internal Medicine
ACVIM
Open Access
Standard Article
J Vet Intern Med 2016

Effect of Pimobendan in Dogs with Preclinical Myxomatous Mitral Valve Disease and Cardiomegaly: The EPIC Study—A Randomized Clinical Trial

A. Boswood, J. Häggström, S.G. Gordon, G. Wess, R.L. Stepien, M.A. Oyama, B.W. Keene, J. Bonagura, K.A. MacDonald, M. Patteson, S. Smith, P.R. Fox, K. Sanderson, R. Woolley, V. Szatmári, P. Menaut, W.M. Church, M. L. O'Sullivan, J.-P. Jaudon, J.-G. Kresken, J. Rush, K.A. Barrett, S.L. Rosenthal, A.B. Saunders, I. Ljungvall, M. Deinert, E. Bomassi, A.H. Estrada, M.J. Fernandez Del Palacio, N.S. Moise, J.A. Abbott, Y. Fujii, A. Spier, M.W. Luethy, R.A. Santilli, M. Uechi, A. Tidholm, and P. Watson

- Main therapy goal: delay CHF
- Dogs ≥6 years of age
- Weight: ≥ 4.1 & ≤ 15 kg
- Systolic murmur MR ≥ Grade **3/6**
- 2D Echo ⇒ characteristic valvular lesions of the mitral valve, LA/Ao (short-axis) **≥1.6 or 1.8 (new US study)**
- M-mode or 2D Echo ⇒ **LV diastolic dimension (cm)/(kg weight$^{0.294}$) ≥1.7**
- Color Doppler ⇒ MR (confirms auscultation)
- VHS ⇒ remodeling: ~~VHS >10.5~~ - More often exceeds 11.5 to 11.8 (breed)
- Therapeutic Impact: start **Pimobendan** (trial dosage: 0.2-0.3 mg/kg PO bid*)

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* USA labeled dosage is **0.25 – 0.3 mg/kg PO bid**

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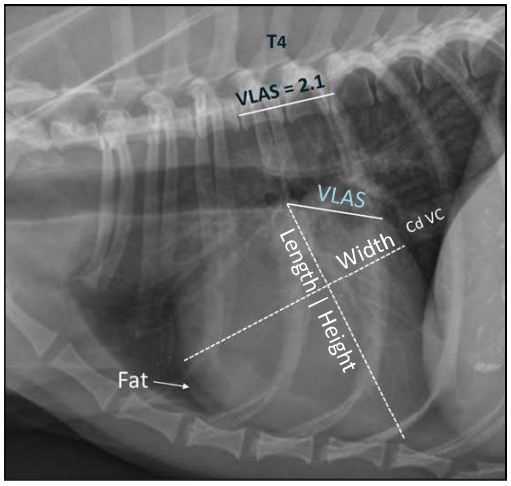
Reference: Alternative Staging using Thoracic radiography
Vertebral Heart Sum (W+L) & Vertebral Left Atrial Score (VLAS)

- **VHS** <10.8 VB is unlikely to fulfill stage B2 criteria (therefore: no therapy!)
- **VHS** >11.5 to 11.8 **likely fulfills B2** (EPIC-study) criteria for cardiomegaly
- **VLAS** useful to identify **LA enlargement**
- **VLAS** >2.2 to 2.3 is likely enlarged >2.8 to (3.0 VB) likely corresponding to at least moderate LA enlargement



Be aware of *breed-specific VHS* data

Poad et al., JVIM Vol 34, 2020
Stepien, et al., JAVMA Vol 256, 2020
Vezzosi, et al., Vet Radiol Vol 61, 2020
Wesselowski, et al. JVC, 2025

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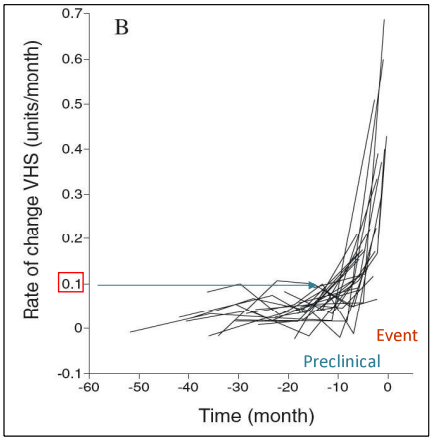
Reference: Vertebral Heart Sum "Velocity" (change/month)



From: **Lord PF**, et al., JSAP, 2010
Also see: Lord et al. JVIM 2011

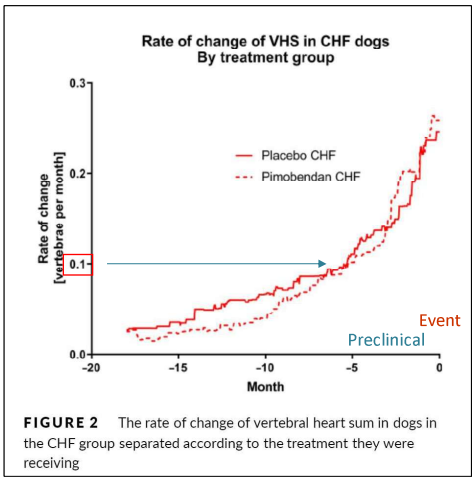


FIGURE 2 The rate of change of vertebral heart sum in dogs in the CHF group separated according to the treatment they were receiving

From: **Boswood A,** et al., JVIM, 2020

VHS "velocity" Δ ~0.1 VB/month ⇒ high risk for future CHF (≈"B2")

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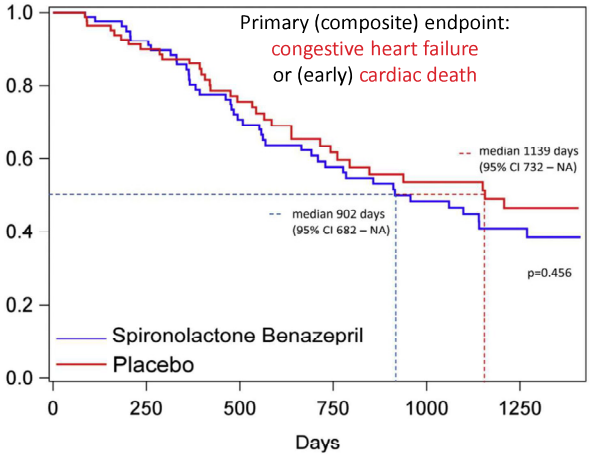
Stage B2: *DELay Study* of Spironolactone & Benazepril

J Vet Cardiol. 2020 Jan 10;27:34-53. doi: 10.1016/j.jvc.2019.12.002. [Epub ahead of print]

DELay of Appearance of sYmptoms of Canine Degenerative Mitral Valve Disease Treated with Spironolactone and Benazepril: the DELAY Study.



Borgarelli M et al., J Vet Cardiol 2020

- Combination ACE-inhibitor (**benazepril**) + a mineralocorticoid (aldosterone) receptor blocker (**spironolactone**)
- Did not delay onset of CHF in stage B2 MMVD dogs (≈EPIC entry-criteria)
- Potentially less adverse **remodeling**?
- Optimal dosing?
- Not tested with **pimobendan**

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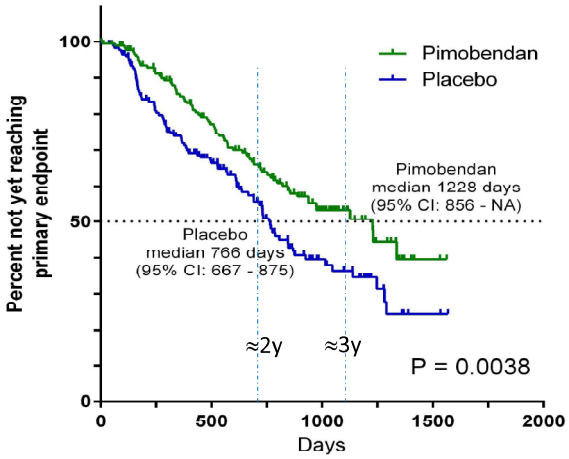
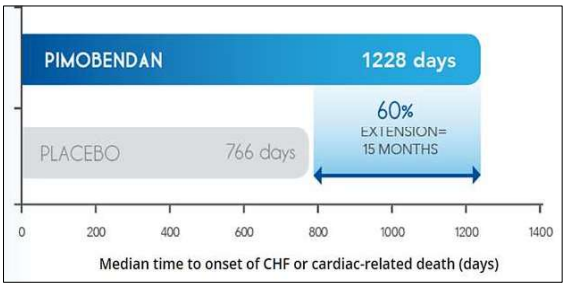
Stage B2: *EPIC Clinical Trial* of Pimobendan – Time to Endpoint

Composite endpoint: **CHF or cardiac death**





Pimobendan (Vetmedin®) dosed in the clinical trial at 0.2 to 0.3 mg/kg PO q12h*

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*USA label dosage of Vetmedin® CA1 is **0.25 to 0.3 mg/kg** PO b.i.d.

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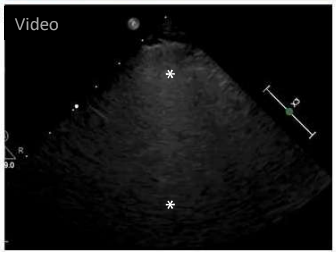
Reference: Diagnosis of Left-sided CHF

History:
⇑ RR, Effort ± Cough

♥Auscultation
↑HR + **Murmur** ±S3

Lung auscultation
↑bronchial sounds, crackles
– But r/o lung disease



↑(NT-pro)BNP: Supports (does not confirm) Dx (and not POC)

Thoracic Radiography ⇒ Signs of L-CHF (upcoming)

Thoracic POCUS ⇒ B-lines (nonattenuating reverbs *) ± Pl Eff

Echo ⇒ Heart disease, enlargement ↑filling pressures

Metabolic ⇒ Hypoxemia, ↑Lactate, ↑ BUN (+ effects of therapy K^+ Cl^-)

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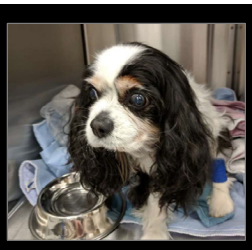
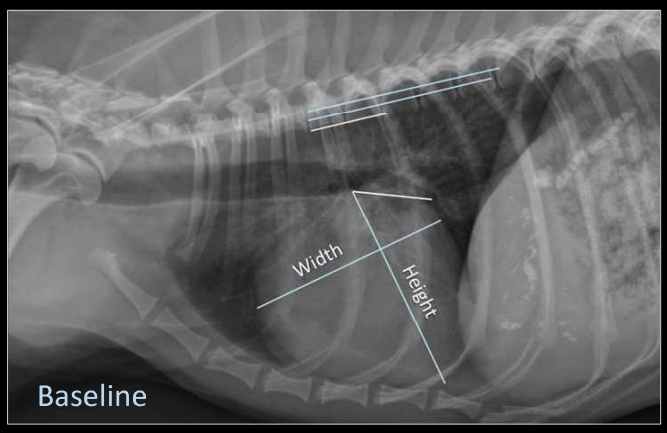
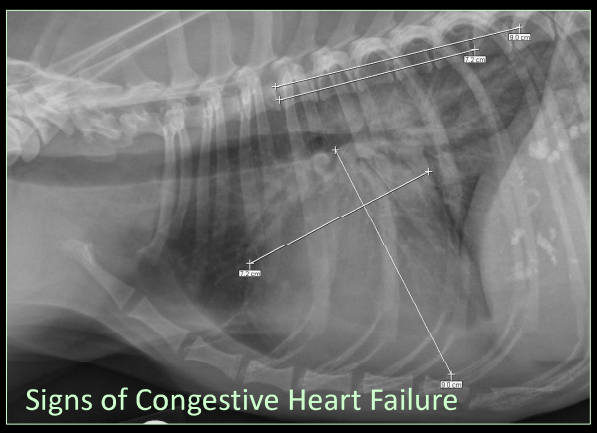
Do we need an Echo to "Diagnose" Stage C - CHF?

Many clinical trials are "significant" for echo variables because they include Stage C patients.

The Echo helps to confirm presence/severity of Heart Disease but cannot "diagnose" CHF – that is a clinical + pulmonary Dx







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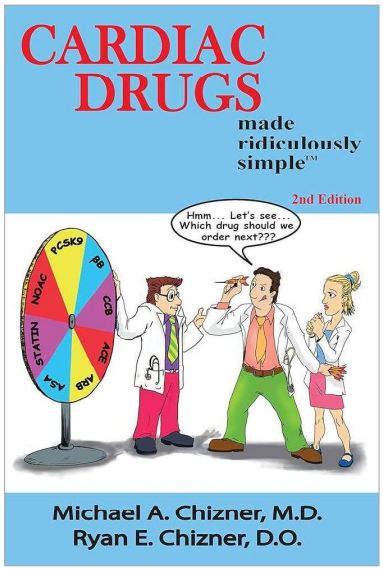
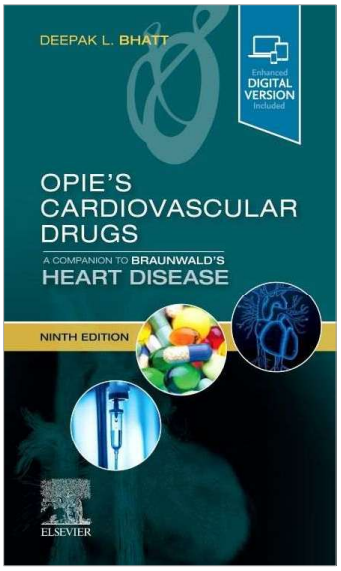
Cardiovascular Drugs for MMVD & Heart Failure
– Overview –





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Cardiac Drugs, Dosages & Potential Treatment Plans
are summarized at:
https://CardiacEducationGroup.org

CARDIAC EDUCATION group ...bringing cardiology into practice

CEG Formulary:
Cardiac Medications for Dogs

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Furosemide
Salix®, Lasix®

Torsemide
Upcard®
Isemid®

Spironolactone
(Prilactone®)

Pimobendan
Vetmedin® Tablets/Solution

Salcubitril/Valsartan

Benaz + Spiro
(Cardalis®)

Angiotensin-Converting Enzyme Inhibitors
(Enalapril, Benazepril, Others)

Digoxin
Lanoxin®

Diltiazem
Dilt-XR, ER

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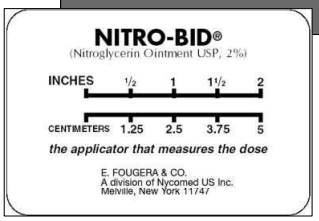
'Direct' Vasodilators for Decompensated CHF & PH

Use is based mostly on models, clinical experience & case reports

Preload reduction (?)



Afterload reduction

Preload + Afterload reduction

Revatio® sildenafil citrate

Pulmonary vasodilation

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Hospital Therapy of Pulmonary Edema: "SO-FINE"

Sedation (butorphanol)

Oxygen (kennel, Hi-flow)

Furosemide (IV furosemide by bolus or possibly CRI)

Pimobendan (t.i.d. → b.i.d.)

± direct vasodilators

± centesis if needed

} **E**xtra treatments

Not Oliver…but related!

Dosages: See CardiacEducationGroup.org

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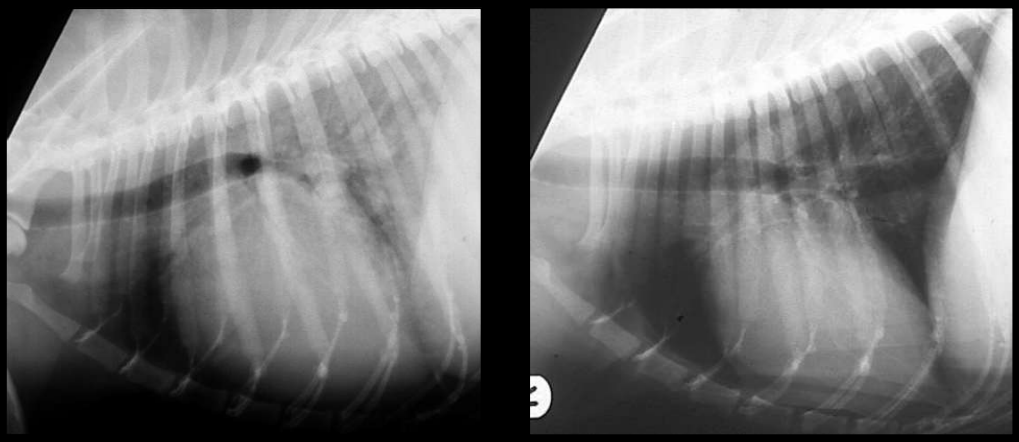
Left CHF: Response to Diuretic Therapy



Useful finding if the diagnosis of CHF is uncertain
Objective demonstration of therapeutic benefit

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Post-Tap + Diuresis

Clinical Response

* Respiratory Rate *

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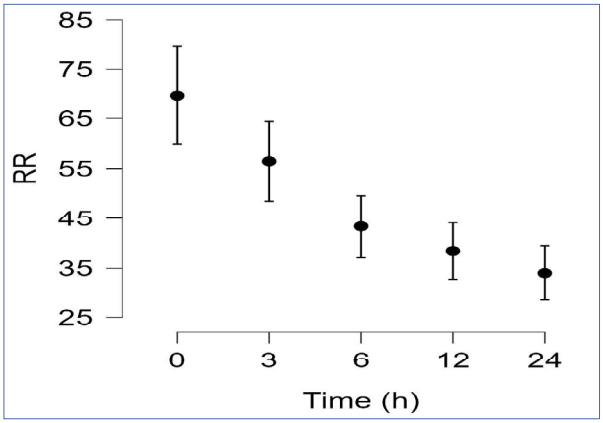
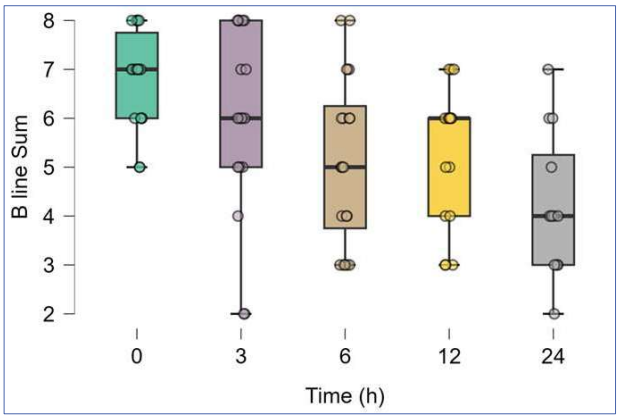
Respiratory Rate vs. Thoracic "B-lines"

Admission to 24h - All released from hospital)





Mean (95% CI of the mean)
n = 20 (6h) to 12 (24h)
1 outlier deleted 140/min @ Time 0

Like radiographs –
Lung US "lags" clinical signs

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Transition from Hospital → Home Therapy

- Sedation & Oxygen → Discontinued
- Injectable furosemide → Oral furosemide bid
- Pimobendan (t.i.d.) → Continued at bid
- Initiate Spironolactone
- ±Nitrate → ±ACE inhibitor (at recheck)
- Recheck: Sleeping RR + QOL indicators + Renal panel ± Radiography
- Add/Adjust dosages (signs & renal function)
  - **Stage D or Ascites** ⇒ **Torsemide** ?Sacubitril (Entresto®)
  - ***Symptomatic* PAH** ⇒ Sildenafil or Tadalafil

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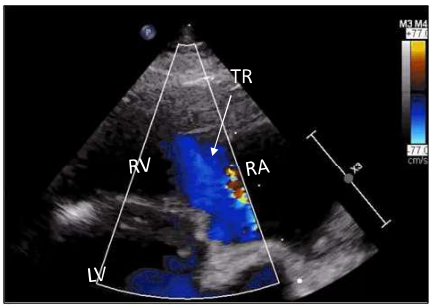
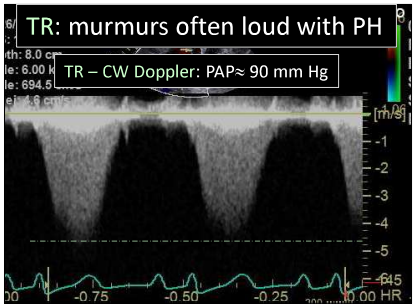
Outcomes: Right-sided Failure





- Symptomatic PH: ↓↓ exercise tolerance
  exertional collapse or syncope | possibly R-CHF
- Ascites typically caused by a combination of
  tricuspid regurgitation + PH ± AF
- Paracentesis ⇒ torsemide ± sildenafil (PAH)

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Reference: Summary – of Chronic Medical Therapy: Key Drugs for Chronic CHF in MMVD (Stages C & D)

Furosemide & Torsemide

Treats CHF
↓ pulmonary edema | effusions
Stage D → Torsemide
(Balance: renal function vs. CHF)

Pimobendan (Vetmedin®)

Potent Inodilator
Stages B2 → CHF (Stage C)
Stage D CHF → ↑↑Dosage (***extra-label***)

Spironolactone

Neurohormonal protection
↓K+ loss in CHF
? Incremental value
with Furosemide + Pimobendan

ACE – Inhibitors (? NEP-inhibitors)

Neurohormonal protection ↓load
Enalapril Benazepril
Ramipril Quinapril
? Incremental value
Sacubitril?

80

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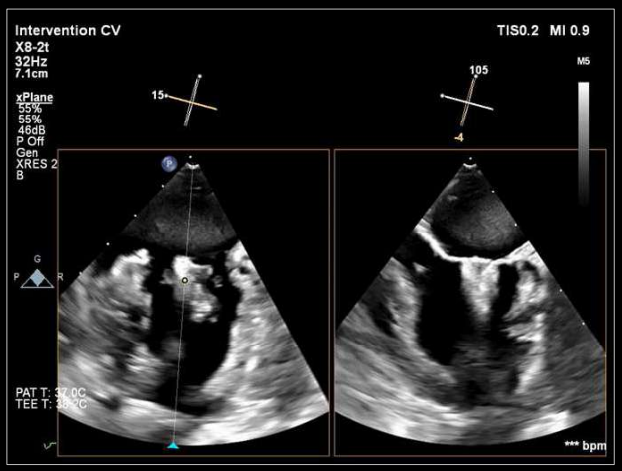
Transcatheter Edge-to-Edge Repair



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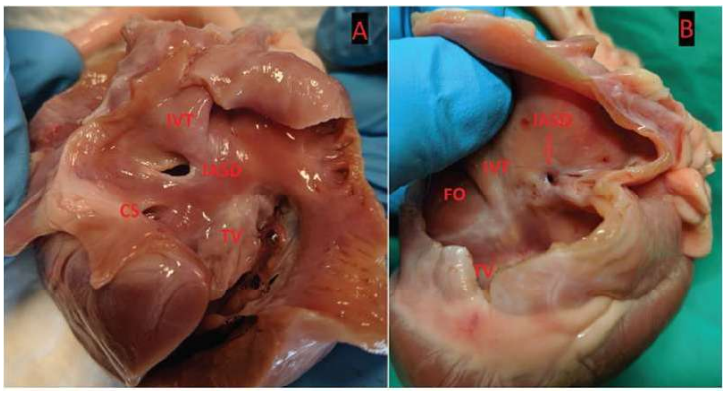
Left Atrial Decompression (Stage D)

Left atrial decompression as a palliative minimally invasive treatment for congestive heart failure caused by myxomatous mitral valve disease in dogs: 17 cases (2018–2019)



Allen J, et al. JAVMA; 2021 | VOL 258 | NO. 6

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Urinary Clinical Challenges

Dominique Penninck, DVM, DACVR, DACVR, DECVDI
Professor, section of Diagnostic Imaging
Cummings School of Veterinary Medicine, Tufts University, USA

Introduction/anatomy:
This presentation covers selected topics of imaging diagnostic challenges of the urinary tract; ultrasound is a resourceful technique and knowing its strengths and limitations is essential to best assist clinical decisions.
As systematic and thorough evaluation of the normal urinary system will be briefly covered, addressing pertinent imaging features of the kidneys, ureters, and bladder, keeping in mind the adjacent organs and structures such as lymph nodes, vessels, adrenal glands, uterus/prostate, urethra and colon.

Renal disorders include changes affecting the cortex, medulla and/or collecting system (renal pelvis/diverticuli).
The animal's signalment and the clinical presentation guide the list's order of differential diagnosis when the size, shape, contours of the kidney(s) are affected.
Examples of diffuse and focal parenchymal changes will be discussed. Increased renal echogenicity is a common finding in dogs and cats with diseases such as renal dysplasia/juvenile nephropathy, interstitial and glomerular nephritis, acute tubular necrosis, end-stage renal disease, and nephrocalcinosis. Benign renal cyst and polycystic renal disease and other conditions with cystic component can be differentiated with ultrasound.
A common example of focal hyperechoic lesion is renal infarct; its features will be discussed.
Renal tumors vary in appearance from focal or multifocal renal changes to diffuse infiltration. In feline lymphoma, the kidneys are typically enlarged, irregular, variably echogenic with often an irregular hypoechoic subcapsular thickening. Other tumors, such as squamous cell carcinoma, papillary carcinoma and nephroblastoma, may extensively distort the renal architecture.
Disorders affecting the collecting system include pyelectasia/ hydronephrosis (obstructive condition), pyelonephritis (with or without diverticular extension), pyonephrosis, neoplasia. Assessing the ureters is important, especially if the renal pelvis is involved.
Bladder disorders include wall and content abnormalities.
Wall abnormalities cover focal or diffuse thickening, mural nodules or masses, or rupture. It is important that the bladder be sufficiently distended to evaluate its thickness. Cranio-ventral wall thickening is most seen in cystitis, although the inflammation/infection can affect more extensively the bladder. Nodules/masses are often seen with neoplasia. Carefully evaluating the luminal surface of the mucosa with a linear (high frequency) probe is recommended, to detect subtle erosions/ulcerations.
Polypoid cystitis may appear as one or several nodules/pedunculated masses projecting within the lumen. A suction biopsy is required for definitive diagnosis.

Gas can be seen within the bladder wall in cases of emphysematous cystitis; it has been previously described mostly in diabetic animals; however, it is not limited to that population. Pseudomembranous cystitis is often found in animals presented with urinary obstruction. Echogenic membranes of variable thickness, number and echogenicity contribute to the mechanical obstruction.
Encrusting cystitis, resulting in hyperechoic lining (with or without shadowing) has been described and associated with infections such as Corynebacterium, but not exclusively. Pseudomembranous cystitis with mineralized component has been also recently described.

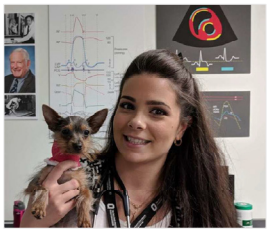
Transitional cell/urethelial carcinoma (TCC) is the most common neoplasm of the urinary bladder. It is commonly an irregular bladder wall mass with a broad-based attachment. The echogenicity is often mixed and has an overall appearance that can be hyperechoic (mineralized foci), isoechoic or hypoechoic compared to the bladder wall. The TCC masses are most commonly located at the bladder trigone region and dorsal bladder wall. When affecting the trigone, unilateral or bilateral hydroureter can occur. At times, the mass extends into or originates from the proximal urethra. A wide variety of other bladder tumor types exists, including epithelial (squamous cell carcinoma) and mesenchymal tumors (botryoid rhabdomyosarcoma, chemodectoma, leiomyosarcoma, leiomyoma, fibroma, fibrosarcoma, hemangioma, hemangiosarcoma, lymphoma, mast cell tumor).
Urinary **bladder rupture** may be challenging to diagnose ultrasonography, as the defect is often not obvious. Not finding the defect does not rule out bladder rupture. Also, edge shadowing artifact may give the impression of a bladder wall defect that is not actually present. If abdominal effusion is noted, an abdominal centesis is performed to confirm the presence of uroabdomen. A positive contrast cystourethrogram is a useful method for confirming the presence and location of suspected rupture.
Abnormal contents include gas, calculi, blood clots, cellular or mineralized sediment, or foreign bodies. Calculi and mineralized sediment are found in the dependent portion of the bladder and are commonly associated with strong shadowing, whereas gas is found in the nondependent portion of the bladder. Blood clots are often echogenic without acoustic shadowing, possibly adherent to the bladder wall. It can be difficult to distinguish them from neoplasia or polyps. Color flow Doppler examination may assist to distinguish blood clot (no flow) from a mass.

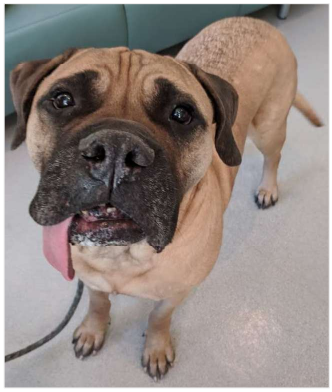
Interventional procedures:
Fine-needle aspiration or core biopsy of kidney lesion(s) can be safely performed by experienced clinicians.
Percutaneous cystocentesis can be readily performed with ultrasound guidance. A 22-gauge needle is easily visible.
Transurethral suction biopsies of bladder and urethral tissue can be obtained using a red-rubber urinary catheter that is sonographically monitored. This technique is used preferentially over trans-abdominal fine needle-aspiration or biopsies, when neoplasia is suspected to avoid the risk of tumor seeding along the needle track. Alternatively, tissue fragments can be obtained using endoscopic forceps.

Echocardiography: Common Congenital Heart Diseases

John D Bonagura, DVM, DACVIM (Cardiology, Internal Medicine), FASE

Professor Emeritus, the Ohio State University College of Veterinary Medicine
Adjunct Professor – Cardiology, Colorado State University College of Veterinary Medicine & Biomedical Sciences
Adjunct Professor of Cardiology, North Carolina State University College of Veterinary Medicine





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Relative Frequency of Congenital Heart Disease

Dogs (n=4694)

- **Patent ductus arteriosus (PDA) 25.7%**
- **Subvalvular aortic stenosis (SAS) 23.5%**
- **Pulmonary stenosis (PS) 22.1%**
- **Tricuspid valve malformation** } **8.9%**
- **Mitral valve malformation** }
- **Ventricular septal defects** (VSDs) 8.8%
- Tetralogy of Fallot – Pulm Atresia 2.3%
- Atrial septal defects (ASDs) 1.9%
- Others: DORV, TGA, CTA
- Vascular including coronary anomalies
- Arrhythmias (AP, LQT, Channelopathies)

Summarized by: Scansen, Cober & Bonagura (2014):
Kirk's Current Veterinary Therapy CVT XV

Cats (n=435)

- **Ventricular septal defects 18.4%**
- **Patent ductus arteriosus 11.3%**
- **Tricuspid valve malformation 10.8%**
- **Mitral valve malformation 10.1%**
- **Atrioventricular septal defects 9.7%**
- **Aortic stenosis 7.1%**
- Tetralogy of Fallot 6.9%
- Atrial septal defect (isolated) 6.0%
- Pulmonary stenosis 3.9%
- Vascular rings 5.3%
- Others ~10%

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Recent Surveys

Smaller dogs | More PS

RESEARCH ARTICLE

Epidemiological study of congenital heart diseases in dogs: Prevalence, popularity, and volatility throughout twenty years of clinical practice

Paola Giuseppina Brambilla[1]*, Michele Polli[1], Danitza Pradelli[2], Melissa Papa[2], Rita Rizzi[1], Mara Bagardi[1], Claudio Bussadori[2]

1 Department of Veterinary Medicine, University of Milan, Lodi, Italy, 2 Department of Cardiology, Clinica Veterinaria Gran Sasso, Milan, Italy

PLOS1 PLoS ONE 15(7): E0230160, 2020

Table 1. Summary of congenital heart defects of the included p

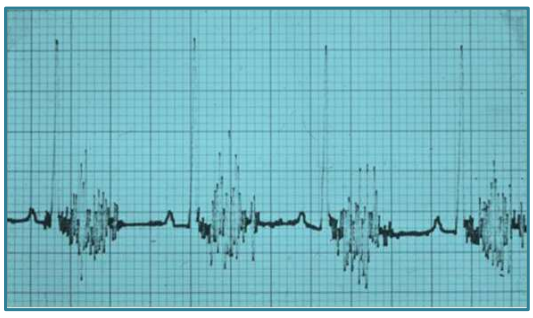
CHDs	TOTAL		CHD_i		CHD_a	
	N	%	N	%	N	%
PS	689	34.1	570	82.7	119	17.3
PDA	534	26.4	490	71.1	44	8.2
SAS	296	14.6	220	31.9	76	25.7
VSD	98	4.8	39	5.7	59	60.2
AS	95	4.7	80	11.6	15	15.8
TD	69	3.4	51	7.4	18	26.1
ASD	42	2.1	21	3.0	21	50.0
DCRV	37	1.8	21	3.0	16	43.2
MD	32	1.6	27	3.9	5	15.6
TOF	21	1.0	0	0.0	21	100.0
rPDA	15	0.7	15	2.2	0	0.0
MVS	12	0.6	6	0.9	6	50.0
BAV	10	0.5	5	0.7	5	50.0
PLCVC	10	0.5	0	0.0	10	100.0
AVCD	10	0.5	5	0.7	5	50.0
others[a]	52	2.6	18	2.6	34	65.4
	2,022	100	1,568		454	

CHDi, isolated congenital heart diseases
CHDa, associated congenital heart diseases

3

Most CHD Patients have a Heart Murmur

Pulses (arterial & venous)
Precordium (heaves & thrills)
Mucous membranes
Careful auscultation
…in the *standing* patient



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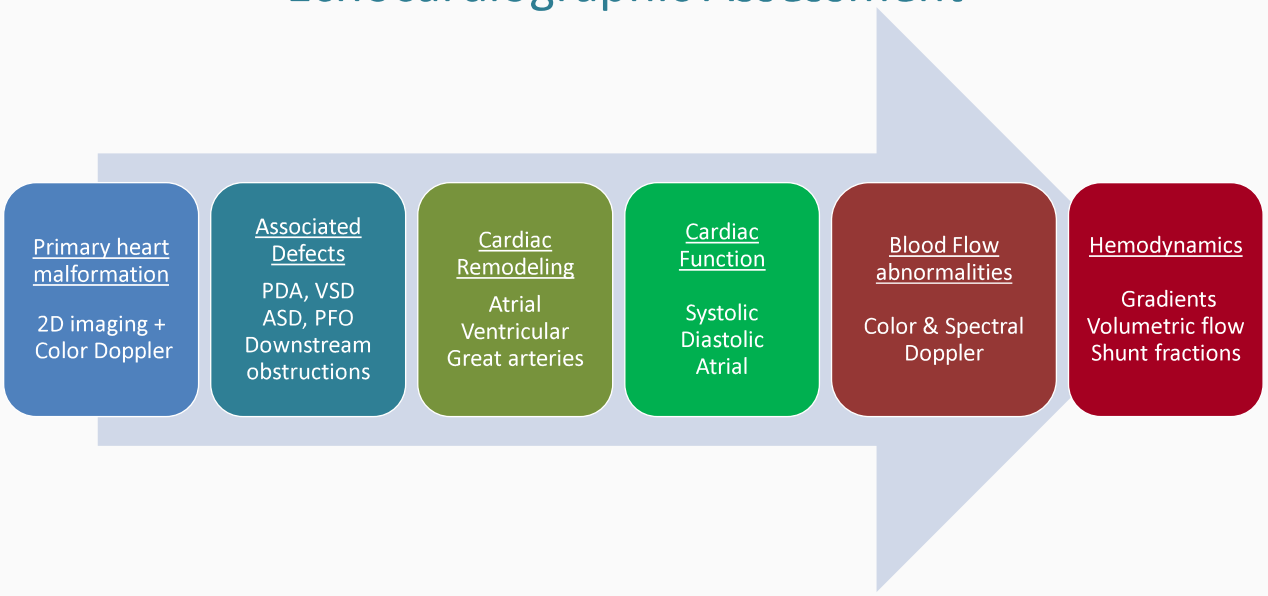
Congenital Heart Disease
Echocardiographic Assessment



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Notes about this Presentation

- *Reference Slides*:
  - Additional information not discussed during the presentation
- *Management of congenital heart defects*
  - Should be discussed with a cardiologist
  - Relates to primary malformation, concurrent lesions & with shunts identifying pulmonary vascular disease
  - Therapies: Catheter-based, Surgical & some Medical options
  - Not considered in any detail in this introductory presentation
  - Focus is on Echocardiographic Recognition

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Common Cardiac Malformations

1. Introduction
2. Shunts
   - Patent ductus arteriosus
   - Ventricular septal defect
   - Atrial & Atrioventricular septal defects
3. Pulmonary Stenosis
4. Subaortic Stenosis

Also discussed with *Doppler imaging of valvular disease*

5. Atrioventricular valve malformations
   - Mitral valve malformations (MV dysplasia)
   - Tricuspid valve dysplasia

Discussed with Valvular Doppler & Case Studies

7

Patent Ductus Arteriosus

Collie Littermates with
Patent Ductus Arteriosus
Before & After Closure

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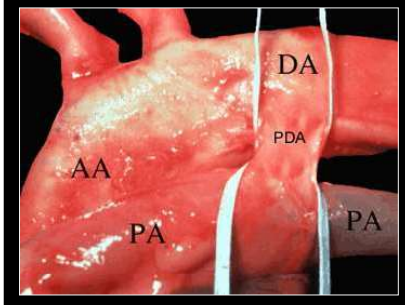
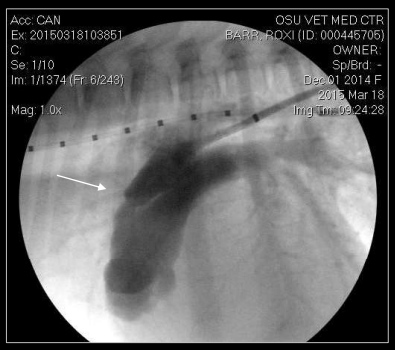
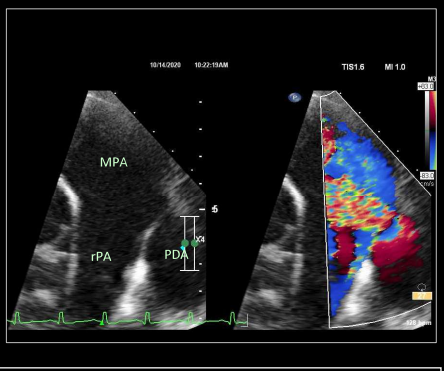
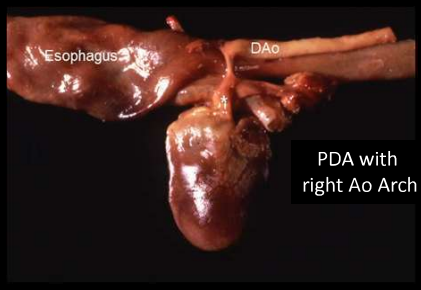
Patent Ductus Arteriosus









Persistence of fetal ductus arteriosus: PDA (DAo → PA)
Functionally: Left to right shunt at level of great vessels

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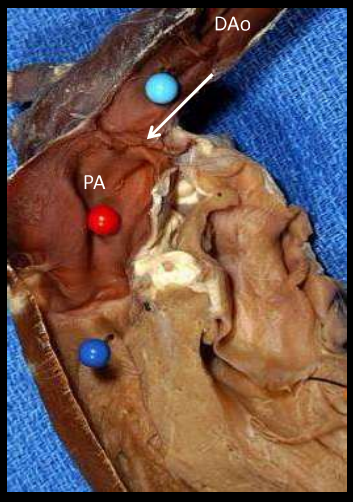
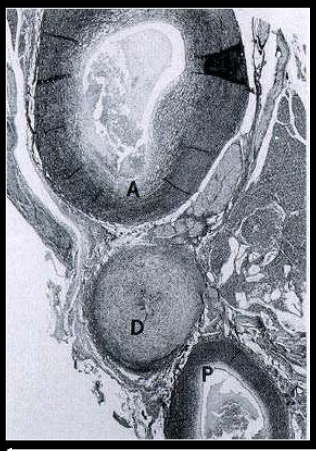
Patent Ductus Arteriosus (canine) – Histology

Management Point: NSAIDs, such as indomethacin, will not cause the ductus to constrict in dogs



Normal



↓ VSM

Courtesy of Dr. James Buchanan

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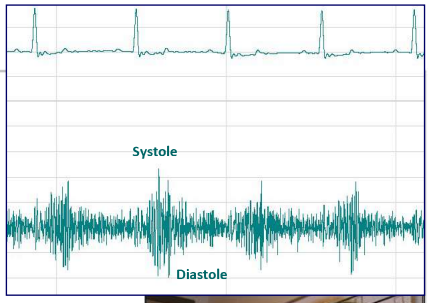
Reference: Clinical Recognition

- Pulses: Hyperdynamic
- Precordium: Active (caudoventral)
- Auscultation:
  - Continuous murmur (left base/dorsal)
  - Often murmur of function MR (apex)
- ECG: LA (widened) LV (↑voltages)
- Radiography: Overcirculation with
  ↑LA ↑LV ↑MPA ↑Descending Ao



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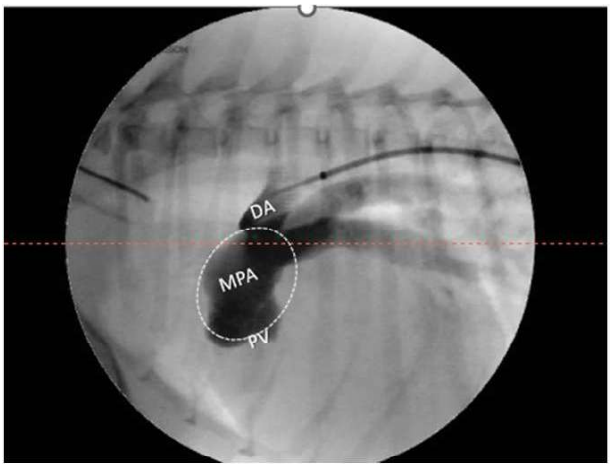
Identification: Continuous Murmur at the Left Craniodorsal Base

If *continuous*: it is unlikely to be associated with important pulmonary hypertension



Cats: More likely to have slowly-progressive pulmonary arterial hypertension (PAH)
Murmur in cats is often a "long-systolic" or just systolic in timing

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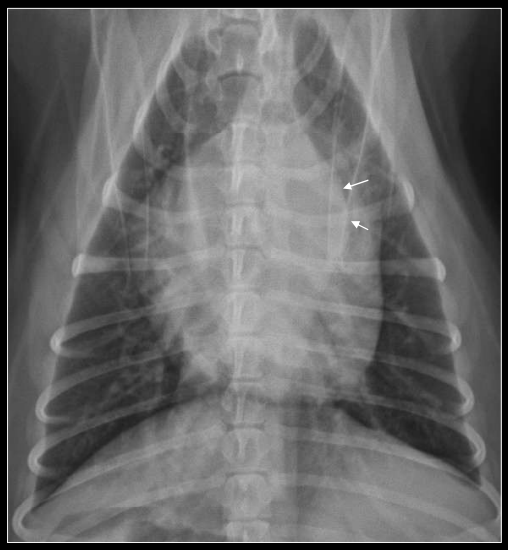
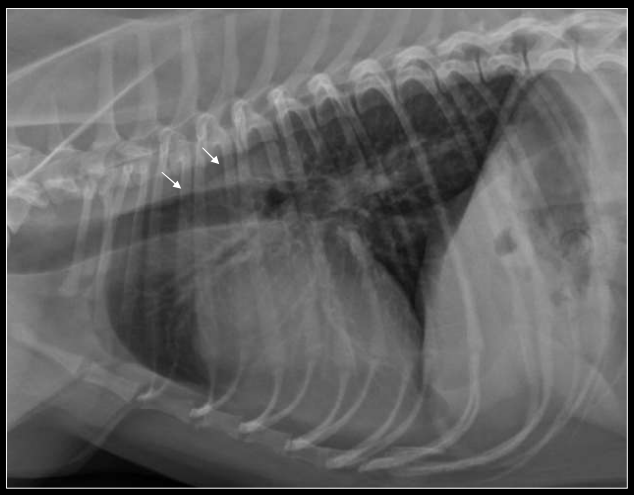
Reference: PDA – “Ductus bump” (Dilated descending aorta)





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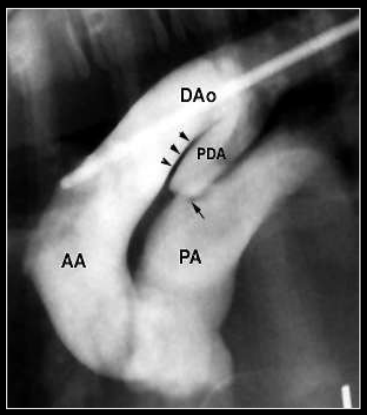
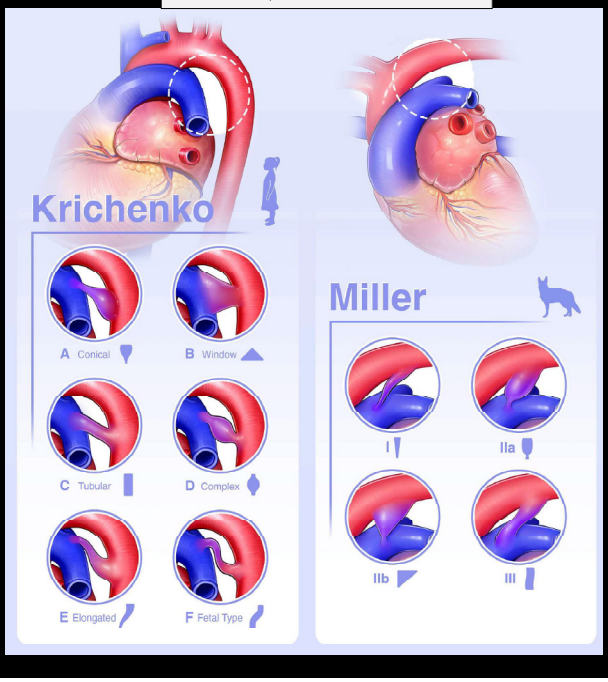
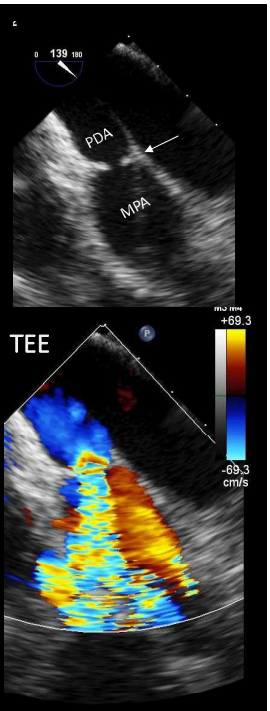
Ductal Anatomy



- Ampulla (diam/length)
- Minimal diameter (mm)
- Shape & Tapering
- Various classifications

Markovic L, et al. J Vet Cardiol 2024





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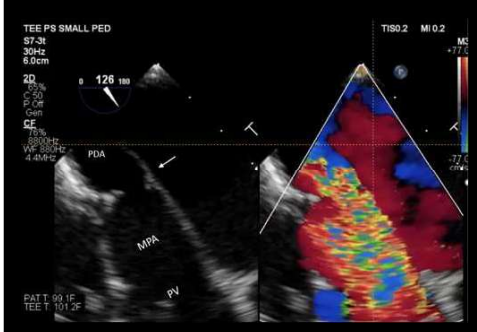
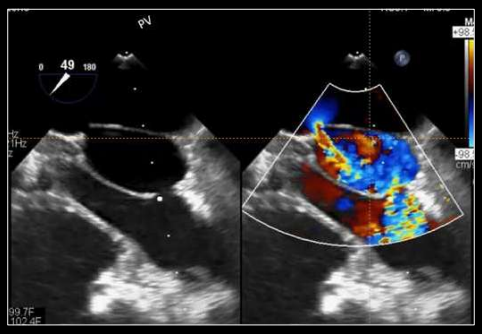
Examples: Patent Ductus Arteriosus – Transesophageal Echo

Typical (left) & Atypical Morphologies (two narrowed segments)





En face view of Ductal Opening

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Reference: PDA – Key Echocardiographic Findings

- Anticipate (L→R PDA): Dilation of the LA , LV, Ao & Pulmonary trunk
- Ductus (ampulla) visualized from right or left cranial intercostal positions
- PDA: best appreciated from left cranial, angled image plane of the pulmonary artery or left cranial inflow-outflow image of the right heart
  - The ductal ampulla is imaged in most cases
  - The minimal ductal diameter is more difficult to evaluate (TEE or angiography are best for evaluating ductal size & morphology)
  - Color Doppler/Spectral Doppler shows continuous flow (>4.5 m/sec unless there is pulmonary hypertension of the patient is hypotensive)
- Normal right heart size & function (unless there is pulmonary hypertension)
- LV ejection fraction: normal to decreased – but do not rely on M-mode
- Screen for concurrent congenital heart defects

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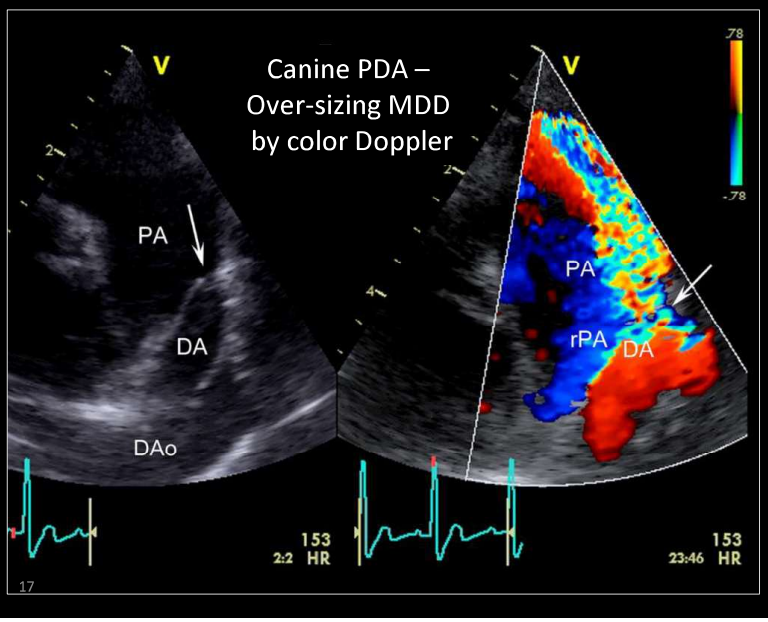
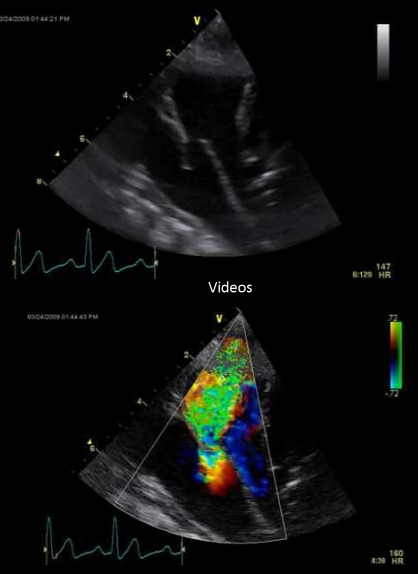
PDA – Transthoracic 2D & Color Doppler Imaging
Recognize Artifacts – Color bleeding (lateral resolution & pixel prioritization)





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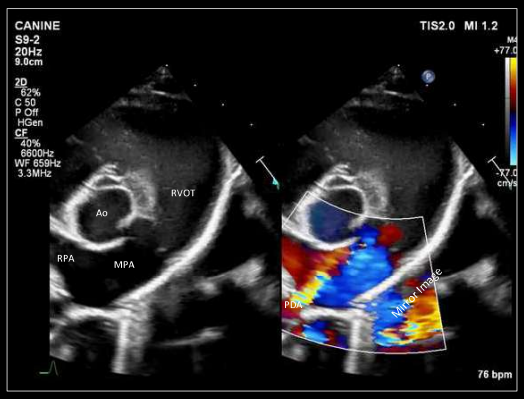
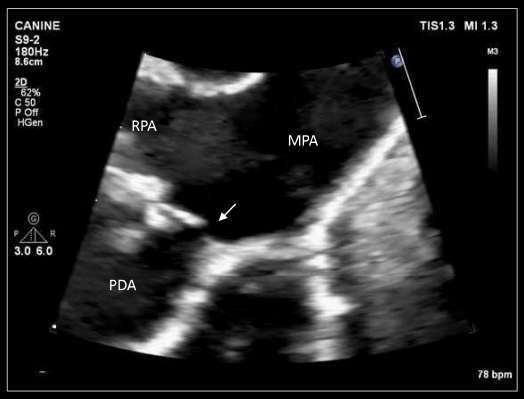
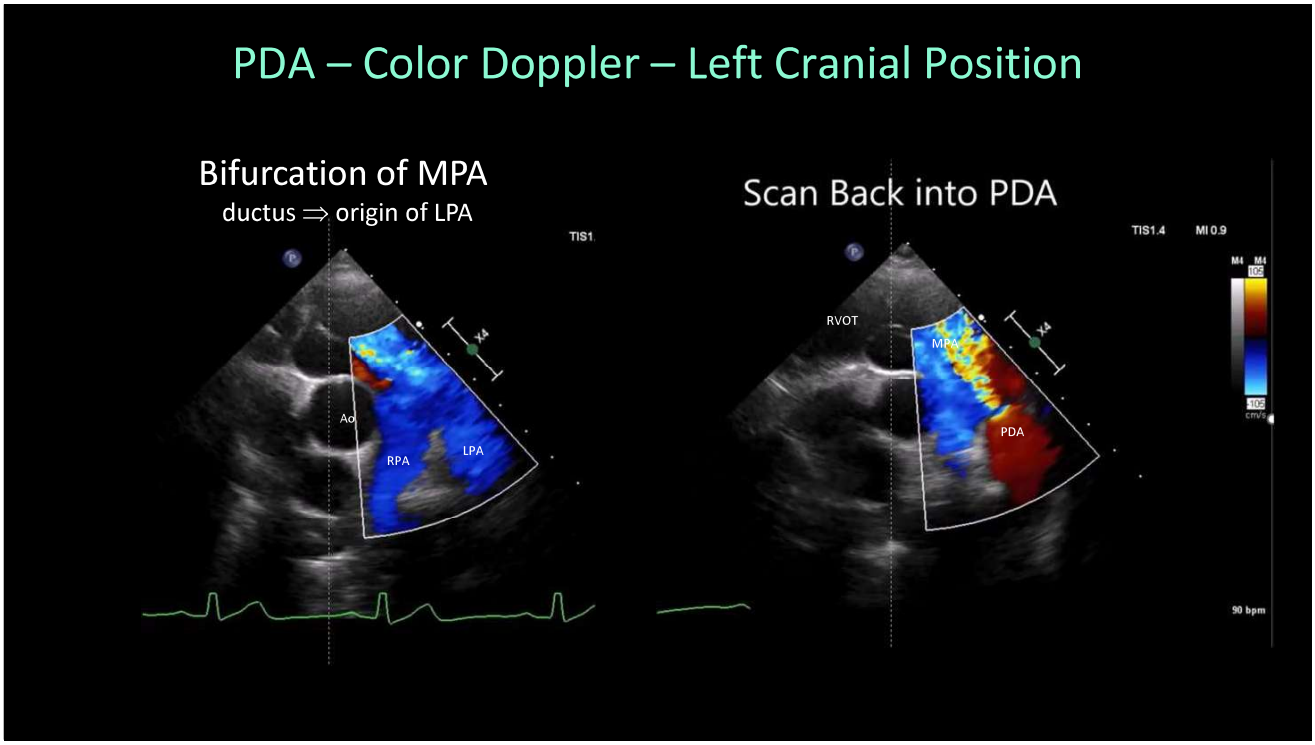
PDA (Right Parasternal) – Case #1



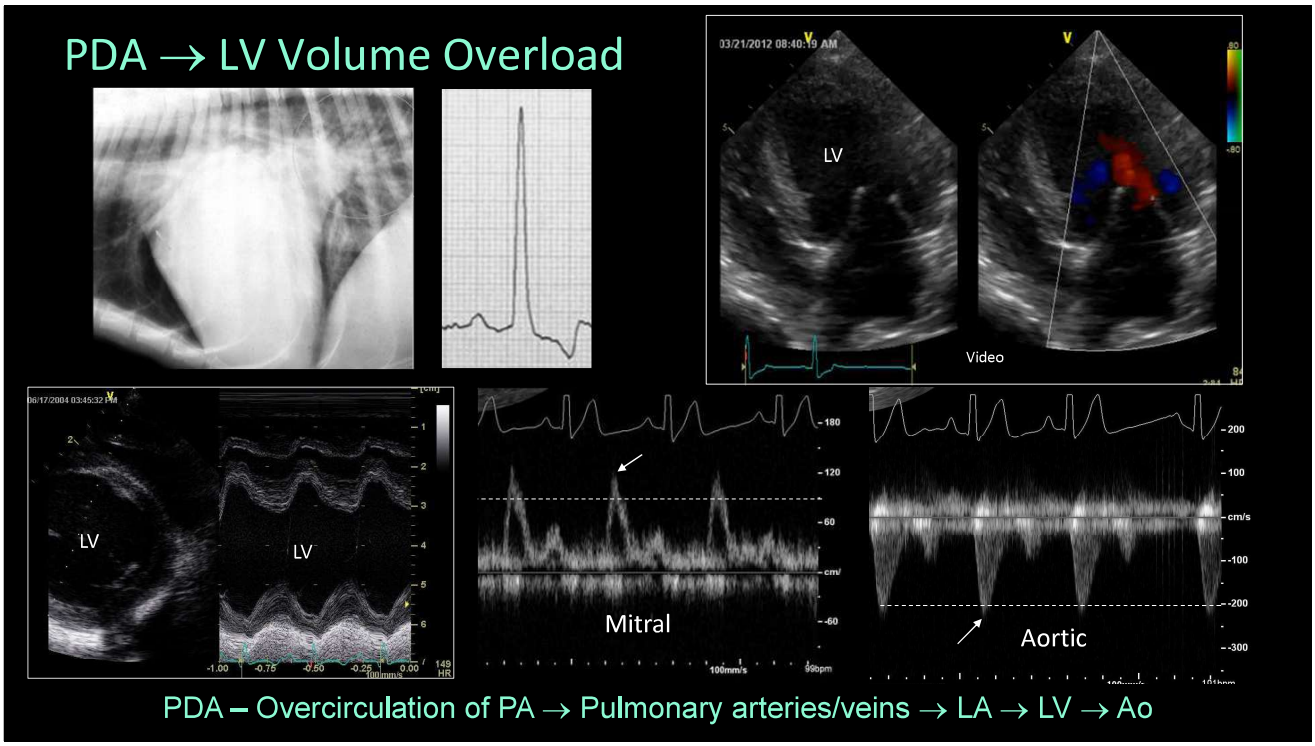


Videos

18


PDA – Color Doppler – Left Cranial Position
Bifurcation of MPA
ductus ⇒ origin of LPA
Ao
RPA
LPA
Scan Back into PDA
RVOT
MPA
PDA
90 bpm

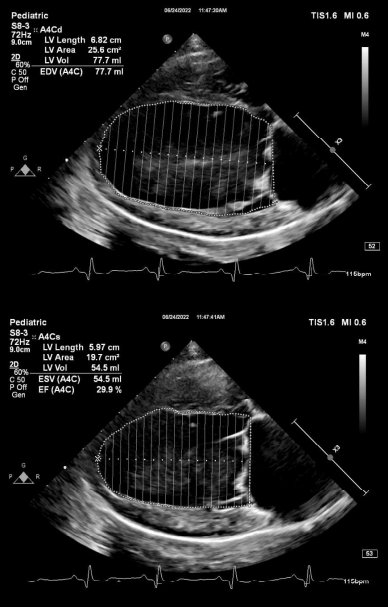
19

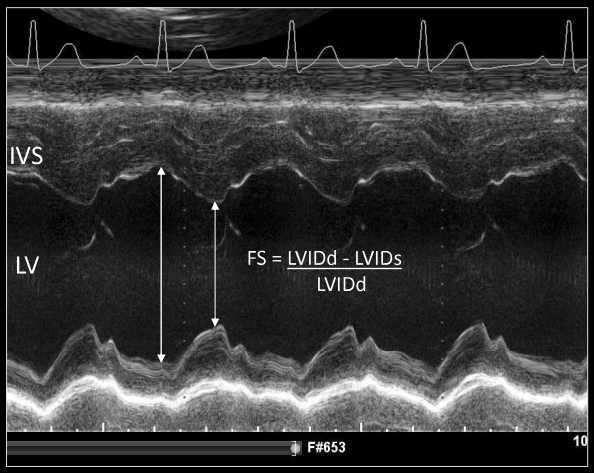

PDA → LV Volume Overload
LV
Video
LV
LV
Mitral
Aortic
PDA – Overcirculation of PA → Pulmonary arteries/veins → LA → LV → Ao

20

LV Systolic Function – Do not rely only on Fractional Shortening

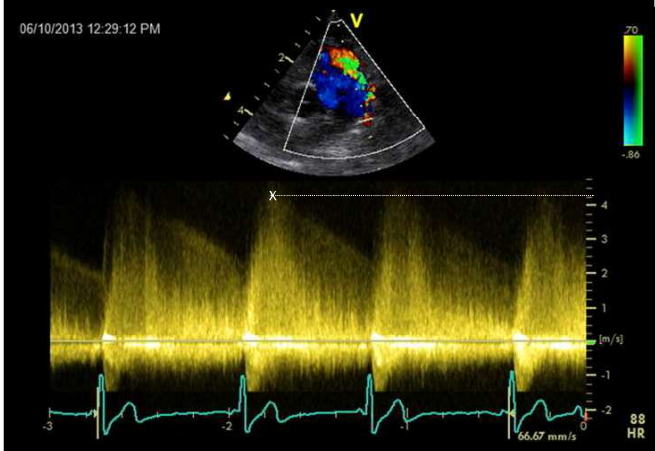
Anticipate Reduced LVSF after ductal closure





21

PDA – CW Doppler (left-to-right PDA)

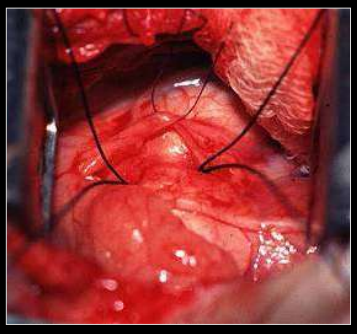


Transthoracic Echo
Canine PDF – Left-to-Right
High-velocity shunting

PDA – highly restrictive orifice
Systolic forward flow in PA

22

PDA Therapies: Device Closure (Catheter) or Surgical Ligation



Device Closure or Surgical success should be 95% or higher

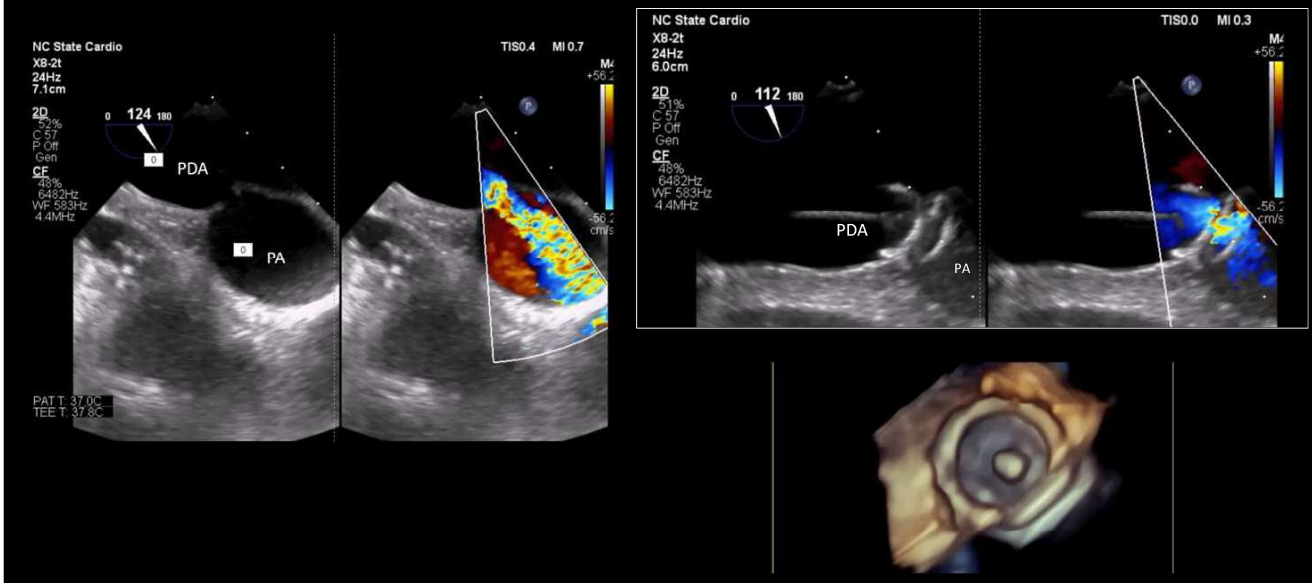
Nearly all successfully treated Dogs live normal lives – minimal follow-up

Issues: Large dogs (delayed closure, Labs!) | AFib | Older dogs | Cats | PAH

23

PDA Closure with Amplatz Canine Ductal Occluder (ACDO)

Transesophageal Guidance



24

Ventricular Septal Defects

25

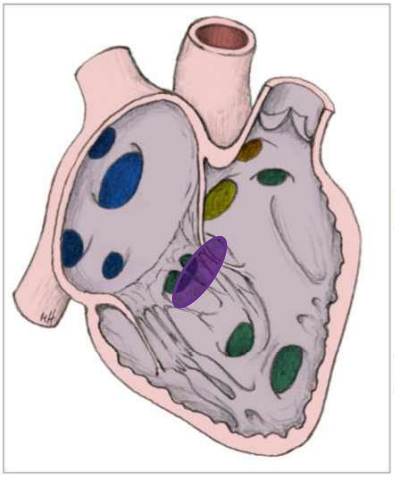
Septal Defects – Typical Classification(s)

Atrial (PFO, ASD) **Atrio-ventricular (AVSD)** **Ventricular (VSD)**

PFO
Secundum ASD

Primum ASD (AVSD)
Common AV canal

Sinus venosus defects
Coronary sinus defect



Ventricular Septal Defects

Perimembranous
Can extend towards RV inlet or outlet

Subpulmonic (subarterial)

Muscular
(inlet, trabecular, outlet)

Courtesy Dr. Colin Schwarzwald, DACVIM

© Vetsuisse Faculty, University of Zurich

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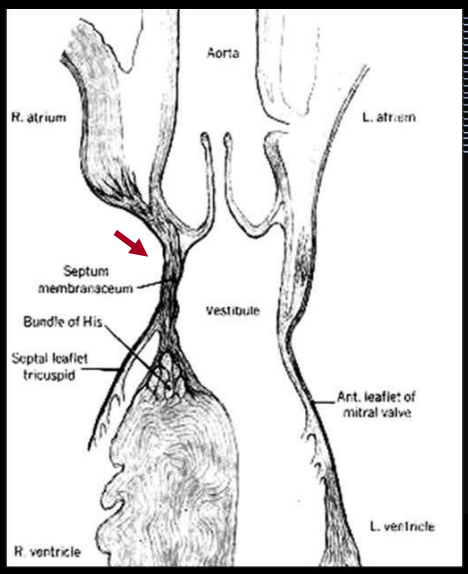
Reference: VSD Classification(s)

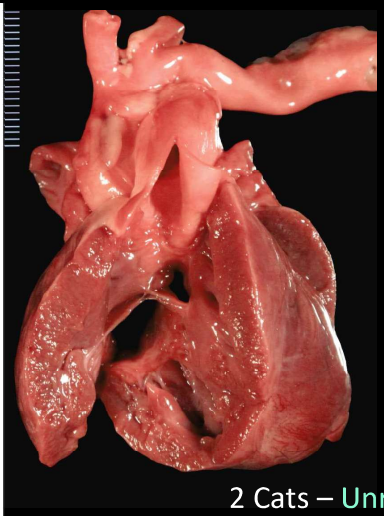
1) Older
   - Infracristal (beneath the supraventricular crest – membranous septum)
   - Supracristal | subpulmonary (Subarterial)
   - Muscular/trabecular including "Swiss cheese" type
   - Inlet (part of an AVSD in most cases) – ventral to the septal tricuspid leaflet
2) Commonly used
   - Peri- (para)- membranous (continuity with aortic valve, TV annulus/RA)
   - Sub- or juxta-arterial
     - Usually doubly-committed to both arterial trunks
   - Inlet (including AVSD)
3) Anderson
   - Define by VSD margins (fibrous, muscular, AV & PV fibrous tissues)
   - Location of the VSD opening within the right ventricle
   - Perimembranous, muscular, or doubly-committed juxta-arterial
4) Detailed: see 11th Iteration of the International Classification of Diseases

27

Ventricular Septal Defects



Membranous Septum



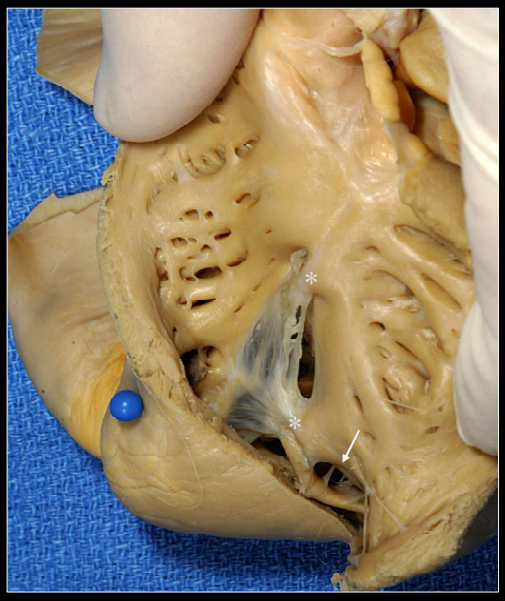
2 Cats – Unrestrictive VSD
Perimembranous inlet (L) and outlet (R)
RVOT perspective

28

29

Canine – Muscular/Apical VSD & TV Dysplasia

Note direct insertions of TV parietal leaflet into papillary muscles *

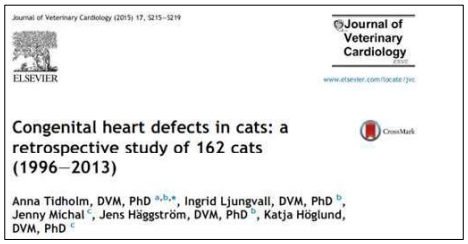


Color Doppler is often needed to visualize muscular defects

29

Reference: Clinical Features of VSD

- Most important CHD of cats (50% of cases in this retrospective)
- K9 breeds at risk: Shibu Inu, English bulldogs English Springer spaniels, WHWT, others
- Murmur – holosystolic, typically at the right sternal border (perimembranous VSDs)
- ECG: variable, possible ↑LV + LA | intraventricular conduction disturbance


Journal of Veterinary Cardiology (2015) 17, S215–S219

ELSEVIER

Journal of Veterinary Cardiology

Congenital heart defects in cats: a retrospective study of 162 cats (1996–2013)

Anna Tidholm, DVM, PhD [a,b,*], Ingrid Ljungvall, DVM, PhD [b], Jenny Michal [c], Jens Häggström, DVM, PhD [b], Katja Höglund, DVM, PhD [c]

- Echo: Findings depend on the shunt direction & shunt volume
  - Left-to-right: Increased pulmonary blood flow (overcirculation) → LA → LV → MPA
  - Right-to-left: Obstruction to pulmonary flow (PAH) | PS | Double-chamber RV
  - Complication: Aortic regurgitation from aortic root prolapse into the VSD

30

Canine: VSD – Cardiomegaly & Pulmonary Over-circulation

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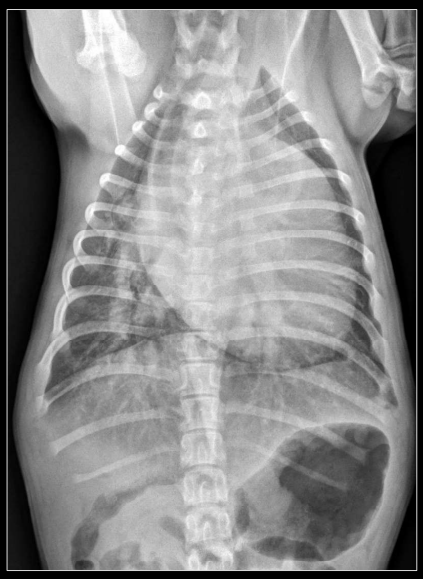
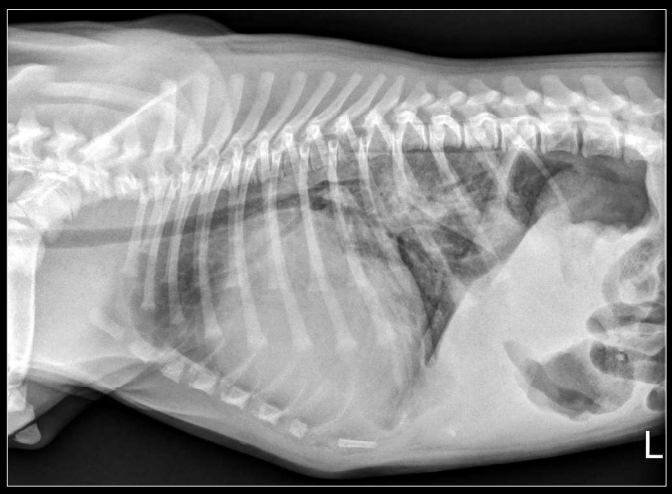
Left-sided enlargement and PA dilation is typical of L→R VSD





From Ware WA & Bonagura JD:
Cardiovascular Disease in Companion Animals

31

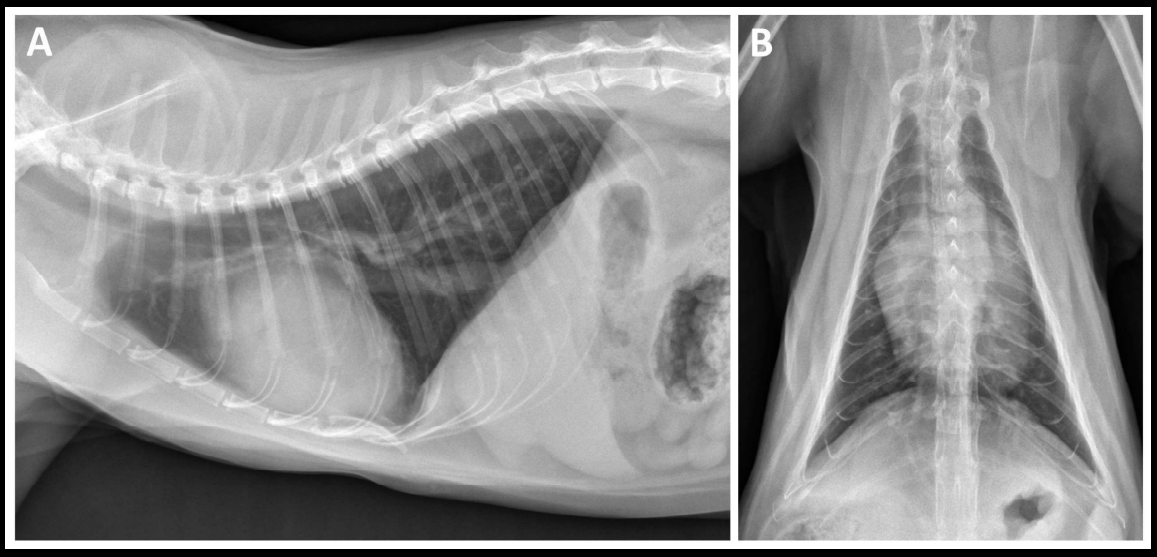
Left to right VSD – Dilated Pulmonary trunk on VD

Can also be seen with Pulmonary Arterial Hypertension (but not in cats!)

32

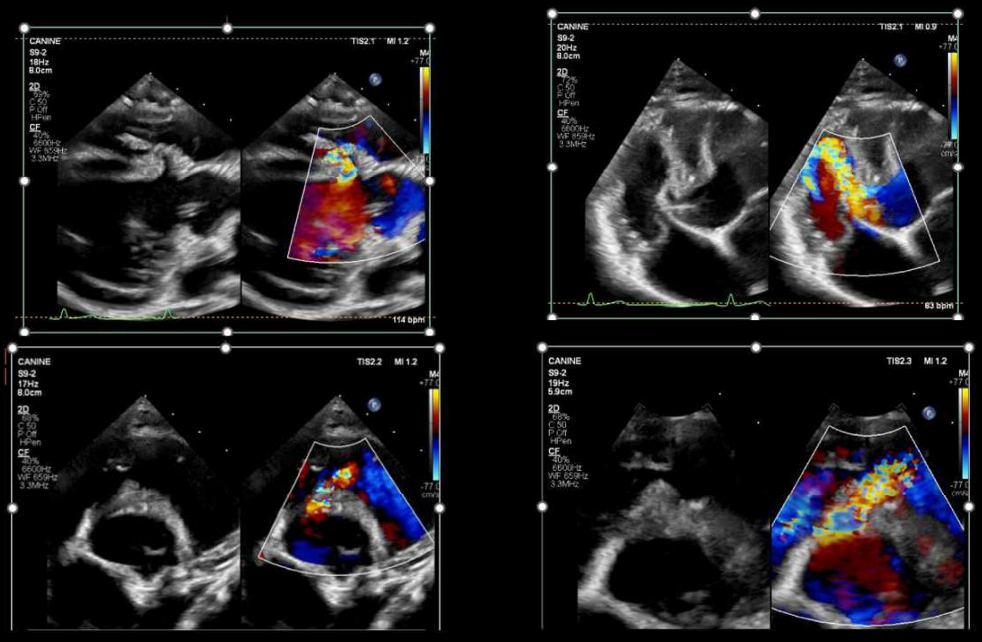
33

Feline VSD with Pulmonary Arterial Hypertension



33

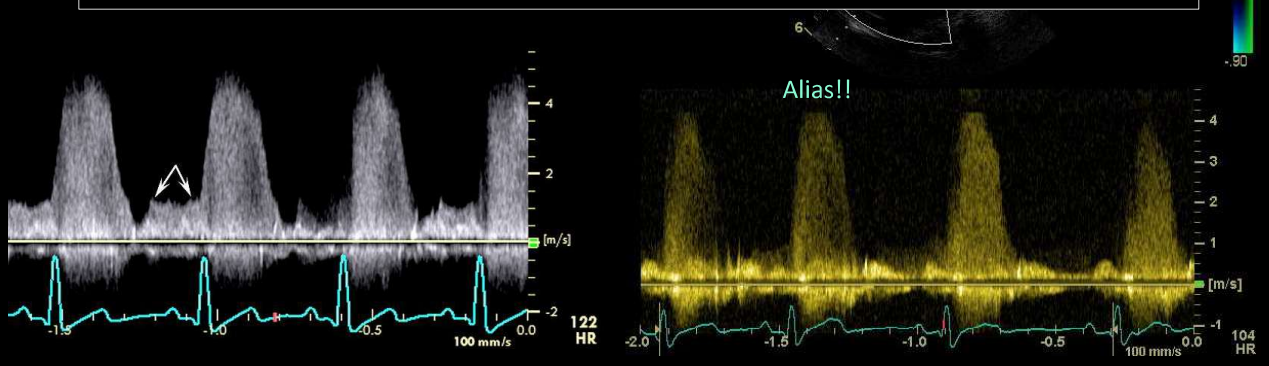
Perimembranous VSD (Typical) – Restrictive



34

VSD – CWD: Restrictive Defects

Velocities > 4.5 m/sec are indicative of restrictive defects
Measure noninvasive systolic blood pressure as well for LV-RV gradient



Color Doppler Imaging might indicate if the diastolic signal represents diastolic L → R shunting, trans-tricuspid inflow (off angle) or both

35

Reference: Key Issues in VSD – Management usually unnecessary

- Defect diameter: VSD/Aorta (<0.4 to 0.5 prognosis *favorable*)
- Peak velocity across VSD (>4.5 m/s prognosis *favorable*)
- Expect some LA + LV dilation (Qp/Qs of 1:5:1 well-*tolerated*)
  - Don't assume a pulmonary artery band is needed for "cardiomegaly"
- Aortic Regurgitation (unfavorable if mod-severe or audible)
- Concurrent RV outflow obstruction (prognosis is variable)
  - Evaluate for double-chambered RV
  - PS – helpful (↓ L → R shunting) or harmful (R → L shunting)
- Alive @ 6M, No: PAH, severe AR, DCRV/PS – good prognosis
- Management – none, interventionalist | surgeon (band, CPB)

36

Prognosis of VSD after Diagnosis

Signalment, clinical features, echocardiographic findings, and outcome of dogs and cats with ventricular septal defects: 109 cases (1992–2013)

Eric Bomassi, DVM; Charlotte Misbach, DVM, PhD; Renaud Tissier, DVM, PhD; Vassiliki Gouni, DVM, PhD; Emilie Trehiou-Sechi, DVM; Amandine M. Petit, DVM; Aude Desmyter, DVM; Cécile Damoiseaux, DVM; Jean-Louis Pouchelon, DVM, PhD; Valérie Chetboul, DVM, PhD

"Most dogs and cats with isolated VSDs had a long survival time; few had clinical signs at diagnosis, and **none with follow-up developed clinical signs after diagnosis**."

J Am Vet Med Assoc 2015;247:166–175

37

Reference: General Management for Right-to-Left Shunting Patients

- Sildenafil: **Only** if due to PAH
- Consider phlebotomy
  - Optimal PCV (?) 62-65%
- Hydroxyurea has been used
- Encourage hydration!! Na^+ intake
- *Avoid*:
  - Drugs that lower systemic BP
  - Acepromazine or ACE-inhibitors
- *Palliation*: β-blocker
  - Propranolol if possible
- Systemic → Pulmonary shunt (TF)

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Atrial Septal Defects & AVSD

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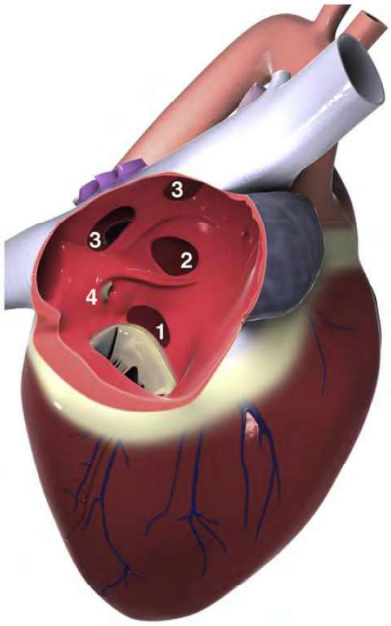
Atrial Septal Defects – Location(s)

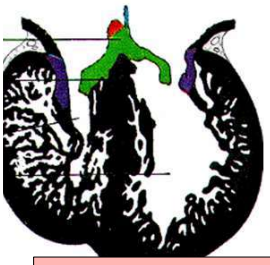
1. Primum defect (Incomplete AVSD)
2. Secundum defect
3. Sinus venosus defects
4. Unroofed coronary sinus



Scansen BA, Schneider M, Bonagura JD: JVC (2015)

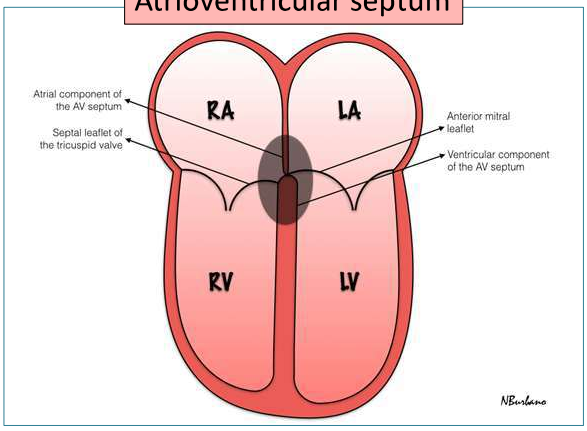
40

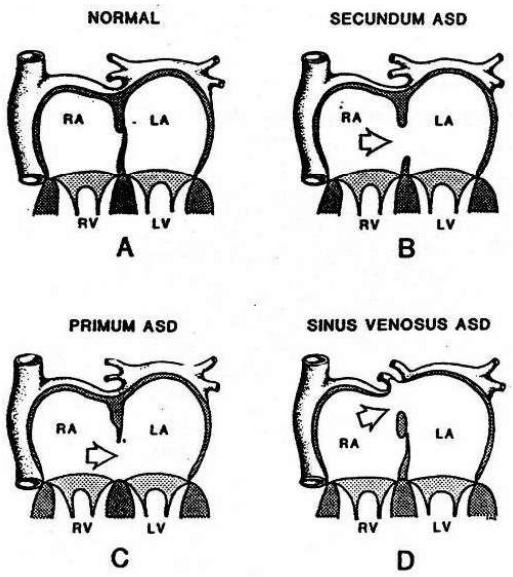
Netter 1968



Reference: Atrial Septal Defects

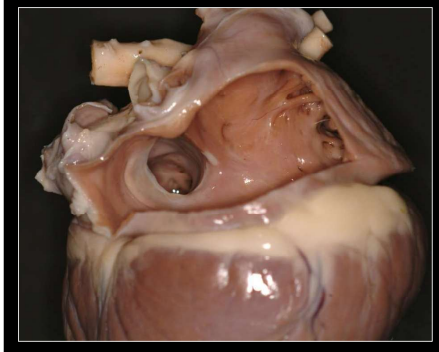
Atrioventricular septum



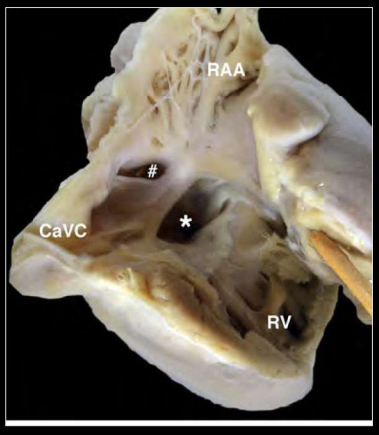


41

Atrial Septal Defects



Secundum ASD
Canine Specimen

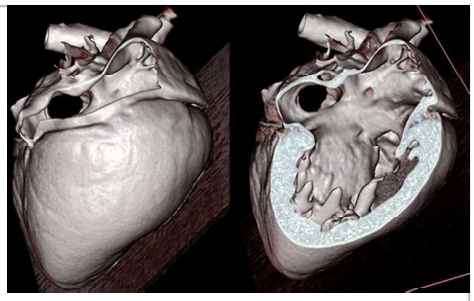


Secundum ASD #
Primum ASD *
Feline Specimen

AVSD
Feline Specimen

42

Reference: Secundum or isolated Primum ASD – Clinical Features



- Breed risk: Boxer, ? Doberman
- Usually asymptomatic
- Auscultation
  - Systolic ejection murmur
  - Splitting of second heart sound
- ECG: Right ventricular enlargement & RA dilation
- Imaging: Right-sided volume overload (RA + RV + PA ~~LA~~)
- Staging: No objective information – this is an uncommon defect
- Prognosis: worse if atrial fibrillation or R-CHF
- Pulmonary vascular disease (reversal) – has been observed (late)

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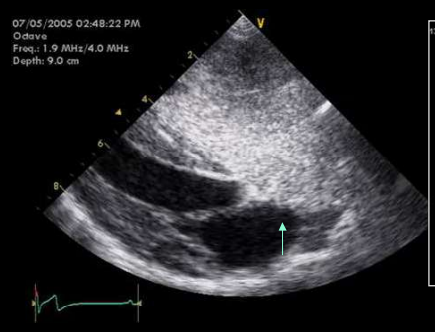
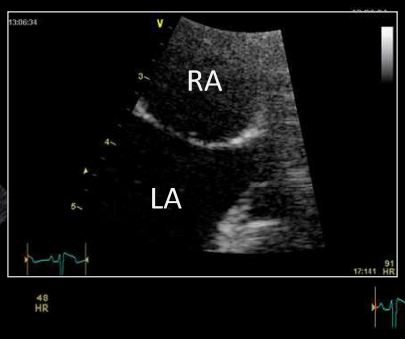
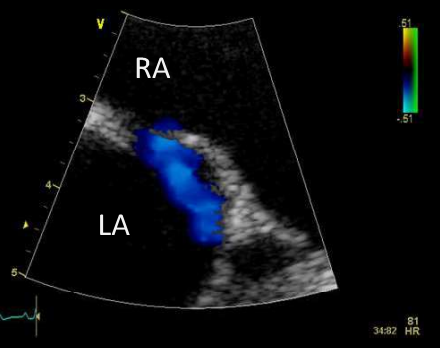
Canine Secundum ASD & Patent Foramen Ovale

Contrast Echocardiography & Color Doppler Imaging



Secundum ASD Dog
Negative contrast study
(Bidirectional)
Courtesy Matt Miller, DVM, DACVIM

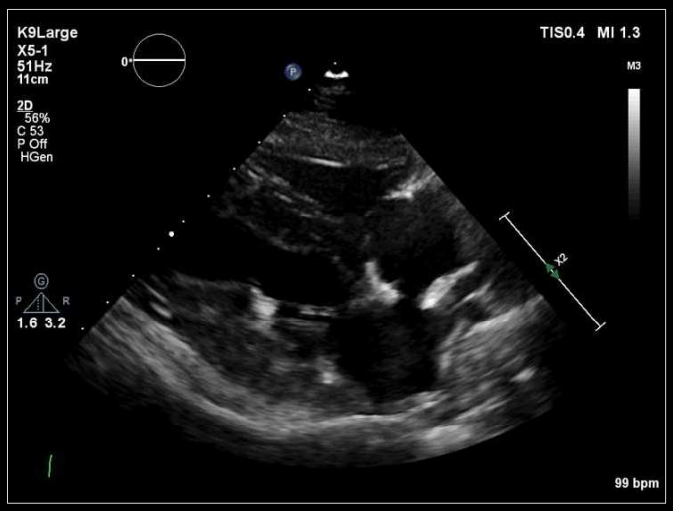




PFO (Dog) with
pulmonary stenosis

44

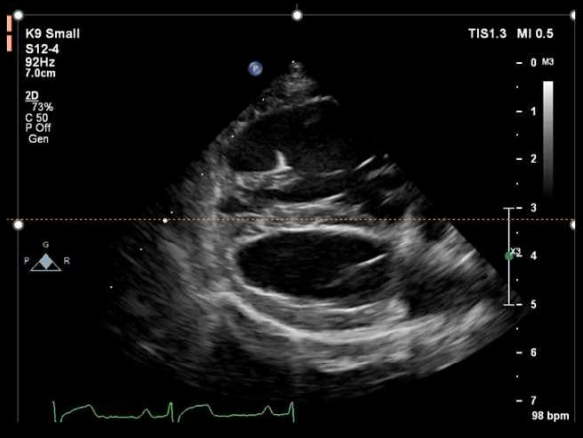
Secundum ASD – Note entry of right PV confluence

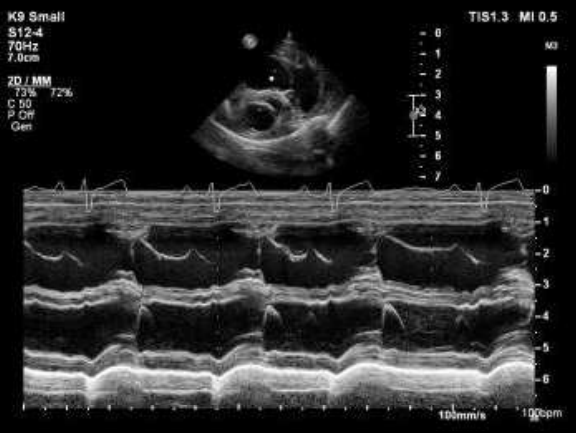


Video

45

RVVO & Paradoxical Septal Motion – r/o ASD





46

Reference: ASD – M-mode & 2D Imaging

- Usually appreciated in the right parasternal long-axis 4C view
  - Determine location in septum
  - Beware of the normal thinning of IAS (fossa ovalis)
- Drop out of atrial septal echoes
- With PFO – both membranes might be evident but a "gap"
- Dilation of RA, RV & pulmonary trunk + branches (Not LA)
- Paradoxical ventricular septal motion (LV → RV during systole)
- AVSD: Primum defect + common AV valve (±LA ↑ if MR)
- Saline contrast echocardiography is useful

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Reference: ASD – Doppler Studies

- Abnormal flow across the atrial septum
  - Left to right shunt encoded in red + turbulence in RPLAx view
  - With right to left PFO – low velocity blue color mapping
  - *Beware*: Caudal vena caval flow along septum
- Low velocity of shunting can confuse Doppler studies
  - Saline Contrast Echo is useful
- With large left to right shunting lesions relative TS/PS
  - From increased transvalvular velocities (relative PS causes systolic murmur)
- Can have concurrent TR or MR, esp. with AVSD
- Search for TR to estimate PA pressure (r/o PH)

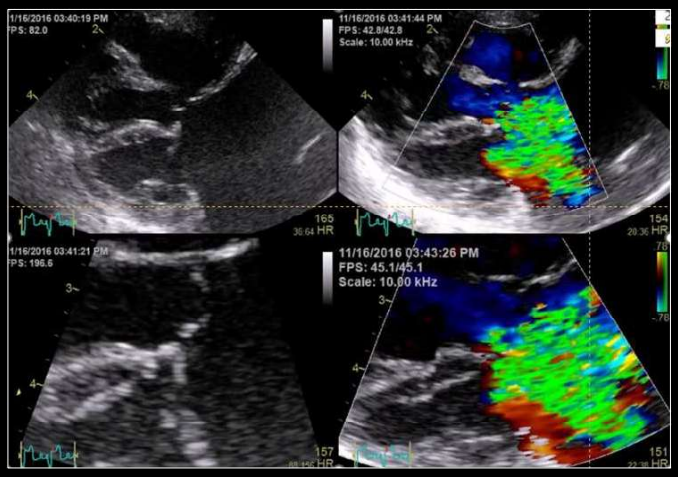
48

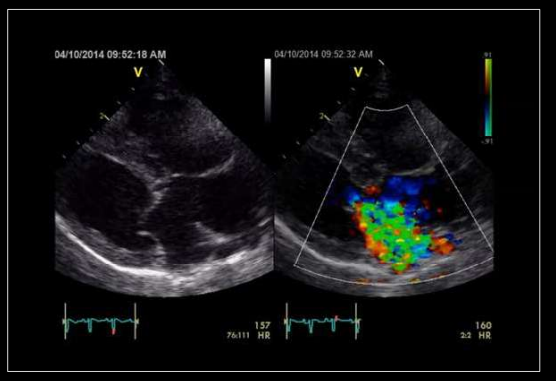
Feline: Atrioventricular Septal Defects (AVSD)

49

Note path of AV regurgitant jets

Two Cats





Primum ASD + bridging leaflet

49

Reference: ASD – Key Issues & Management

- Do not over-interpret normal fossa ovalis
- Degree of cardiac dilation typically corresponds to shunt volume
- If there is a primum ASD or AVSD…prognosis is worse –
  - Complications include MR / TR or pulmonary vascular disease (PAH)
- Pulmonary hypertension, concurrent PS, or severe TR can reverse the shunt or maintain PFO creating cyanotic heart disease
- Management: Refer to interventional specialist for further assessment by TEE, device closure, surgery, pulmonary banding
- Medical management for CHF or severe pulmonary hypertension

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Common Cardiac Malformations

1. Introduction
2. Shunts
   - Patent ductus arteriosus
   - Ventricular septal defect
   - Atrial & Atrioventricular septal defects
3. Pulmonary Stenosis (also discussed with Doppler principles)
4. Subaortic Stenosis (also discussed with Doppler principles)
5. Atrioventricular valve malformations
   - Mitral valve malformations (MV dysplasia)
   - Tricuspid valve dysplasia

Examples with Valvular Doppler & Case Studies

51

Canine Pulmonary Stenosis

52

Reference: Pulmonary Stenosis – Definition & Pathophysiology

- Congenital narrowing of the RV outflow tract - typically valvular
- Among most common congenital defects in dogs (criteria vary)
- Concurrent problems are common: PFO, VSD, TV malformation
- Obstruction to RV outflow
  - Compensated by generation of a systolic pressure gradient
  - Systolic pressure in the RV> PA pressure; High-velocity flow
- Varying degrees of pulmonary regurgitation (silent unless severe)
- Right ventricular (concentric) hypertrophy develops
  - Secondary dynamic RVOT obstruction
- Long-term: diastolic & systolic heart failure
- Atrial flutter or fibrillation – severely decompensating (⇒R-CHF)
- Risks: Syncope (multiple reasons), CHF & sudden cardiac death

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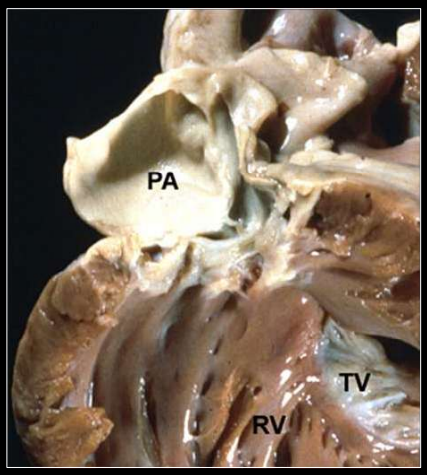
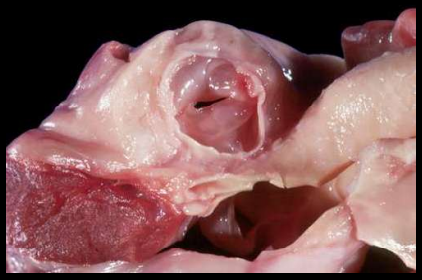
Pulmonary Stenosis



Types “A & B” are *over-simplifications*



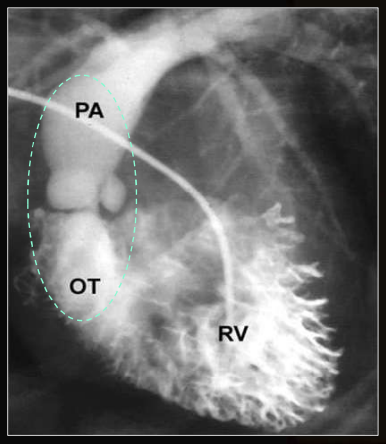
54

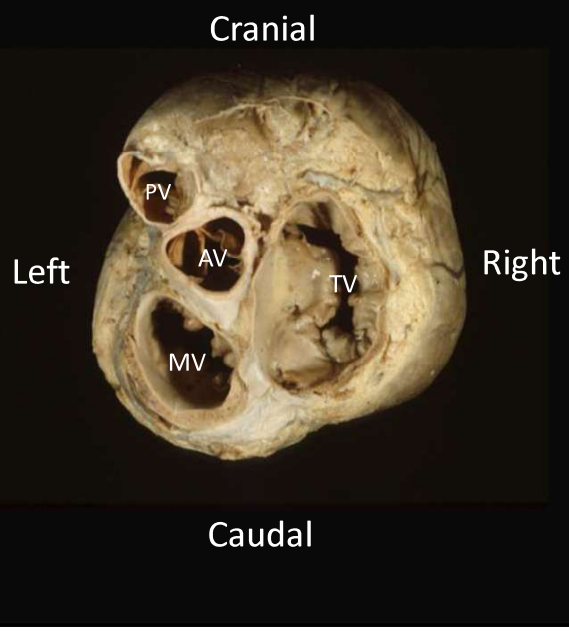
Reference: Clinical Recognition of Pulmonary Stenosis

- Variable history – murmur… *potentially*:
  - Exertional intolerance | collapse | cyanosis (shunt)
  - Hepatomegaly & Ascites (R-CHF)
  - Tachypnea (Pleural effusion or R→ L shunt)
- Systolic ejection murmur
  - Pulmonic valve → Left base
  - Grade + Time-to-peak ≈ severity
  - Possible murmur of TR (right)
- Jugular venous pulse
  - Distension if CHF

55

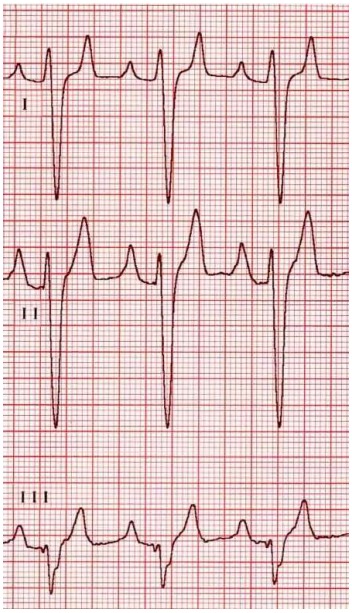
Recognition of PS: Where to Auscultate

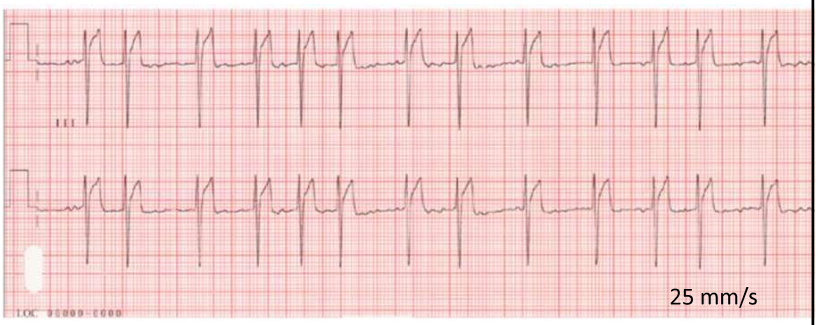




56

Reference: ECG: RV Hypertrophy ± RA dilation | Atrial Flutter/Fib

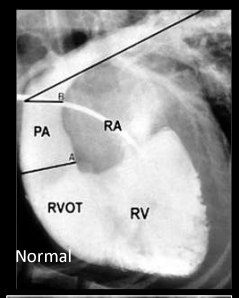


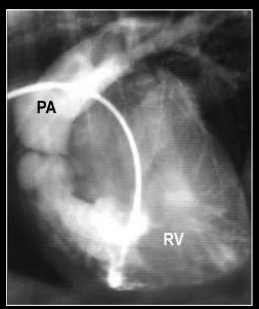


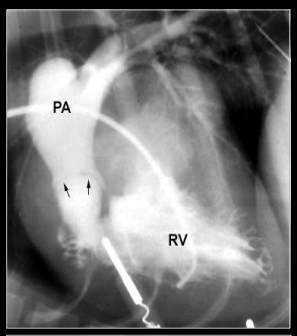
Typically leads to R-CHF

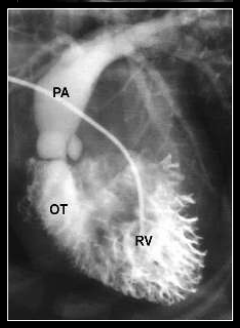
57

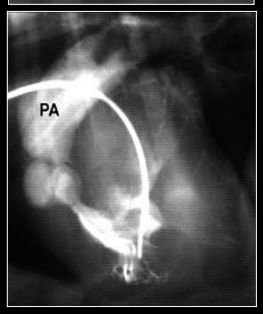
Canine Pulmonic Stenosis (Angiography)

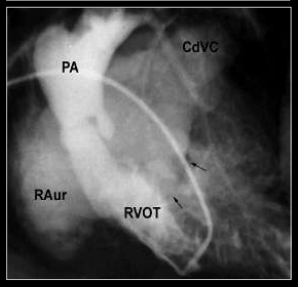








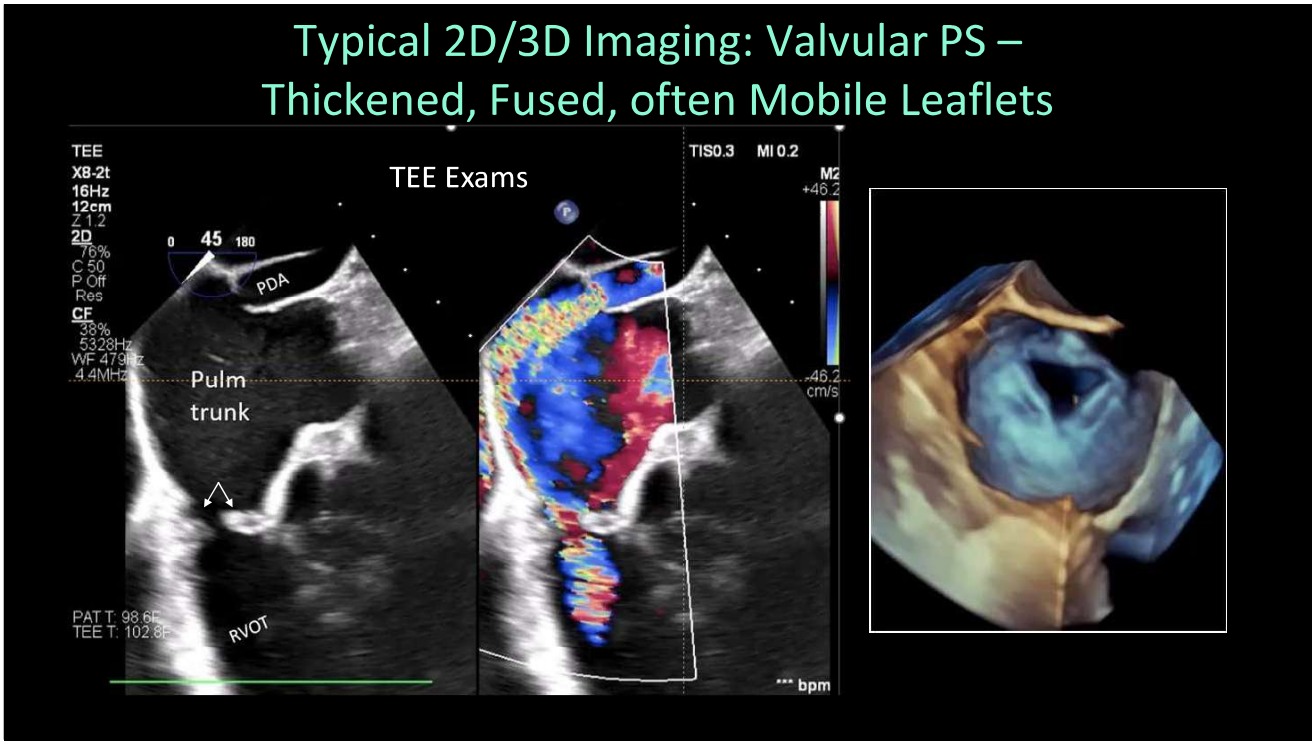




- Valvular thickening
- Fusion along valve commissural margins
- Sinotubular junc tethering
- ± Hypoplasia | Subvalv PS
- Coronary anomalies

58

Typical 2D/3D Imaging: Valvular PS – Thickened, Fused, often Mobile Leaflets



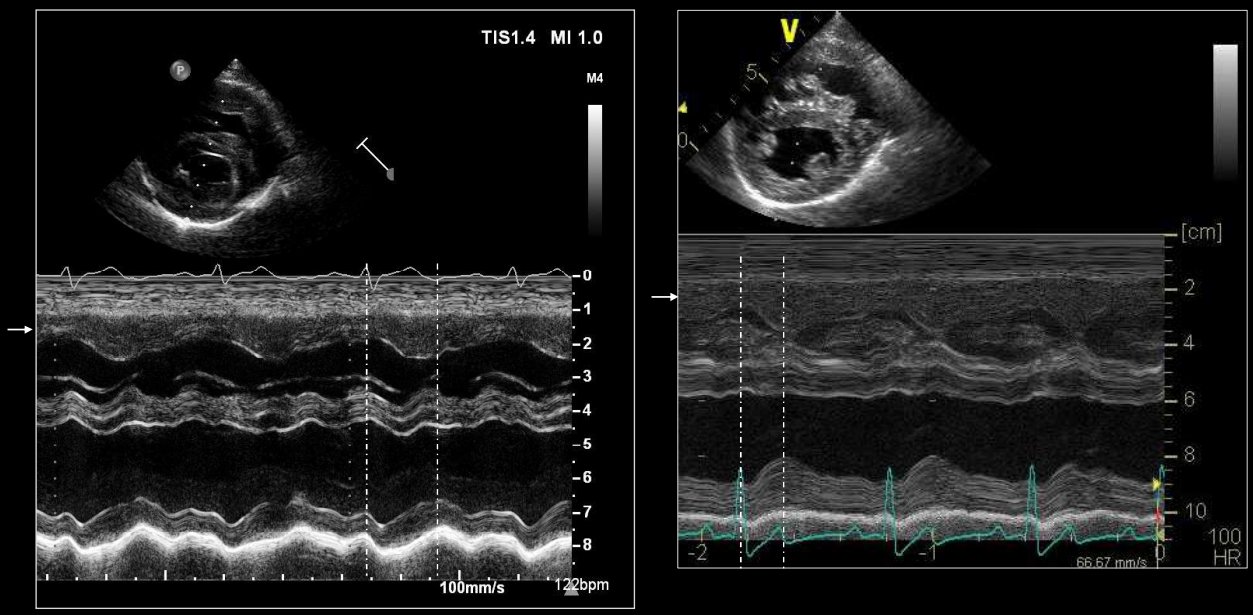
59

Reference: Pulmonic stenosis – 2D & M-mode Imaging

- Lesion(s) of PS (previous slide) – Types A & B are oversimplifications
- RV concentric hypertrophy, flattened IVS and motion
- Post-stenotic PA dilatation – branch PA dilation or hypoplasia
- Possible thickening of tricuspid valve apparatus
  - Can be difficult to distinguish from TV dysplasia
- Right atrium – normal to dilated (typical)
  - RAD – from TR, diastolic or systolic HF, or AF
- Rule out PFO by contrast echo or CDI
  - With CDI need to visualize low velocities – reduce the filters
- Examine the coronary arteries (ostia) – r/o single ostium CA
- r/o dynamic RV outflow obstruction & LVOT obstruction (SAM)

60

RV Hypertrophy – Flattened to Paradoxical IVS motion

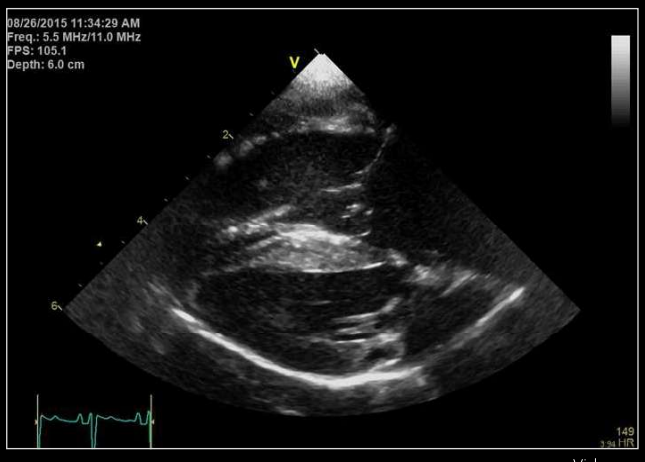


61

PS – Right Sided CHF – RV systolic failure

Causes:

- *Atria tachyarrhythmia* (Flutter/Fib)
- Concurrent *tricuspid regurgitation*
- *Critical PS* – systolic RV failure
- *Florid* pulmonary regurgitation (+ PS)

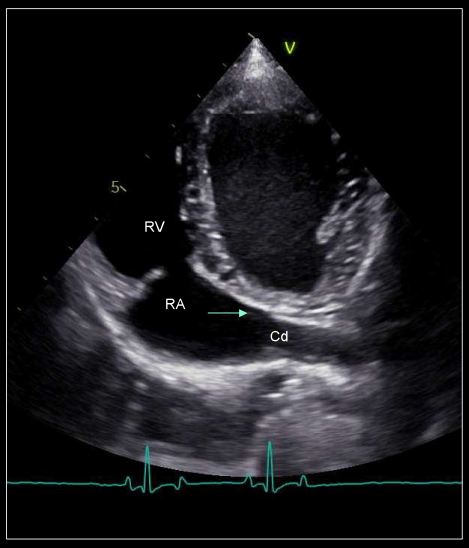


Video

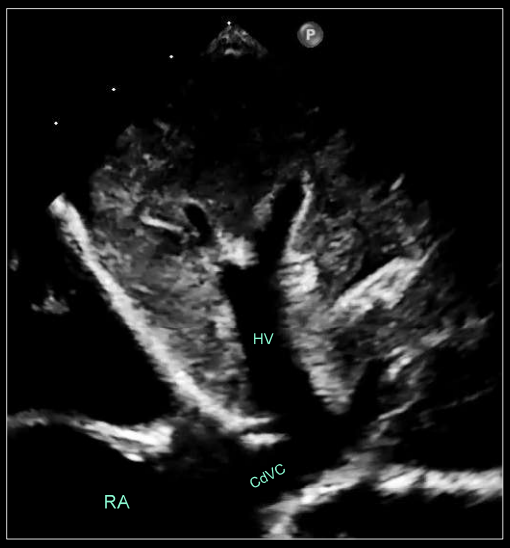
RV function discussed with:
"Is the heart sick?"

62

Evaluate Caudal Coronary Sinus & Caudal VC



Videos



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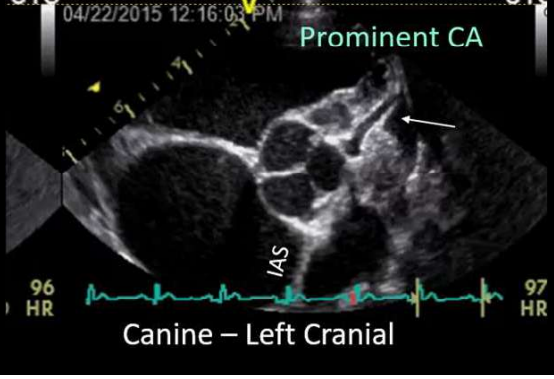
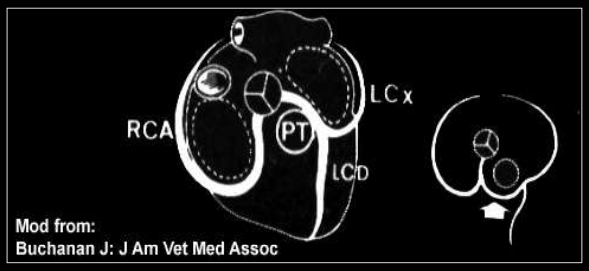
Fusion + doming

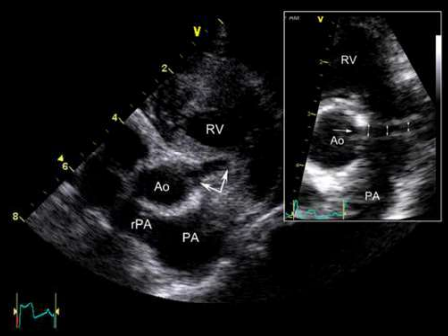
Prominent CA



Canine – Left Cranial

Coronary Anatomy in PS

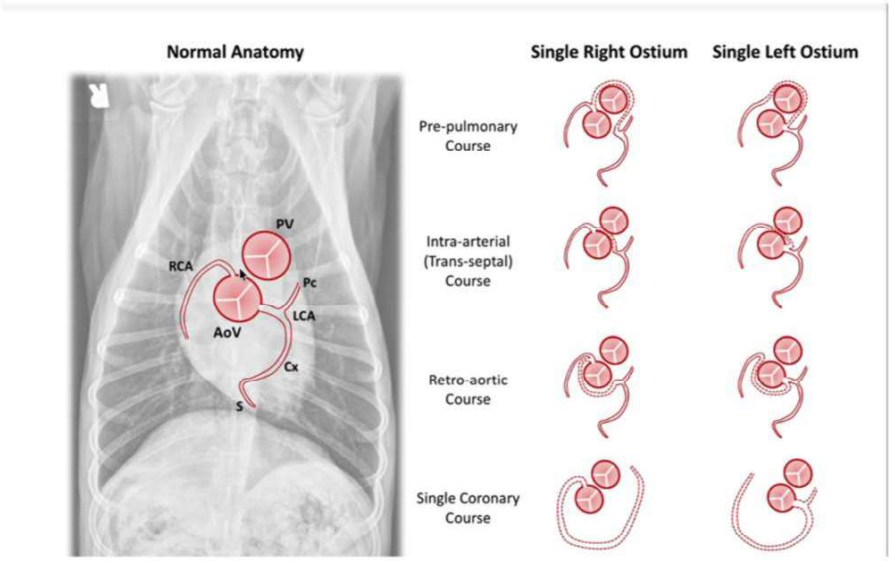




64

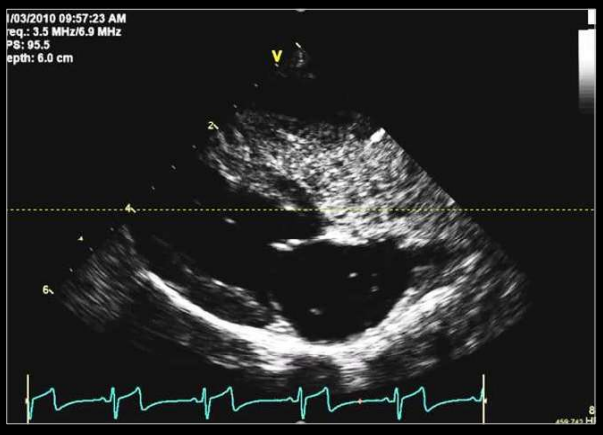
Reference: Coronary Arterial Anomolies

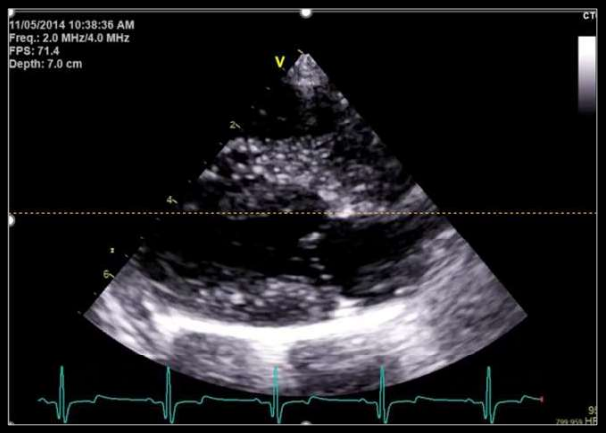
From: Brian Scansen, DVM, MS, DACVIM



65

(Agitated) Saline Contrast Echocardiography
Assessing the Foramen Ovale





Small R → L shunt
Should appear within 3-4 cardiac cycles

Videos

False Positive
(Reverberation artifacts)

66

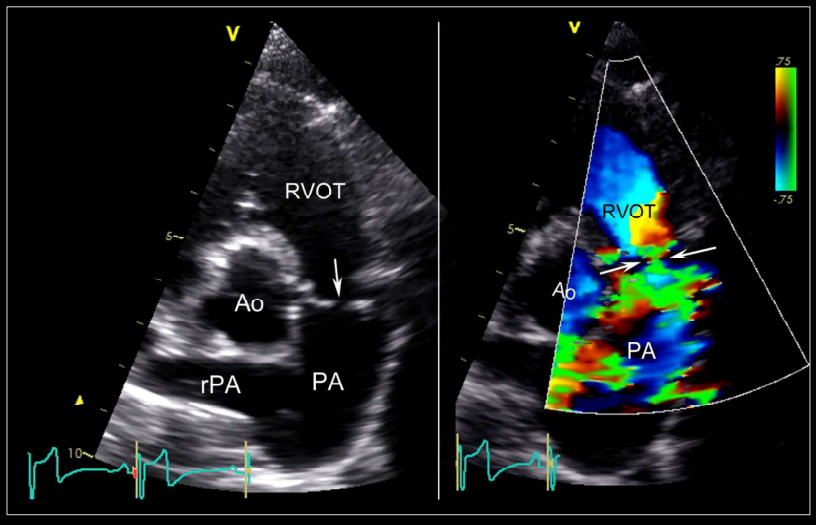
Reference: Pulmonic Stenosis – Color Doppler Imaging

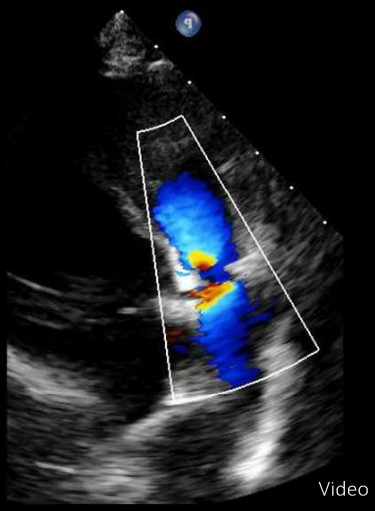
- Flow acceleration in RVOT with aliasing & turbulence
  - Must distinguish from a normal signal flow
  - Requires spectral Doppler verification
- Turbulent pattern of flow through & distal to the obstruction
- Pulmonary insufficiency is present: often silent to auscultation
- Varying degrees of tricuspid regurgitation
- Rule out PFO with CDI and optimally using saline contrast
  - With CDI use low velocity – lower filters
- Other findings – VSD (tetralogy of Fallot) – shunting low velocity

67

PS – Color Doppler Imaging

Proximal acceleration → Aliasing → VC → Post-stenotic turbulence





Pulmonary Insufficiency is common with Valvular PS

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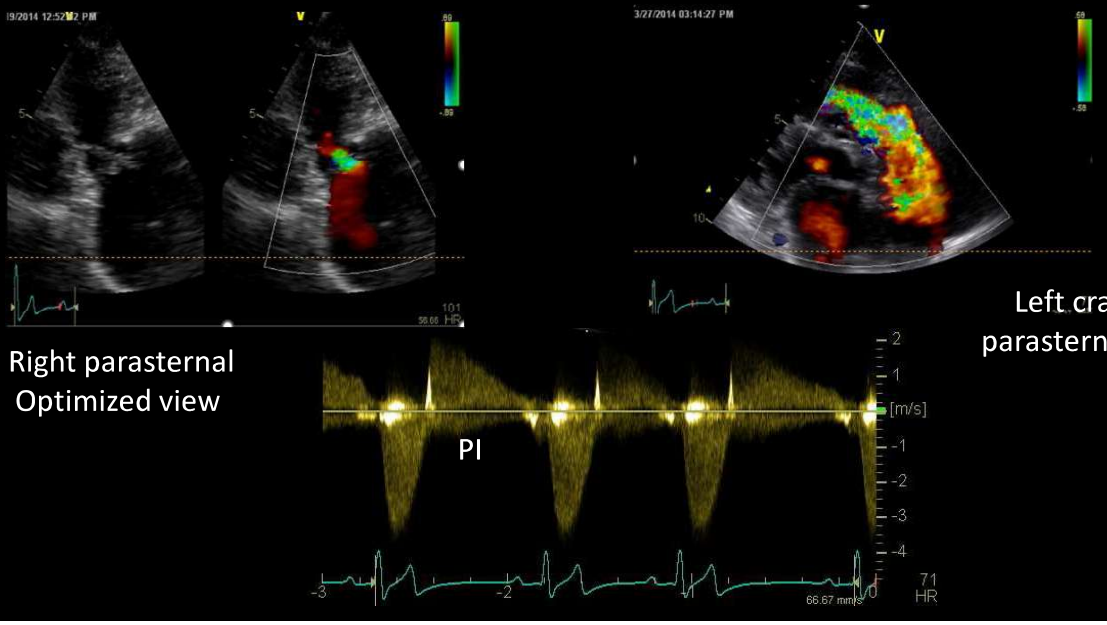
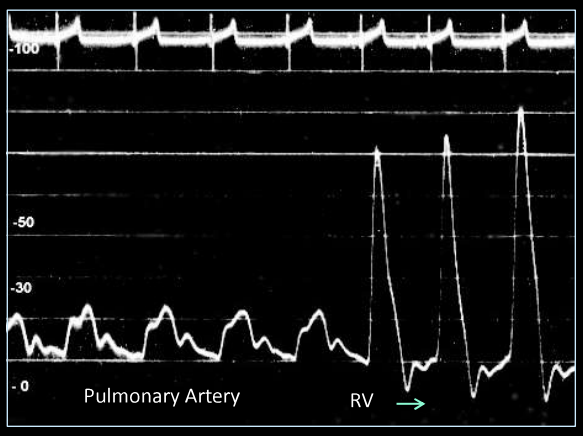
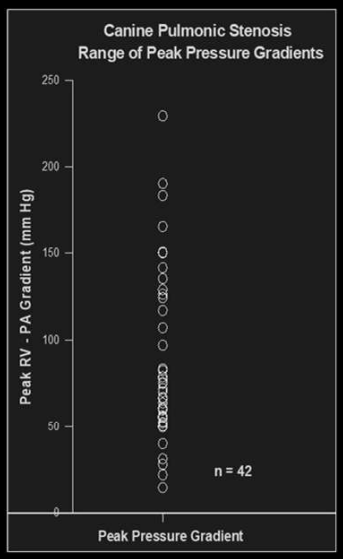
PI – Before & After Balloon Valvuloplasty



69

Reference: Spectral Doppler: Canine PS – Gradients





Severe PS
80 / 100 mmHg
Max grad

60 mmHg mean

Management Points:

- Wide variety of pressure gradients
- Beware with *rapidly growing* dogs
- Many dogs with mild to moderate PS + some with severe live relatively-normal lives

70

Reference: Pulmonic Stenosis: PW & CW Doppler

- "Step up" in velocity in the RVOT + turbulence
  - Peak velocity > 1.5 m/sec is suspicious (if no left-to-right shunt)
  - Concurrent pulmonic regurgitation is typical
- High velocity tricuspid regurgitation – functional vs. TV dysplasia
- Other findings (e.g., dynamic component of RVOT)
- V1 + V2 should be measured to assess subvalvular components
- Consider flow (stroke volume) when estimating severity
  - Measure VTI ratios (PV/AV) – should be congruous with gradient
  - Calculate effective orifice area/BSA (continuity)
- Dynamic obstruction + PI often worse after balloon valvuloplasty

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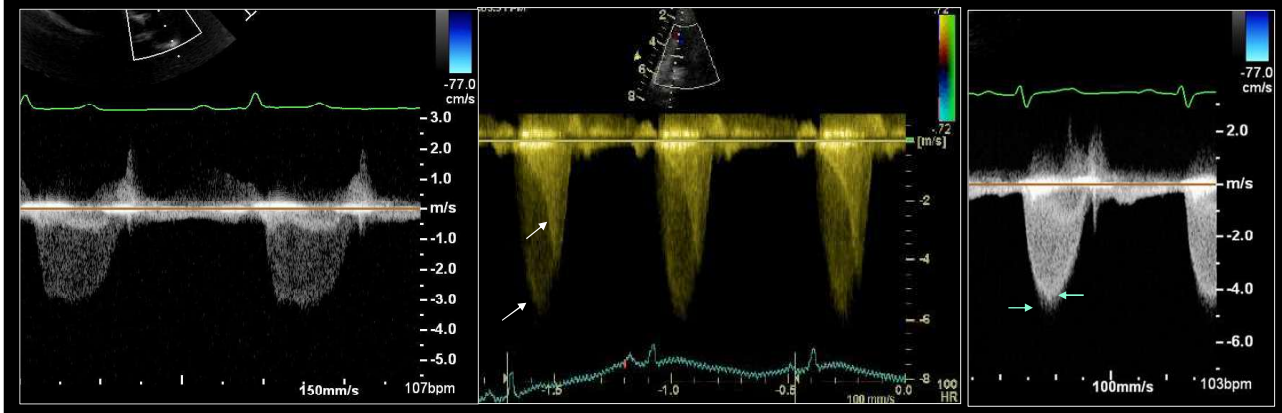
Canine PS – CW Doppler Studies



Find peak of the modal velocity (dense envelope)
Look for late peaking V1 (dynamic, subvalvular component)
Dogs with significant dynamic RVOT obstruction might benefit from vigorous beta blockade
Also measure VTI ratios and calculate functional cross-sectional area
(also see "Valvular Heart Disease: Doppler Assessment")

72

Reference: Pulmonic stenosis – Key Management Issues
Assessment of the Patient

- Nature of obstruction by 2D echo
  - Valve fusion, mobility & thickness (dysplasia)
  - Subvalvular disease – dynamic or fixed
  - Diameters of valve "annulus" & PA for BV (also compare to aorta)
- Pressure gradient (awake or minimal sedation)
  - Peak grad of <50 mm Hg considered mild
  - Peak grad of >80 to 100 (to 125) considered "severe"
  - Progression of gradient in growing dogs
  - Contribution of subvalvular dynamic or fixed component
- VTI ratio of PV to aorta (flow affects PG) and calculated CSA

73

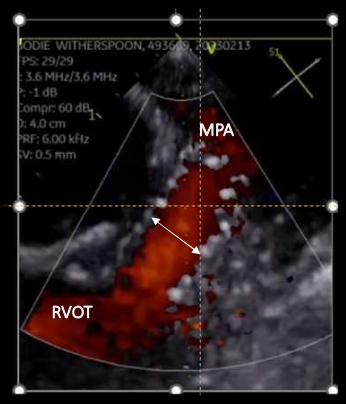
Reference: Pulmonic stenosis – Key Management Issues
Assessment of the Patient (2)

- RV: Systolic function, thickness & echogenicity | Diastolic function
- Tricuspid valve competency
- Presence of Shunts
  - VSD (look carefully – including apex – low velocity with ↑RV pressure!)
  - Patent Foramen Ovale (right to left)
  - Perform saline contrast echocardiogram to rule out if Color Doppler ambiguous
- Right atrial size & caudal vena cava/hepatic venous assessment
- Cardiac rhythm (AF: poor prognosis)
- Post-intervention assessments & complications
  - Regression of RVH? Beta-blockers? Worsened PI? PA dissection? Restenosis?
- Single origin or pre-pulmonic coronary artery
  - CTA (optimal), Angiogram or TEE in high-risk breeds

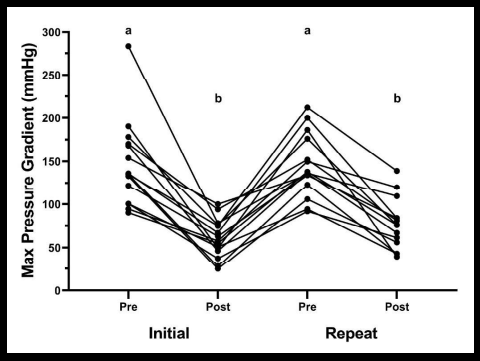
74

Treatment: Balloon Pulmonary Valvuloplasty or Stenting
Be certain to index to stroke volume (Flow ⇒ Gradient)

Transcatheter Pulmonary Balloon Valvuloplasty



Transpulmonary stent



Cohort of dogs with "restenosis" Post-BV
Unadjusted for Stroke Volume (**Winter R** et al., J Vet Cardiology)

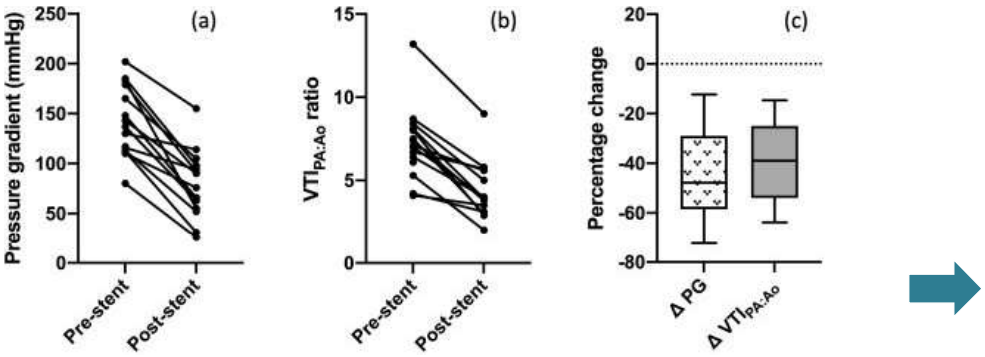
75

Reference: Pulmonary Valve Stenting – Long Term Outcomes

J Vet Cardiol. 2021 Dec:38:1-11. doi: 10.1016/j.jvc.2021.09.002. Epub 2021 Sep 24.

Transvalvular pulmonic stent angioplasty: procedural outcomes and complications in 15 dogs with pulmonic stenosis

K Borgeat [1], S Gomart [2], E Kilkenny [3], G Chanoit [4], M J Hezzell [2], J R Payne [4]



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Reference: Pulmonic stenosis – Management

- Balloon catheter dilation of the valve
  - If valve is not "too" hypoplastic | a "salvage" procedure is a stent
  - Relative contraindication: Prepulmonic coronary artery (done with care)
  - Re-stenosis seems to occur in ~ 15-20% (depending on the definition)
- Surgical techniques – patch graft or conduit – rarely done today
- Dynamic outflow tract obstruction
  - May persist and may respond to Beta blockers (atenolol)
- Reduction of gradient to moderate range or 50% decrease in PA/Ao VTI ratio = "success" or similar **increase** in valve CSA
  - Measuring only peak gradients does not account for changes in flow
- Reflex-mediated syncope can persist even with successful BV

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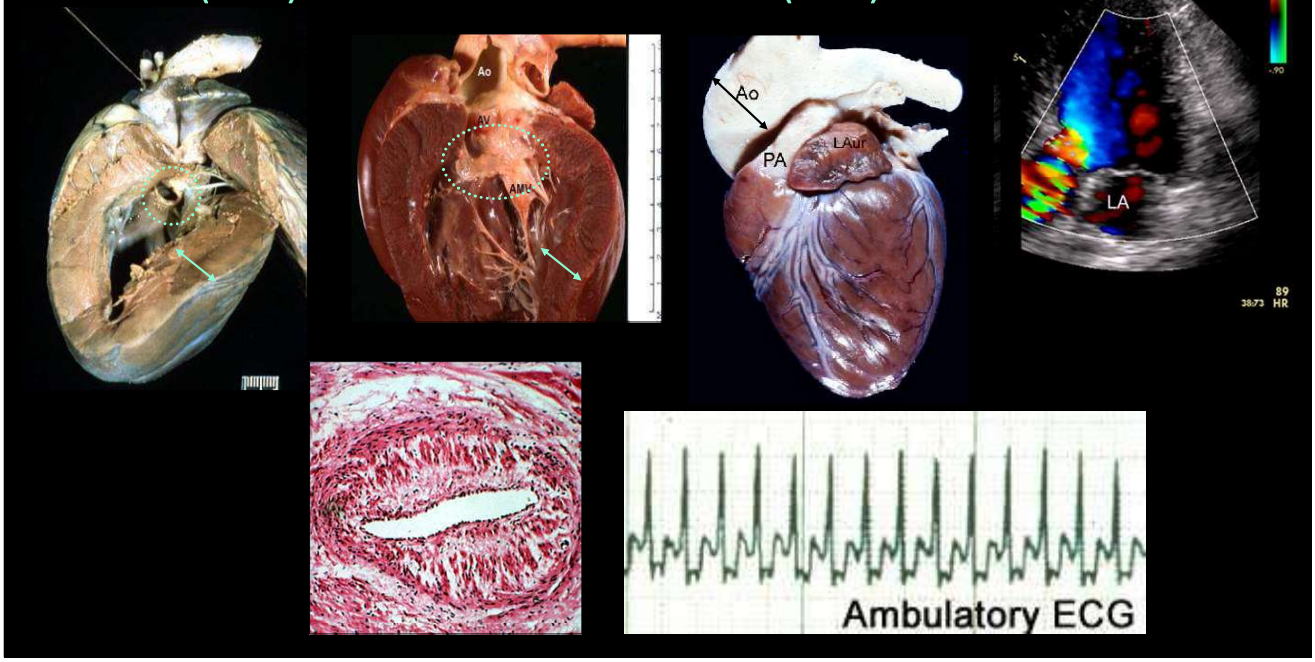
Canine (Sub)Valvular Aortic Stenosis (SAS)



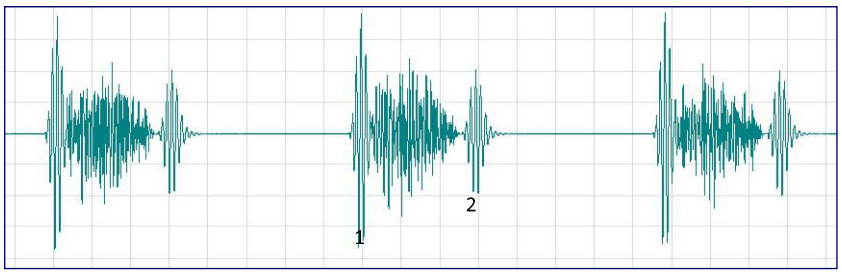
78

Reference: Aortic Stenosis – Definition & Pathophysiology

- Congenital narrowing of the LV outflow tract - typically subvalvular (SAS)
- Among most common congenital defects in dogs (criteria vary)
- Obstruction to LV outflow
  - Compensated by generation of a systolic pressure gradient
  - Pressure in the left ventricle > aortic pressure
  - High-velocity flow across stenosis
- Varying degrees of aortic regurgitation
- Left ventricular (concentric) hypertrophy develops
  - Subendocardial ischemia is common
  - Long-term: diastolic & systolic heart failure or sudden cardiac death

79

Recognition: Auscultation – Often ↓Arterial Pulses



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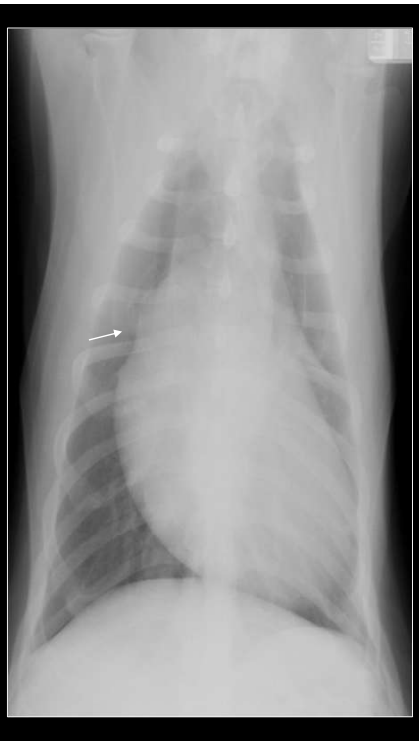
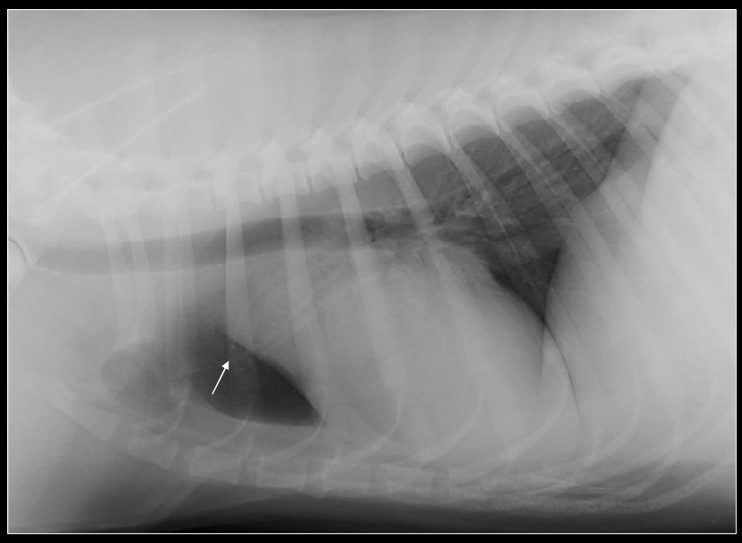
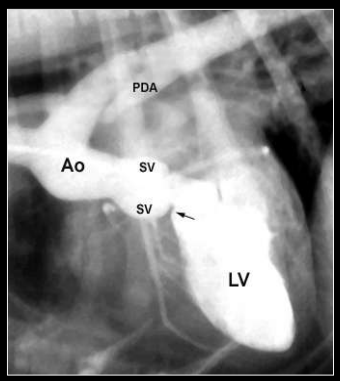
SAS – Dilated Ascending Aorta

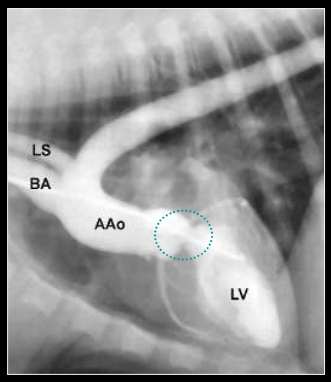


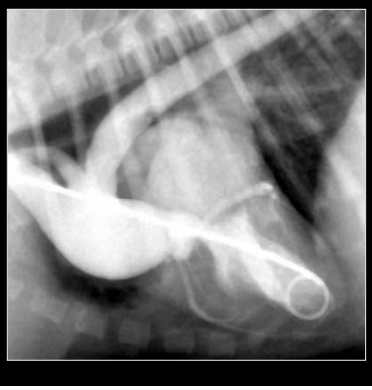


81

Canine Subvalvular Aortic Stenosis (SAS)







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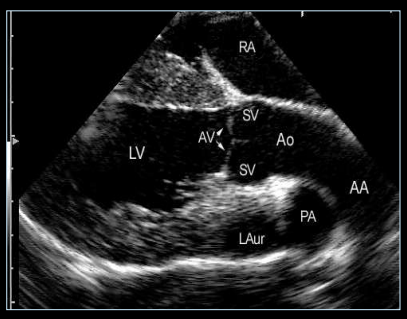
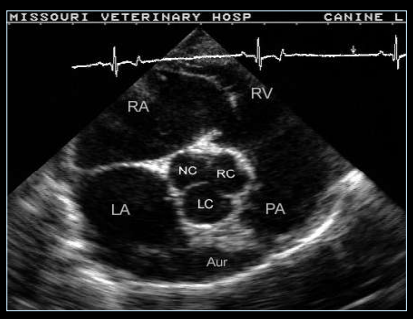
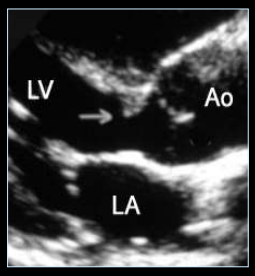
Echocardiography in Aortic Stenosis – 2D Imaging

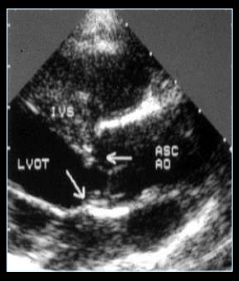
N

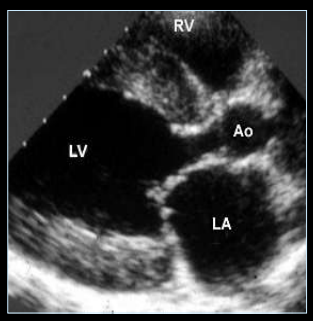




SAS



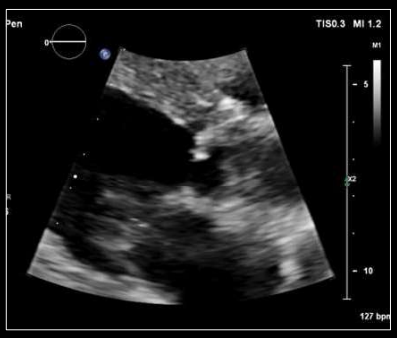




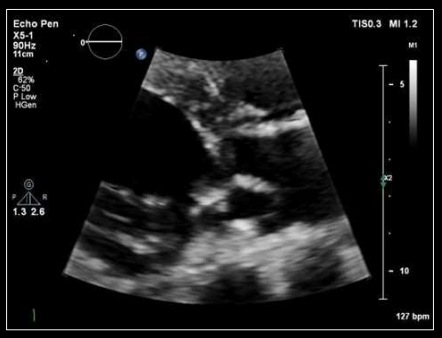
Most cases of AS are Subvalvular

83

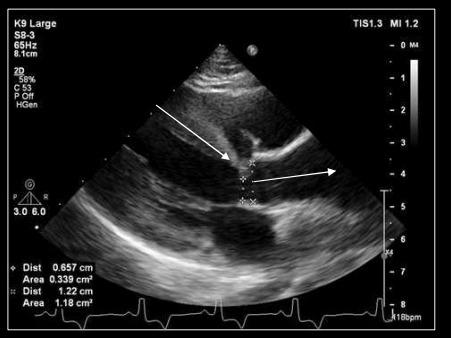
Aortic Stenosis – LVOT obstruction(s)



Subvalvular & Valvular



Subvalvular & Valvular
& Supravalvular



Aorto-septal Angle
Dilated ascending Ao

Videos

84

Reference: Pathogenesis: Aortoseptal Angle in SAS

J Vet Intern Med 2014;28:1498–1503

Association between Aortoseptal Angle in Golden Retriever Puppies and Subaortic Stenosis in Adulthood

M.C. Belanger, E. Côté, and G. Beauchamp

Background: Predicting subaortic stenosis (SAS) in adult Golden Retriever dogs (GRs) by evaluating them as puppies is hampered by the progressive expression of the SAS phenotype in youth. In some children who develop SAS as adults, an abnormal aortoseptal angle (AoSA) precedes development of stenosis.

Objectives: To determine the normal AoSA in young adult GRs using echocardiography; to assess the value of AoSA in GR puppies for predicting development of the SAS phenotype.

Animals: Forty-eight 2- to 6-month-old GR puppies.

Methods: Prospective study. Puppies were recruited from clients and breeders. Puppies were evaluated with a physical examination and an echocardiogram, and this evaluation was repeated when they were 12–18-month-old adults. Puppies were classified as unaffected (WNL) or affected (SAS) retroactively, based on their results as adults.

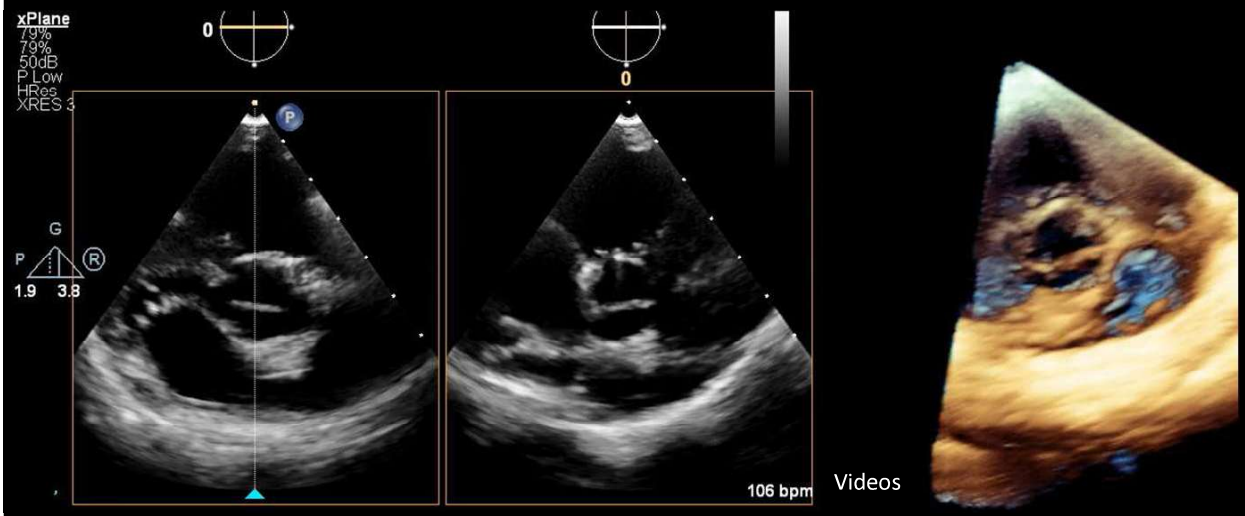
Results: In WNL young adult GRs, mean ± SD AoSA was 152.3 ± 6.5°. Mean ± SD AoSA in SAS puppies (144.9 ± 8.6°) was significantly different from mean AoSA in WNL puppies (155.7 ± 8.8°, $P < .01$). No puppy with AoSA >160° had the SAS phenotype as a young adult; 93% (75.7–99.1%) of puppies with AoSA <145° had the SAS phenotype as young adults. Peak LVOT velocity increased significantly between evaluations ($P < .0001$) whereas AoSA did not ($P = .45$).

Conclusion and Clinical Significance: A steep AoSA in GR puppies is associated with the SAS phenotype in young adulthood. Some GR puppies have an abnormal AoSA that persists in young adulthood and is detectable before peak LVOT velocity reaches levels consistent with SAS.

Key words: Aortic; Cardiovascular; Dog; Echocardiography; Heart.

85

Concurrent Valvular Aortic Stenosis (Bicuspid Valve)



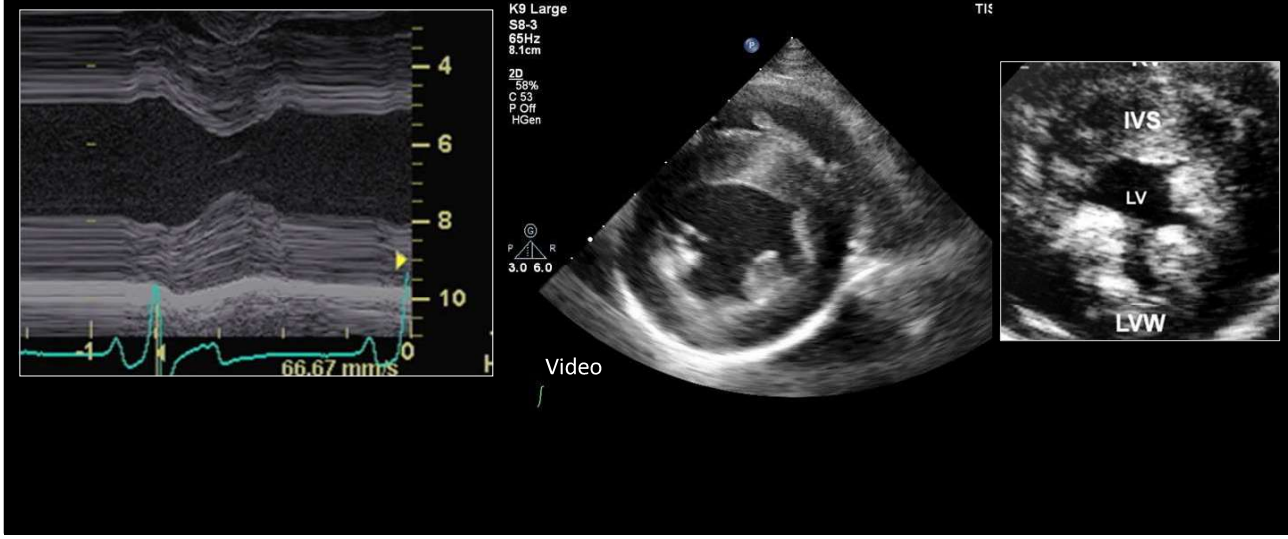
Videos

86

Aortic Stenosis: LV Concentric Hypertrophy

LV Systolic Function (compensated vs. LV failure)

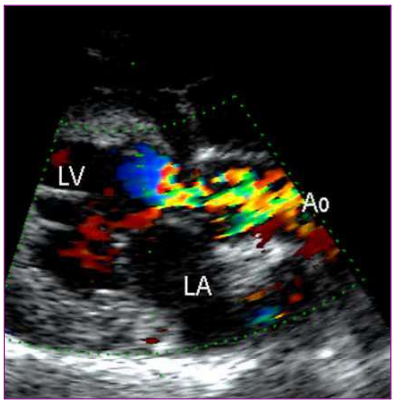
Subendocardial Fibrosis (ischemic injury) ⇒ Arrhythmic Substrate



87

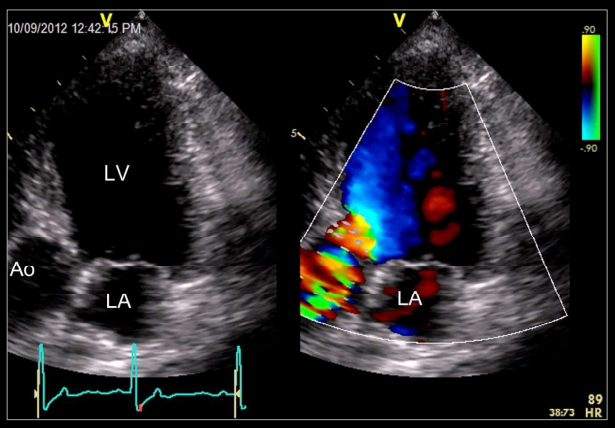
Reference: Aortic Stenosis: Color Doppler Imaging

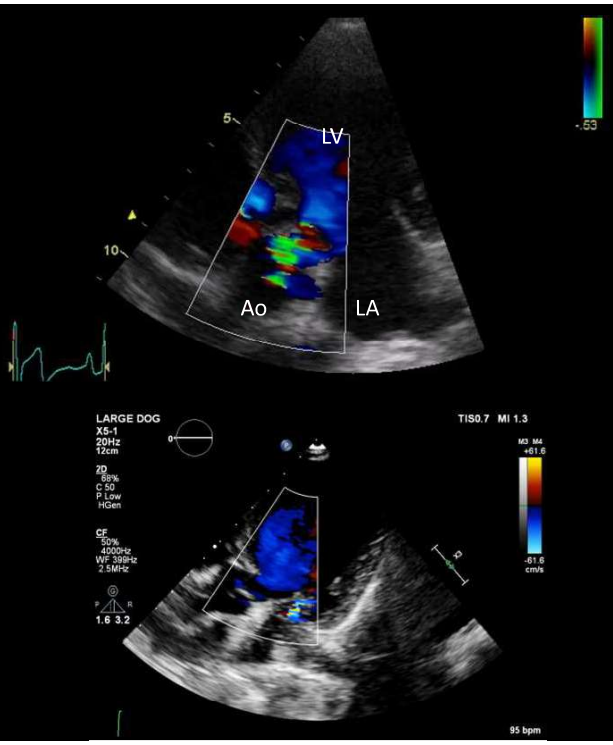
- Flow acceleration, aliasing & turbulence in LVOT
  - DDx: Normal signal alias
  - Requires CW Doppler verification
- Often aortic regurgitation
  - Usually silent to auscultation
- May have concurrent MR
  - Functional from LV remodeling
  - Concurrent mitral valve dysplasia
- Also examine PA for flow of PDA



88

SAS – Color Flow Imaging





Proximal acceleration → Aliasing → VC → Post-stenotic turbulence
(Silent) Aortic regurgitation is common

89

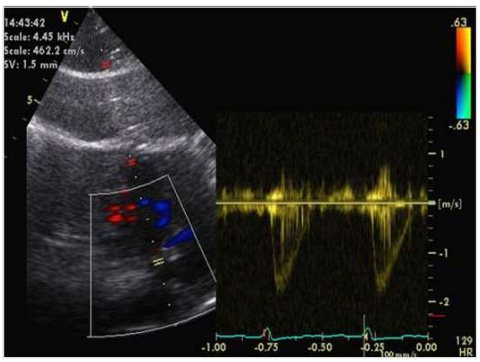
Reference: Aortic Stenosis: PW & CW Doppler

- "Step up" in velocity in the LVOT + turbulence
  - Must distinguish from normal step up
- Trivial cases – flow may not appear disturbed
  - What is the Doppler "gold standard" for Dx??
  - Peak velocity > 1.7 to 2.0 m/sec "suspicious" (Left apical position; PW-Doppler)
  - Averaged Subcostal Vel > 2.0 to 2.2 m/s is "suspicious"
  - Cycle length, Stroke Volume and SNS effects; breed variations (small aorta)
  - Quantify gradients from subcostal imaging plane
  - No specific CWD "cut-off" for SAS: progressive liability with ↑velocity
- Aortic (AR) and mitral regurgitation (MR) are common with "true" SAS
- LV diastolic dysfunction can be observed
- Other findings (e.g., dynamic component due to SAM)

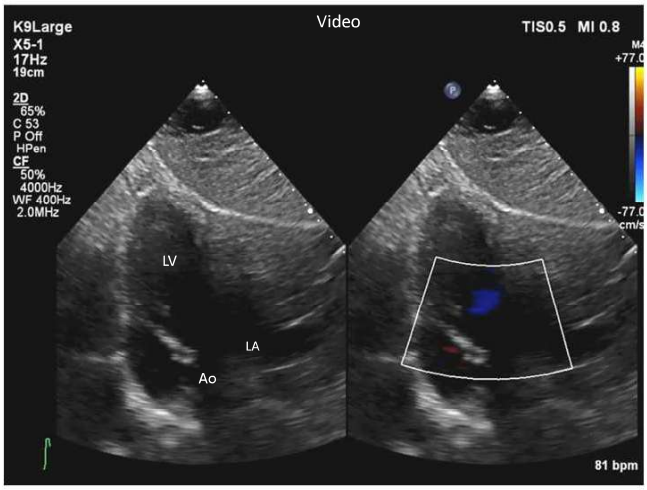
90

Subxiphoid or Subcostal Imaging

(usually best for obtaining optimal velocity spectrum & gradient)

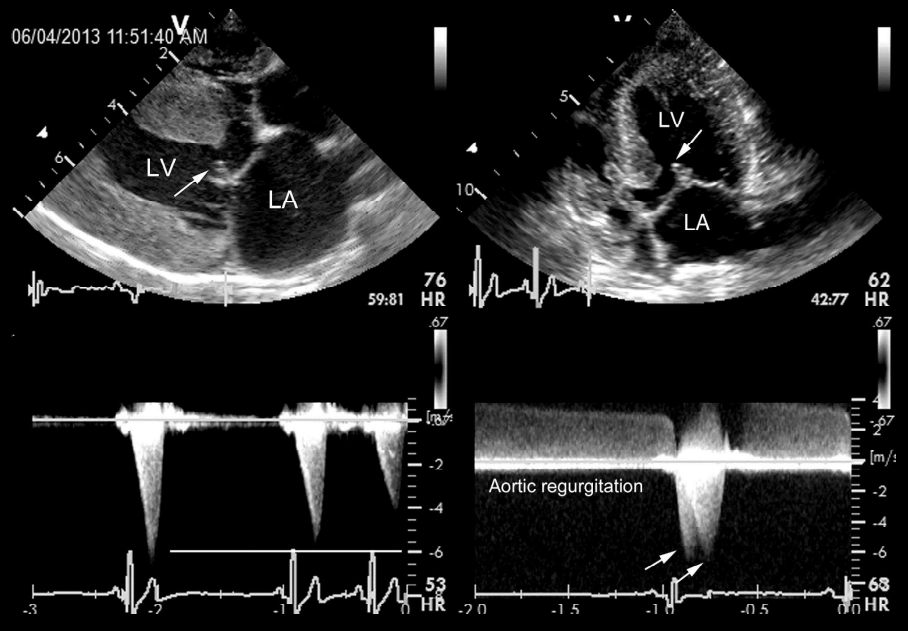


Begin with sector oriented in the DV plane then direct beam cranially for heart/aorta and rotate index towards operator.



91

Fixed + Dynamic LVOT Obstruction



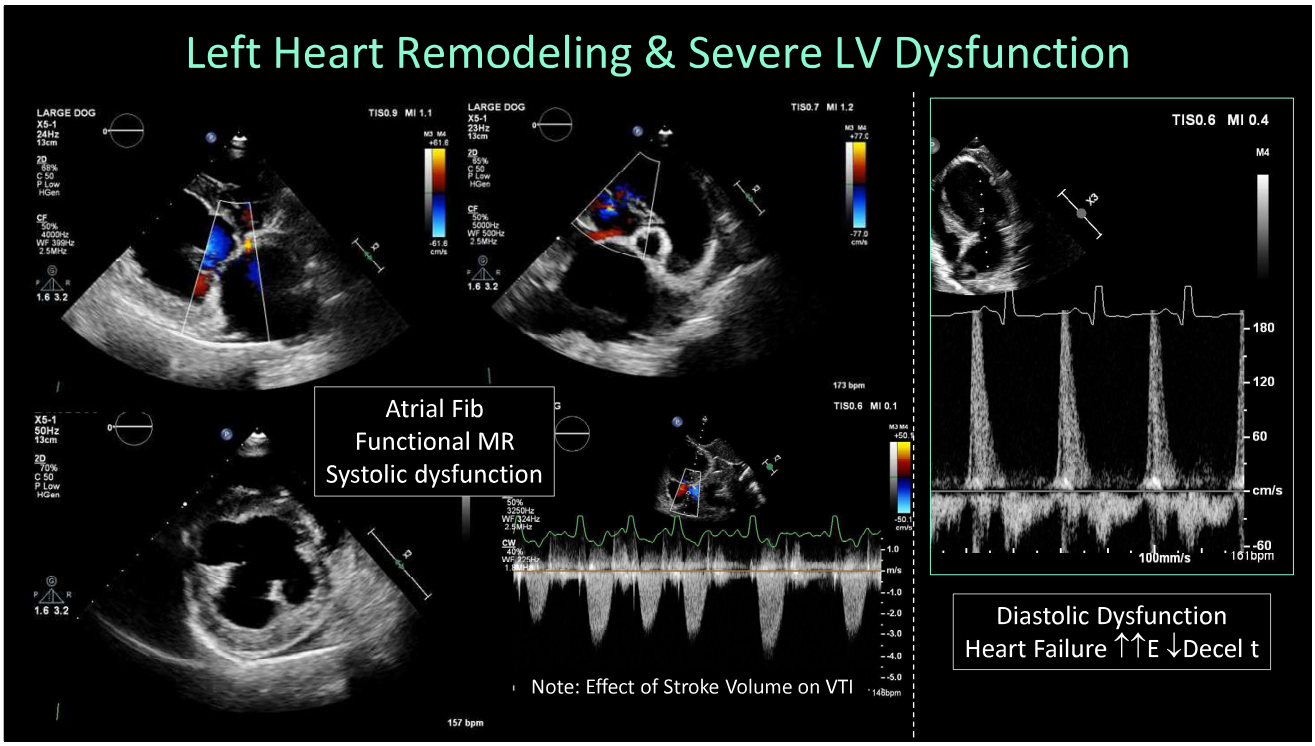
92

Reference: Canine Subvalvular Aortic Stenosis – CW Doppler

- Definitive diagnosis of SAS is achieved by combining: 2D imaging & Doppler studies
- Diagnosis of trivial AS remains controversial but requires no treatment – however, it can affect breeding status
- Gold standard for Diagnosis: imaging lesion
- Suspicious of SAS: ↑ Velocity + holodiastolic AR
- Be mindful of factors that can affect the stroke volume
  - Varying cycle length – preceding long ⇒ higher velocity
  - Sympathetic tone (sedation)

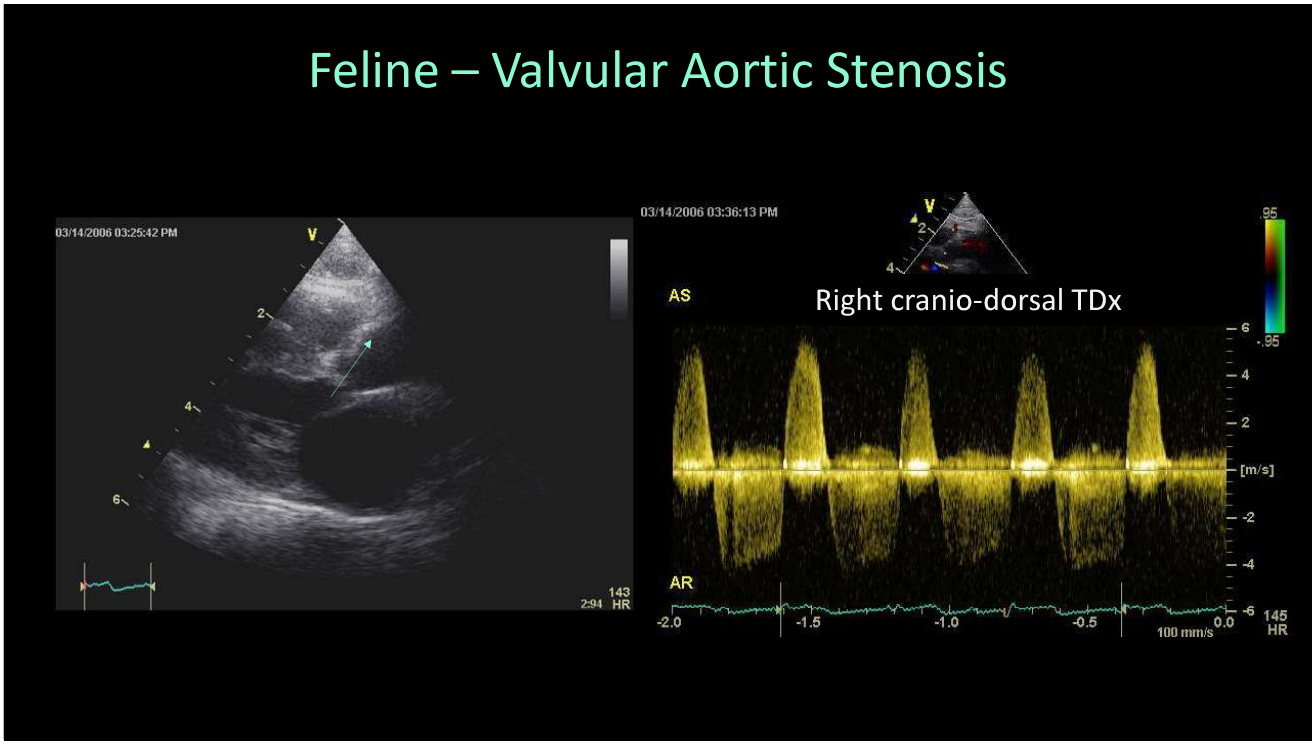
93

Left Heart Remodeling & Severe LV Dysfunction



94

Feline – Valvular Aortic Stenosis



95

Reference: Aortic stenosis: Key issues

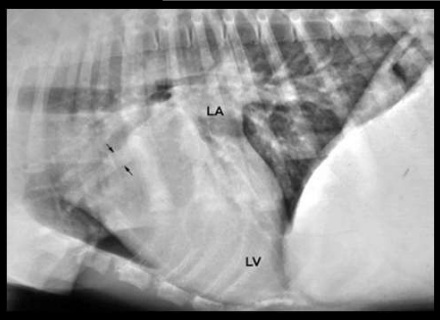
- Diagnosis of trivial SAS (no imaging lesion)
  - Peak velocity vs. averaged velocity measures
  - Step-up and turbulence (how important? – some of this is normal)
  - PW Doppler vs. CW Doppler examinations
  - Site of examination: Left apex vs. subcostal
- Pressure gradient (awake or mild sedation)
  - Peak grad of > 80 to 100 considered "severe" in the *literature*
  - Effect of stroke volume (cardiac output) on gradient
  - Progression of gradient in growing dogs
- Valvular regurgitation: Aortic & Mitral (problematic if dysplasia)
- LV changes: Hypertrophy, Tissue density & Function (S&D)
- Cardiac rhythm: Ventricular ectopy; reflex-mediated bradycardia; AF

96

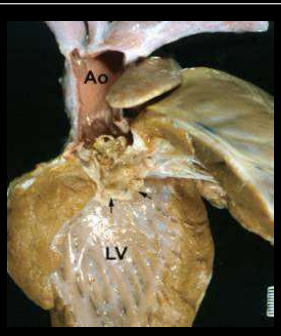
Canine SAS – Natural History

Management is Uncertain

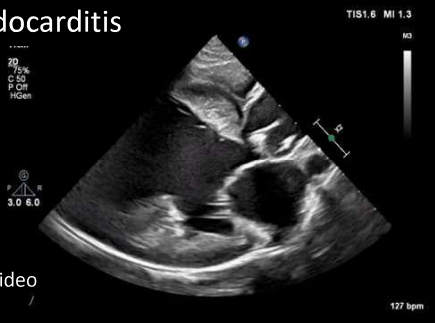
Trivial to mild SAS – normal life but breeding implications



Congestive Heart Failure



Endocarditis



Video

Syncope with exertion
Sudden Cardiac Death (arrhythmia)

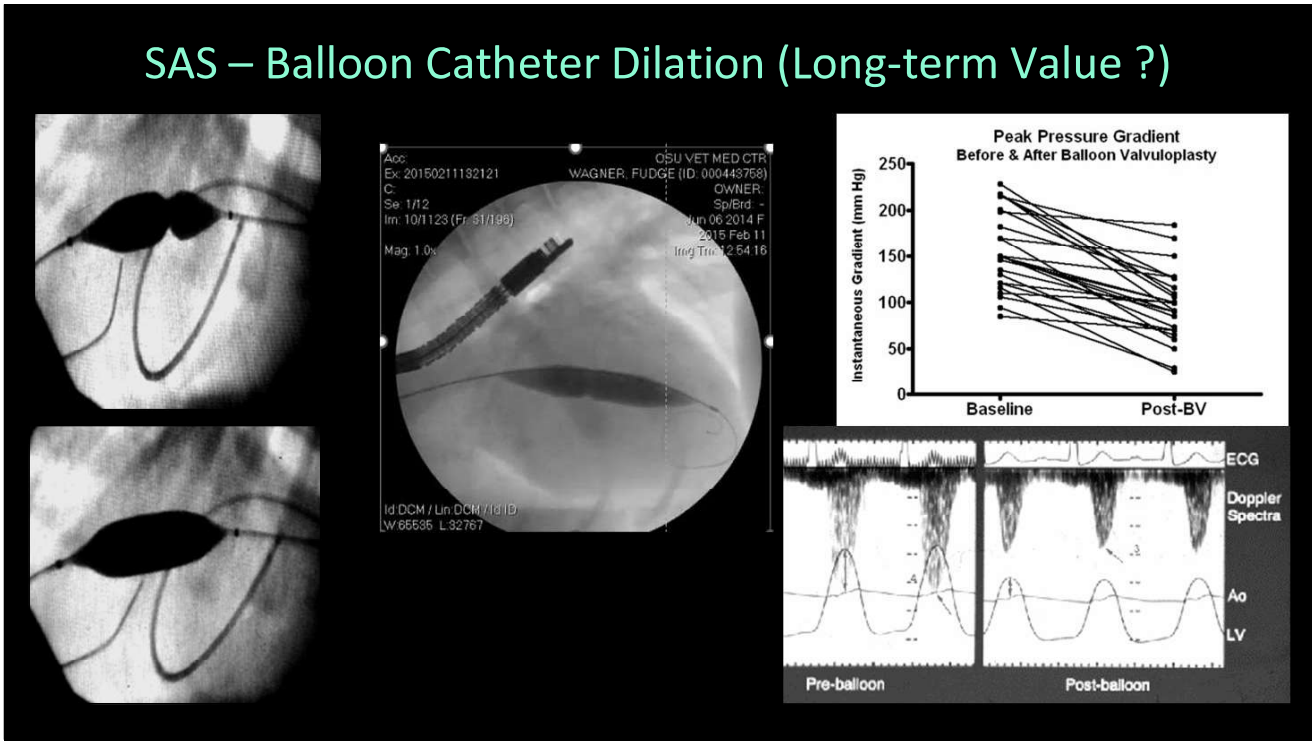
97

Reference: Subvalvular aortic stenosis – Management

- Assess: Clinical signs, pressure gradients, ECG, associated lesions
- Prophylaxis against endocarditis – any gradient
- Balloon catheter dilation of the stenosis – cutting + high-pressure balloon
  - Immediate benefit usually 50% reduction in gradient
  - Long-term benefit less certain; more AR develops
  - CHF and sudden death still occur – we only consider for dogs with CHF or syncope
- Dynamic outflow tract obstruction & PVC's
  - May respond to Beta blockers (atenolol or others)
- Routine cardioprotection(?): atenolol for severe AS | Sotalol for ectopy
  - Atenolol usual dose 0.75 to 1 mg/kg PO, q12h – reduce/stop if CHF
- Surgical techniques – requires by-pass – not shown to improve survival

98

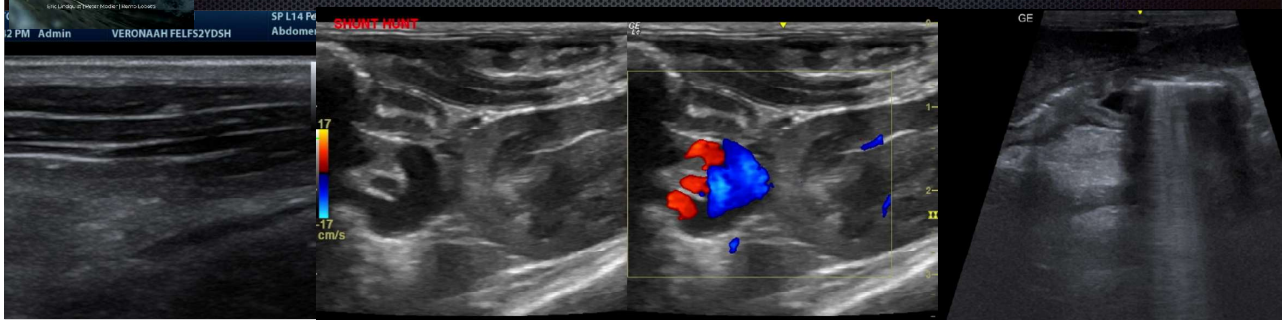
SAS – Balloon Catheter Dilation (Long-term Value ?)

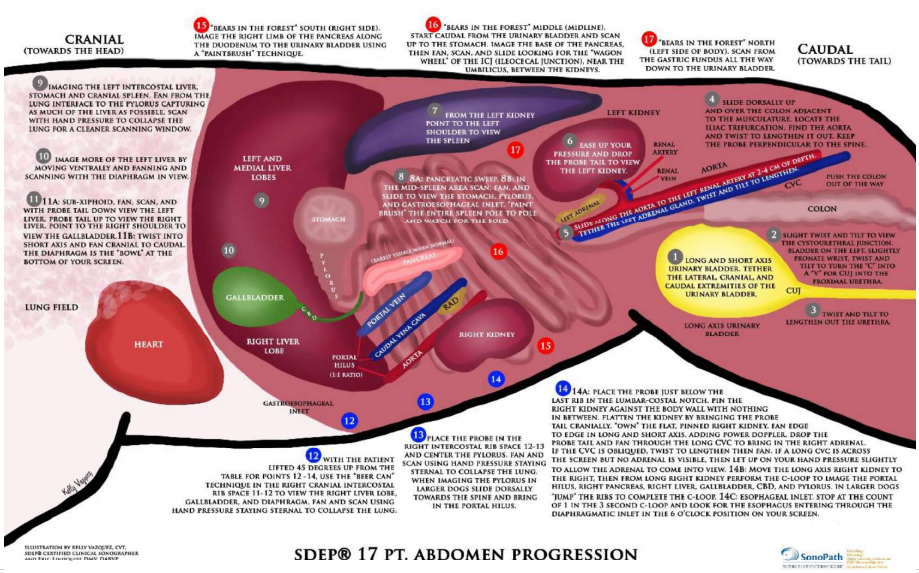


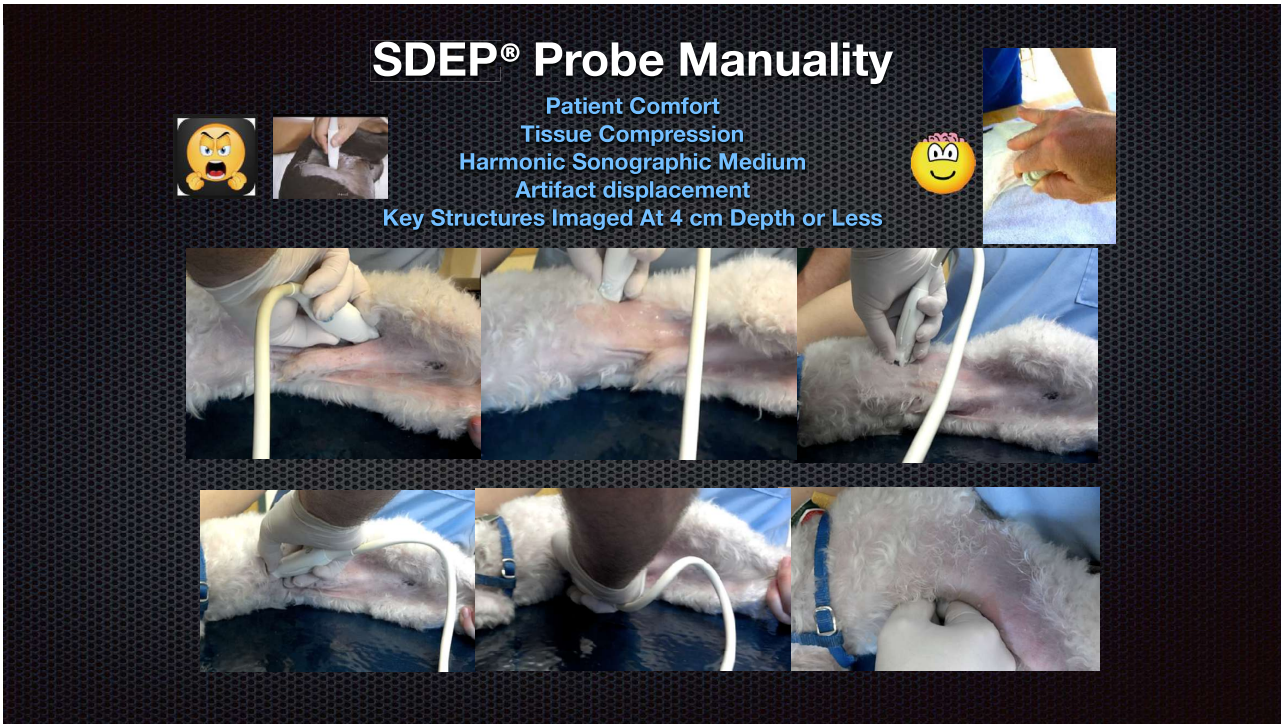
99

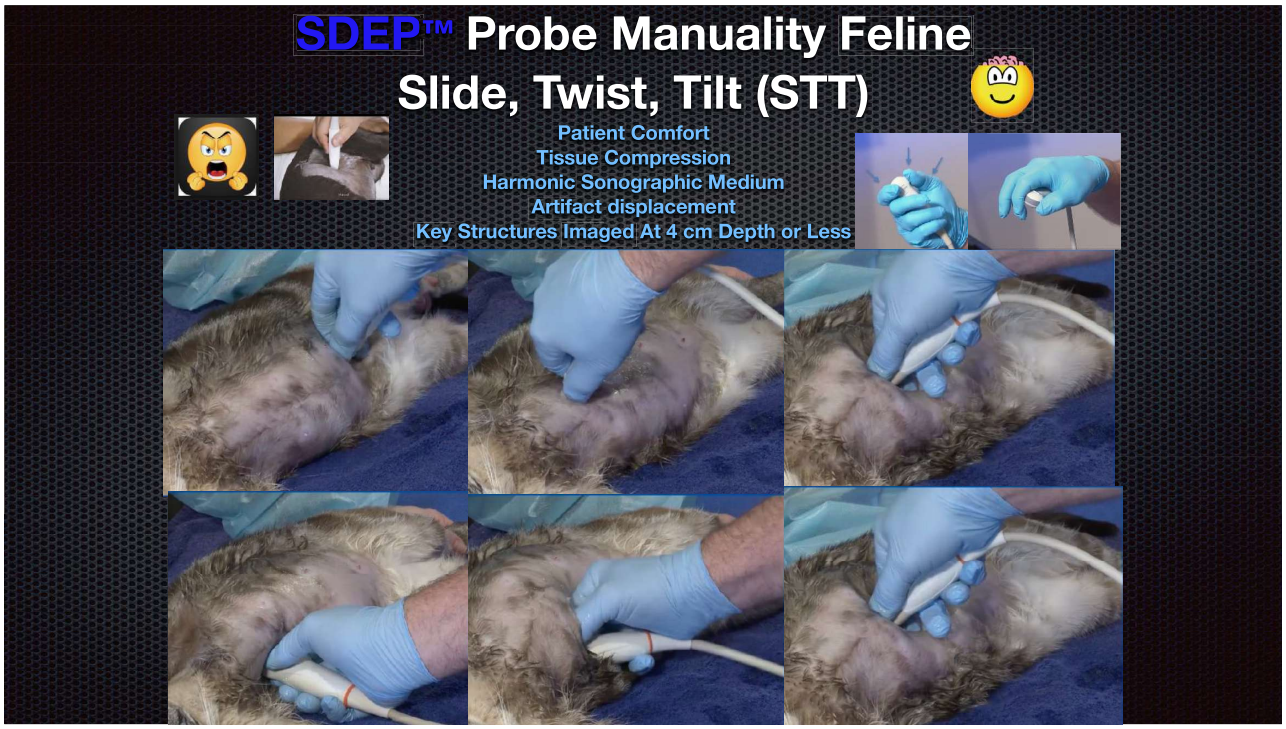
From Probe To Pathology: Mastering the SDEP® 17-point Abdominal Ultrasound Method

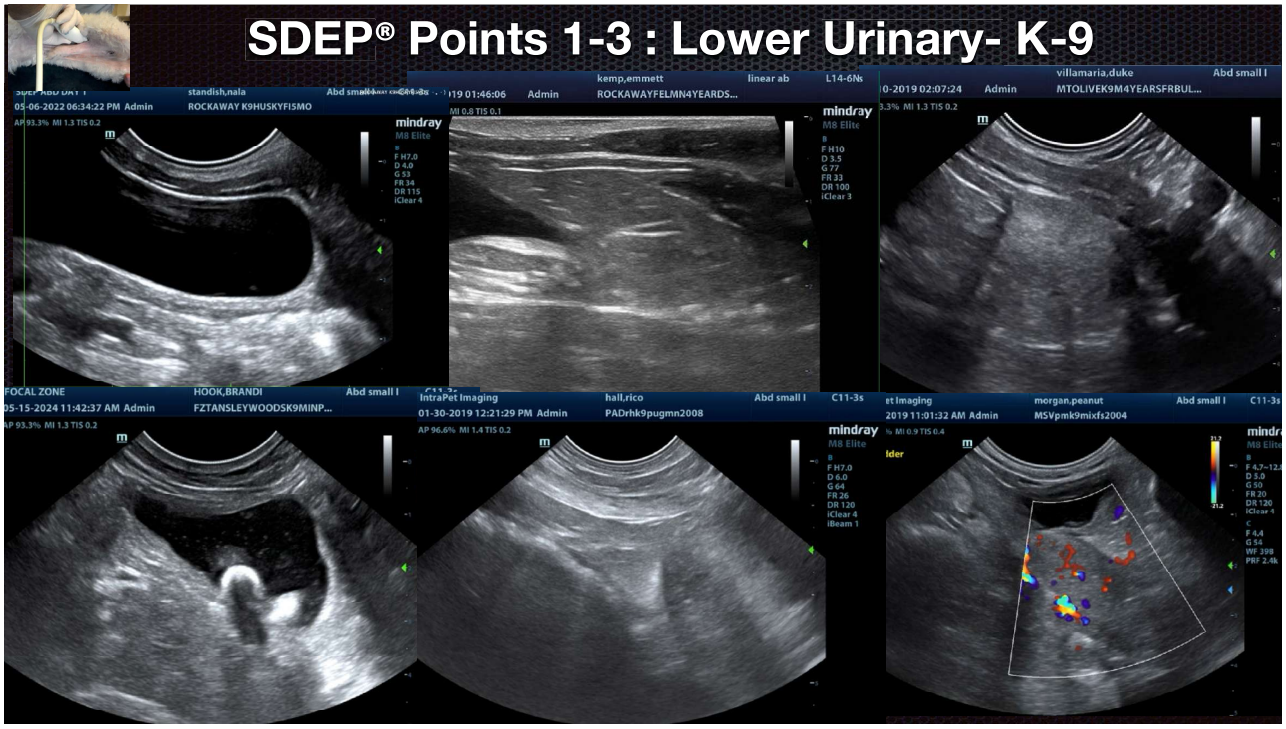
Eric Lindquist DMV, DABVP, Cert. IVUSS
CEO/Founder SonoPath.com

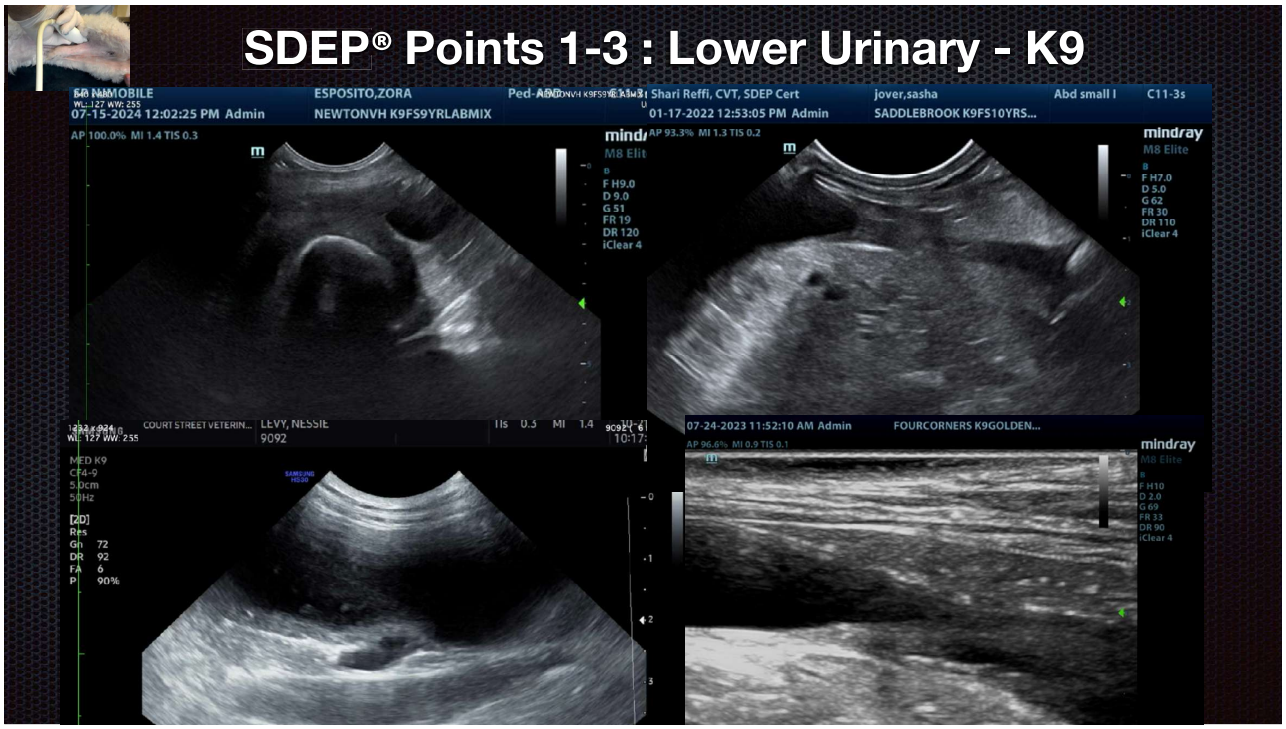


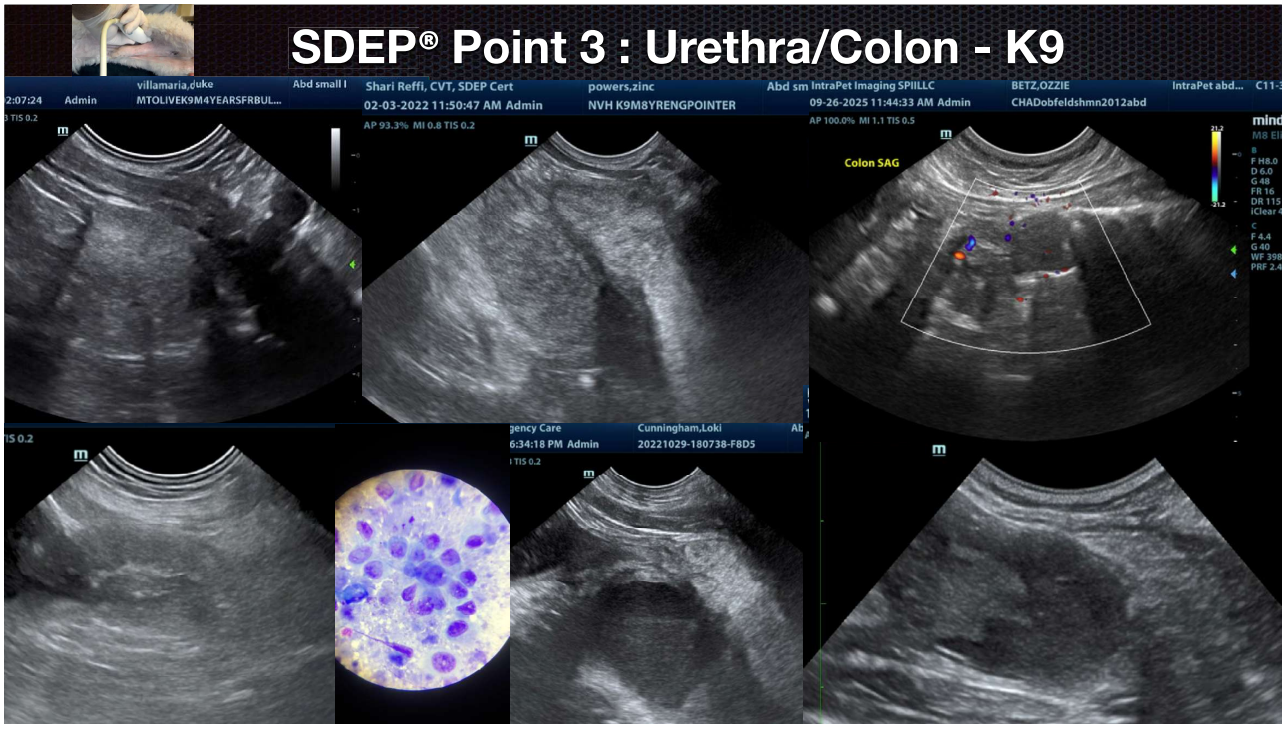

SDEP 17 POINTS, FOLLOW THE POSTER
SonoPath
CRANIAL
(TOWARDS THE HEAD)
CAUDAL
(TOWARDS THE TAIL)
LEFT KIDNEY
LEFT AND MEDIAL LIVER LOBES
STOMACH
GALLBLADDER
LUNG FIELD
HEART
RIGHT LIVER LOBE
PORTAL HILUS
RIGHT KIDNEY
AORTA
CVC
COLON
LONG AXIS URINARY BLADDER
SDEP® 17 PT. ABDOMEN PROGRESSION

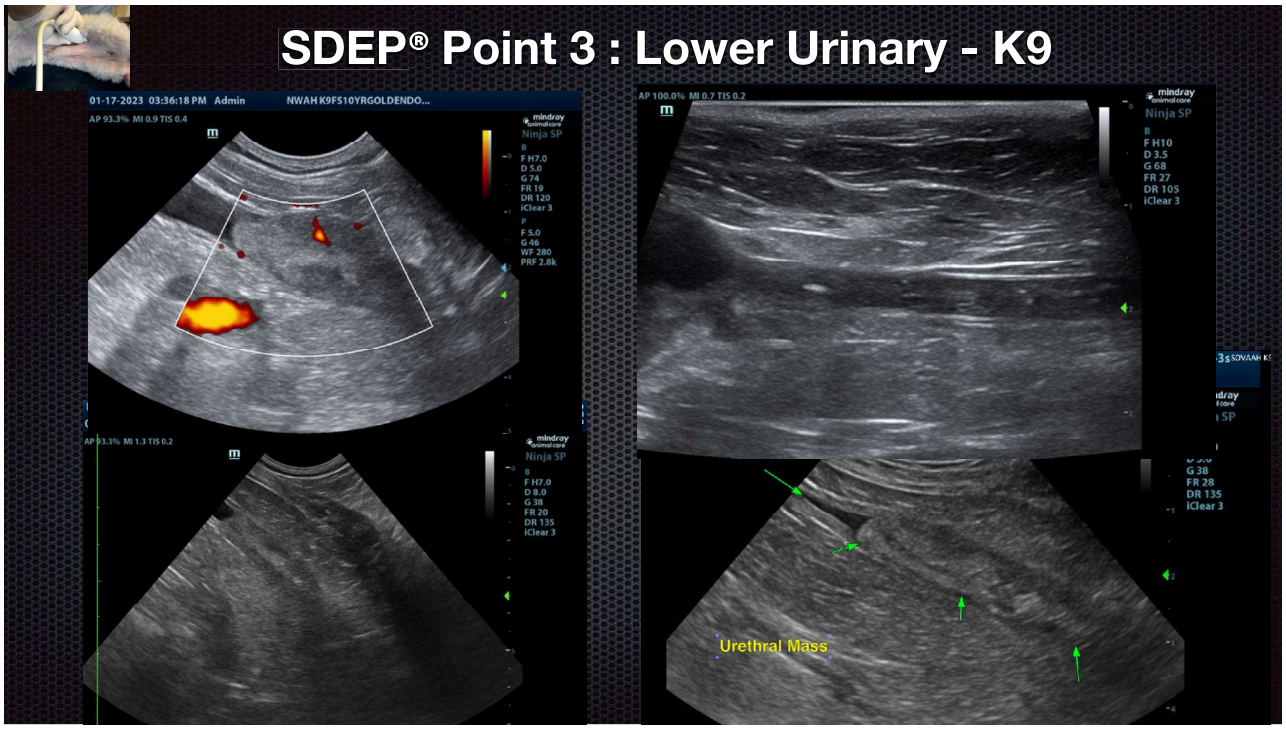

SDEP® Probe Manuality
Patient Comfort
Tissue Compression
Harmonic Sonographic Medium
Artifact displacement
Key Structures Imaged At 4 cm Depth or Less

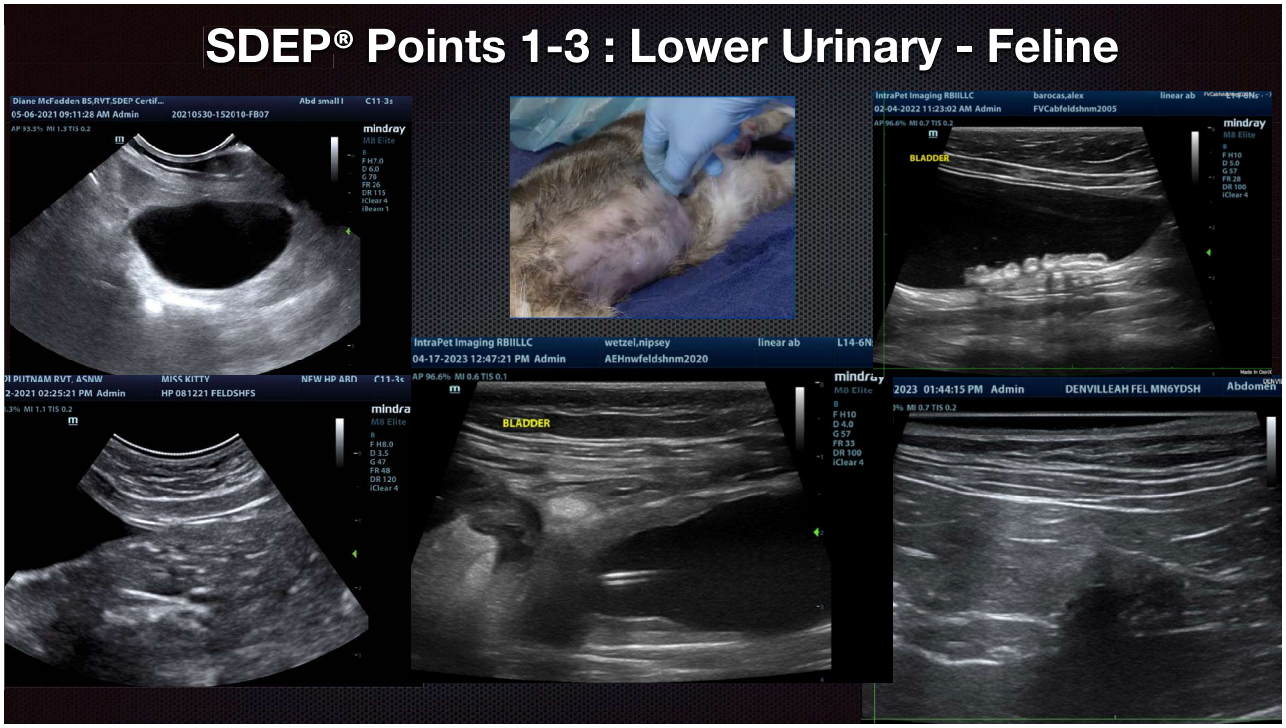

SDEP™ Probe Manuality Feline
Slide, Twist, Tilt (STT)
Patient Comfort
Tissue Compression
Harmonic Sonographic Medium
Artifact displacement
Key Structures Imaged At 4 cm Depth or Less

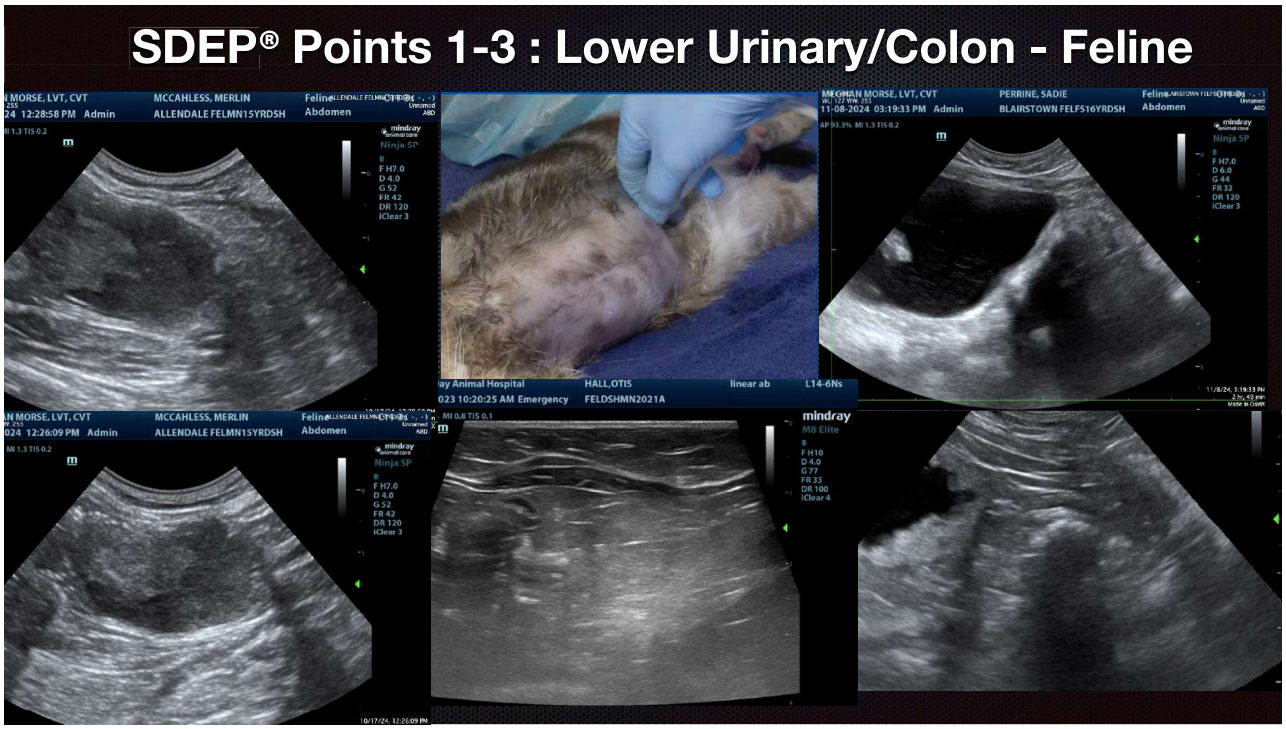

SDEP® Points 1-3 : Lower Urinary- K-9

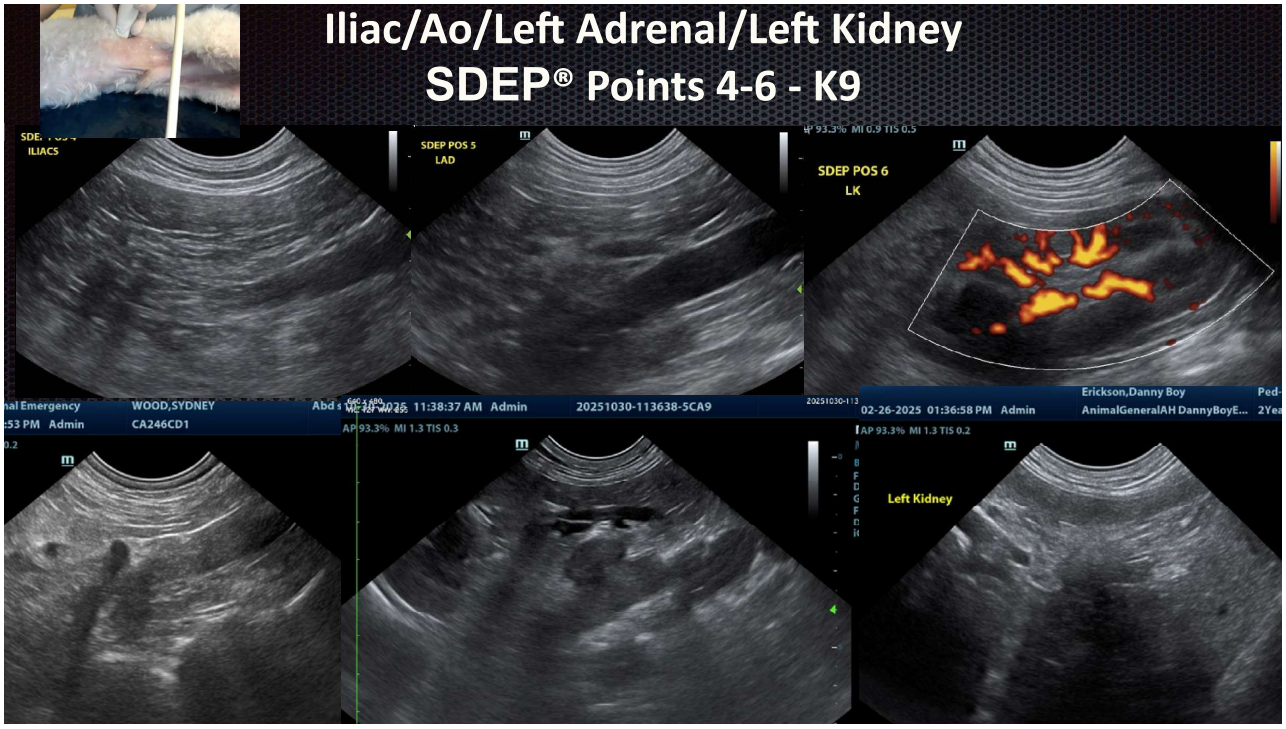

SDEP® Points 1-3 : Lower Urinary - K9
Shari Reffi, CVT, SDEP Cert
01-17-2022 12:53:05 PM Admin
jover,sasha
SADDLEBROOK K9FS10YRS...
Abd small I
C11-3s
07-15-2024 12:02:25 PM Admin
NEWTONVH K9FS9YRLABMIX
ESPOSITO,ZORA
07-24-2023 11:52:10 AM Admin
FOURCORNERS K9GOLDEN...
mindray
M8 Elit

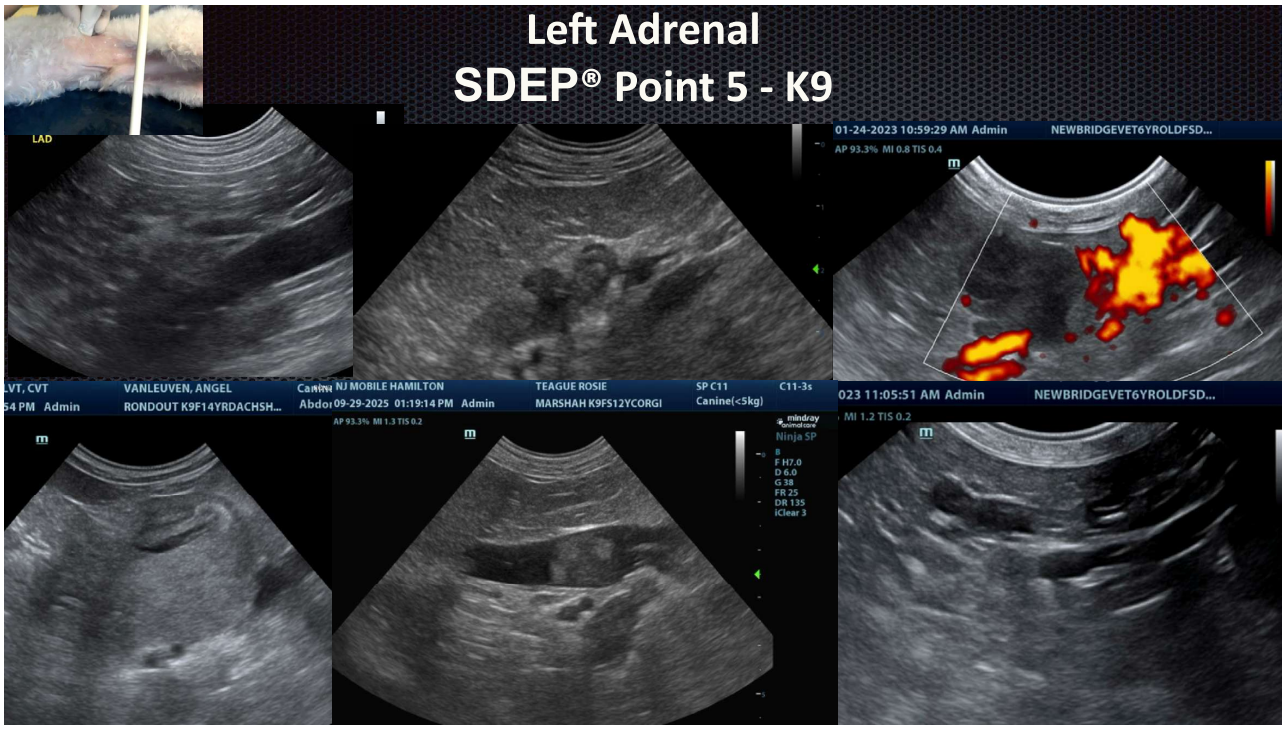

SDEP® Point 3 : Urethra/Colon - K9
Shari Reffi, CVT, SDEP Cert
02-03-2022 11:50:47 AM Admin
powers,zinc
NVH K9M8YRENGPOINTER
Abd small I
09-26-2025 11:44:33 AM Admin
BETZ,OZZIE
CHADobfeldshmn2012abd
Colon SAG
Cunningham,Loki
20221029-180738-F8D5

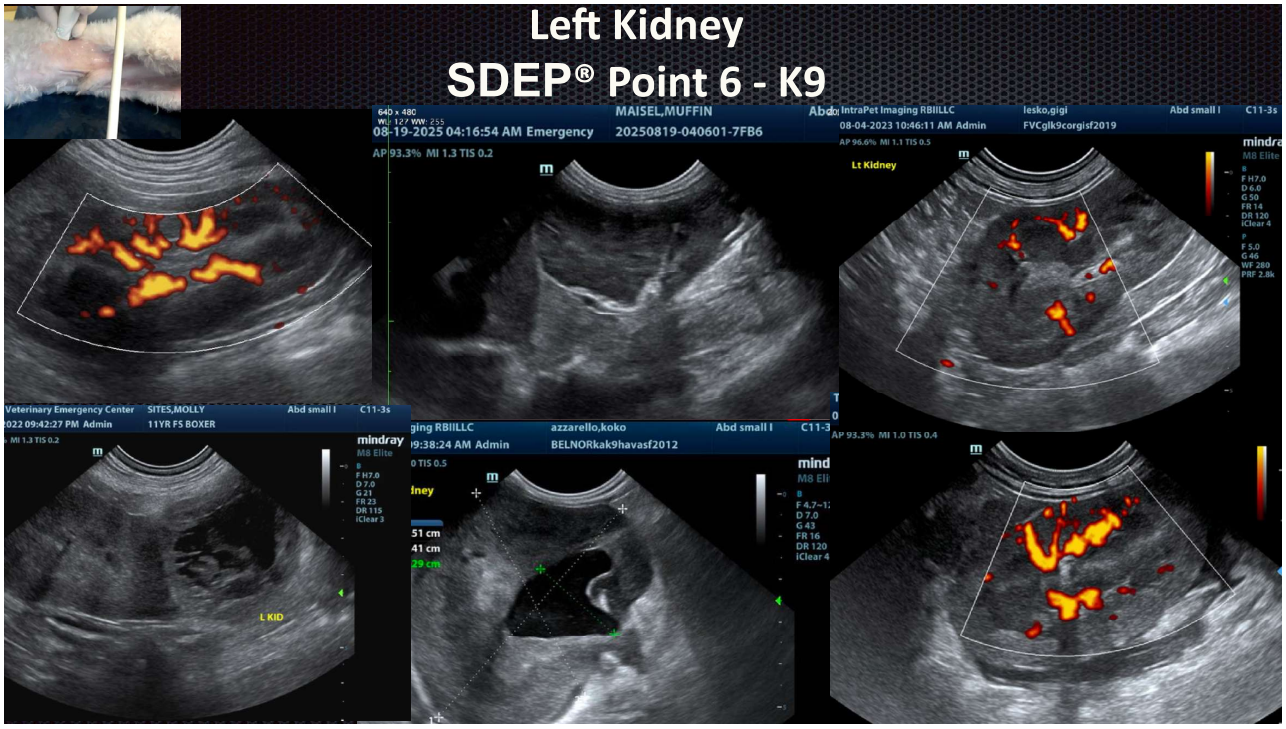

SDEP® Point 3 : Lower Urinary - K9
Urethral Mass

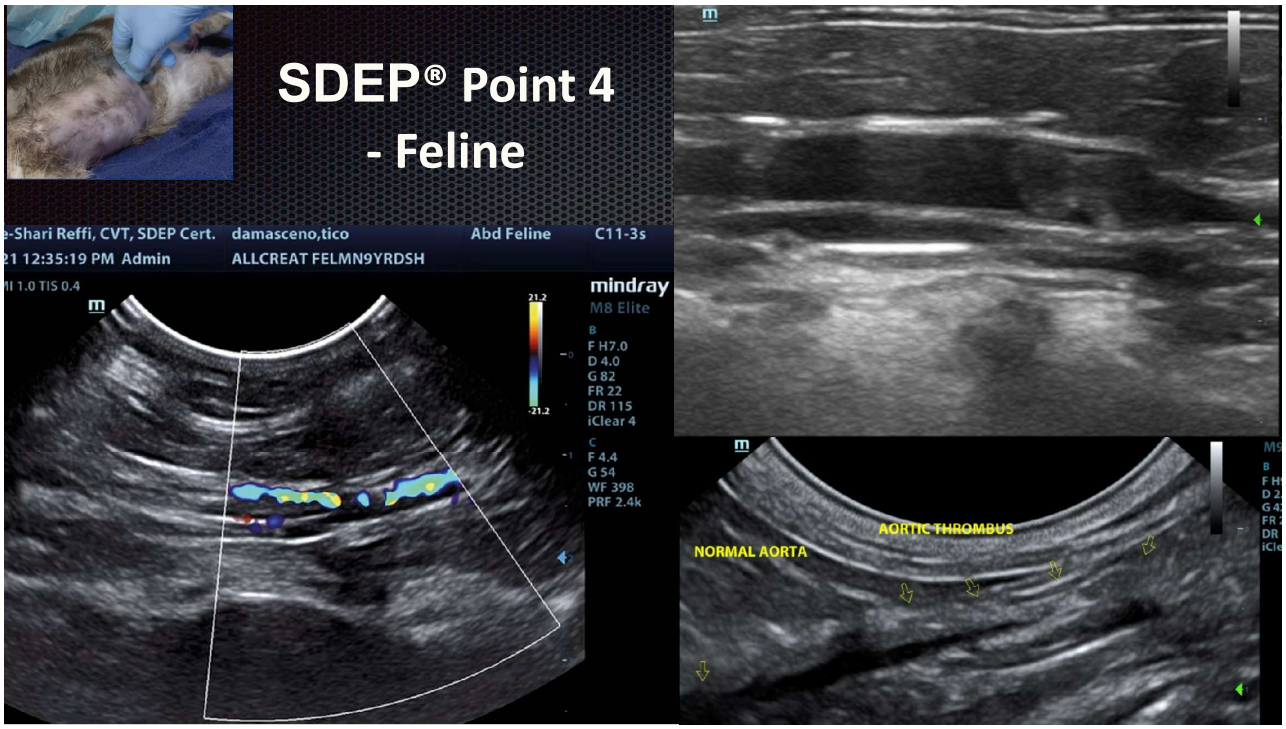

SDEP® Points 1-3 : Lower Urinary - Feline
BLADDER
BLADDER

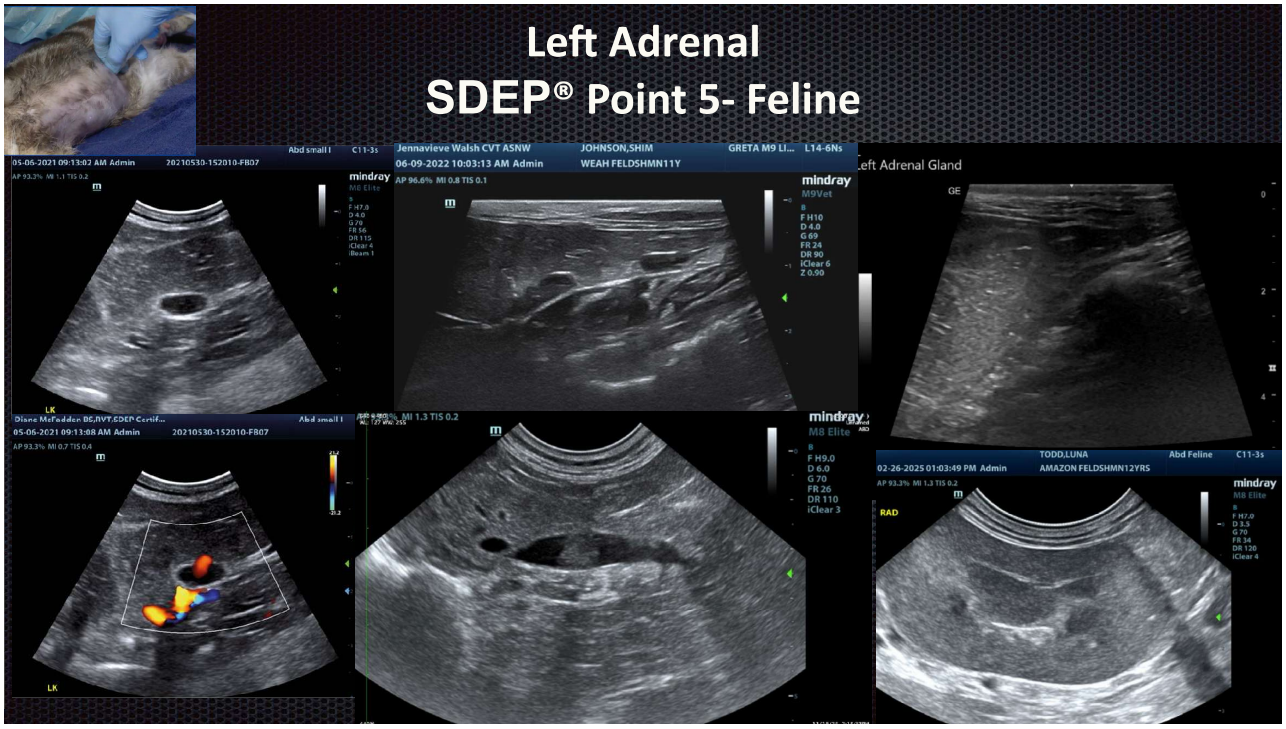

SDEP® Points 1-3 : Lower Urinary/Colon - Feline

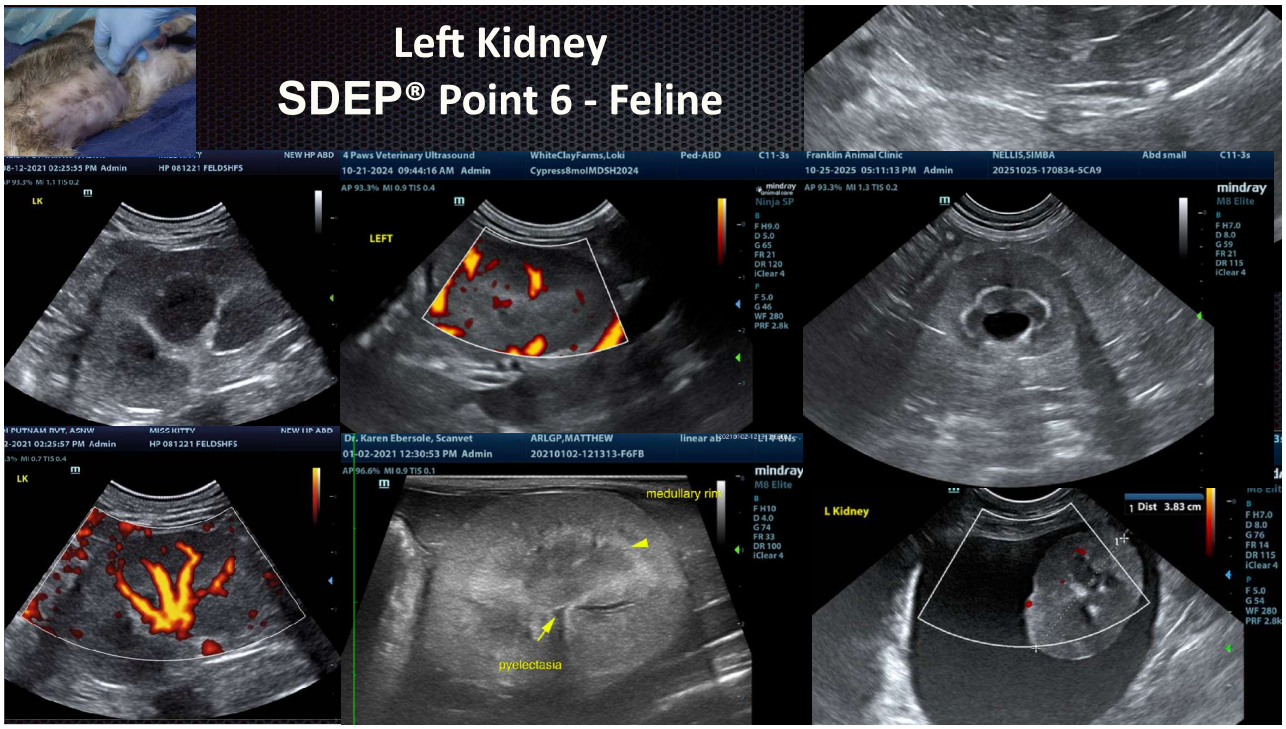

Iliac/Ao/Left Adrenal/Left Kidney
SDEP® Points 4-6 - K9
ILIACS
SDEP POS 5
LAD
SDEP POS 6
LK
Left Kidney

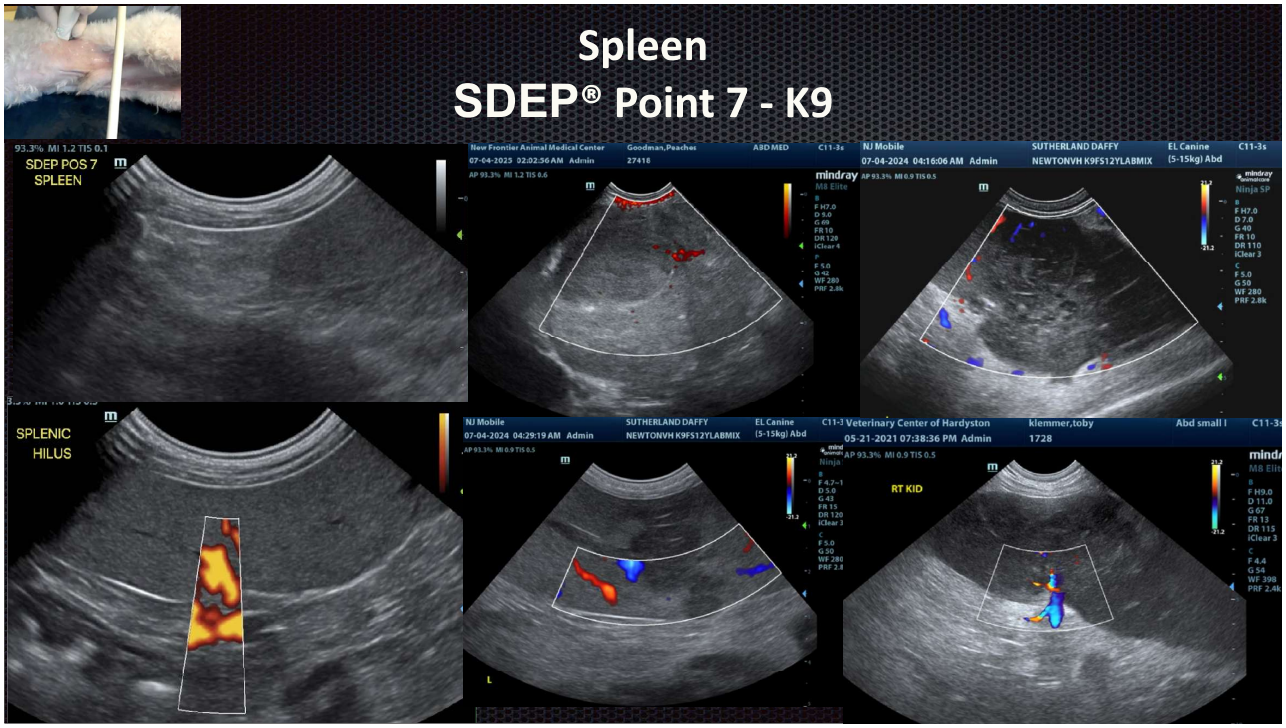

Left Adrenal
SDEP® Point 5 - K9

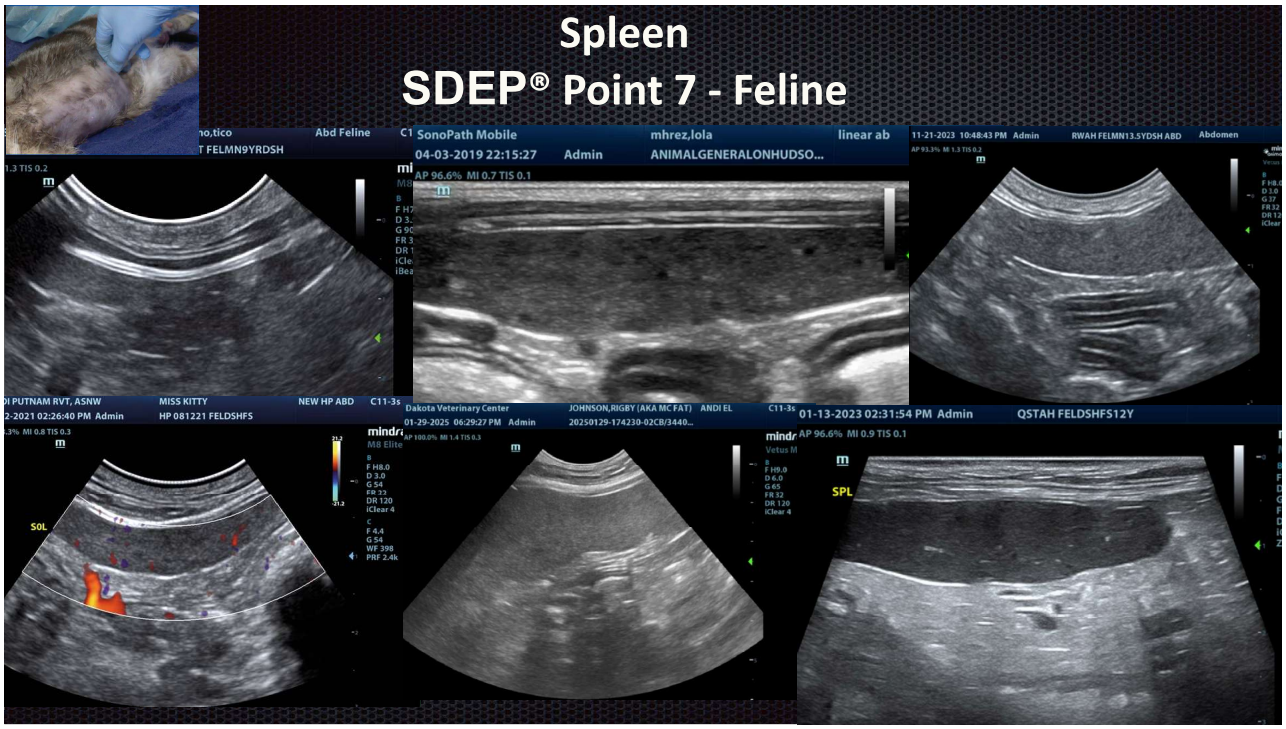

Left Kidney
SDEP® Point 6 - K9

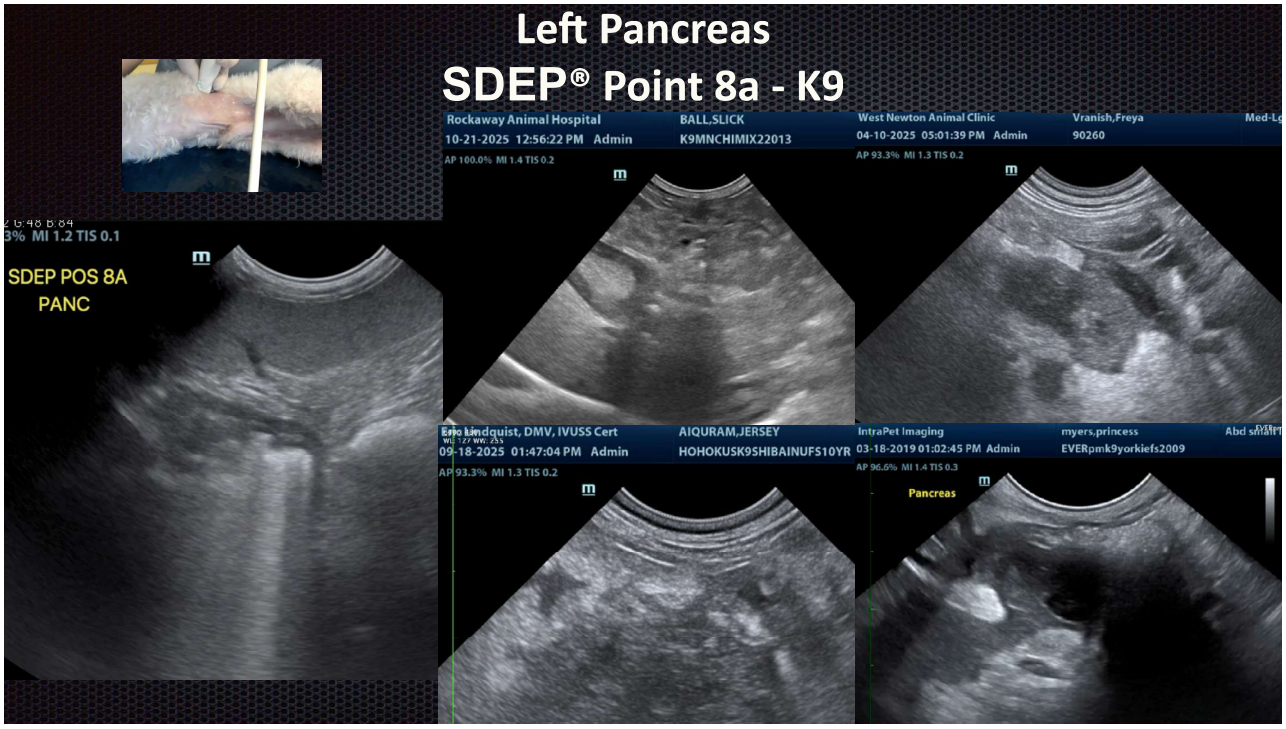

SDEP® Point 4
- Feline
mindray
M8 Elite
AORTIC THROMBUS
NORMAL AORTA

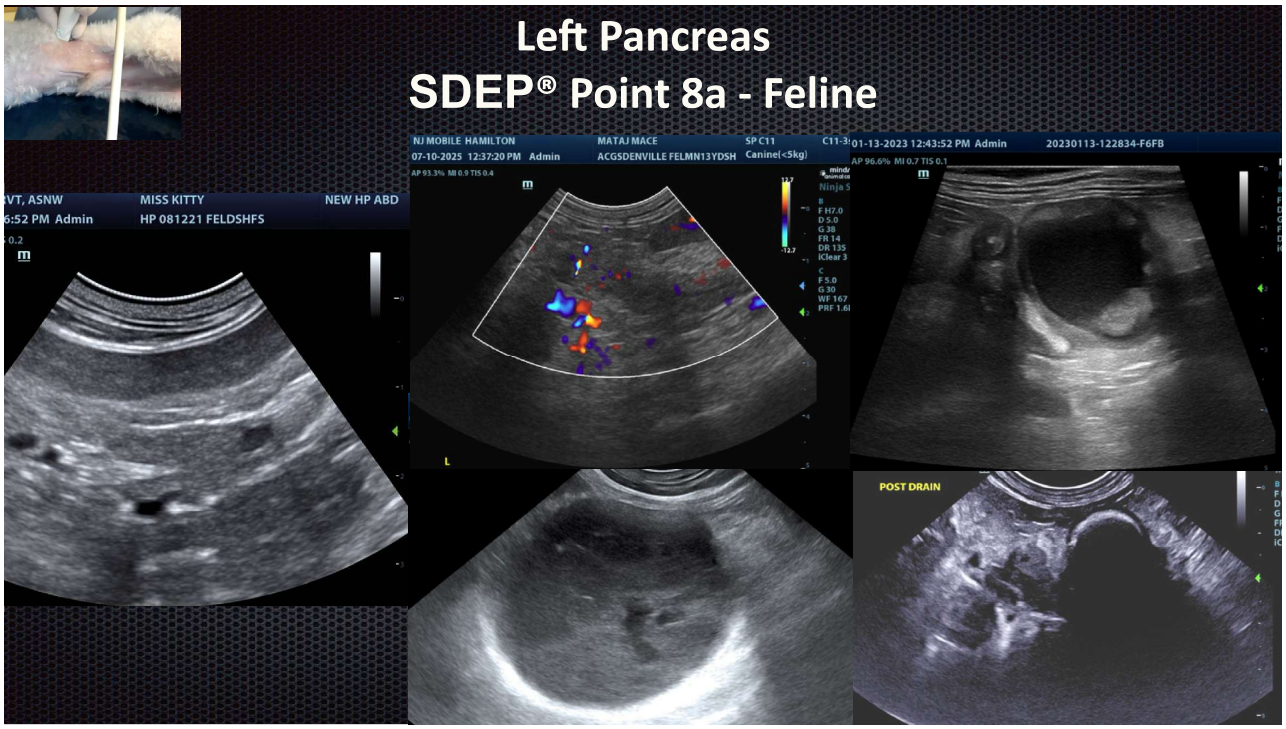

Left Adrenal
SDEP® Point 5- Feline
mindray

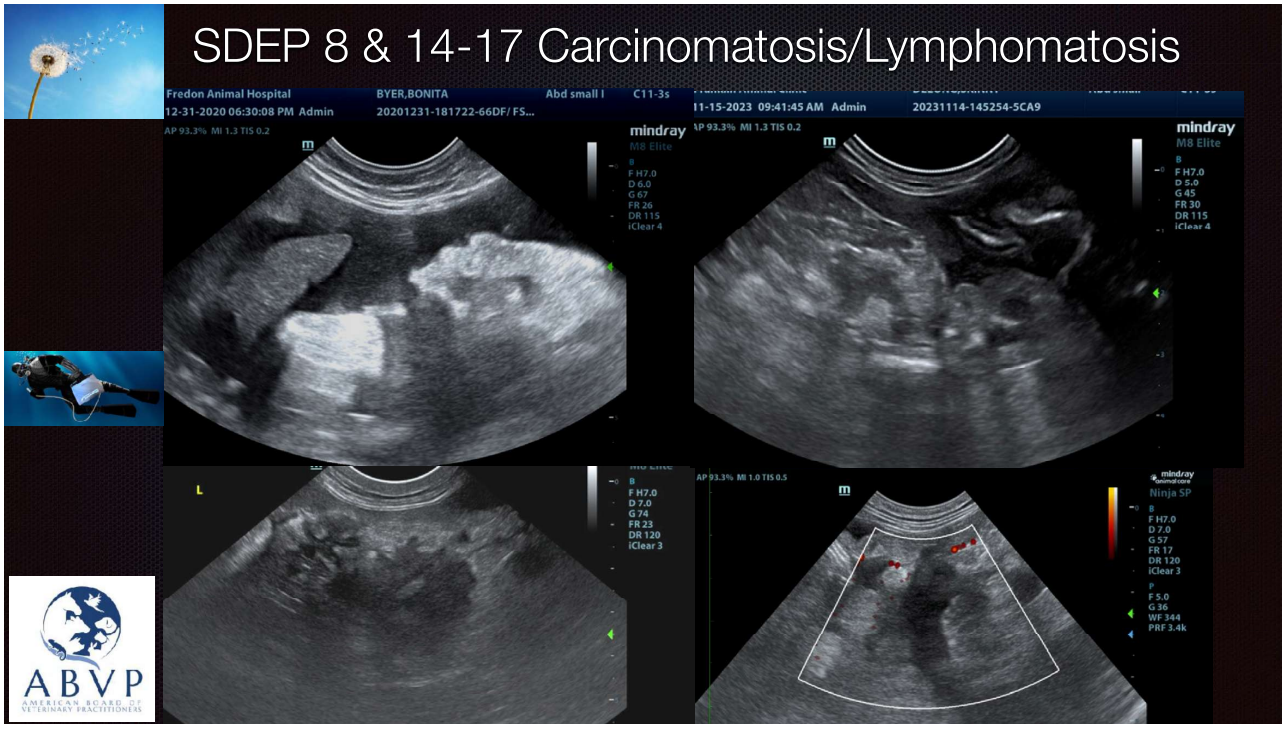

Left Kidney
SDEP® Point 6 - Feline
LEFT
medullary rim
pyelectasia
L Kidney
Dist 3.83 cm

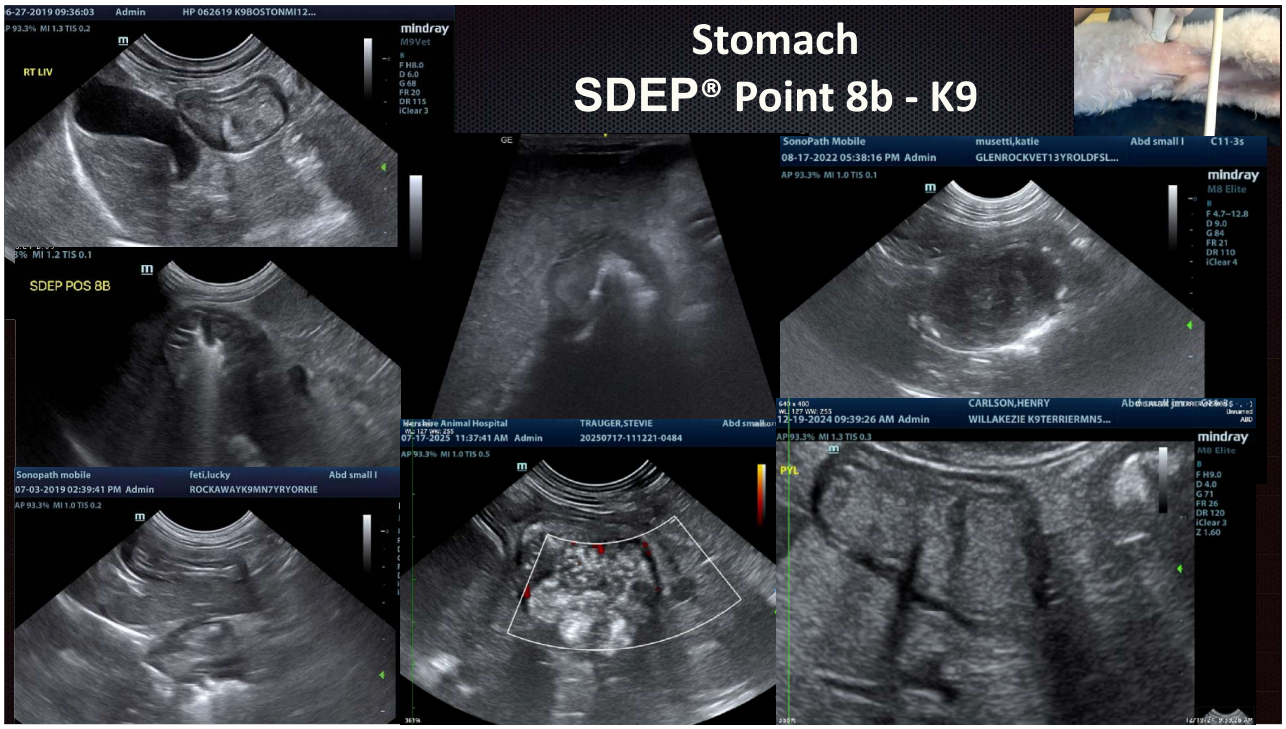

Spleen
SDEP® Point 7 - K9
SDEP POS 7
SPLEEN
SPLENIC
HILUS
RT KID

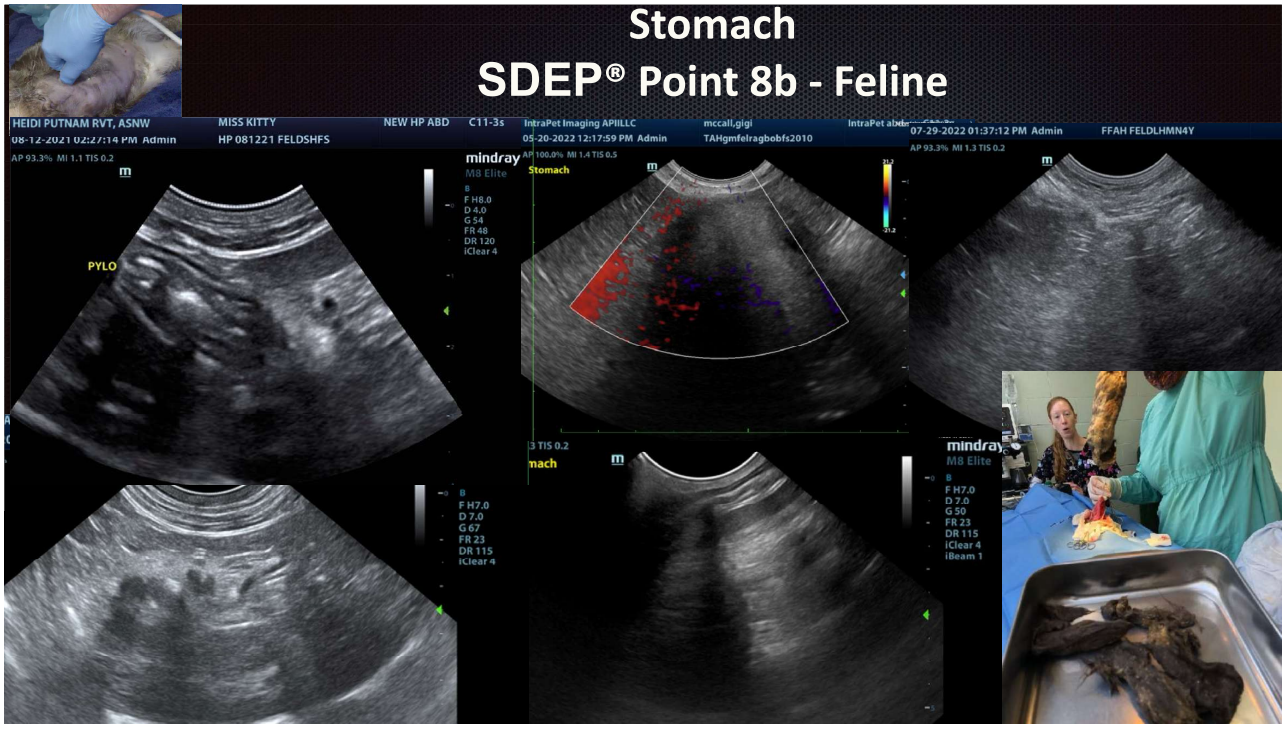

Spleen
SDEP® Point 7 - Feline
SOL
SPL

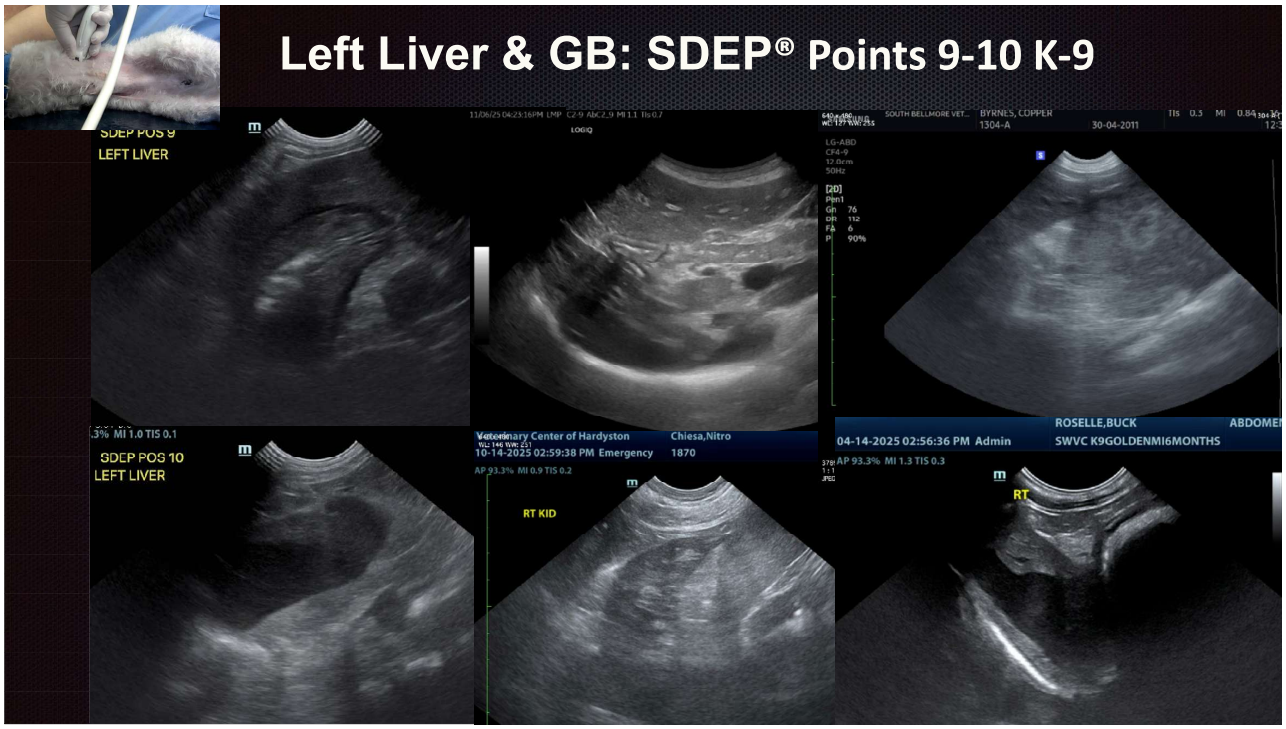

Left Pancreas
SDEP® Point 8a - K9
SDEP POS 8A
PANC
Pancreas

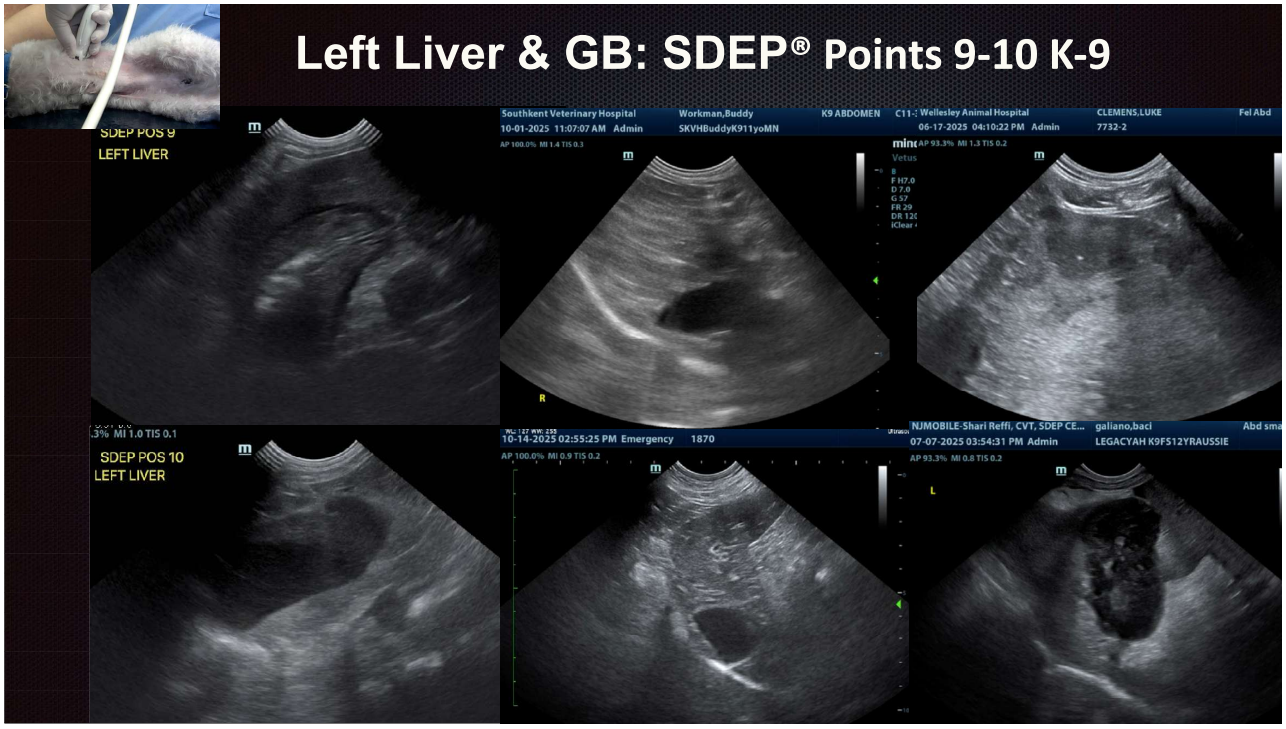

Left Pancreas
SDEP® Point 8a - Feline
POST DRAIN


SDEP 8 & 14-17 Carcinomatosis/Lymphomatosis
ABVP


Stomach
SDEP® Point 8b - K9
RT LIV
SDEP POS 8B
PYL


Stomach
SDEP® Point 8b - Feline
PYLO
Stomach


Left Liver & GB: SDEP® Points 9-10 K-9
SDEP POS 9
LEFT LIVER
SDEP POS 10
LEFT LIVER
RT KID
RT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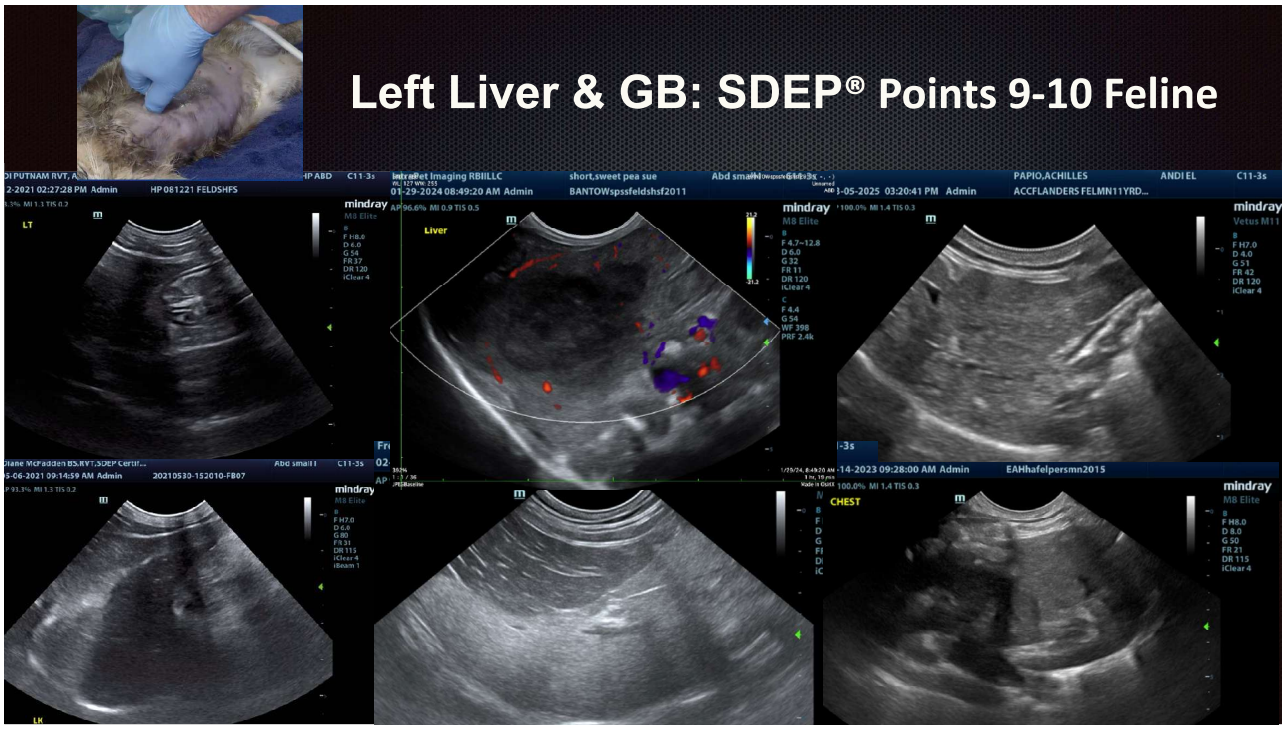
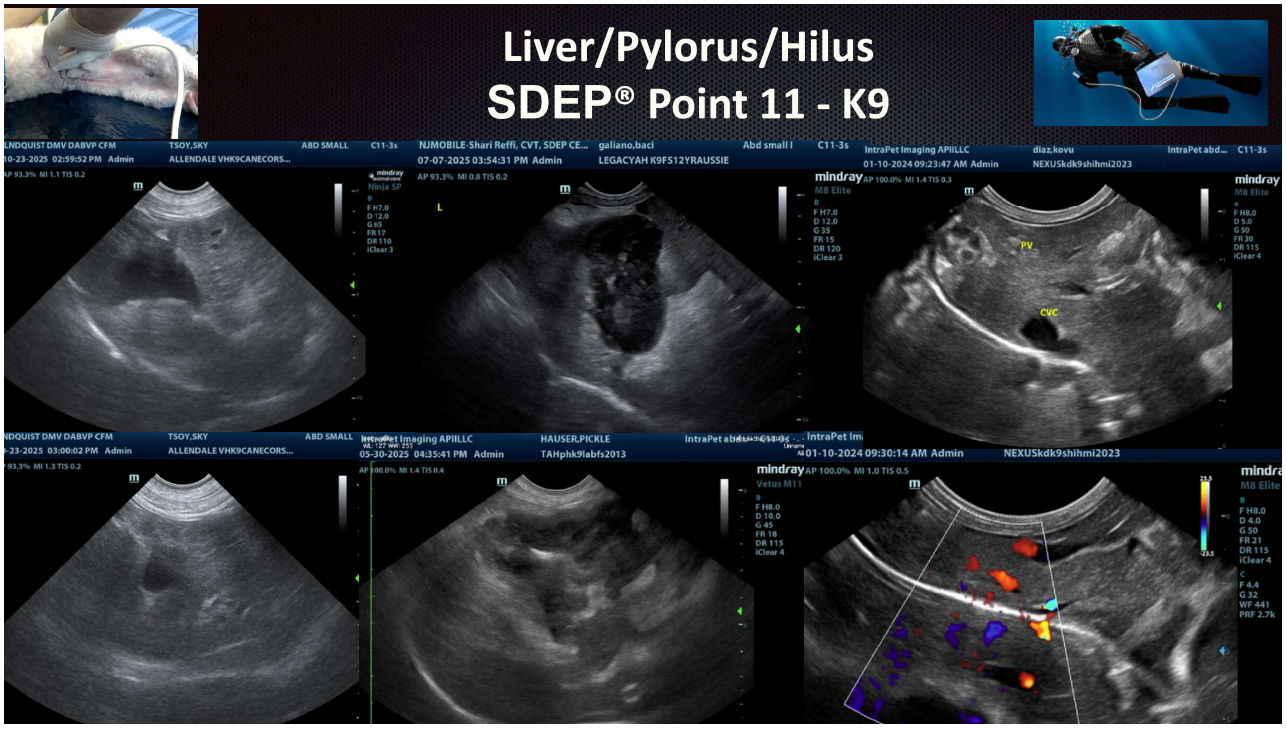
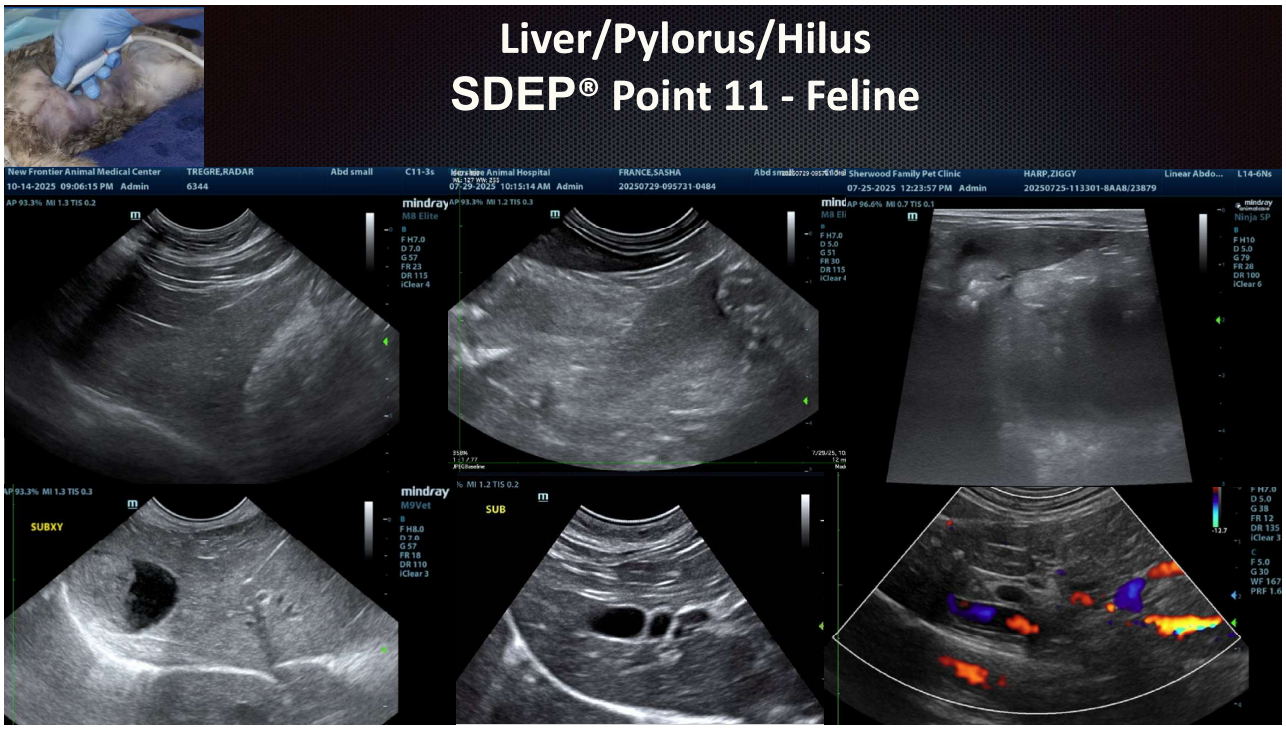
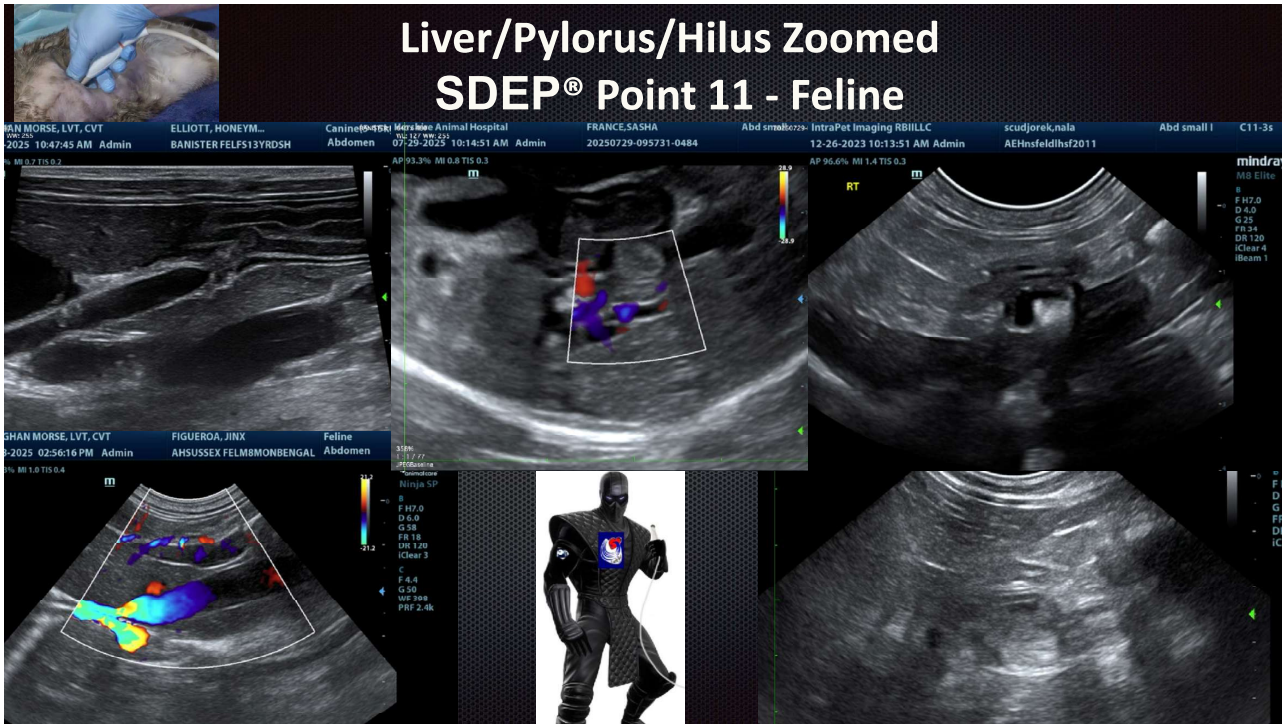
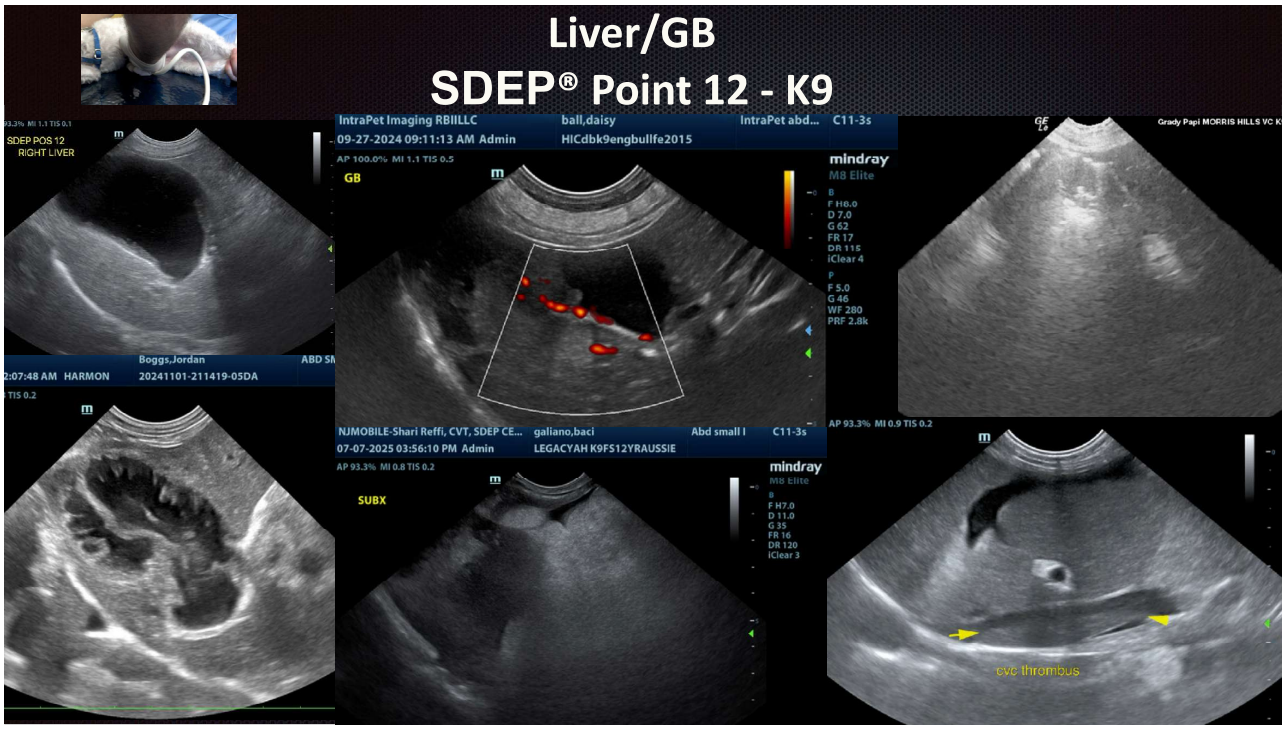
SDEP POS 9
LEFT LIVER
SDEP POS 10
LEFT LIVER

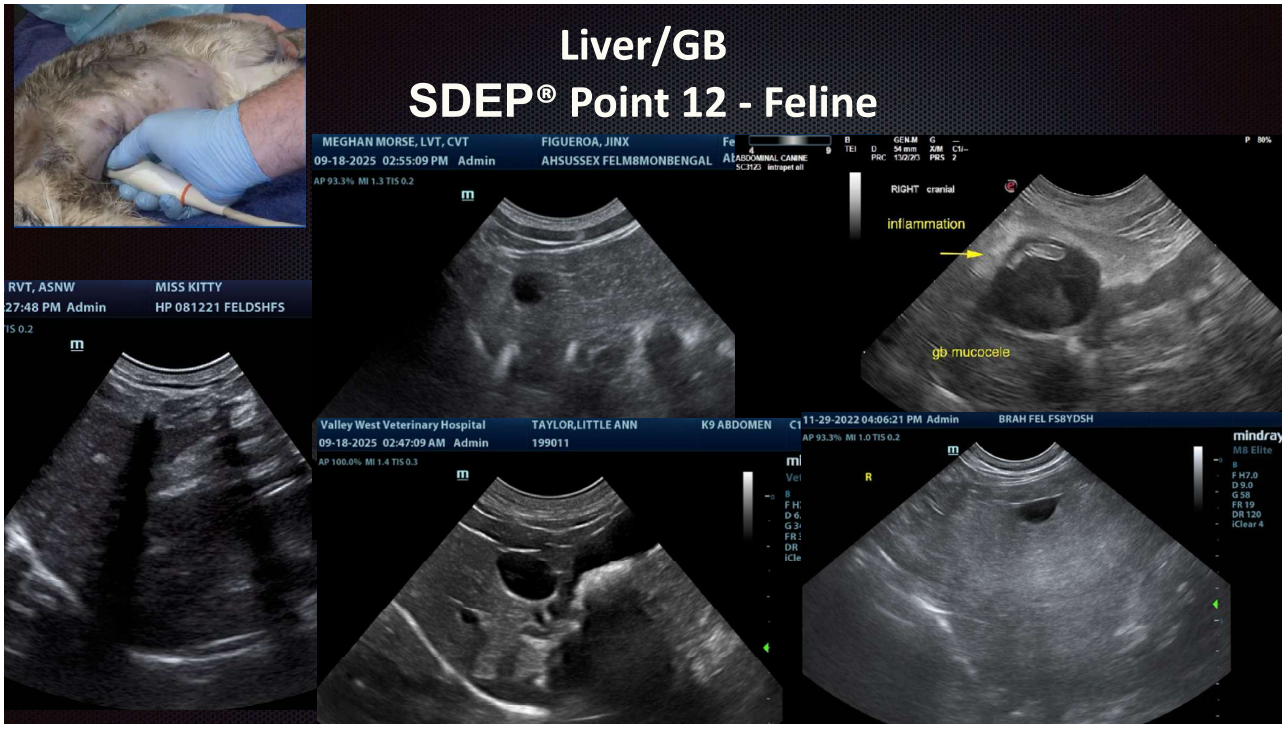

Left Liver & GB: SDEP® Points 9-10 Feline
Liver
CHEST

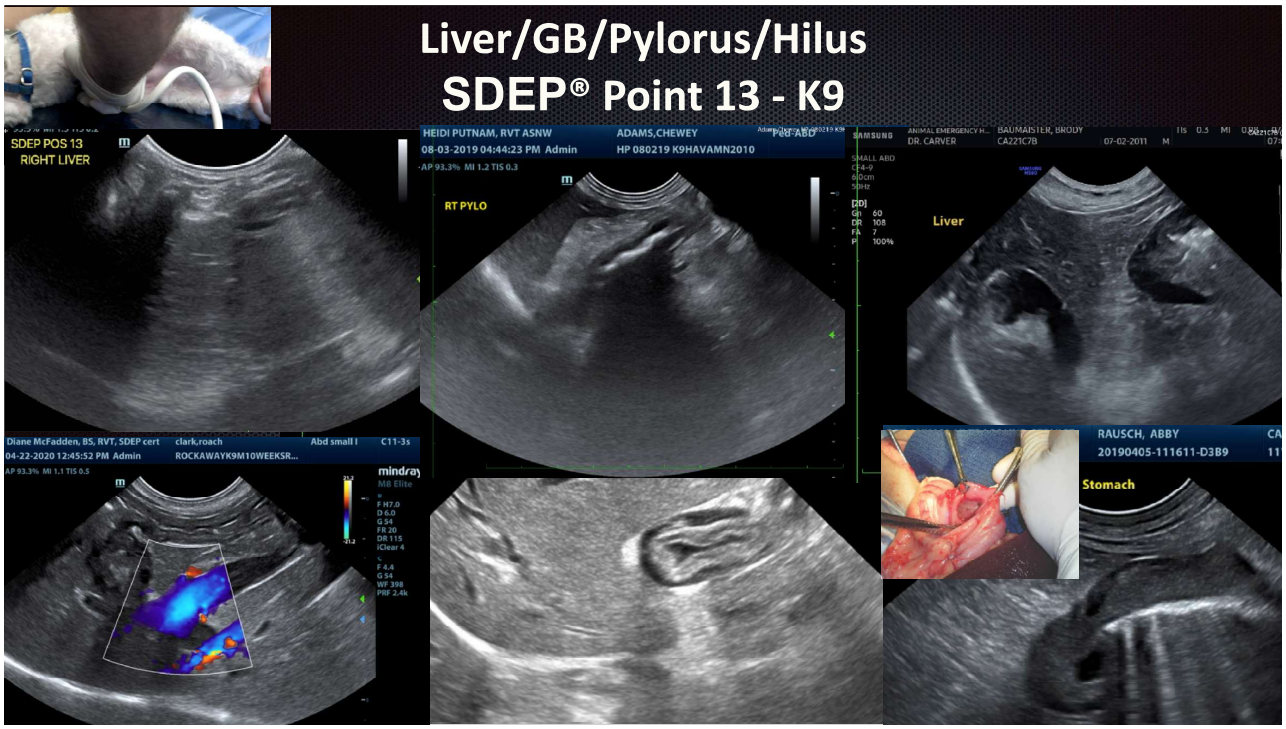

Liver/Pylorus/Hilus
SDEP® Point 11 - K9
PV
CVC

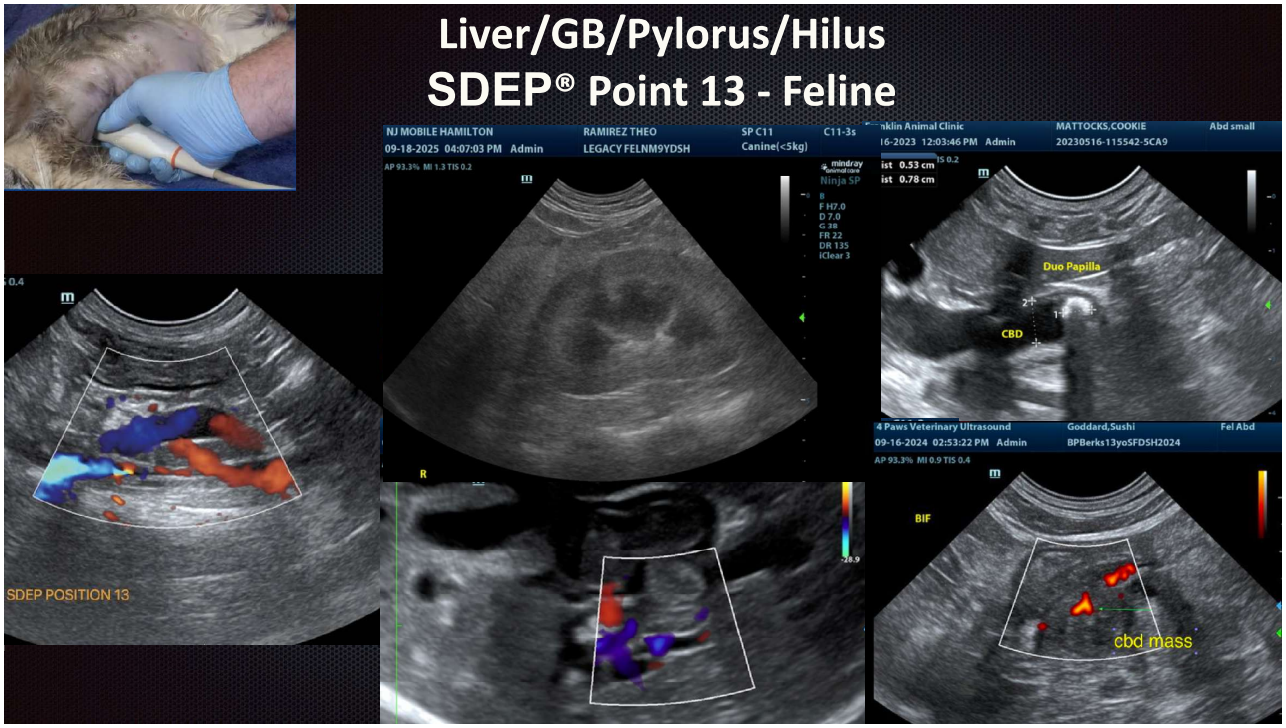

Liver/Pylorus/Hilus
SDEP® Point 11 - Feline

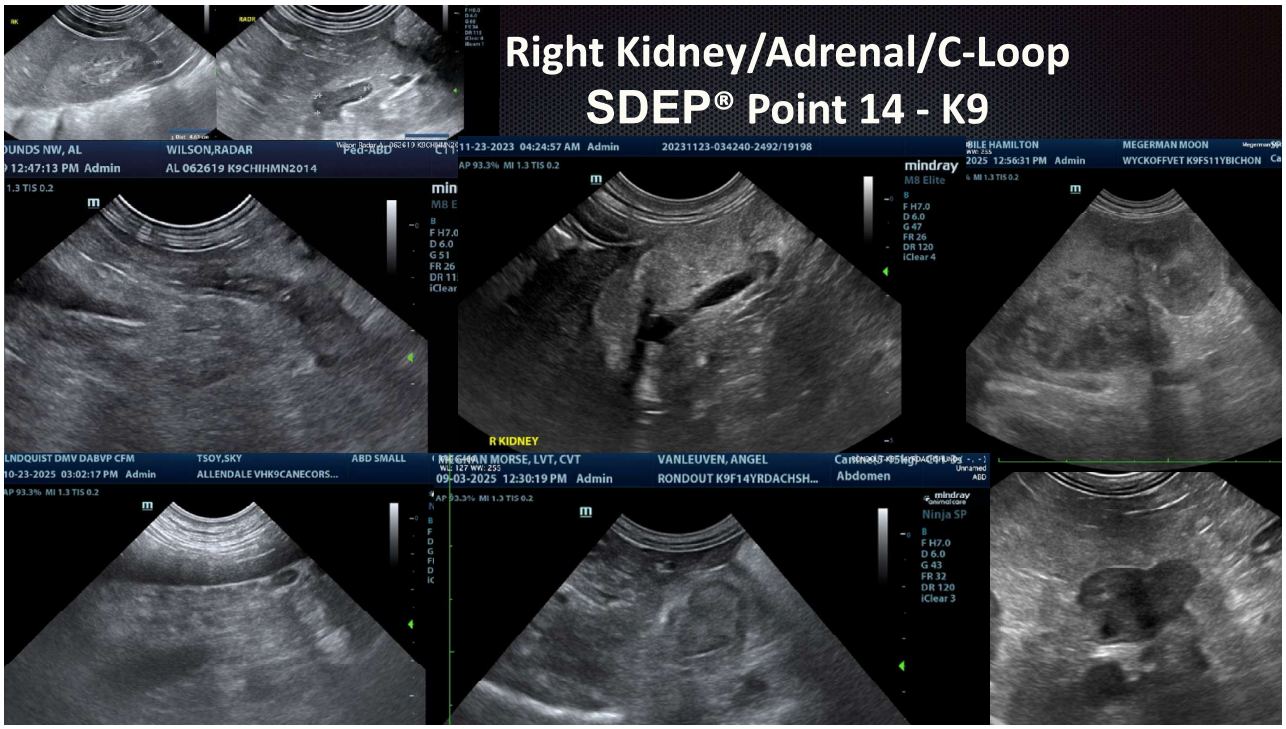

Liver/Pylorus/Hilus Zoomed
SDEP® Point 11 - Feline

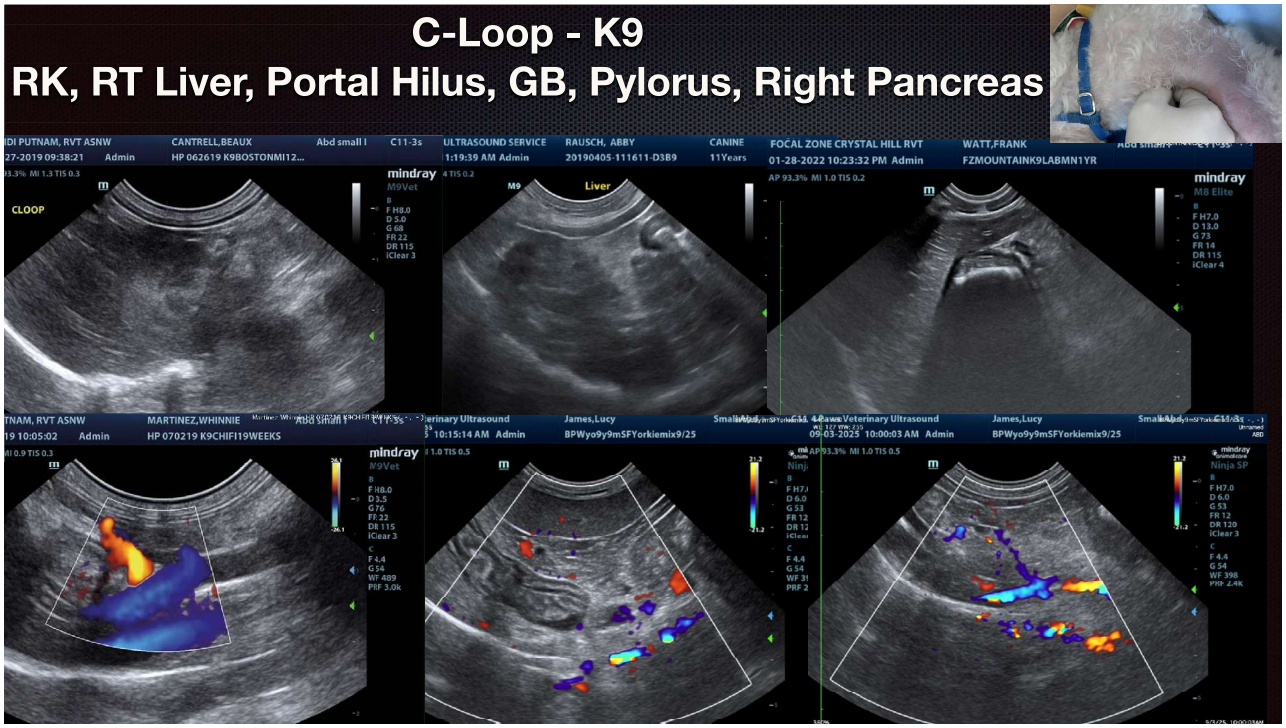

Liver/GB
SDEP® Point 12 - K9
SDEP POS 12
RIGHT LIVER
GB
SUBX
evc thrombus

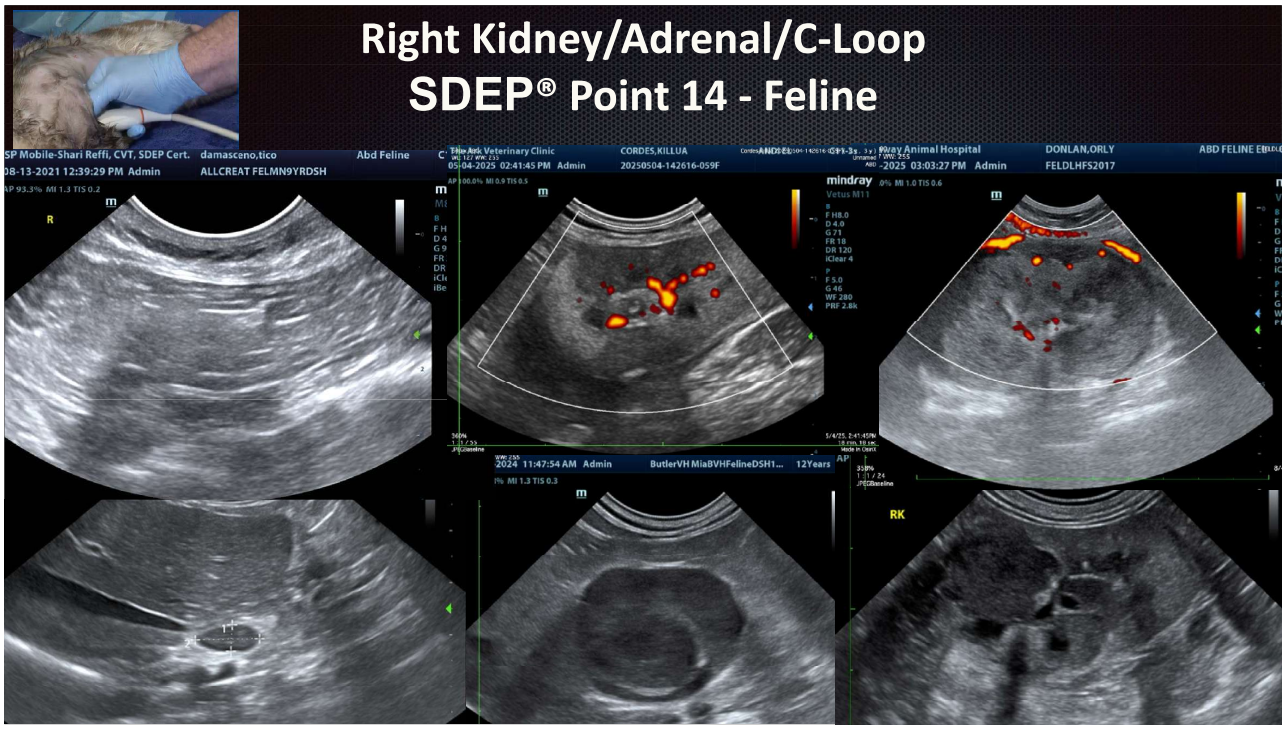

Liver/GB
SDEP® Point 12 - Feline
inflammation
gb mucocele

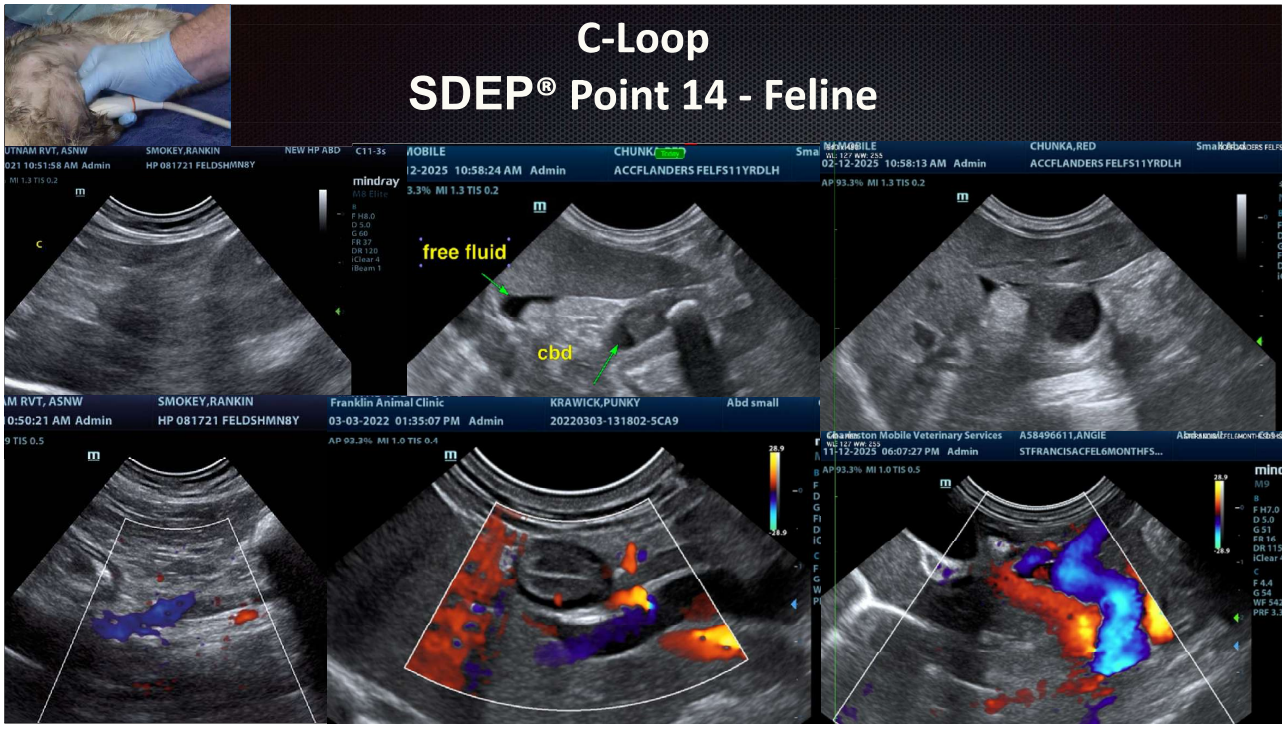

Liver/GB/Pylorus/Hilus
SDEP® Point 13 - K9
SDEP POS 13
RIGHT LIVER
RT PYLO
Liver
Stomach


Liver/GB/Pylorus/Hilus
SDEP® Point 13 - Feline
SDEP POSITION 13
Duo Papilla
CBD
BIF
cbd mass


Right Kidney/Adrenal/C-Loop
SDEP® Point 14 - K9
R KIDNEY


C-Loop - K9
RK, RT Liver, Portal Hilus, GB, Pylorus, Right Pancreas
CLOOP
Liver


Right Kidney/Adrenal/C-Loop
SDEP® Point 14 - Feline


C-Loop
SDEP® Point 14 - Feline
free fluid
cbd

SDEP® Points 15-17 - “Bears In The Forest”
Bears in the Forest
Sandwiches!
BIF SOUTH
Elephino Lesions

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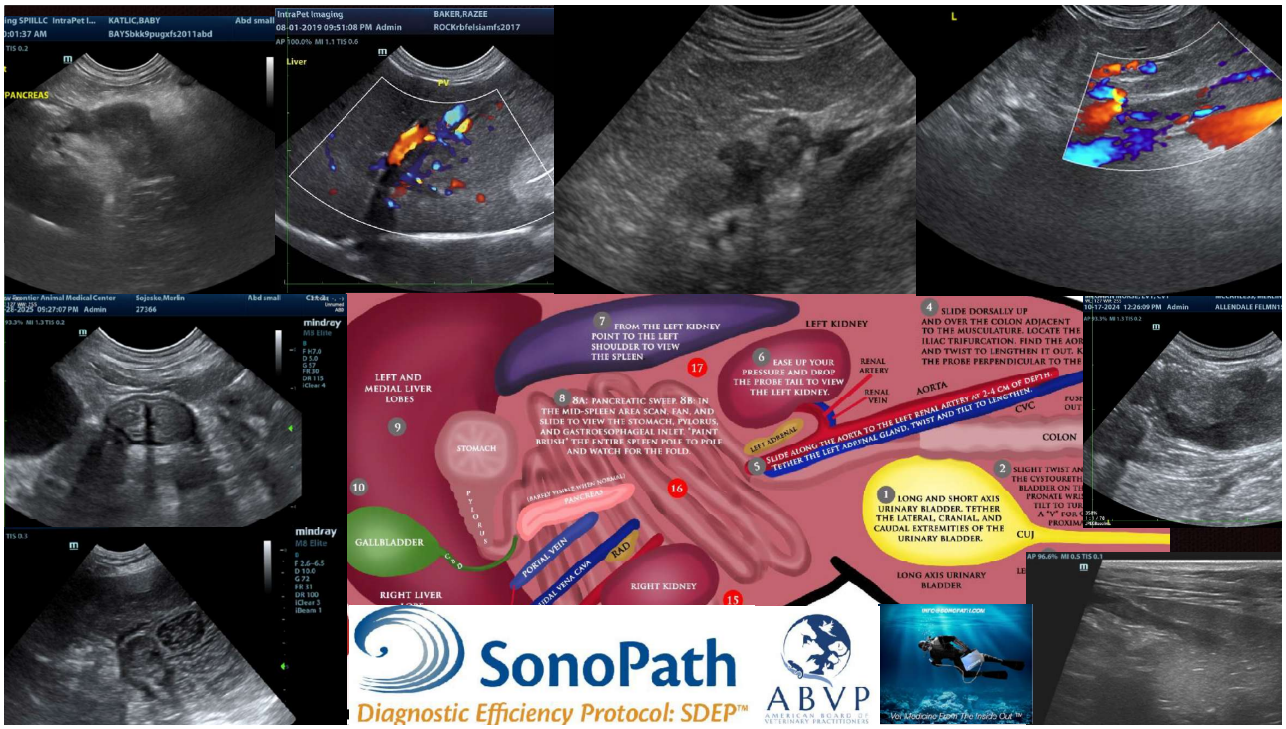
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Nova Scotia
July 2027

Some (Echo) Case Vignettes

John D Bonagura, DVM, MS, DACVIM (Cardiology, Internal Medicine), FASE

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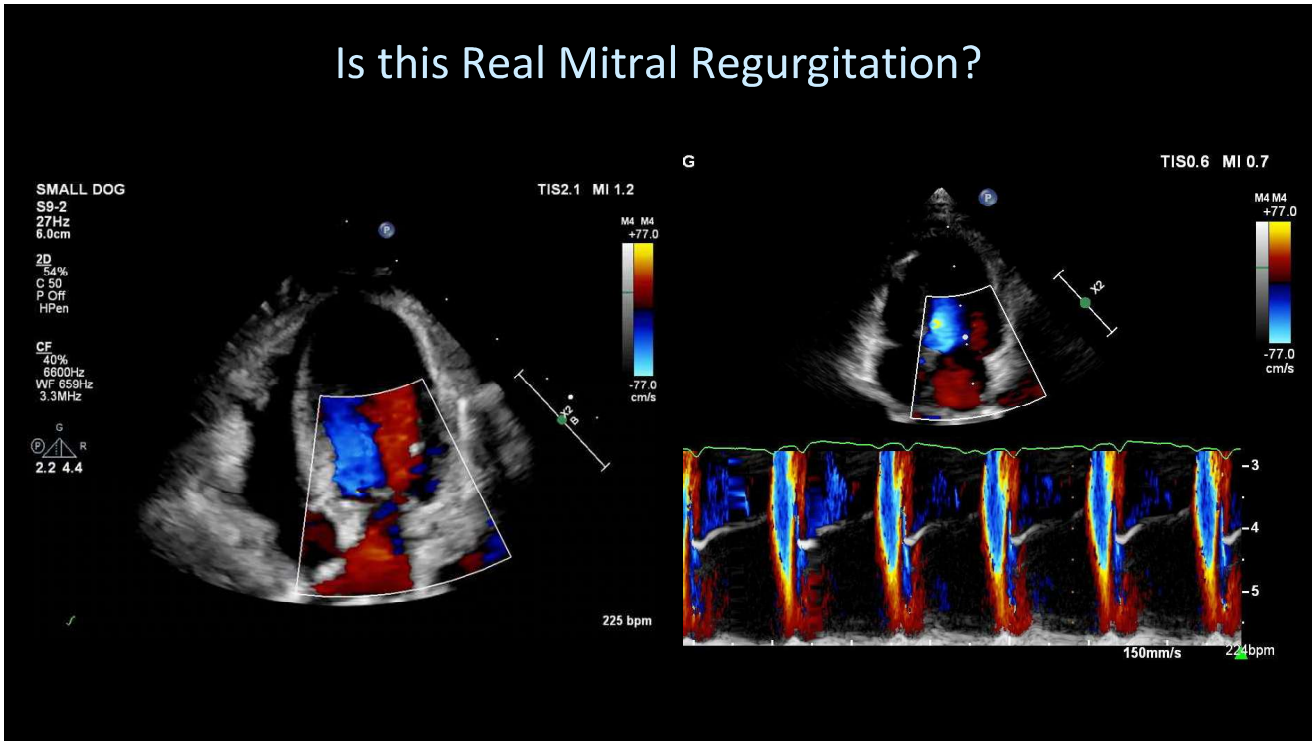
Adjunct Professor of Cardiology, North Carolina State University
College of Veterinary Medicine
jdbonagu@ncsu.edu

1

1

Is this Real Mitral Regurgitation?



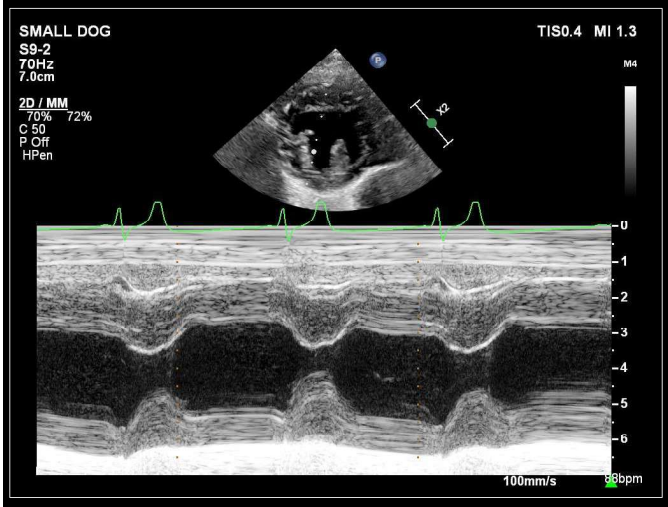
2

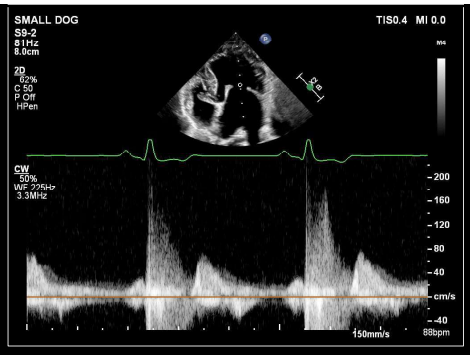
Abbey – Golden Doodle

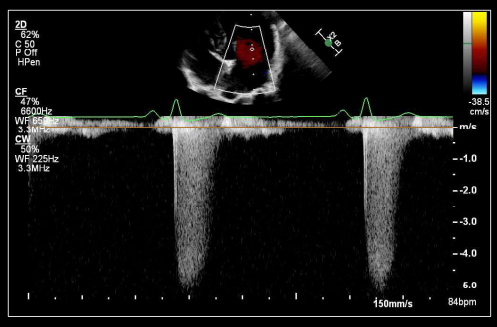
- Medical Rec #: 1106981
- Weight: 10.2 kg BSA: 0.48 m²
- DOB: 8/25/2014 Age: 11 years FeS
- ER Admission: "Severe respiratory distress
  - Recent onset" – Some Travel history (East coast→ CO↑)
- Multiple B-lines; systolic murmur, left sided; dusky
- Diffuse bilateral lung crackles
- BP-sys: 85 mmHg
- IV furosemide given RDVM and at intake + O2 + Butorphanol
- Request: ER evaluation & **cage-side POCUS** (focused Echo)

3

M-mode (LV) & CW Doppler Mitral Valve

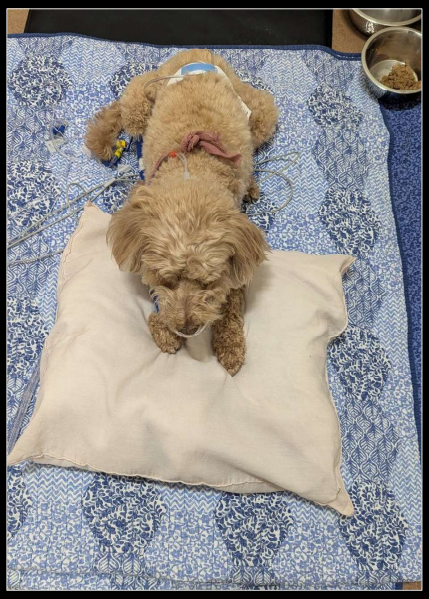






LVIDDn = 1.3 (post diuretics)

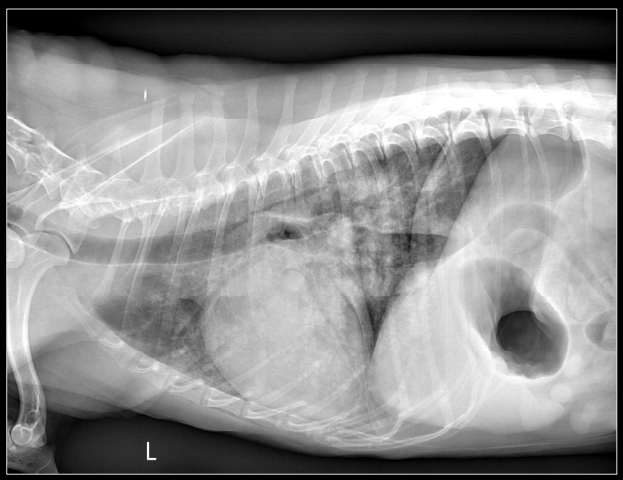
4

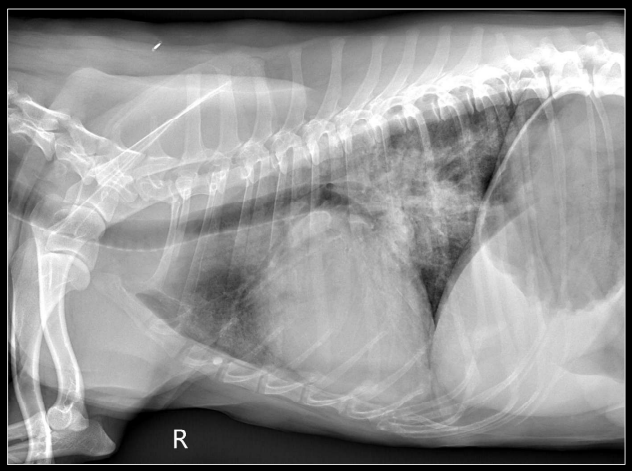


Due to low arterial oxygen saturation & effort:
Placed on high-flow oxygen by our CC service

5

Left & Right Lateral Radiographs (day of admission)
Assessment?





6

Admission – DV

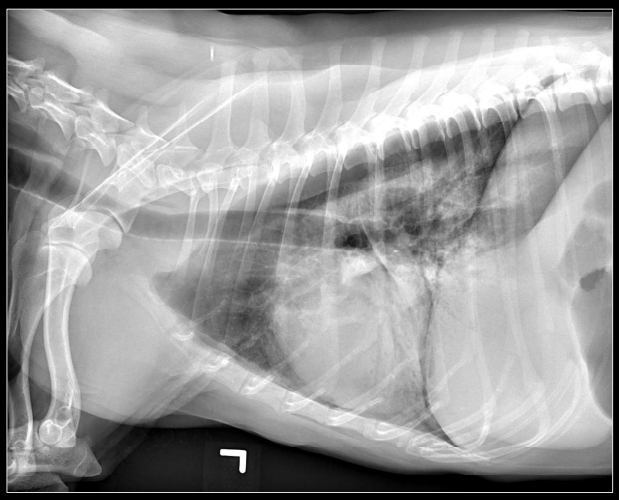
7

Abbey – Follow up (12-18 h)

- *Little improvement* in respiratory effort – better ABG
- Reducing urine output
- Key Lab findings:
  - p02 62 → 76 mm Hg (C02 = 26 to 34 mm Hg)
  - Sodium WNL, Potassium (mildly decreased) Cl 114 – 117
  - CBC = mild mature neutrophilia
  - Serum biochemistries: increased C-reactive protein (25.6 ref <10)
  - Glucose 82 mg/ml (WNL); serum Creatinine 0.66 mg/dl (WNL)
- Follow up radiographs

8

Follow up (≈ 40h post admission)



9

258653 ‘Lexy’
Canine, 11 yr, Maltese, F, 7 kg

Dr. Anna McManamey; Dr. Phil Fox (Pathology)

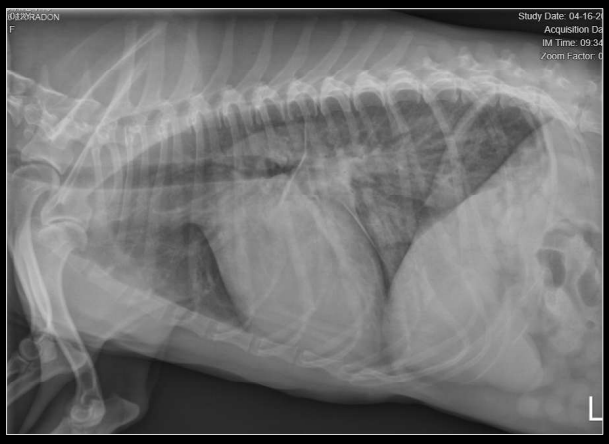
Presented for acute respiratory distress

- Heart murmur detected about 6 months PTA
- History of UTI, Rx Amoxicillin; Hx of dry cough, Rx Doxycycline
- Developed acute hepatopathy; Symptomatic Rx at RDVM
- ER for acute respiratory distress dyspnea, B lines noted on TFAST
- Grade 4/6 systolic murmur of MR
- SBP (Doppler) forelimbs up to 250 mmHg; rear limbs 70 mmHg

10

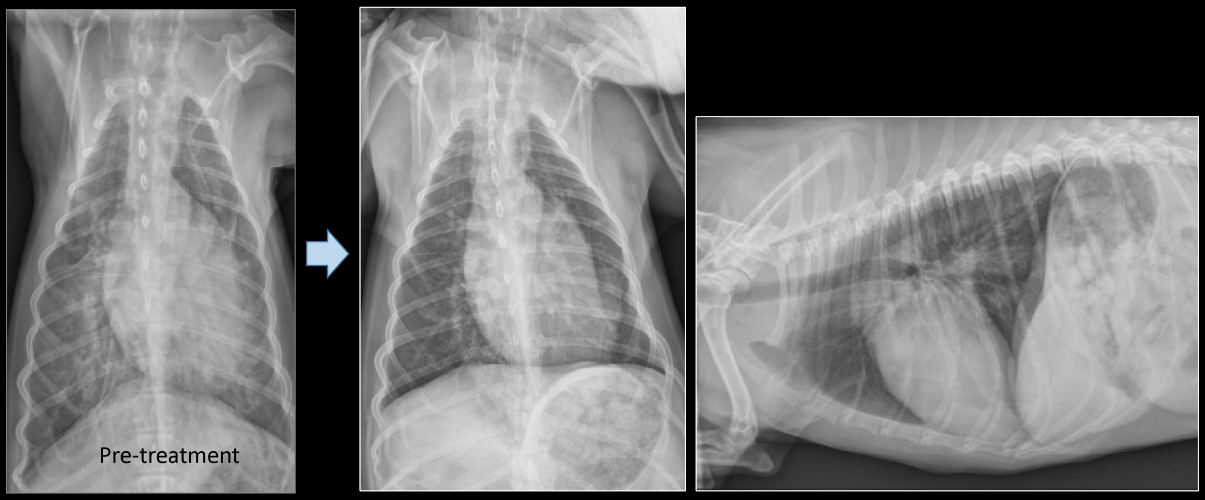
10

Admission Radiographs –
What is your tentative diagnosis?
What therapy would you administer?

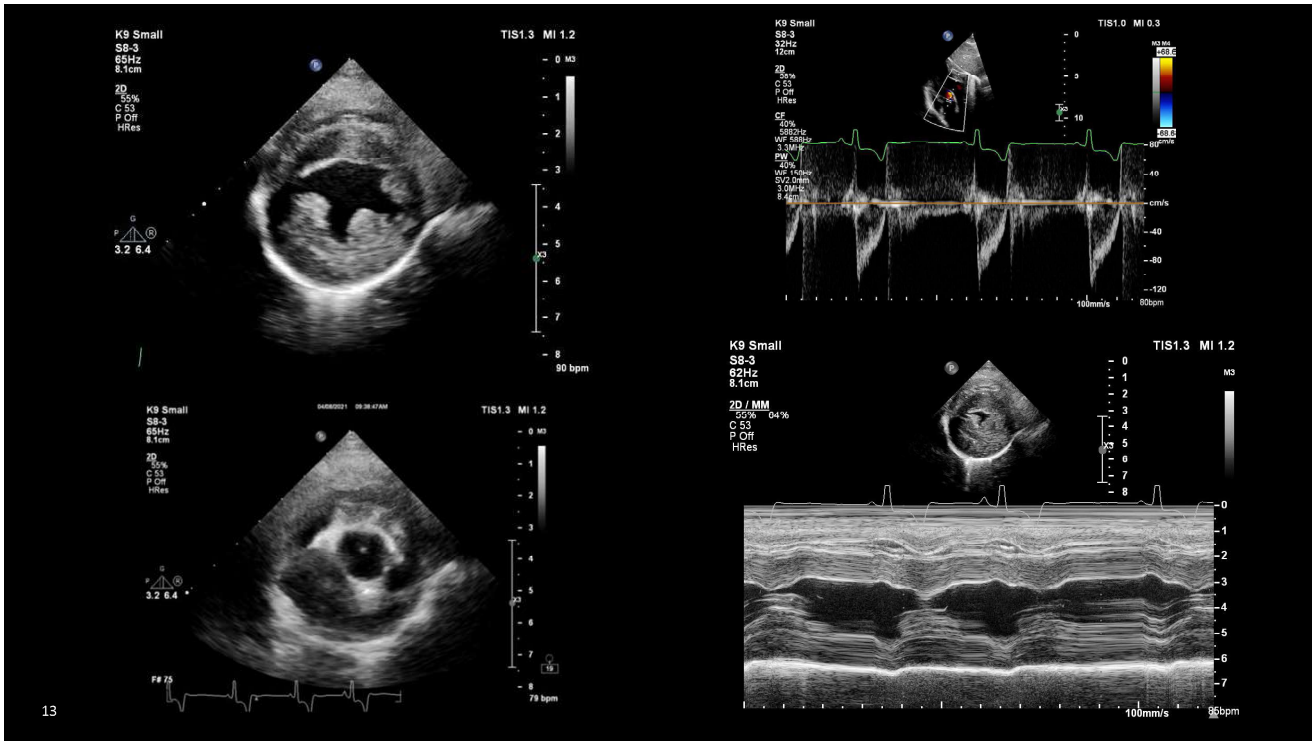


11

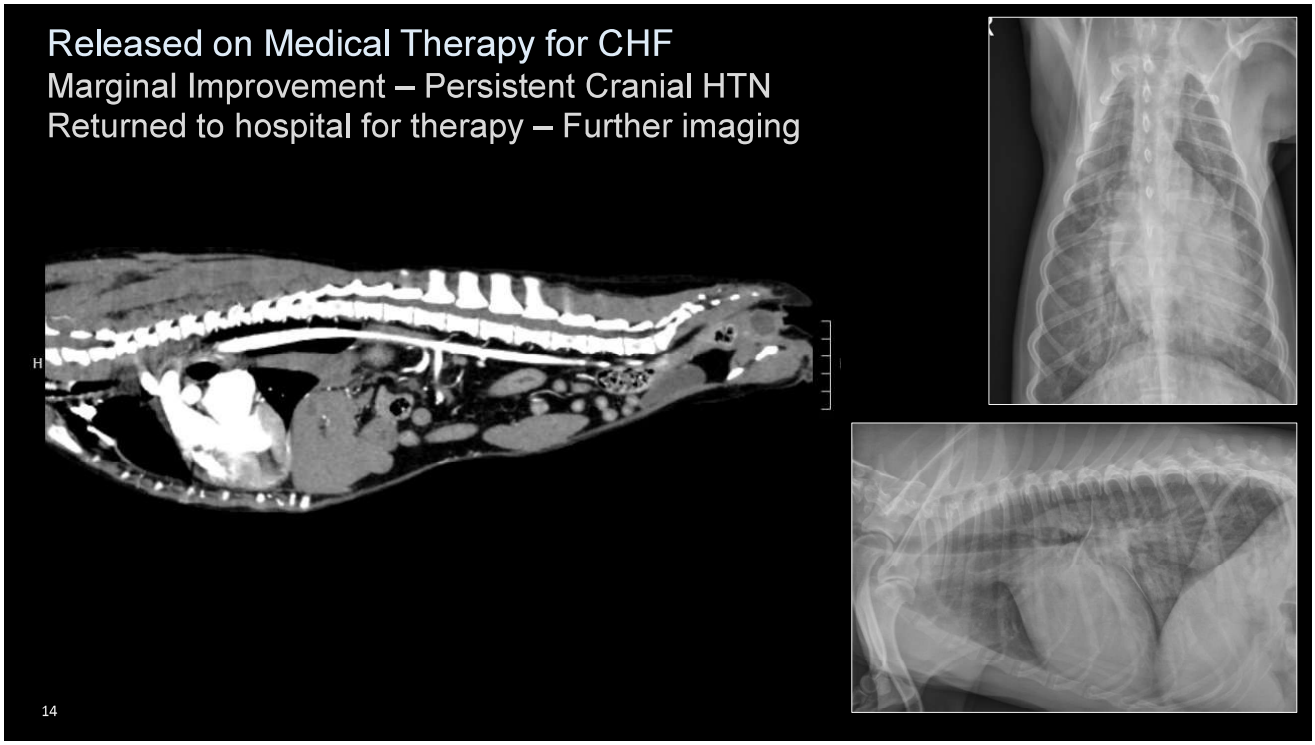
Post-Rx Radiographs



12


K9 Small
S8-3
65Hz
8.1cm
TIS1.3 MI 1.2
90 bpm
K9 Small
S8-3
32Hz
12cm
TIS1.0 MI 0.3
100mm/s
80bpm
K9 Small
S8-3
65Hz
8.1cm
TIS1.3 MI 1.2
79 bpm
K9 Small
S8-3
62Hz
8.1cm
2D / MM
TIS1.3 MI 1.2
100mm/s
86bpm
13

13


Released on Medical Therapy for CHF
Marginal Improvement – Persistent Cranial HTN
Returned to hospital for therapy – Further imaging
14

14

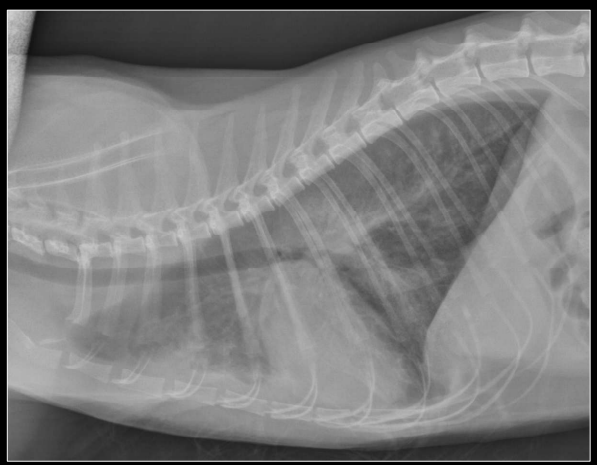
234188 Tiger 5-year-old FeS DSH Cat

- Presented for respiratory distress; referred for Cardiac Eval
- Indoor/outdoor cat noted to be lethargic, vomited once
- Breathing faster – eventually labored
- RDVM – cardiomegaly and thoracic fluid – IV furosemide (↑ dose)and pimobendan were administered with sedation
- Snap NT-pBNP "positive" and FeLV/FIV tests negative.
- Exam: No murmur evident; tachypnea; Work-up → Imaging
- Clinical Labs: BUN severely elevated (133 mg/dl, normal <30)

15

15

Admission Radiographs (after Lasix)



Echo Videos ⇒

16

16

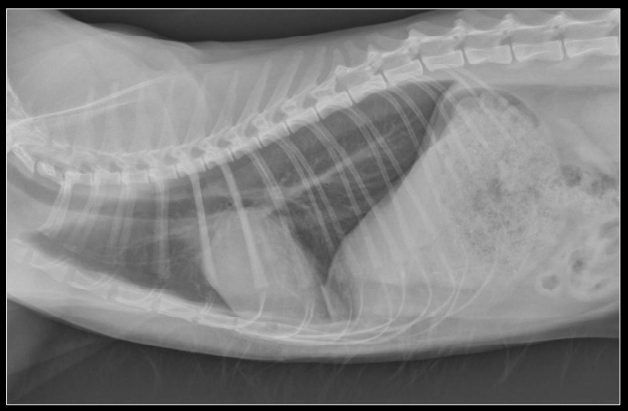
234188 Tiger 5 year old FeS DSH Cat

- Diagnosis?
  - Morphology
  - Systolic function
  - CHF or not?
  - What other diagnostic tests should be done?
- Initial therapy?
  - Already received furosemide & pimobendan at RDVM
  - Was sedated and given O_2
  - Chronic treatment if CHF?

17

17

Eventually improved (marked azotemia)
Radiographs at Discharge from Hosp



18

18

Diesel Vernon (239485)
About 1 year old M Boxer

Dr. Lara Barron & Team

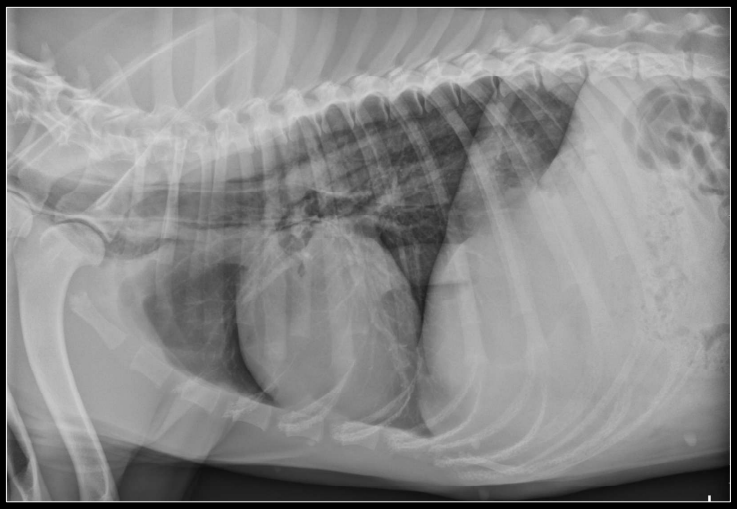
Presented for abdominal distension

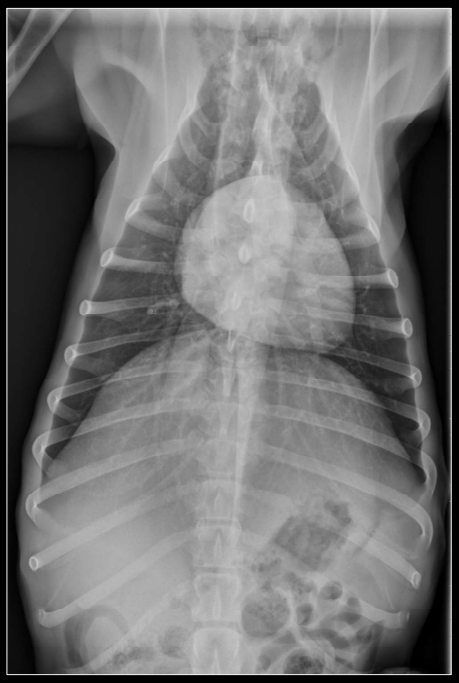
- Noted as a puppy
- Marked ascites (modified transudate)
- No murmurs or arrhythmias evident
- Normal JVP
- Clinical labs do not explain signs
- Selected aspects of workup will be shown

19

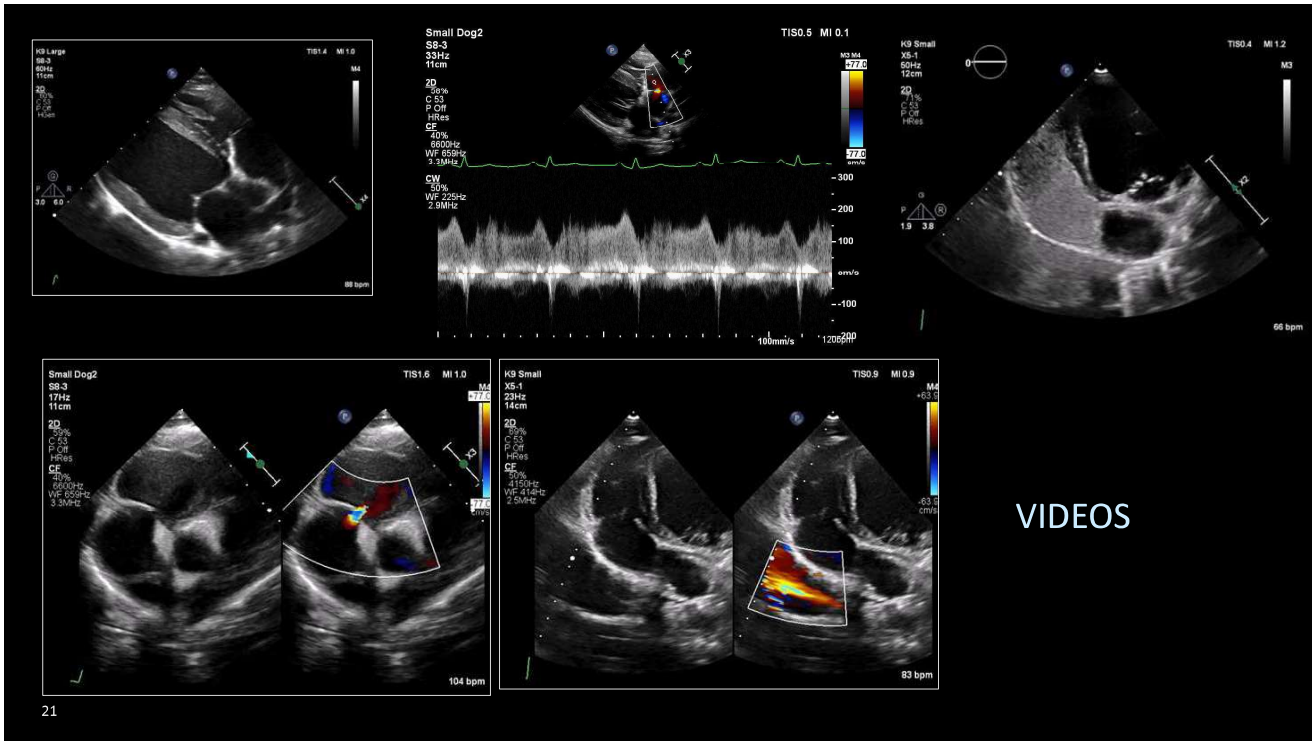
19

Radiography





20



21

Edison

- Medical Rec #: 1106924 Weight:
- DOB: 9/14/2025
- 1 month Male Meishan Pig
- Diarrhea & Cardiac murmur detected
- General PE not too remarkable other than murmur
- Examination: somewhat stressed ? Tachypnea
- Loud 4/6 holosystolic murmur – radiates widely with PMI – left apical region
- Echo (!!!) – Let's try to find all the bits

22

Echocardiographic Interpretation
Case Studies

John D. Bonagura, DVM, DACVIM (Cardiology, SAIM), FASE
Adjunct Professor – Cardiology, Colorado State University College of Veterinary Medicine
Adjunct Professor of Cardiology North Caroline State University, College of Veterinary Medicine
Professor Emeritus, Veterinary Clinical Sciences, The Ohio State University

OVERVIEW

Echocardiography is the noninvasive standard for assessing heart disease in veterinary medicine offering balance between convenience, availability, cost-effectiveness, and diagnostic yield. Echo images delineate morphology and function of the heart, along with the appearance of contiguous great arteries and venous entries. Pleural and pericardial effusions, mass lesions within or around the heart, and clinically relevant congenital and acquired diseases of cardiac valves, myocardium, and great arteries can be recognized. When Doppler Echo studies are included, the velocity patterns of normal and abnormal blood flow can be tracked. Complementary Doppler modalities deliver quantitative estimates of heart function, intracardiac pressures, and blood flow.

The echocardiographic study should contribute to a definitive cardiac diagnosis, delineate the severity of disease, inform the prognosis, and guide medical, interventional, or surgical treatments. The study should be placed in clinical context and cannot replace a careful history and physical examination. For example, it would be unusual to diagnose a clinically relevant valvular lesion by echocardiography in the complete absence of a heart murmur. Likewise, basic thoracic radiography remains a critical examination in patients with acute or chronic respiratory signs, considering the broad differential diagnosis of cough, abnormal ventilation, and hypoxemia. Additional examinations including electrocardiography (for arrhythmias), serum biochemistries, heartworm tests, and circulating cardiac biomarkers are often contributory to the diagnosis or to patient management.

Noncardiac US imaging is an essential part of entry-level echocardiography. Learning to recognize ascites and pleural effusions are first steps in substantiating a diagnosis of right-sided congestive heart failure (CHF). Additionally, pulmonary US can be successful in identify lung infiltration or pulmonary edema (B-lines), especially in the point-of-care emergency room setting. However, simple thoracic radiography is often superior for assessing lung pathology or identifying pulmonary edema in cardiac patients once they are stable.

Echocardiography should be performed, and echocardiograms interpreted by examiners with appropriate technical training and understand the landscape of cardiovascular disease, appreciate the issues pertinent to the specific patient, and recognize the limitations of the study. The study should be interpreted by an individual capable of integrating information from all sources, including the history, physical examination, and laboratory studies, should ultimately direct patient management. Having said this, the sonographer must be sufficiently knowledgeable about cardiac diseases to update and refine the examination based on contemporary (in the moment) findings.

There are a number of diagnostic pitfalls that must be appreciated. For example, examiners should not over-interpret day-to-day variability. Many echocardiographic measurements can change by 10% or more due to biologic variability, differences in operator technique, and interobserver factors when measuring images. For example, a decrease of 5% in ejection fraction of the left ventricle (LV) or ventricular fractional shortening might represent a change of clinical importance or just normal daily or measurement variation. Echocardiographic studies can be misinterpreted when normal physiologic findings are mistaken for evidence of disease. This is common when assessing LV systolic function in large-breed dogs due to the

emphasis placed on minor axis (fractional) shortening while ignoring apical to basilar contraction. When screening dogs for "occult" dilated cardiomyopathy multiple indices of LV systolic function can point to entirely different interpretations! Ambiguous echocardiographic results become clearer when serial examinations are obtained and more definitive when trends in heart size or cardiac function are observed. In most cases, entry-level examiners should focus on assessing patients with symptomatic disease or overt acquired valve disease such as chronic mitral regurgitation in dogs and relegate the diagnosis of most asymptomatic cardiomyopathies or congenital heart defects to more experienced examiners.

APPROACH TO INTERPRETATION

While the sonographer obtain standard images, an ongoing process of image interpretation should also be accomplished. **The following Table** offers a general guide for image interpretation.

Echocardiography: General Approach to Interpretation

Clinical or Imaging Issue

- Key Questions (?) & Common Congenital and Acquired Disease Considerations

Examination Conditions

- *Indication*: What is the clinical problem or reason for echocardiography?
- *Cardiac rhythm and* conduction: is it normal?
- *Sedation*: Was conscious sedation used?
- *Drugs*: What cardioactive drugs were administered to the patient?
- *Study Quality*: What is the overall quality of the echocardiographic study?
  - Comprehensive transthoracic echocardiogram (TTE) or limited/focused exam
  - Artifacts of ultrasound imaging
  - Necessary image acquisitions obtained

Congestive heart failure (CHF)

- Is there a *serous cavity effusion*
  - Pleural effusion
  - Ascites
  - Pericardial effusion (associated with structural heart disease)
- *B-lines* – presence and number of lung fields on thoracic ultrasound examination: r/o left-sided failure
- *Structural heart disease*: potential underlying cause of CHF
- Left or right *atrial dilation*: present in nearly all cases except peracute CHF or post-diuretic therapy
- Increased size or reduced collapsibility of the *caudal vena cava*: r/o right-sided failure
- *Doppler exam*: Spectral/tissue Doppler findings of increased left or right atrial pressure

Pericardial effusion or cardiac-related neoplasia

- *What is the appearance / echogenicity* of any identified effusion?
  - Mixed echoic fluid: rule out (r/o) active/recent hemorrhage or inflammatory effusion
  - Organizing thrombus: r/o cardiac rupture or recent tumor-related hemorrhage
- *What is the volume* of pericardial effusion (estimated)?
  - Scant: systolic separation of the ventricular walls from the pericardium
  - Small to moderate: with no echocardiographic or clinical signs of cardiac tamponade
  - Small to moderate effusions with hemodynamic compromise (tamponade)
    - Acute hemorrhage from a cardiac or heart base tumor without prior effusion
    - Pre-existing cardiomegaly (as with rupture of the left atrium)

- Moderate to large – large volume of effusion relative to cardiac size
  - Exuberant cardiac motion ("swinging") within a large effusion
  - Frequently related to signs of acute or chronic cardiac tamponade

- Is there echocardiographic evidence of *acute or chronic cardiac tamponade*?
  - *Clinical signs*: hypotension, elevated systemic venous pressures, congestive heart failure
  - Diastolic collapse of the right ventricle
  - Prolonged inversion of the right atrial wall
  - Pseudohypertrophy of the ventricular chamber walls
  - Dilation/reduced collapsibility of the caudal or cranial vena cavae
  - Distended hepatic veins
  - Ascites or pleural effusion

- Is there pericardial effusion with *structural heart disease* and atrial dilation?
  - Dilation of the left atrium (in cats): suggests pericardial effusion secondary to CHF
  - Dilation of the right atrium or right heart disease: potentially an effusion from right heart failure
  - Advanced mitral valve disease: consider left atrial tear

- Is a *mass lesion* identified – cardiac, heart base, or within the pericardial space?
  - Right atrial mass in a dog: r/o hemangiosarcoma > other tumors
  - Heart base mass contiguous with aortic root: r/o chemodectoma, ectopic thyroid carcinoma, neuroendocrine tumor
  - Heart base or intracardiac mass: r/o obstruction of pulmonary venous return
  - Heart base mass: r/o obstruction of a pulmonary artery branch (usually right)
  - Effusion with *myocardial thickening involving the right ventricular wall*: r/o lymphosarcoma
  - *Intrapericardial mass*: r/o tumor from cardiac muscle, mesothelioma, granuloma, thrombus
  - Cystic structure within pericardial space: r/o intrapericardial cyst
  - Intrapericardial omental fat, liver, or bowel: r/o peritoneopericardial diaphragmatic hernia

- Is an *Intraluminal mass lesion* identified?
  - r/o tumor, thrombus, or granuloma
  - Organized left atrial appendage mass with spontaneous echo contrast (cat): likely thrombosis
  - Right atrial mass obstructing systemic venous return or causing acquired tricuspid stenosis: likely a neoplasm (extensive differential diagnosis including hemangiosarcoma, neuroendocrine tumors, myxosarcoma/myxoma, rhabdomyosarcoma).
  - Mass on the mitral valve (rare): r/o myxosarcoma/myxoma
  - Mass on the tricuspid valve: r/o tumor or thrombus (especially post-catheterization or pacing)

- Are there signs of *effusive-constrictive pericardial disease*?
  - Thickened parietal pericardium
  - Atrial dilation and signs of right-sided CHF (see above)
  - Restricted diastolic motion of the RV wall (also on M-mode)
  - Diastolic septal bounce (also on M-mode)
  - Loculated pericardial effusion (also r/o mesothelioma or prior surgery)
  - Doppler: spectral and tissue Doppler features suggestive of constriction

Atria

- Are *four cardiac chambers* identified?
  - Venoatrial and atrioventricular connections
  - Mitral and tricuspid valve morphology and motion
  - Relative sizes of the four cardiac chambers on RPLAx and left apical 4-chamber views
  - On RPSAx view: size of the left atrium relative to aorta at the aortic valvular level
- Atrial *chamber size*: Are measurements normal, decreased, or increased?
  - Decreased right and left atrial size: r/o hypovolemia or cardiac compression
  - Decreased left atrial size: r/o right to left shunt or pulmonary arterial hypertension
  - Increased right or left atrial size – multiple causes
    - *Shunts*:
      Right atrial enlargement from ASD, AVSD, anomalous pulmonary venous drainage, systemic arteriovenous fistula
      Left atrial dilation from PDA, VSD, AVSD, AVSD with atrial septal deviation (double outlet right atrium), systemic-to-pulmonary shunts/fistulas
    - *Atrioventricular valve disease*: valvular or supravalvular stenosis, regurgitation
    - *Cardiomyopathies*: dilated, hypertrophic, restrictive, others
    - *Heart failure*: diastolic heart failure, systolic heart failure, overt CHF
    - *Atrial myopathies* (e.g. silent atrium)
    - *Arrhythmia* related: chronic bradycardia or tachycardia
    - *Circulatory volume overloads* (iatrogenic) and volume retentive states (RA > LA)
    - *High output states*: anemia (RA > LA), thyrotoxicosis (multifactorial)
  - Divided atrial chamber: cor triatriatum dexter, cor triatriatum sinister, AVSD with double outlet RA
- Is the *interatrial septum* (IAS) intact with normal appearance and is there evidence of shunting?
  - Defects: atrial septal defects (secundum, primum/AVSD, sinus venosus defect)
  - Absent IAS (common atrium)
  - *Doppler & saline contrast* echocardiography: right-to-left or left-to-right shunting
- Is the appearance of the *interatrial septum* (IAS) normal or is it deviated?
  - Leftward deviation of IAS with AVSD and supra-mitral stenosis: “double-outlet right atrium”
  - Leftward bowing of IAS from increased RA pressures (r/o pulmonary hypertension & cor pulmonale)
  - Rightward deviation of IAS from increased LA pressures (often with mitral regurgitation)
- Is *atrial function* normal?
  - M-mode/2D indices include LA fractional shortening and changes in LA area or LA volume
  - *Doppler*: transmitral and pulmonary venous flow patterns; tissue Doppler imaging
  - Atrial strain indices
  - Also see: Congestive heart failure
- Are *pulmonary veins* (or entries of pulmonary venous confluence) normal?
  - Increased size of right pulmonary veins > adjacent right pulmonary artery: r/o increased LA pressure or chronic mitral regurgitation
  - Increased size of pulmonary veins with dilation of adjacent right pulmonary artery: r/o left-to-right shunting or left heart failure with pulmonary hypertension
  - Reduced size of pulmonary veins relative to the adjacent right pulmonary artery: r/o pulmonary arterial hypertension
  - Abnormal pulmonary venous entry into RA: r/o sinus venosus atrial septal defect

Ventricles

- *Do the ventricular chambers* appear normal?
  - Atrioventricular and ventricular to arterial connections
  - Aortic valve and pulmonary valve morphology and motion
  - Relative sizes of the four chambers on RPLAx and left apical 4-chamber views
- Are *ventricular wall thicknesses* normal, decreased or increased?
  - Decreased from segmental or generalized wall thinning
    - Presumed ischemia/infarction in feline cardiomyopathies
    - Absolute or relative (to chamber size) wall thinning in dilated cardiomyopathy phenotypes
    - Fibrofatty replacement (e.g., arrhythmogenic cardiomyopathy)
    - Tachycardia-induced cardiomyopathy
  - Increased from focal, segmental or generalized wall thickening
    - Pseudohypertrophy of ventricle (volume depletion, cardiac tamponade)
    - Concentric hypertrophy from pressure overload (aortic stenosis, pulmonary stenosis, systemic hypertension, Type I pulmonary arterial hypertension)
    - Mixed hypertrophy (wall thickening with chamber dilation): chronic pressure overload with myocardial failure (aortic stenosis, systemic hypertension), acquired pulmonary hypertension, combined aortic or pulmonary valve stenosis and regurgitation, seminlunar valve stenosis with atrioventricular valve regurgitation)
    - Proximal chamber hypertrophy: double-chamber right ventricle
    - Hypertrophic cardiomyopathy (focal, segmental or generalized wall thickening)
    - Hyperthyroid heart disease
    - Myocardial infiltration (neoplasia, myocarditis | amyloidosis is rare in dogs/cats)
    - Noncompaction
    - Idiopathic subaortic septal thickening (discrete upper septal thickening)
- Are measurements of *ventricular chamber size* normal for the species, body weight, and breed?
  - Decreased: see decreased atrial size
  - Increased (dilation or eccentric hypertrophy; also see mixed hypertrophy above):
    - Shunts – ASD, systemic arterio-venous fistula: RV enlargement
    - Shunts – PDA, VSD, systemic to pulmonary shunts/fistulas: LV enlargement
    - Atrioventricular valve regurgitation: mitral (LV), tricuspid (RV)
    - Semilunar valve regurgitation: aortic (LV), pulmonic (RV)
    - Cardiomyopathies: dilated, arrhythmogenic right ventricular, non-specific, doxorubicin
    - Myocarditis (end-stage)
    - Arrhythmias: tachycardia-induced cardiomyopathy; chronic bradycardia
    - High-output states (e.g. moderate-severe anemia), thyrotoxicosis

- Is the *interventricular ventricular septum* (IVS) intact?
  - Ventricular septal defect defects: perimembranous, subarterial, inlet (AVSD), muscular
  - Related lesions: Ventricular septal aneurysm, Aortic leaflet prolapse into VSD with AR
  - *Doppler*: demonstration of shunt; velocity relates to size of defect RV pressure
- Are *interventricular ventricular septal* thickness, curvature and motion normal?
  - Discrete upper septal thickening or hypertrophy (DUST, DISH) in older cats
  - Large radius of septal curvature – "flattened septum" due to right ventricular disease
  - Abnormal IVS septal motion:
    Paradoxical (rightward systolic) septal motion: right ventricular volume overload
    Flat (systolic) septal motion: right ventricular pressure overload
    Hyperdynamic systolic septal excursion: left ventricular volume overload

Hypokinetic septal motion: myocardial thinning or ischemia/infarction (cats > dogs)
Dyssynchrony with LV posterior wall: multiple associations including arrhythmias and conduction disorders (dogs > cats)

- Is *ventricular function* normal?
  - Subjective assessment of ventricular wall motion across visualized segments?
    - Mitral annular motion, LV radial shortening (short-axis), length-area changes (long-axis)
    - Tricuspid annular motion (TAPSE), RV length-area changes (optimized RV inflow view)
  - Quantitative left ventricular systolic function: see Table 6 and Supplemental Table A5
  - Quantitative right ventricular systolic function: see Table 6 and Supplemental Table A5
  - Ventricular diastolic function and estimates of diastolic ("filling") pressures – Grades (by Doppler)
    - Subjective interpretation of patterns: Normal | Relaxation abnormality | Pseudonormal | Restrictive (± reversible) based on transmitral velocity profiles
    - Quantitative estimates of veno-atrial pressures using PW-Doppler and tissue-Doppler
    - Interpretation in cardiomyopathies vs. volume overloads with preserved systolic function

Great vessels

- Is development of the great vessels normal?
  - Both great vessels are present with connections to their respective ventricles and there is a patient RV outflow tract extending into a visible pulmonary trunk; if not: rule out pulmonary atresia, truncus arteriosus (common arterial trunk), and double-outlet right ventricle
- Is there shunting at the level of the great vessels?
  - PDA, aortopulmonary window, coronary to pulmonary arterial fistula, systemic-to-pulmonary shunts including fistulas, collateral circulation, and major aortopulmonary collateral arteries
  - Doppler: identification of (typically) high-velocity, continuous blood flow
- Are the ostia of the coronary arteries evident?
  - Usually identified examination of the RPSAx at the aortic valve/left atrial image plane, the RPLAx optimized for the LVOT (left coronary artery), and the left-cranial RV inflow-outflow tract views
  - Dilated or enlarged artery: might be anomalous or secondary to ventricular hypertrophy
  - Absent coronary artery ostium: could indicate a single-origin left or right coronary artery
- Are there abnormalities of the aorta or the main pulmonary artery (pulmonary trunk)?
  - Aortic dilation: post-stenotic dilation, primary aortopathy, systemic hypertension, connective tissue disease (breed-related), dissection of the aorta
  - Abnormal septal-to-aortic angle (association with subaortic stenosis and mature cats with discrete upper septal hypertrophy or thickening)
  - Pulmonary trunk dilation: post-stenotic dilation, left-to-right shunt, pulmonary hypertension, idiopathic dilation of the pulmonary trunk
  - Intraluminal abnormalities: pulmonary artery parasites (D. *immitis* in the pulmonary arteries), thrombus, intraluminal mass (aorta or PA) or extraluminal compression (usually PA), intimal dissection (aorta from hypertension or connective tissue disease; PA from cardiac catheterization)
- Are there evidence of pulmonary or systemic hypertension from 2D or Doppler imaging?
  - Remodeling of the ventricular chamber, high-velocity valvular regurgitation on the affected side, dilation: post-stenotic dilation, primary aortopathy, systemic hypertension, connective tissue disease (breed-related), dissection of the aorta

Cardiac Valves

- Do the cardiac valves have normal morphology & motion based on 2D, M-mode and Doppler images?
  - Number of valve leaflets
  - Morphology and thickness of the leaflets/cusps
  - Support apparatus: appropriate length and location of chordal attachments and papillary muscles
  - Valvular motion: normal, restricted, exuberant, prolapse, flail, high-frequency vibration
- Is there evidence of valvular stenosis from 2D and Doppler imaging?
  - Semilunar valve stenosis – *variously*:
    - Leaflet thickening, commissural fusion and restrictive leaflet motion are typical
    - Fibrous adhesions (tethering) at the sinotubular junction
    - Subvalvular or supravalvular – typically fibrous – obstructions
    - Secondary dynamic RV ventricular outflow tract obstruction from infundibular hypertrophy
    - Primary or secondary dynamic LV outflow tract obstruction from systolic anterior motion of the mitral valve (r/o concurrent mitral valve malformation)
    - Infective endocarditis – as an uncommon cause of valvar stenosis
    - *Doppler*: proximal acceleration with increased ejection velocities across the stenosis leading to turbulent blood flow in the great vessel
    - *Doppler*: Valvular regurgitation is usually present
  - Atrioventricular valve stenosis – variously:
    - Thickened, often hypoplastic leaflets with commissural fusion or subvalvular tethering
    - Abnormal leaflets morphology
    - Short chords or abnormal papillary muscle attachments
    - Concordant motion of the leaflets with flat E-to-F slope (M-mode)
    - *Doppler*: increased transvalvular diastolic velocities with prolonged pressure half-time, increased transvalvular A-waves from atrial hypertrophy and preserved atrial function
    - *Doppler*: Concurrent valvular regurgitation is common
- Is there evidence of valvular regurgitation from 2D and Doppler imaging?
  - Atrioventricular valve regurgitation – variously:
    - Abnormal valve morphology from malformation of either atrioventricular valve (see “stenosis”)
    - Tricuspid valve dysplasia: failure of the septal leaflet to delaminate with apical coaptation of the septal and parietal leaflets
    - Myxomatous mitral or tricuspid valvular thickening with rupture of mitral chords
    - Functional mitral or tricuspid regurgitation from ventricular remodeling or atrial dilation
    - Infective endocarditis
    - *Doppler:* verification of regurgitant blood flow with proximal flow convergence, vena contracta and regurgitant jet in the atrium
  - Semilunar valve regurgitation – variously:
    - Associated with subaortic or valvular aortic or pulmonary stenosis
    - Dilation of the aortic root (aortic regurgitation) or pulmonary trunk (pulmonary regurgitation)
    - Pulmonary hypertension (pulmonary regurgitation)
    - Infective endocarditis (aortic regurgitation)
    - Doppler: similar features to atrioventricular valve regurgitation with jet entering the ventricle
    - Doppler: regurgitant velocity and pressure half-time related to pressure gradient and severity

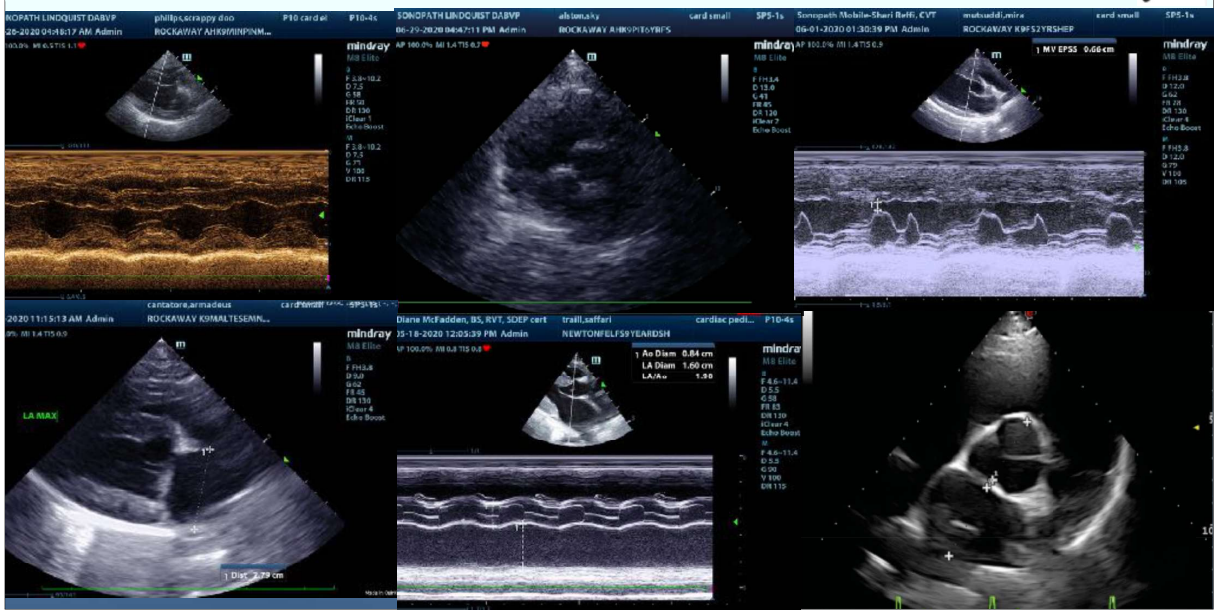
THE SDEP® ECHO PROGRESSION

Overview & Typical Pathology

Eric Lindquist DMV (Italy)
DABVP Canine & Feline Practice, Cert. IVUSS
Founder/CEO: Sonopath.com

Basic M-Mode & B Mode Measurements:
LV M-Mode, EPSS, LA Max, La/Ao M-Mode, La/Ao Heart Base

SDEP Position 1:
Right Parasternal Long (4+5 Chamber) & Short Axis



SDEP ECHO Probe Maneuvers

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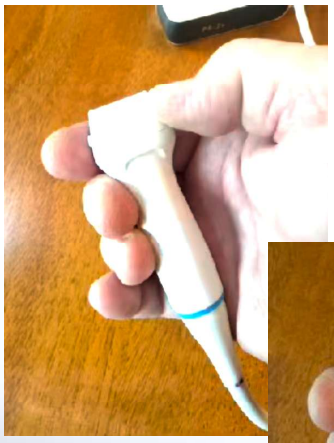
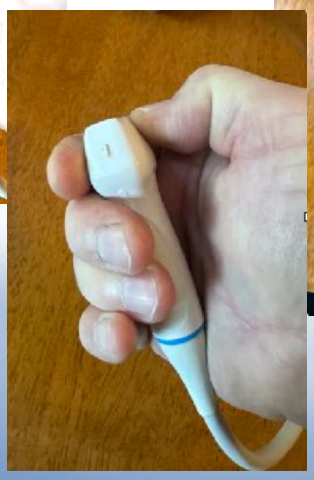
Normal "Brick"

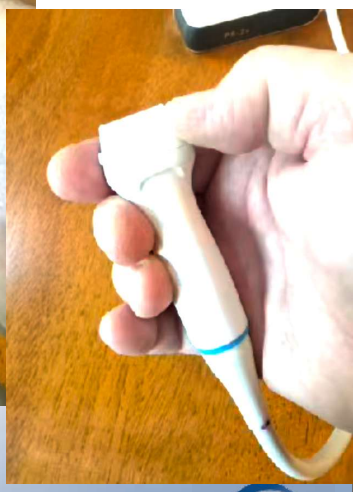


Twist Toward You



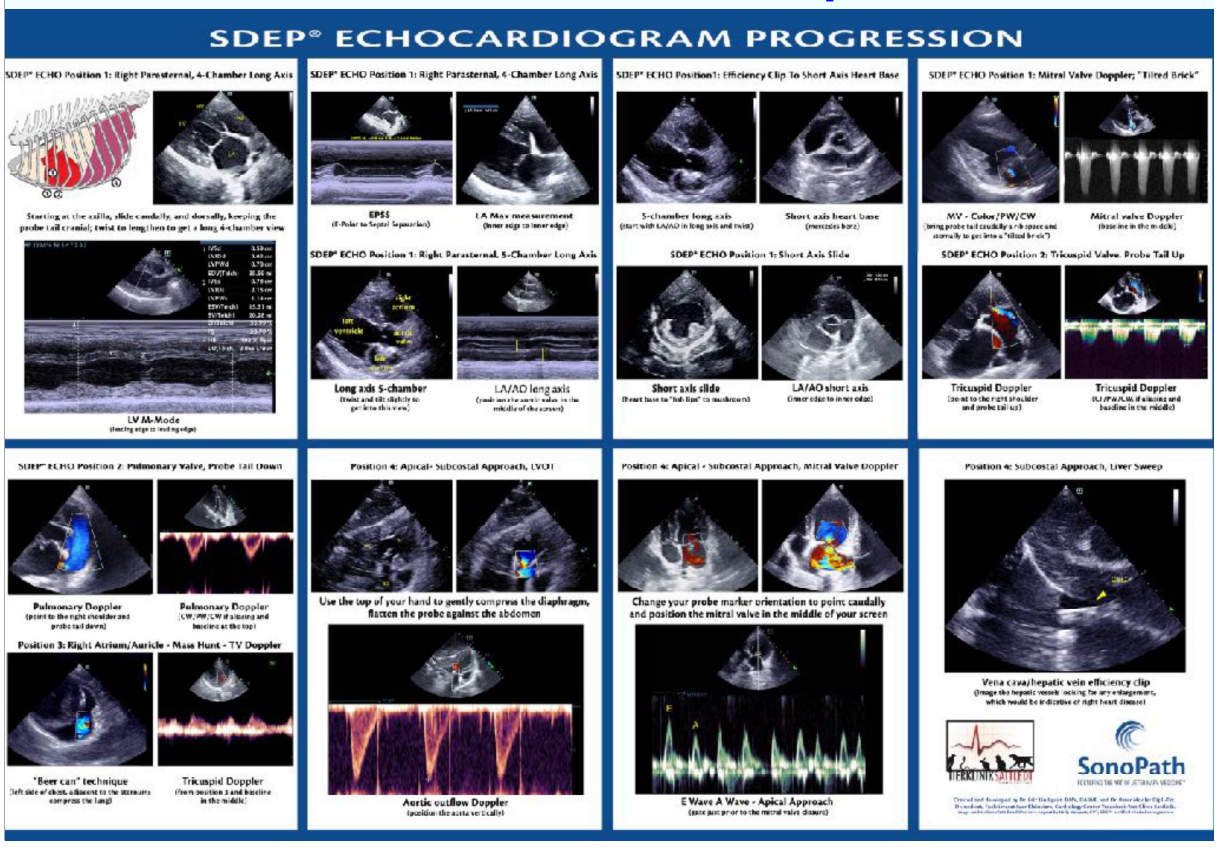
Probe Tail Up

Probe Tail Down

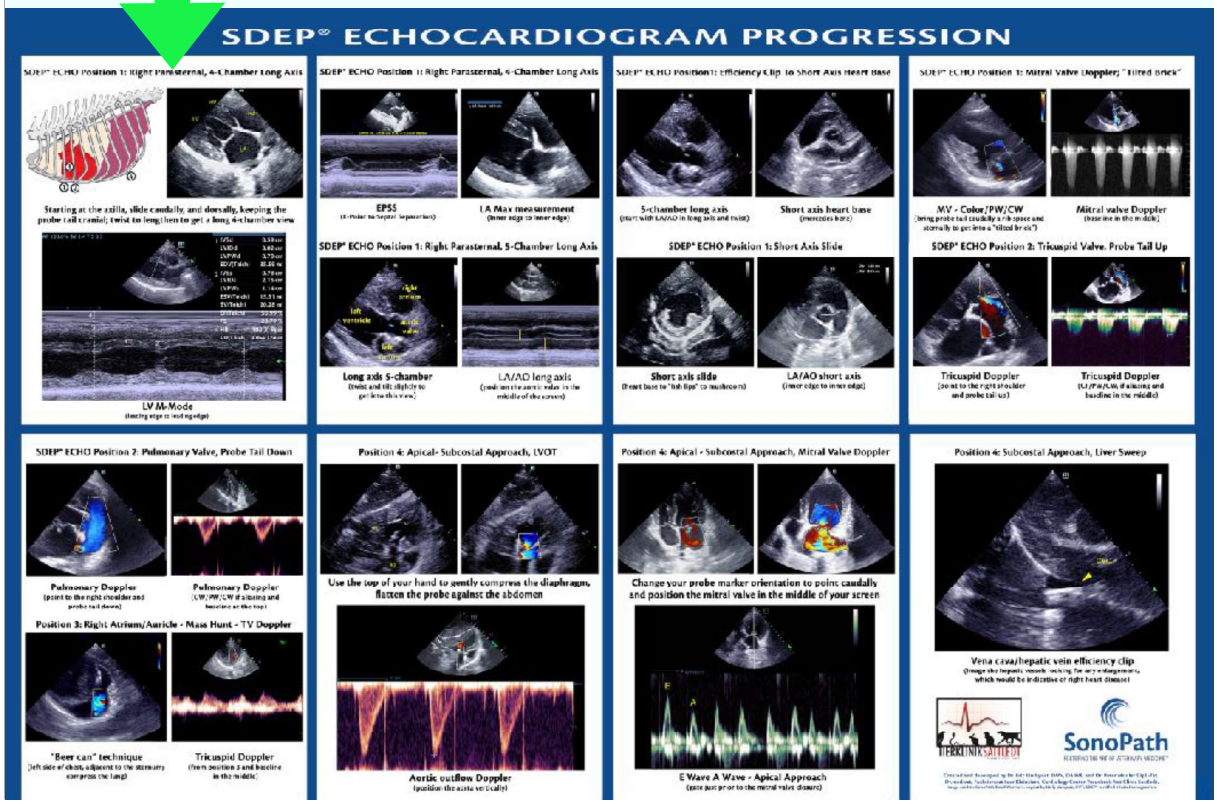


Slide, Tilt, Twist

Follow The Poster: 8 Boxes, 4 SDEPs

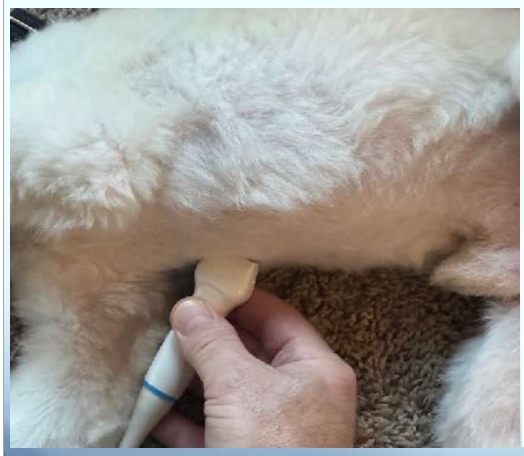


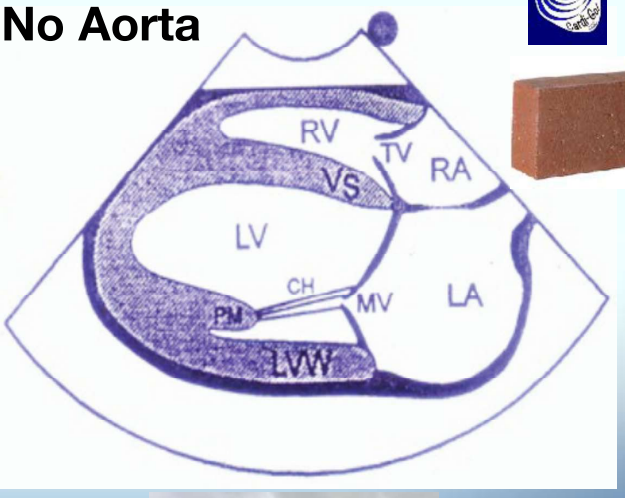
Poster Box 1. SDEP 1. 4-Chamber



SDEP Position 1:

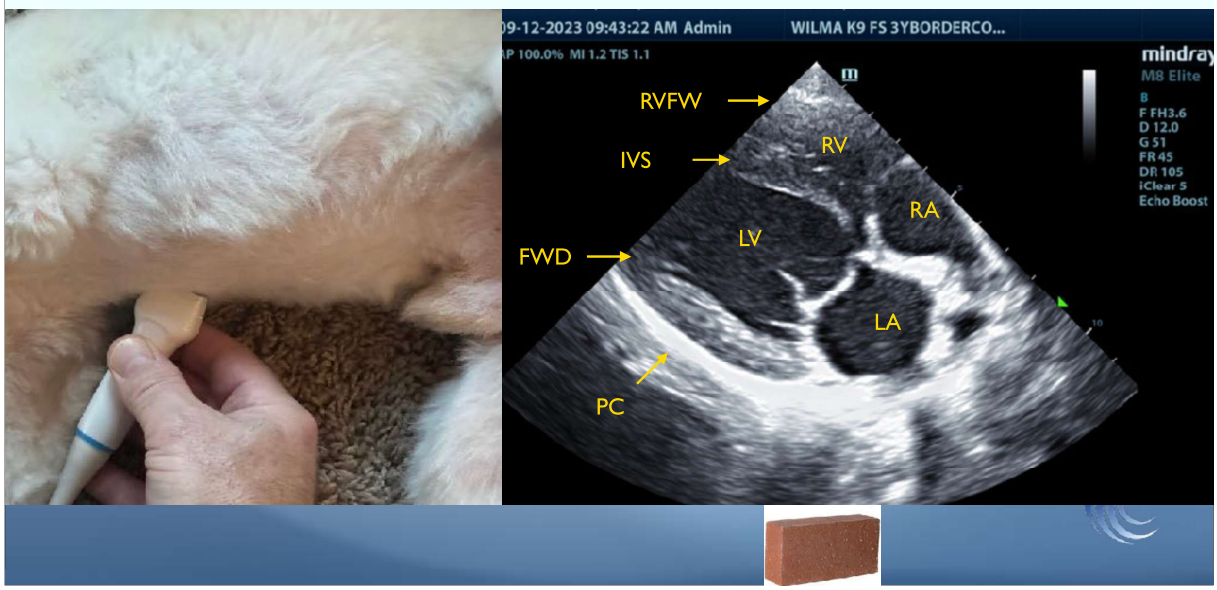
Right Parasternal 4-Chamber Long Axis
"The BRICK"
No Aorta





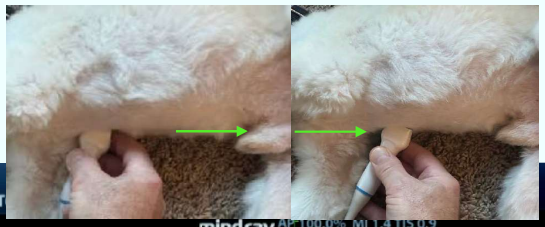
SDEP Position 1:

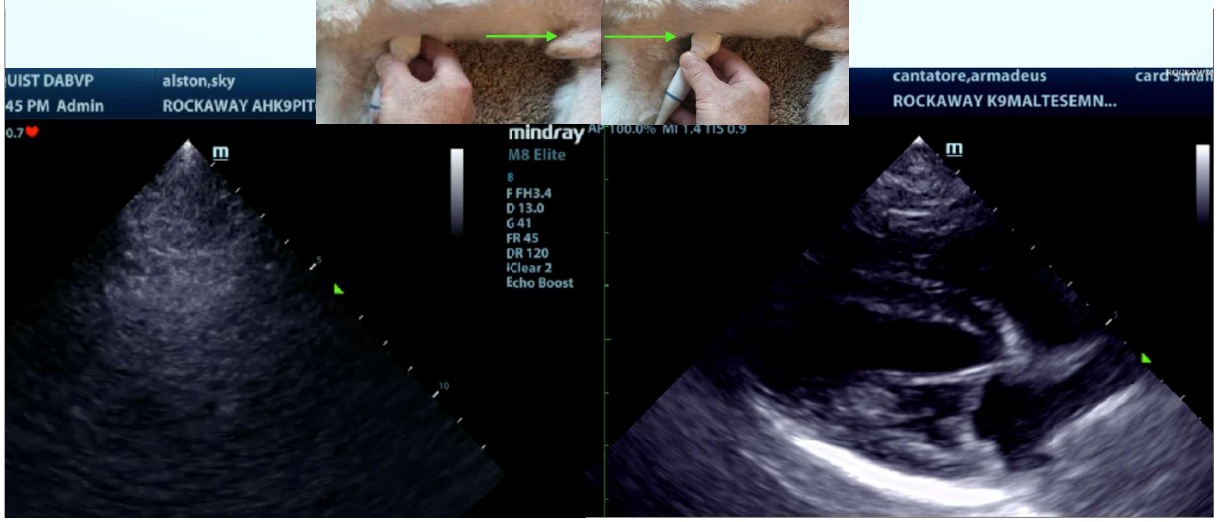
Right Parasternal 4-Chamber Long Axis.
Right Axillary Position & Slide Caudally
"BRICK" of a left ventricle, flat septum, & no papillary muscle.



Road To The Brick:

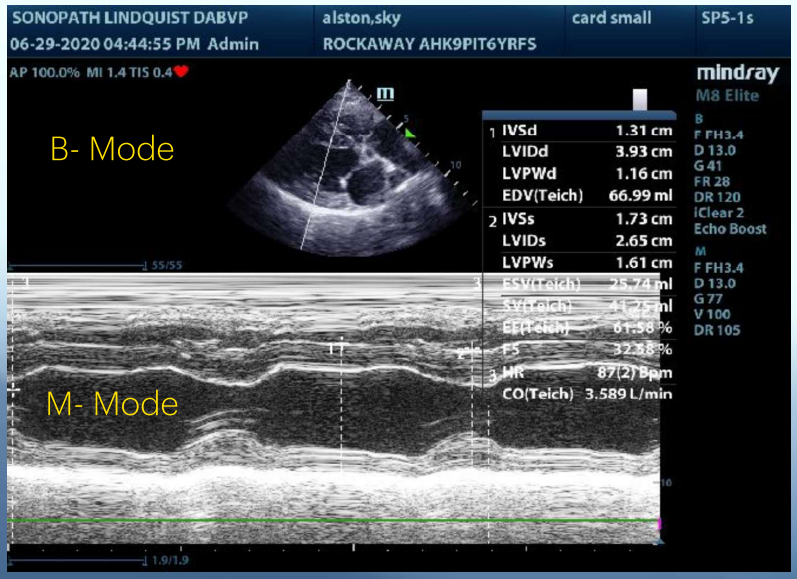
Right Axilla Position
Slide Caudally To The Brick…
Find A Beating Heart, That's A Start:)
Optimize With Twist & Tilt Probe Tail Cranially,
Slide to Spine To Flatten





Measurement I

LV M-mode "measurement mode"



M-mode
on Logiq e.

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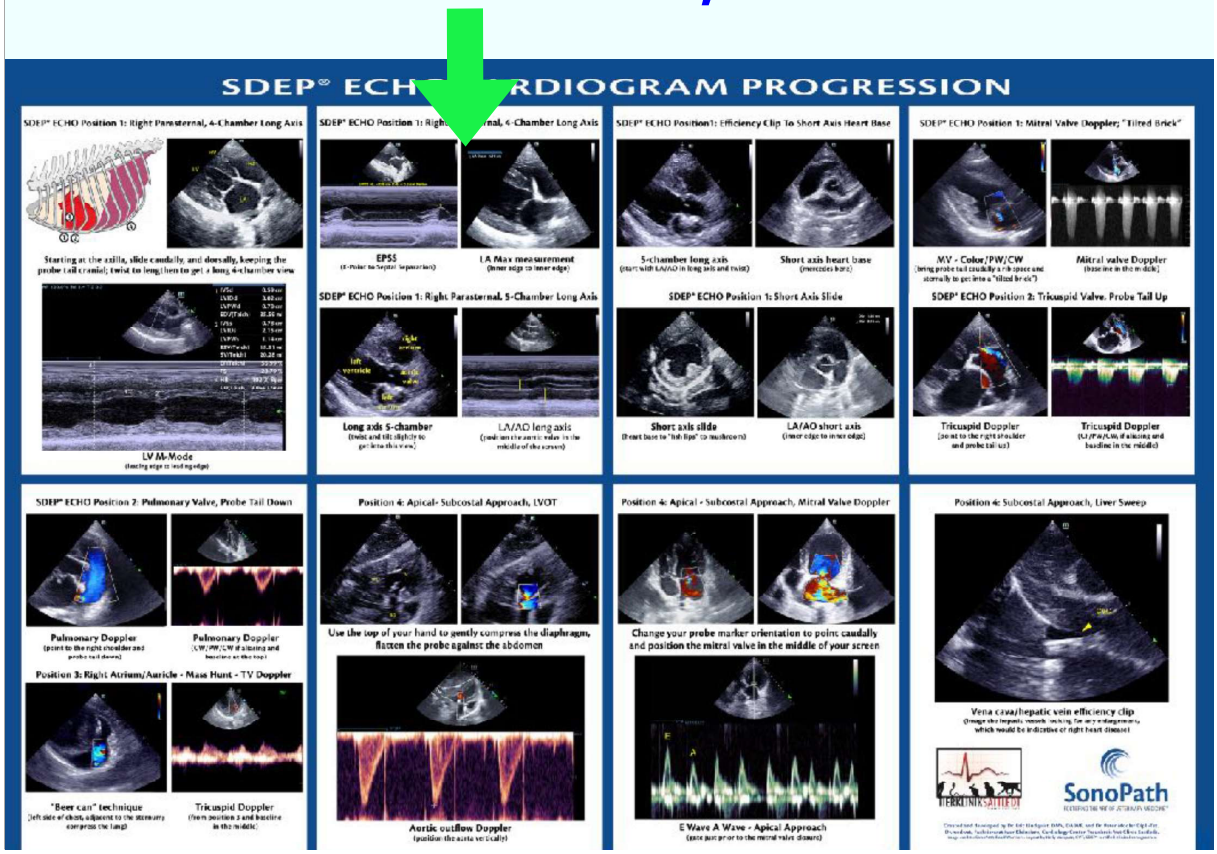
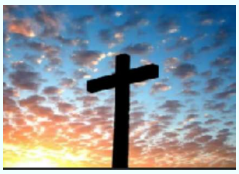
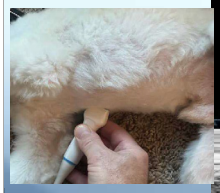
Poster Box 2A. SDEP 1, 4-Chamber

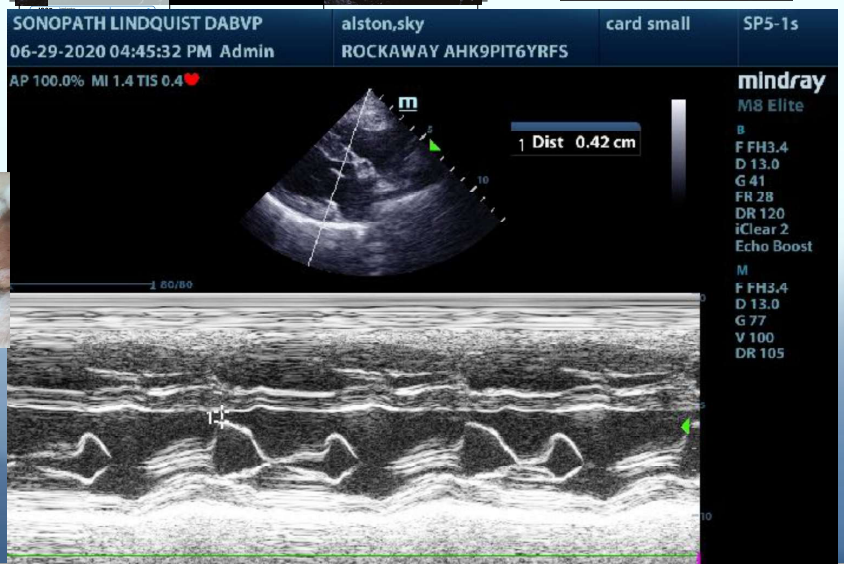


EPSS

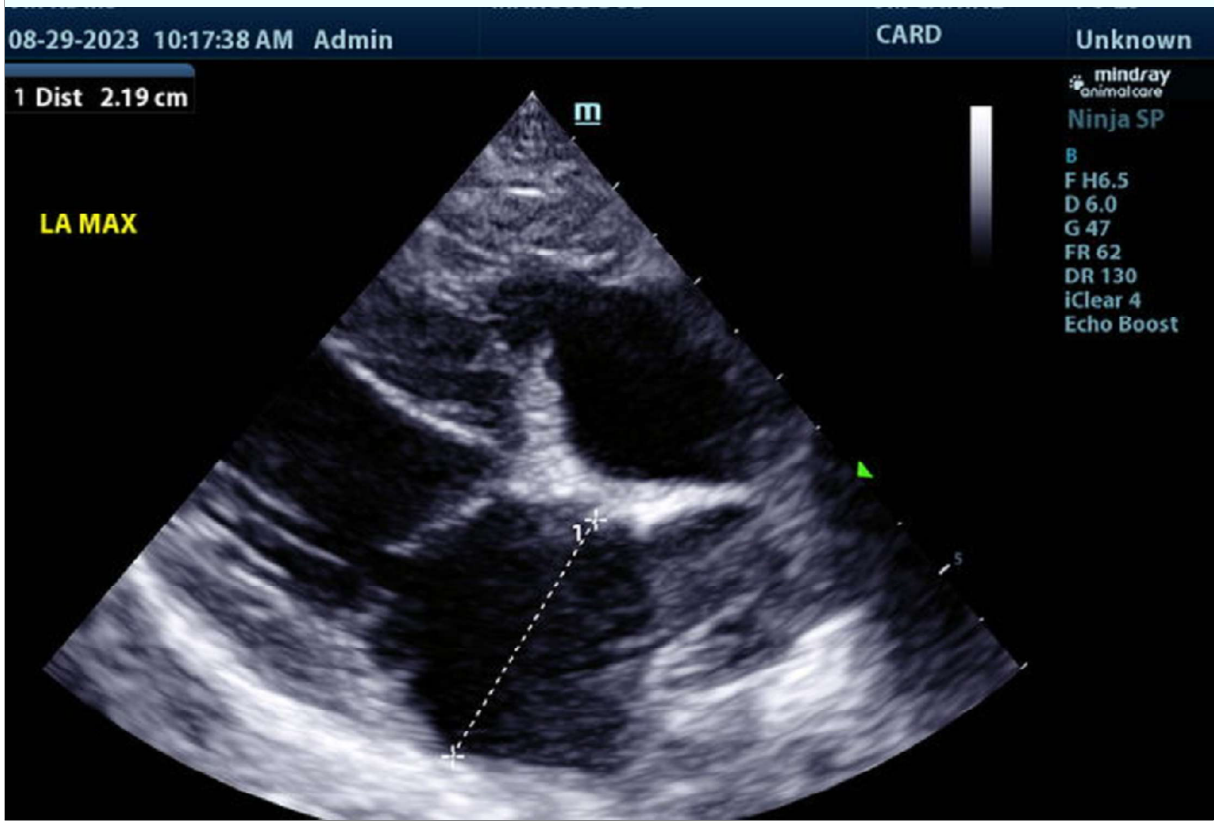
Mitral valve E-Point to
Septal Separation



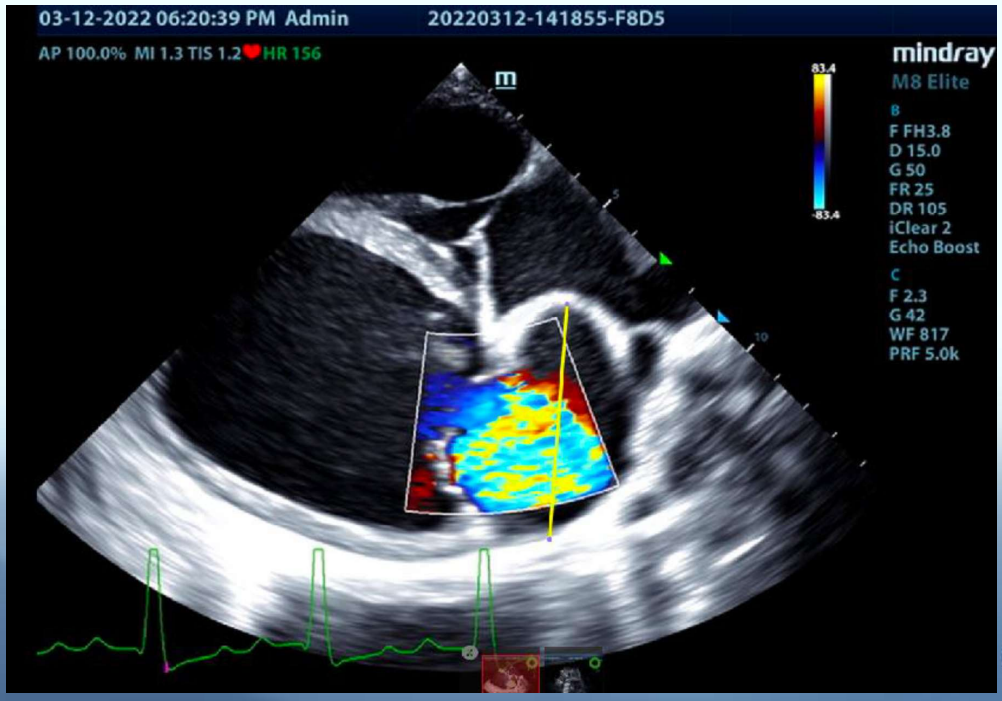




LA Max: Internal Edge AS to LAFW



LA Max Is Mid LA Body



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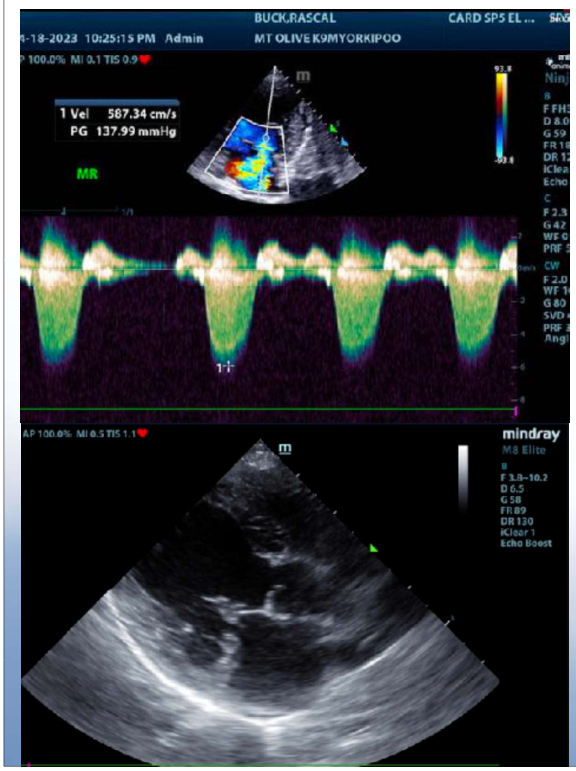
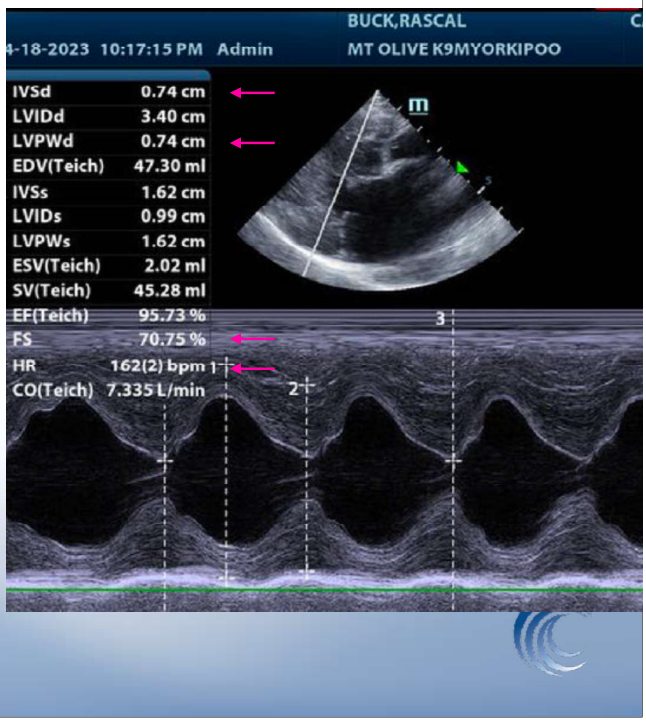
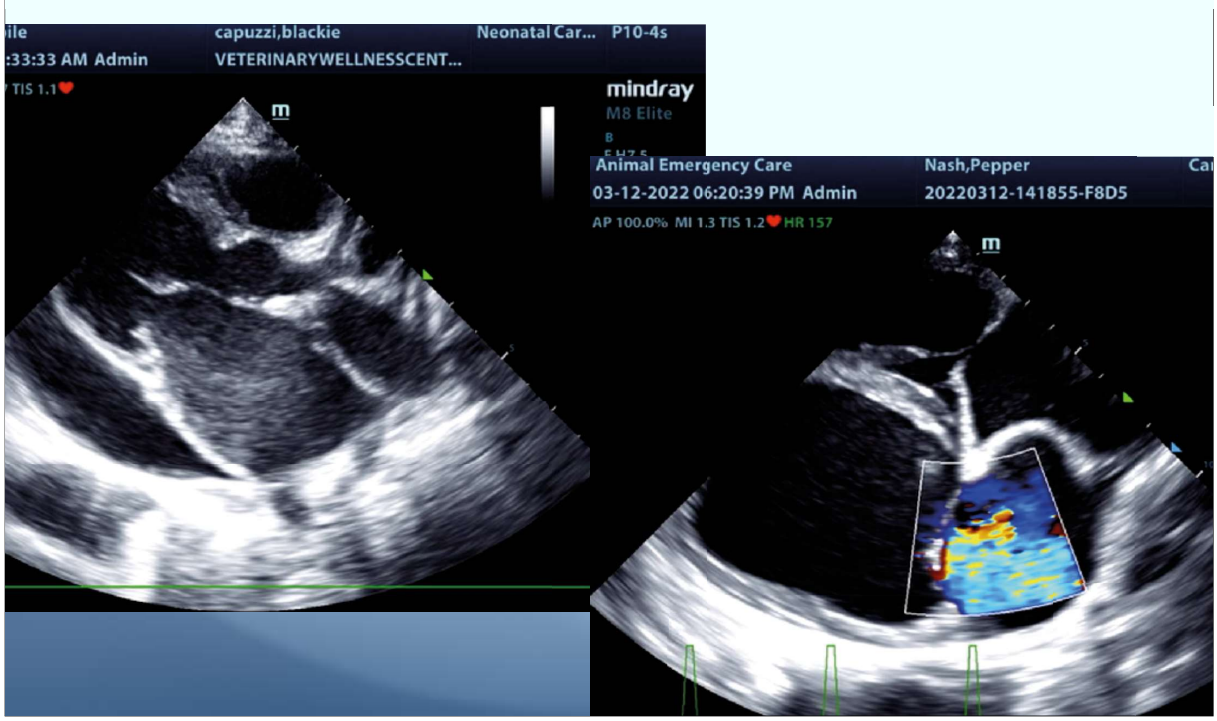
Hyperdynamic LV
LV M-Mode





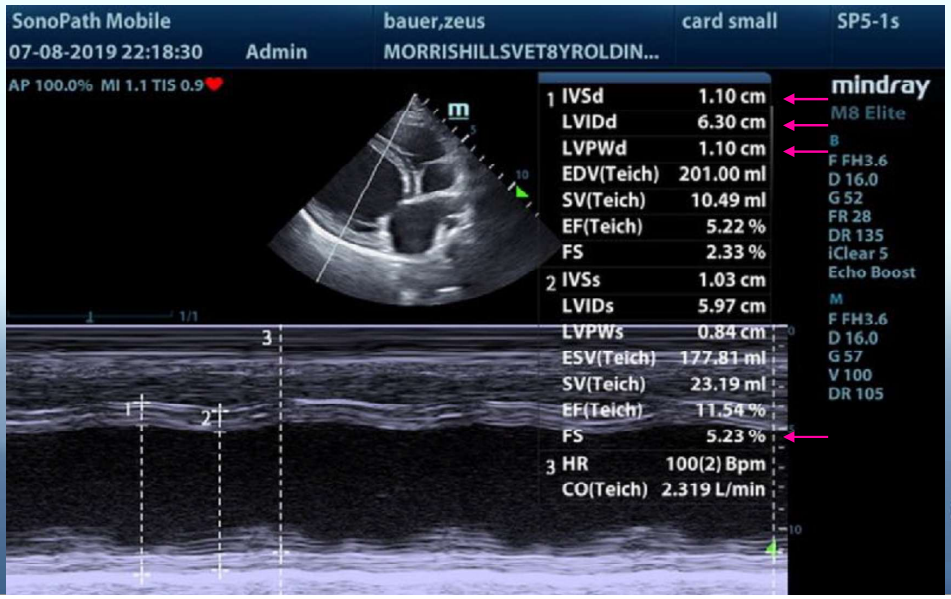
DCM Type Presentation.

Volume Overload Left >> Slide toward the spine

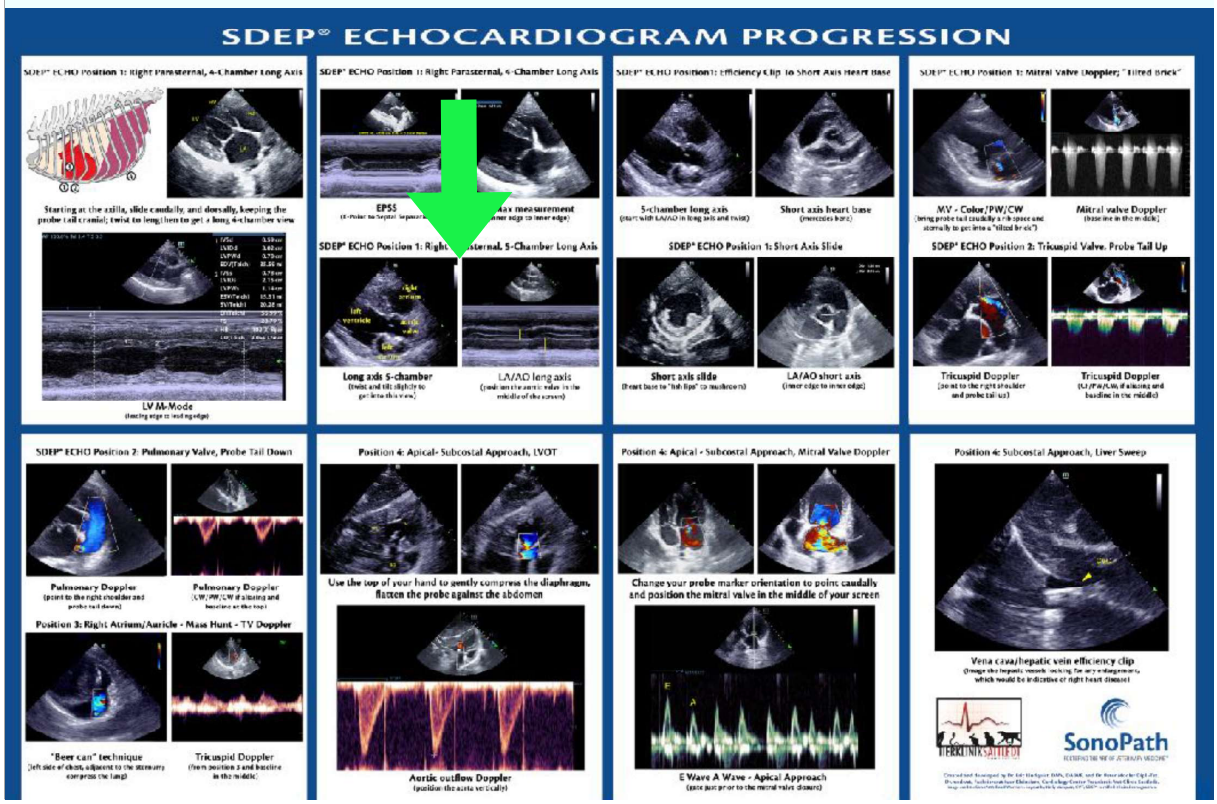


DCM-Type presentations:

Nutritional CMY
Myocarditis
Endocrinopathy: HypoT4, Addisons
End Stage Shock

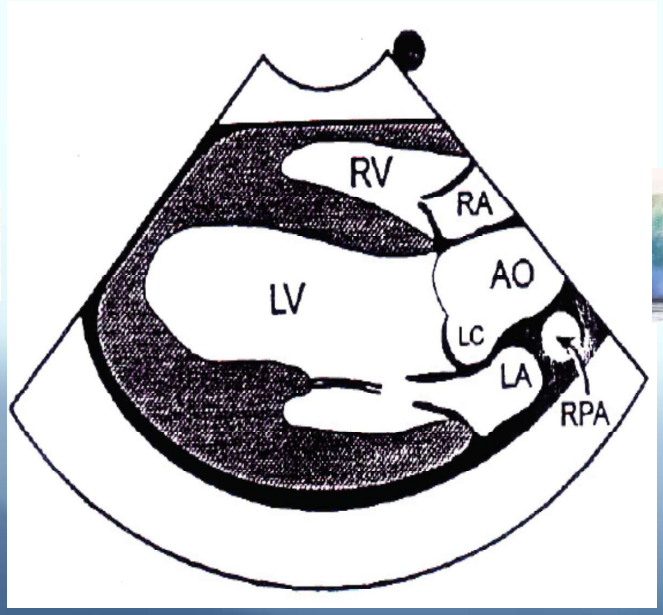


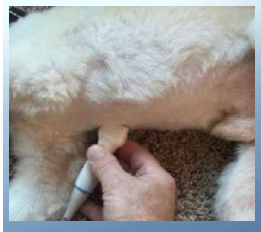
Poster Box 2B: SDEP 1, 5-Chamber



5-Chamber "Brick"
Long Axis With Aorta

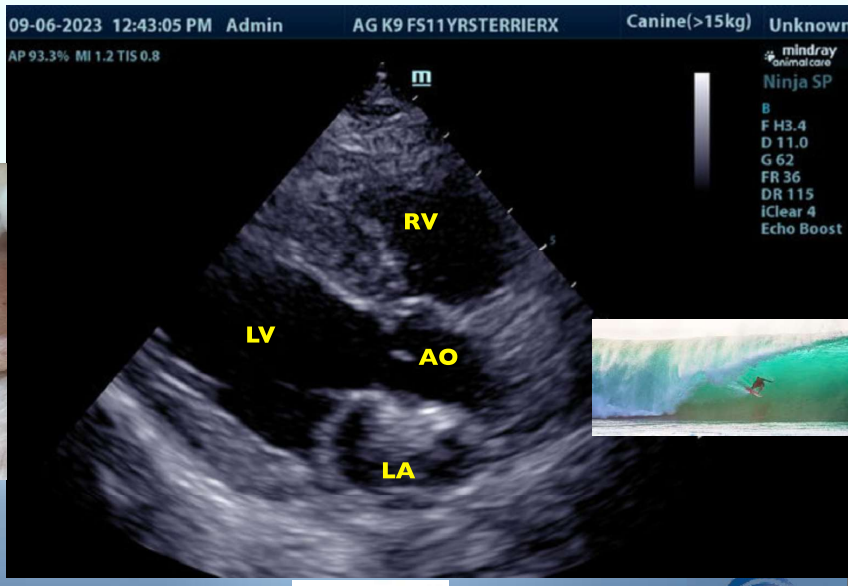
Slight Twist Away, Slight Tilt
Open Up The "Pipe" (Aorta)



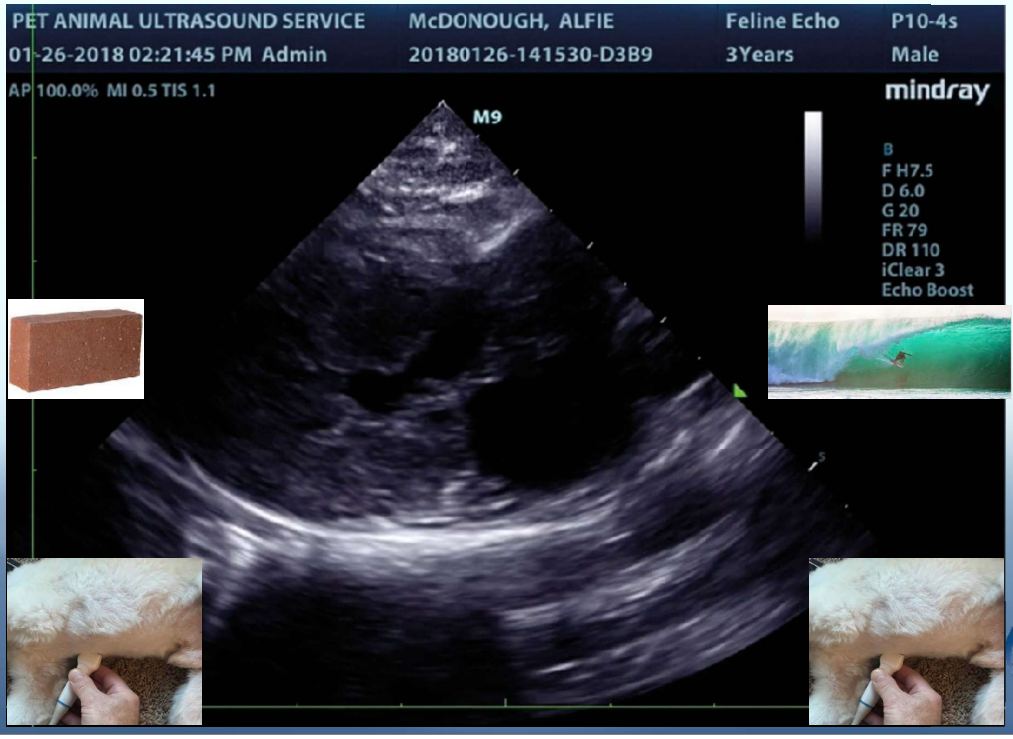


5-Chamber

Ensure the LA/AO is in the middle of the screen.
Tiny twist +/- tiny tilt slightly until the aorta comes into view.
Slide To Spine To Widen The AO— —Open *The "Pipe"*

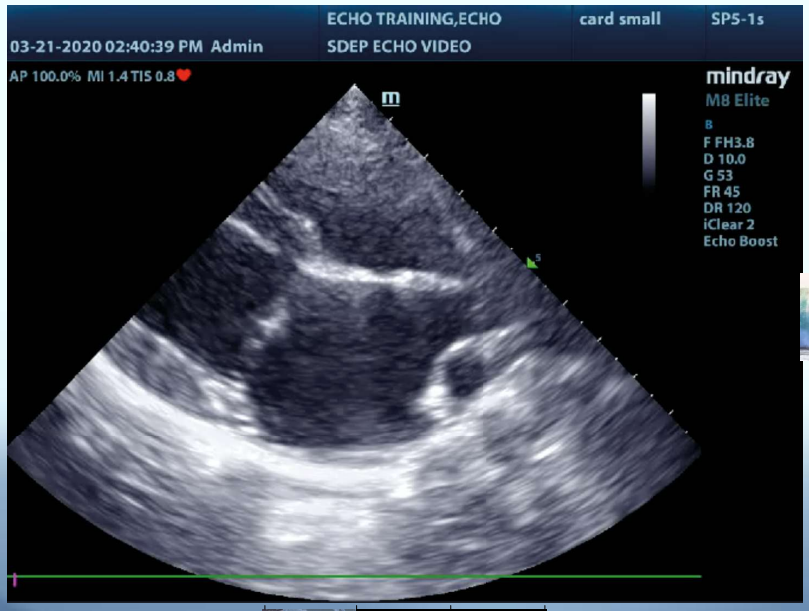


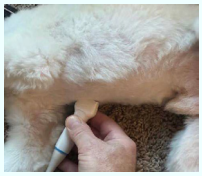
Feline 5-Chamber Long Axis
The "Brick" & *The "Pipe"*

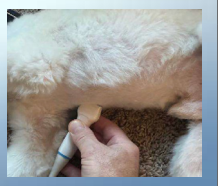


SDEP 1 Efficiency Clip

4 to 5 Chamber Long Axis



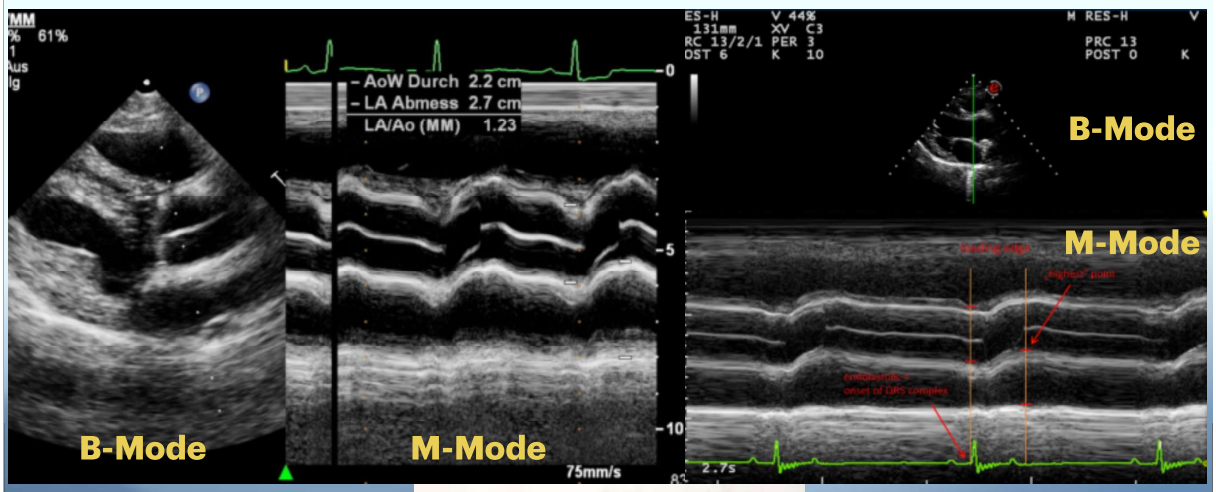




LA/AO M-Mode Method in 5-Chamber

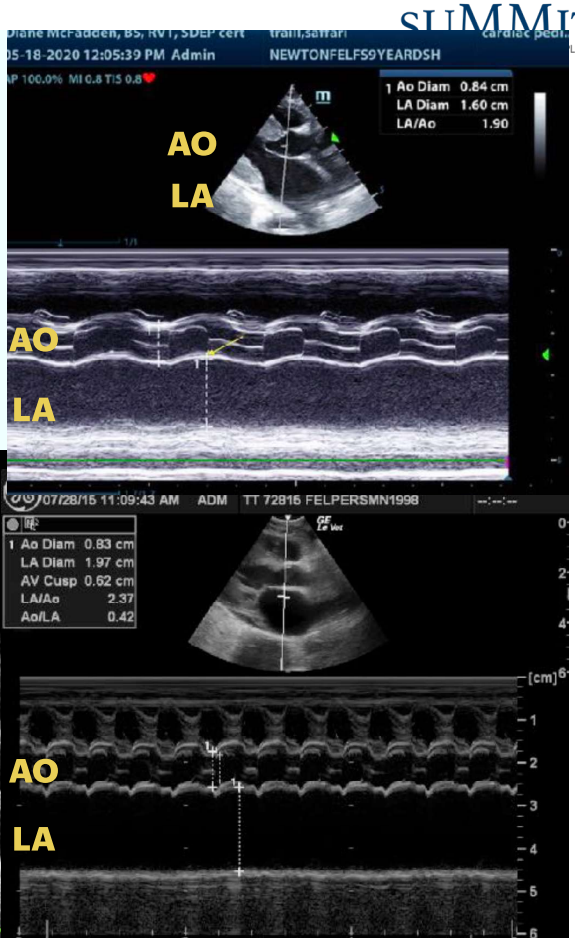
Try to position the aorta right in the middle of the screen.

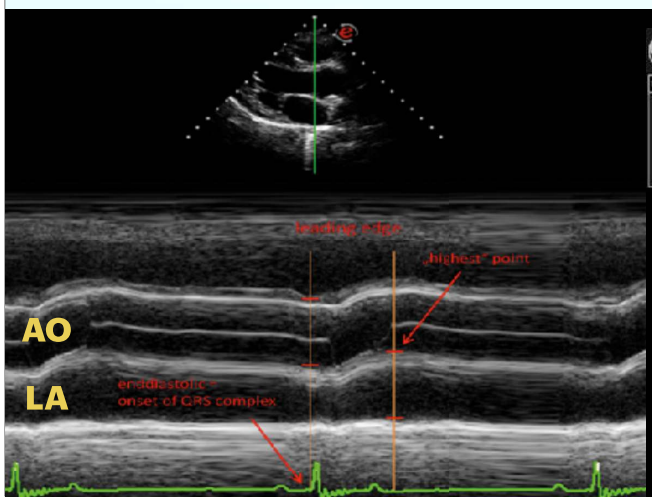
Slide Dorsally To Open The Aorta



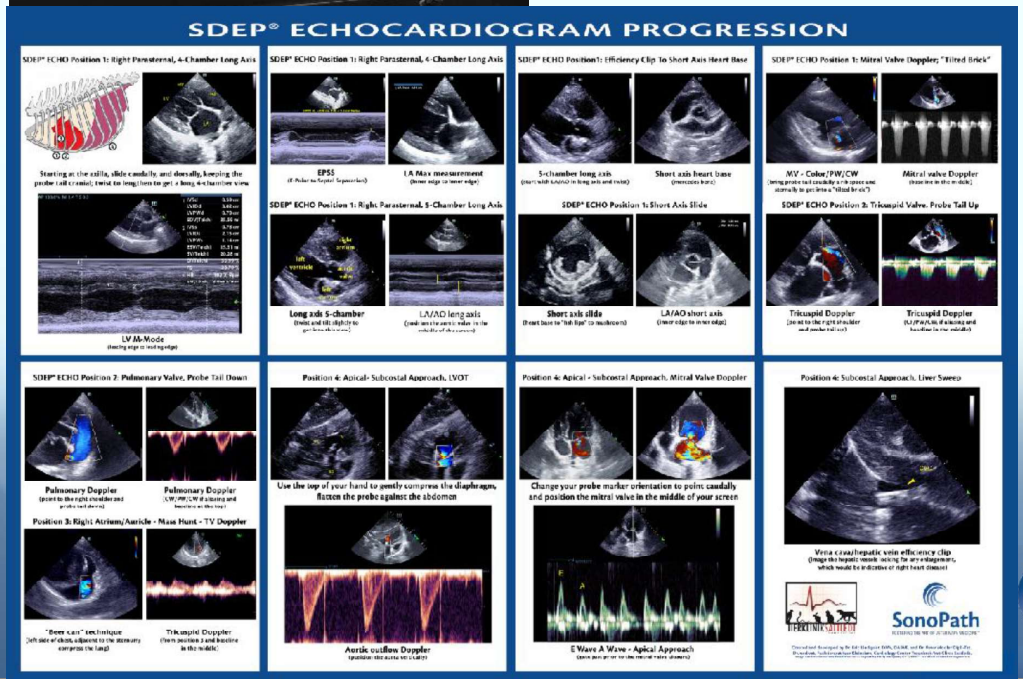
La/Ao M-Mode

Wide AV in B-Mode
AO: End AV closure,
LA: Begin AV Closure
Don't Measure Artifact

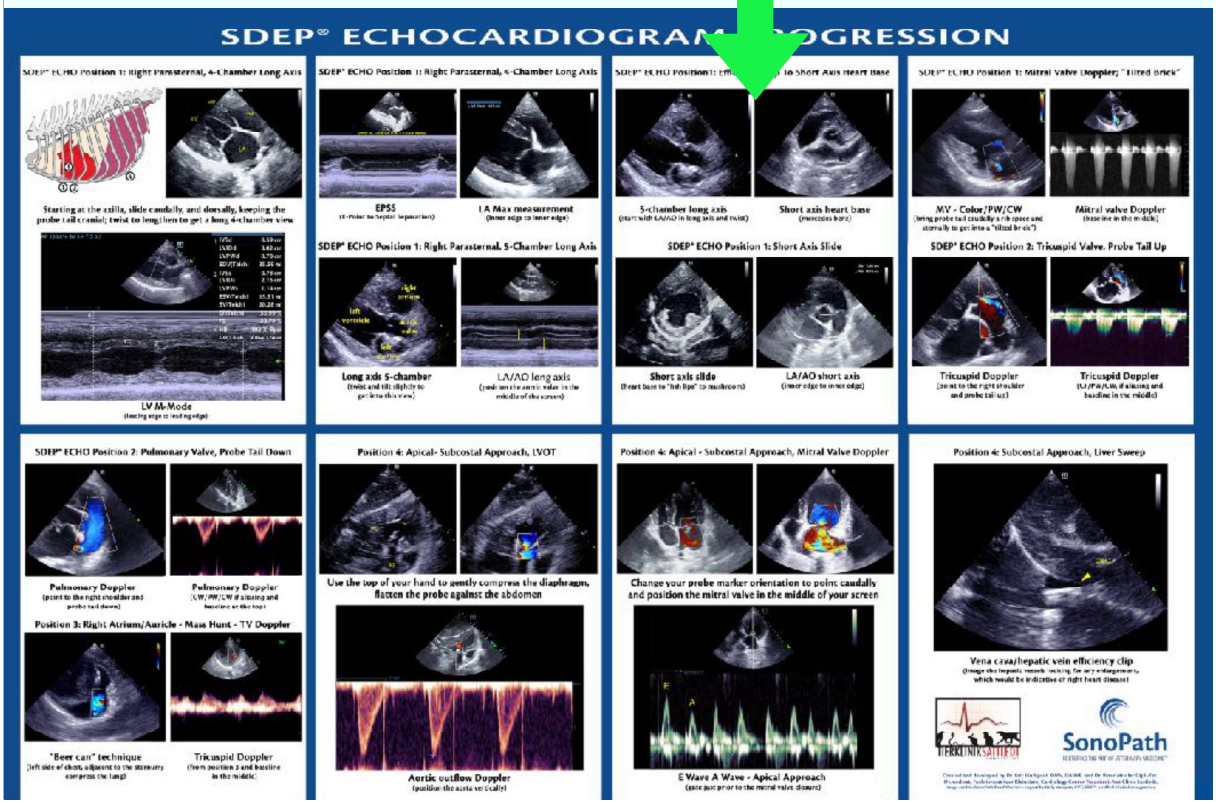




Stick To The Progression….. Don't miss a step

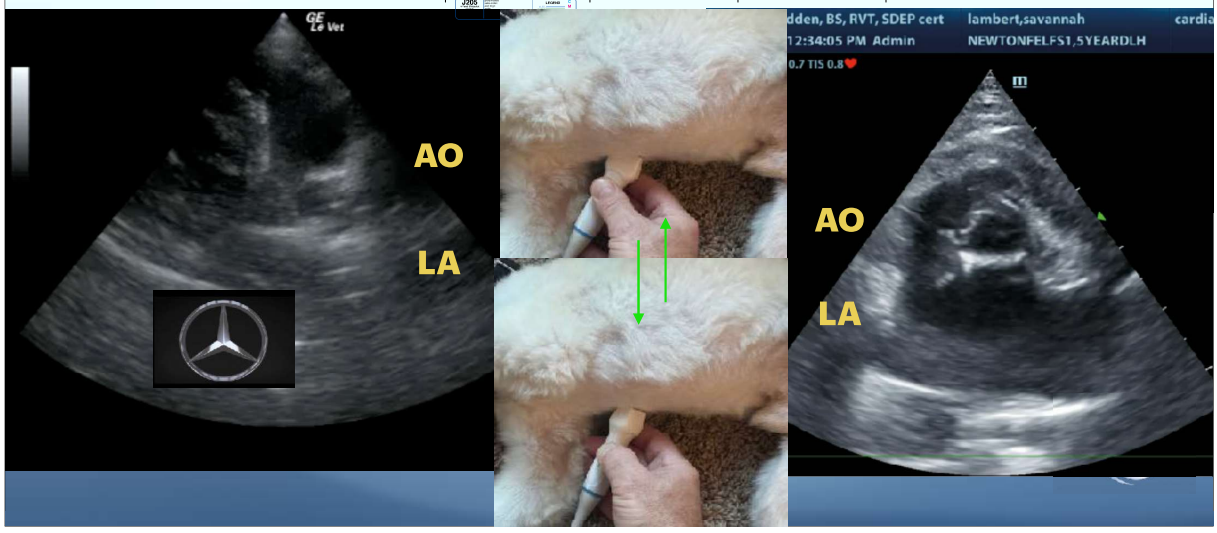


Poster Box 3. SDEP 1. Long To Short Axis



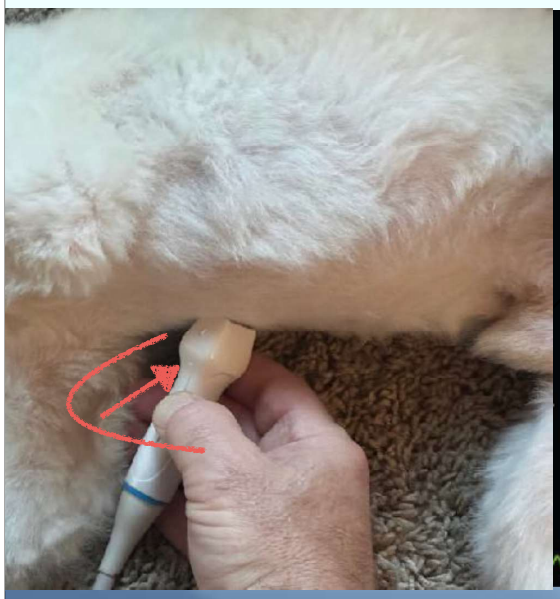
SDEP Pos 1

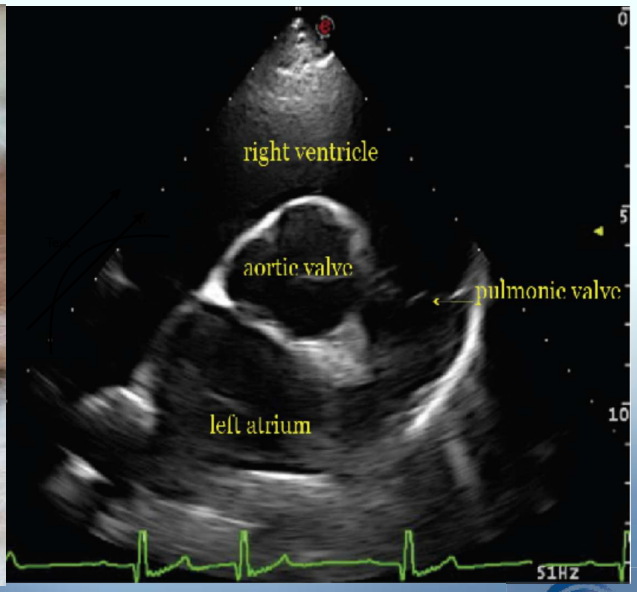
Right Parasternal Long To Short Axis
Pipe To Mercedes



Position 1 Short Axis "Mercedes"

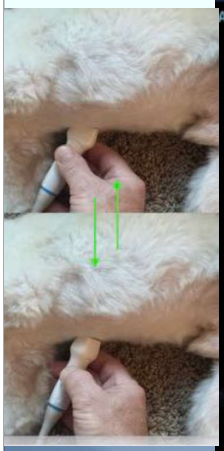
Heart Based = Home Base

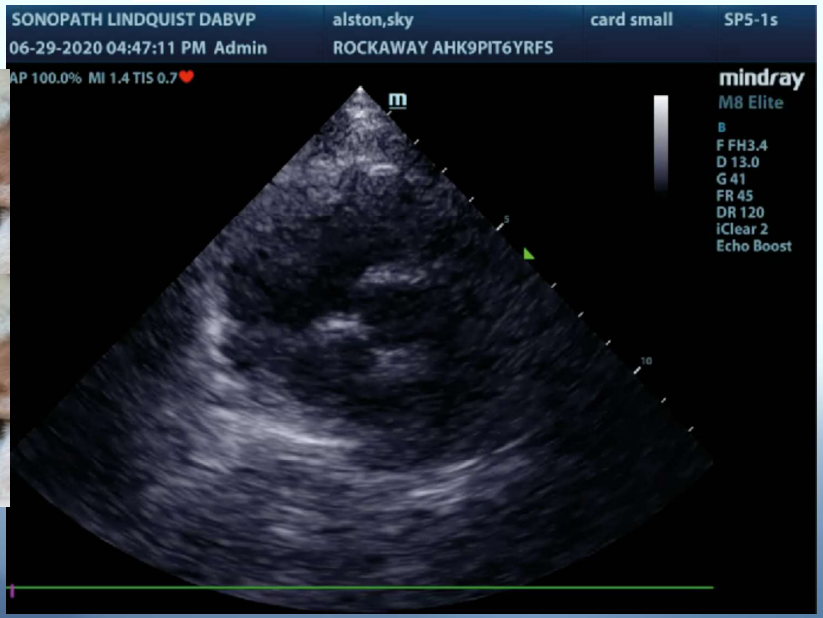




SDEP Position 1

La/Ao Long Axis >>> Short Axis Heart Base Efficiency Clip: "7 to 11". 90 degree Rotation

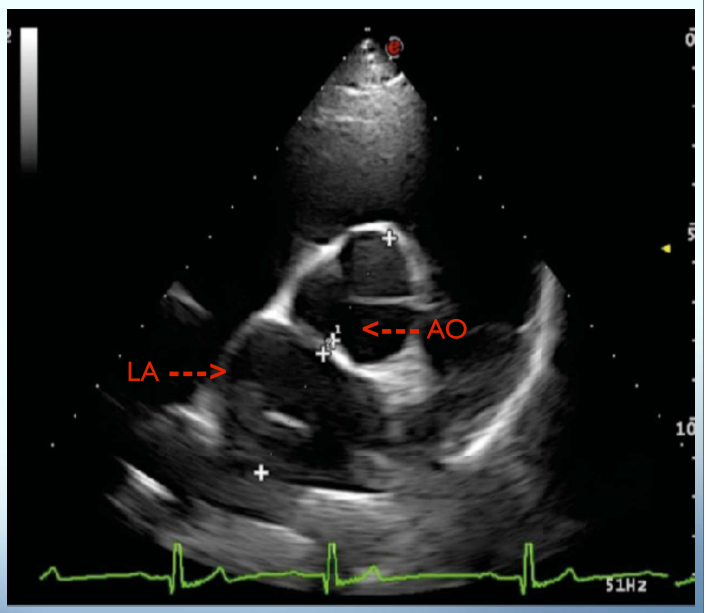




Be creative with the efficiency clips….Why not?

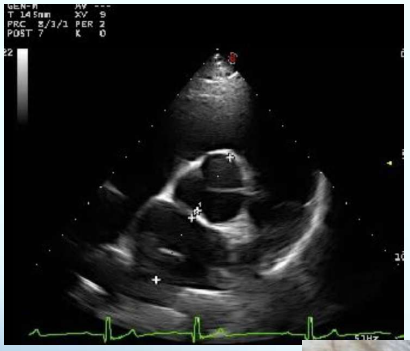
LA/AO Heart base Measurement

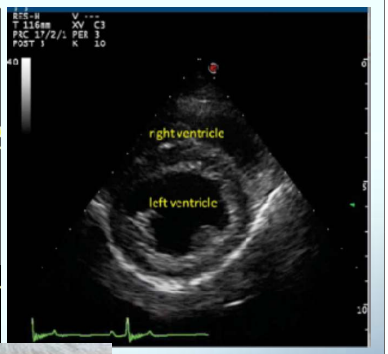
LA/AO: Measure from inner edge to inner edge.

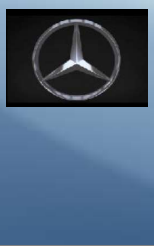


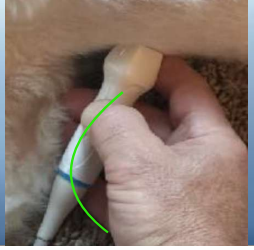
Position 1: SHORT AXIS efficiency clip

Heart base (*Mercedes Benz*) To Mitral Valve (*Fish Lips*)
to Papillary View (*Mushroom*)

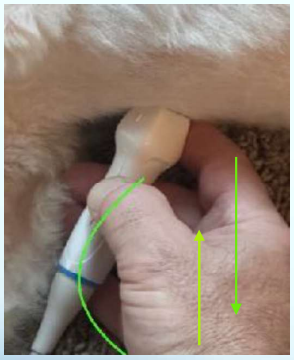


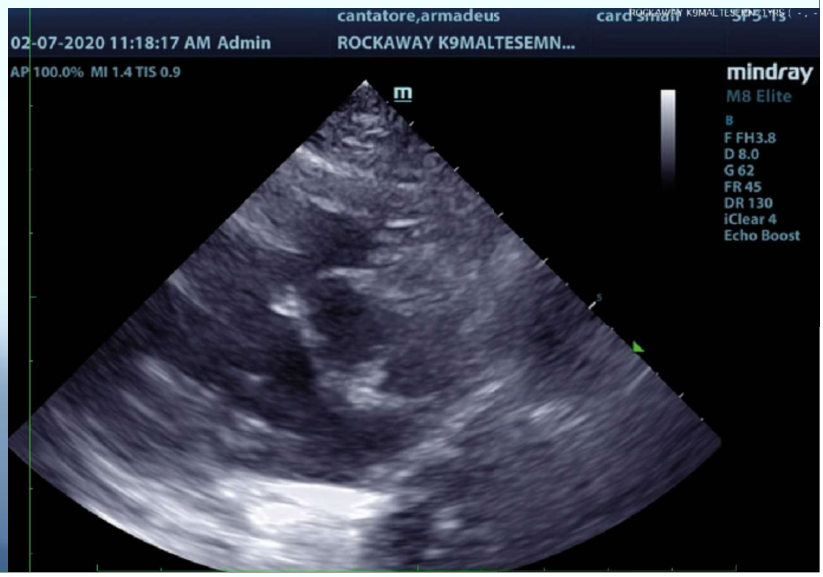




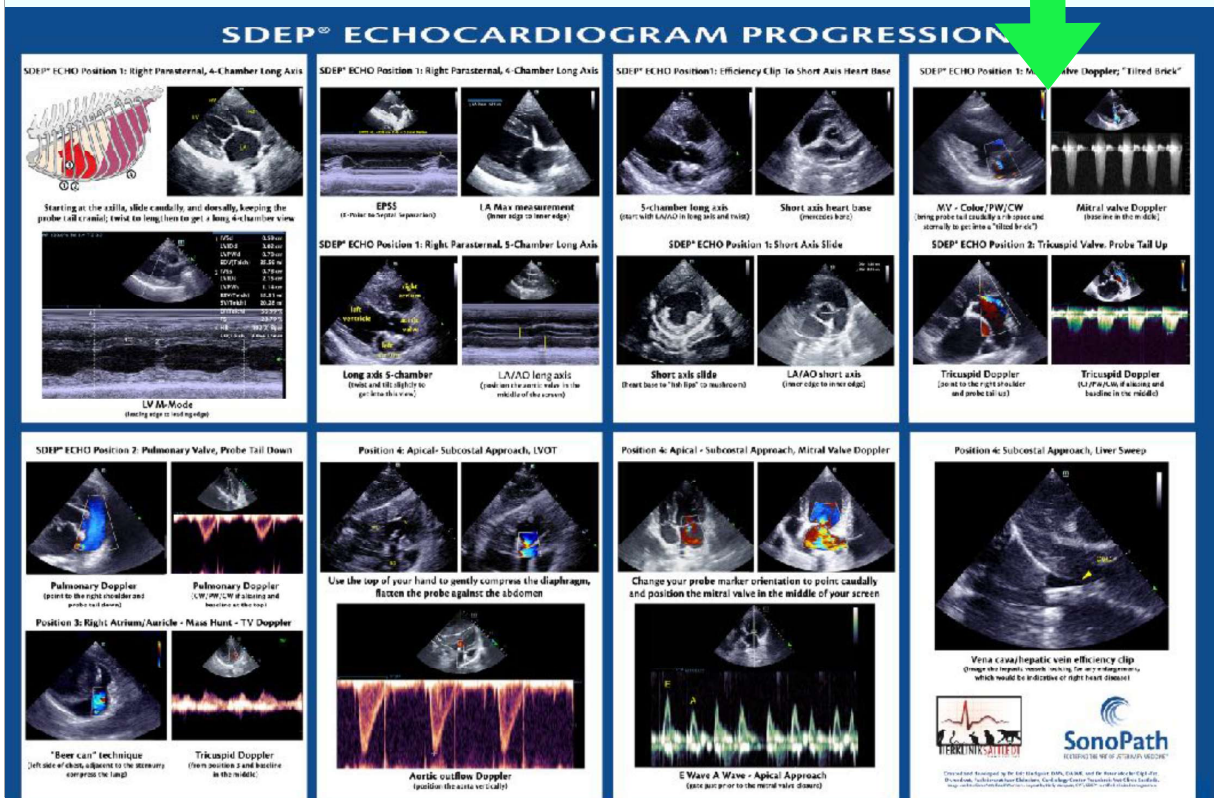


Mercedes - Fish lips - Mushroom: Efficiency clip





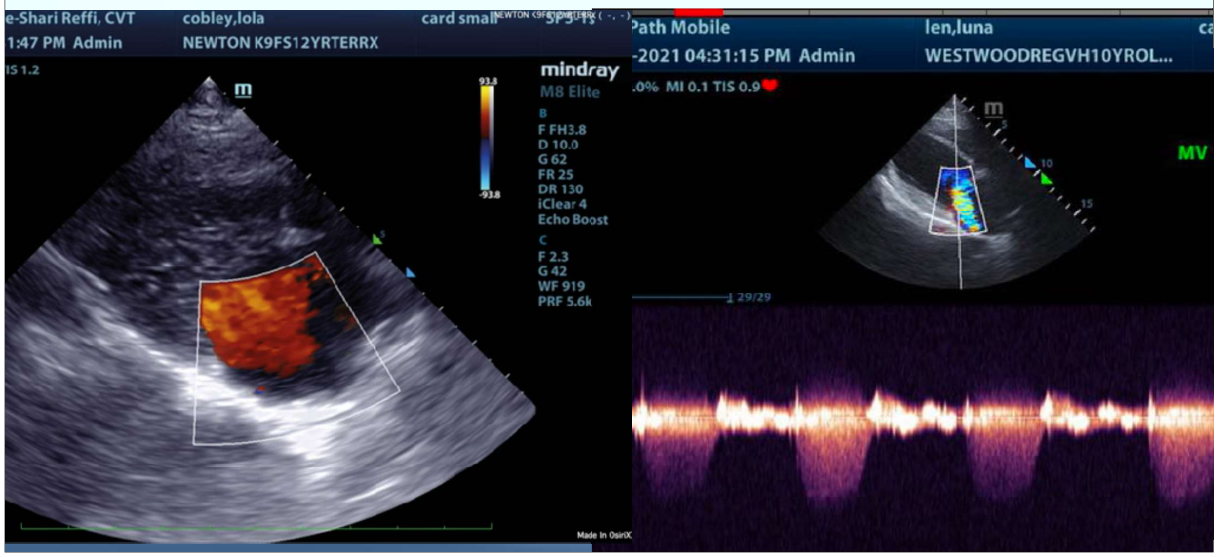
Poster Box 4A. SDEP 2. Tilted Brick



"Tilted Brick" MV Doppler

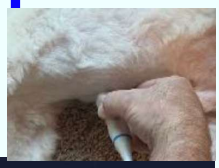
Position your left atrium as far to the right as possible.

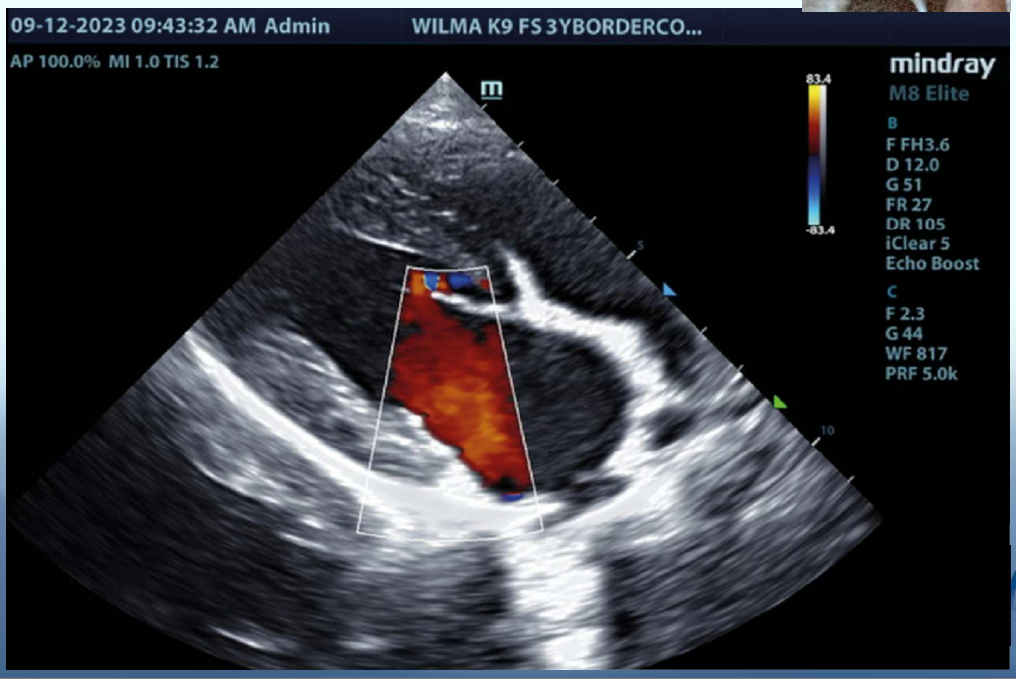
Add Color Flow (CF),
Then Couple With
Continuous Wave (CW)
Raise the baseline to make room for velocities greater than 5 per sec.
BE IN LINE WITH CF JET DIRECTION

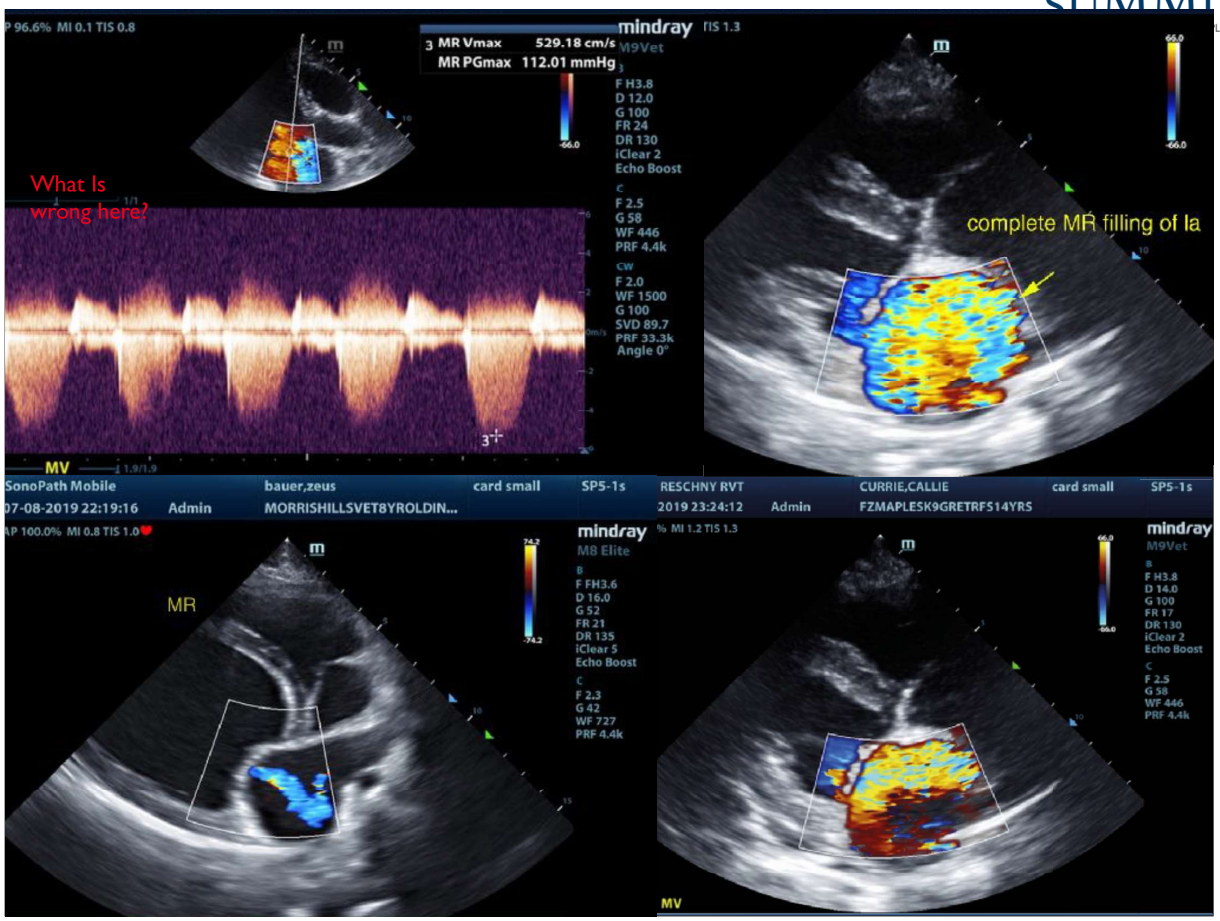


Normal Mitral Valve CF Doppler

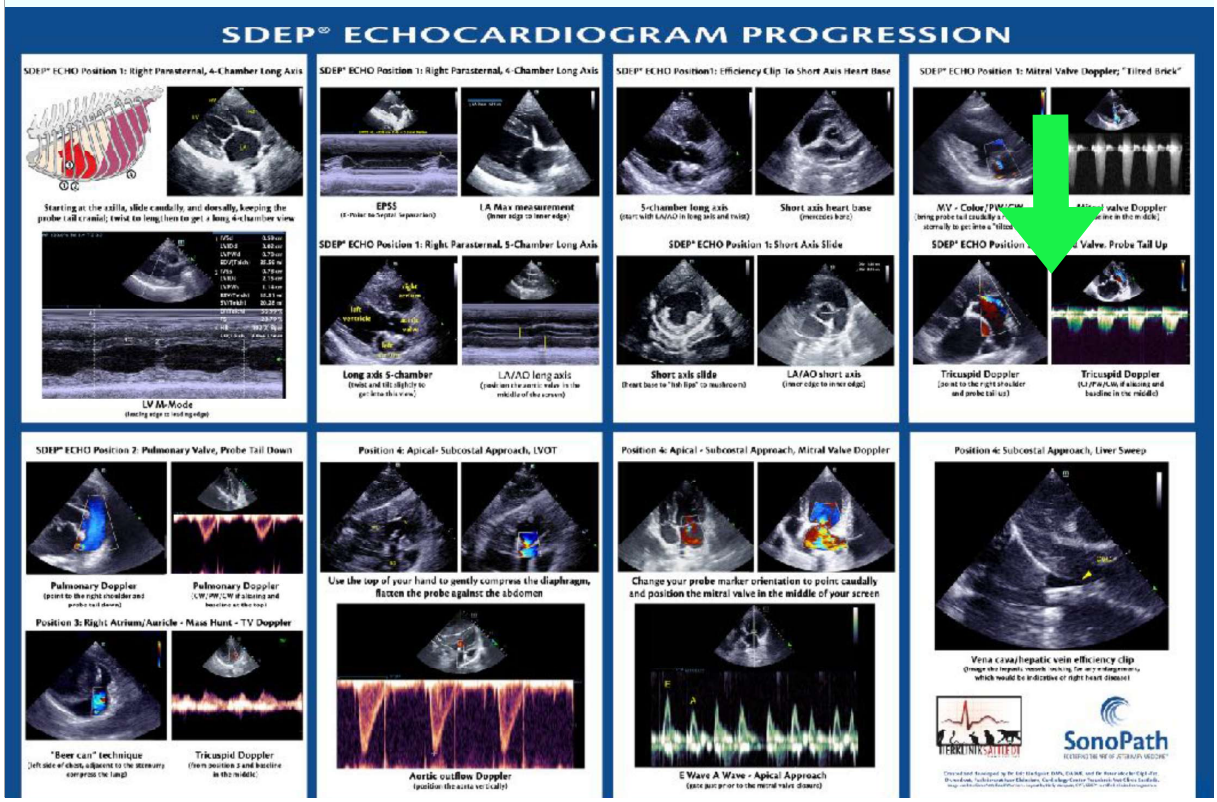
Note: CF Sector Position
1/3 left of MV, 2/3 right of MV





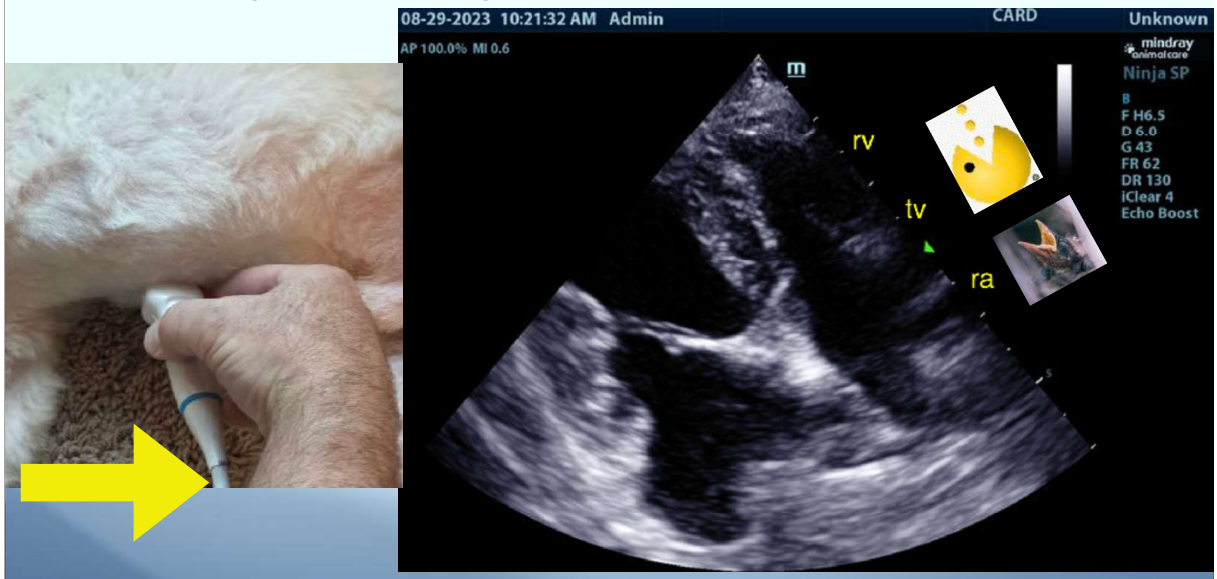


Poster Box 4B. SDEP 2, TV



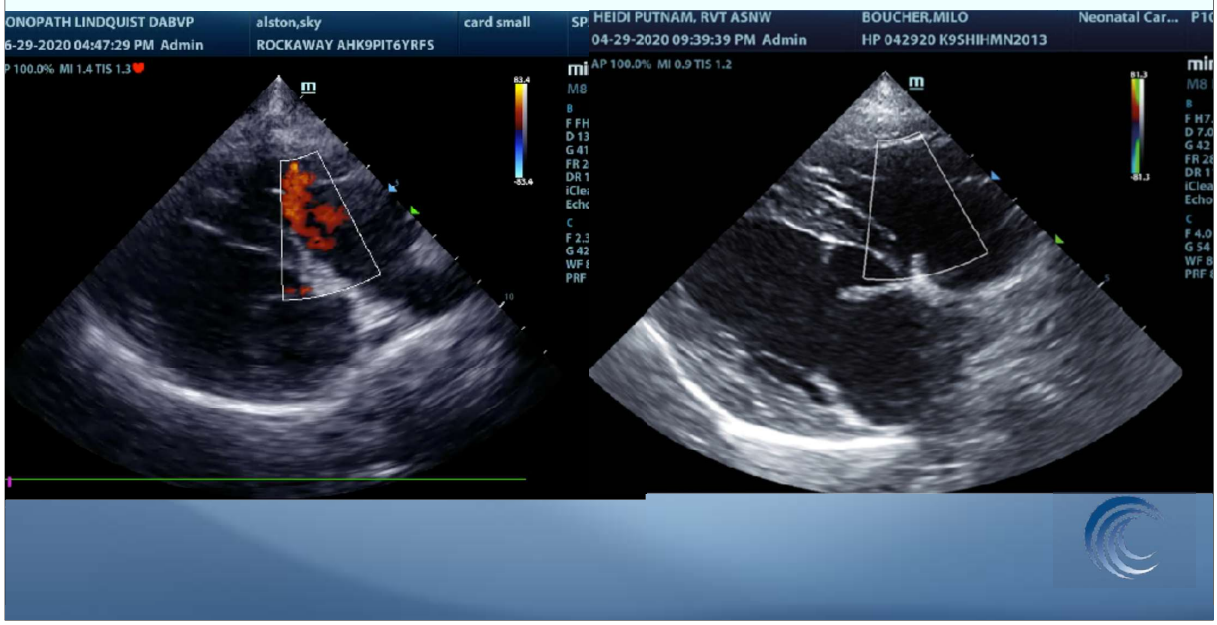
Position 2: *Probe Tail Up*

Right atrium (RA) and pulmonary artery (PA).
For the right atrium bring the probe tail up & **tail of probe caudally.**



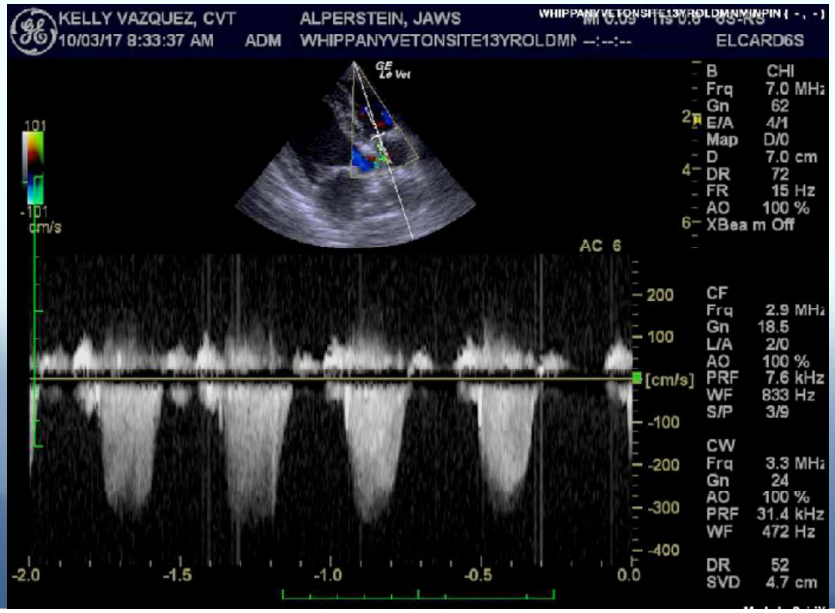
Tricuspid Doppler

Place the doppler gate at the TV closure & direct toward the atrial septum following the color flow mosaic pattern.
Position the TV in view, CF first, PW second, CW if aliasing as shown on the right.

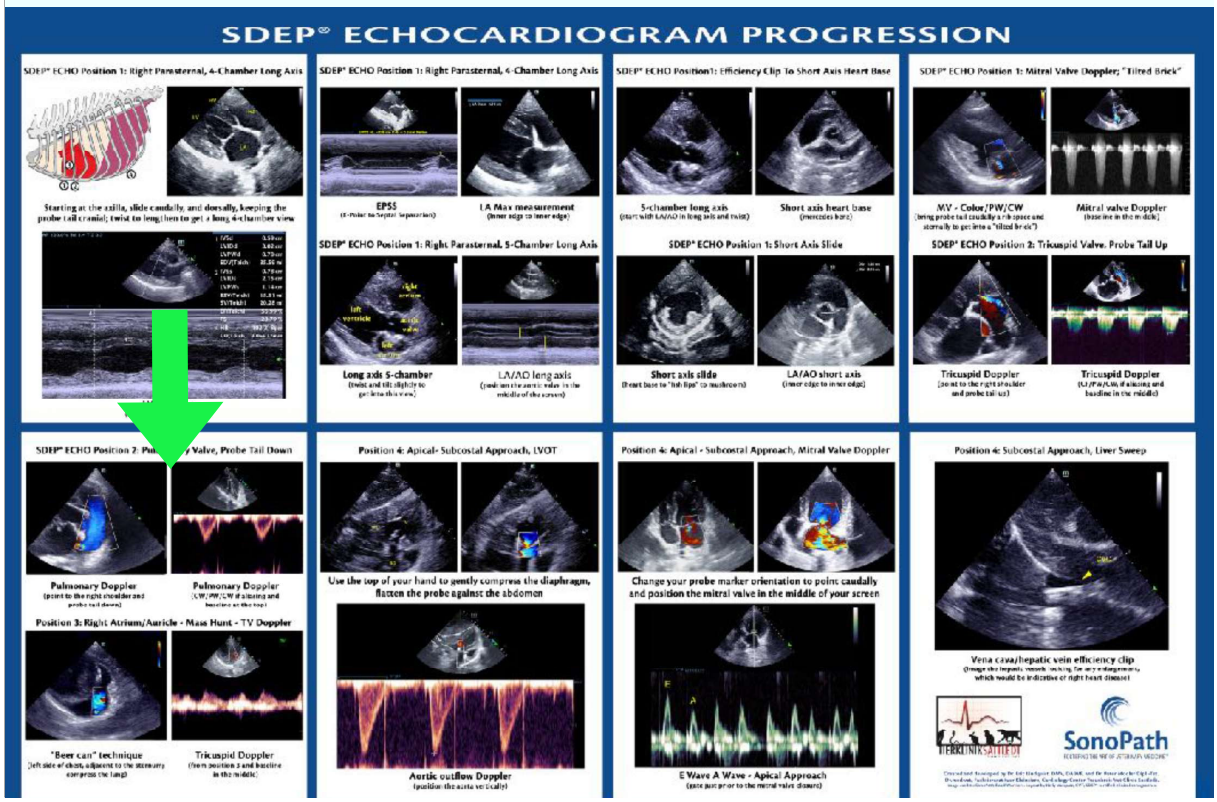


Tricuspid Doppler

Place the doppler gate at the TV closure & direct toward the atrial septum following the color flow mosaic pattern.
Position the TV in view, CF first, PW second, CW if aliasing as shown on the right.



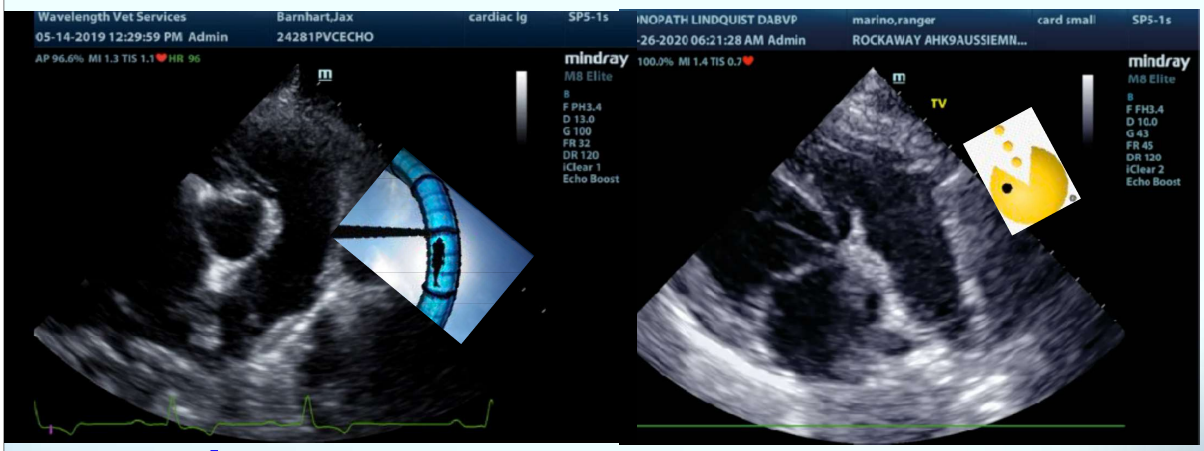
Poster Box 5A. SDEP 2. PA



Position 2: *Probe Tail Down*

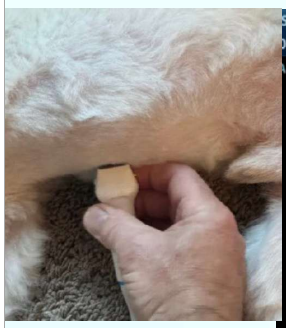
Pulmonary artery (PA)>> probe tail down.
Keep tail of probe caudal.

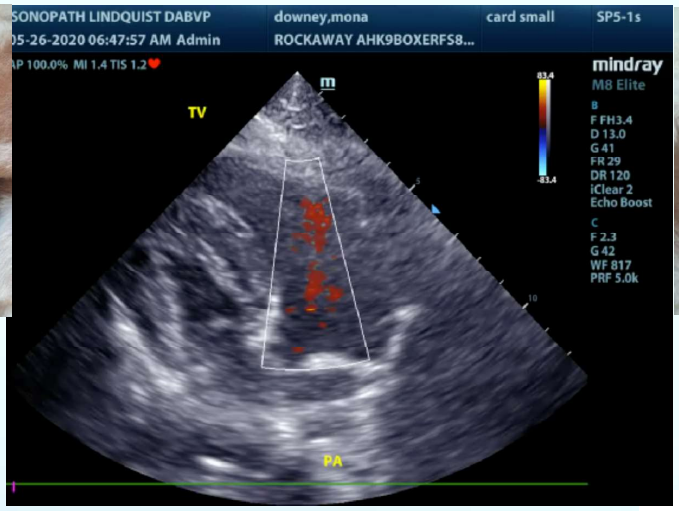
SDEP 2: RA/PA Efficiency Clip

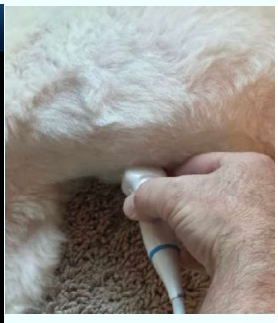


Pulm. Artery
-Probe Tail DOWN

Right Atrium
-Probe Tail UP







Pulm. Artery
-Probe Tail
DOWN

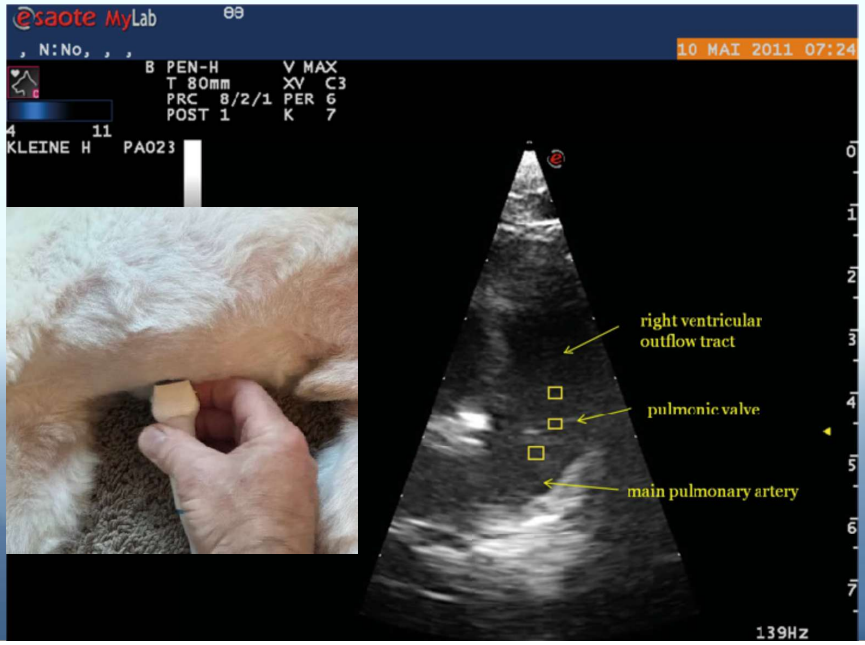
Right Atrium
-Probe Tail UP

Position 2:

Probe Tail Down = PA
Probe Tail Up = RA

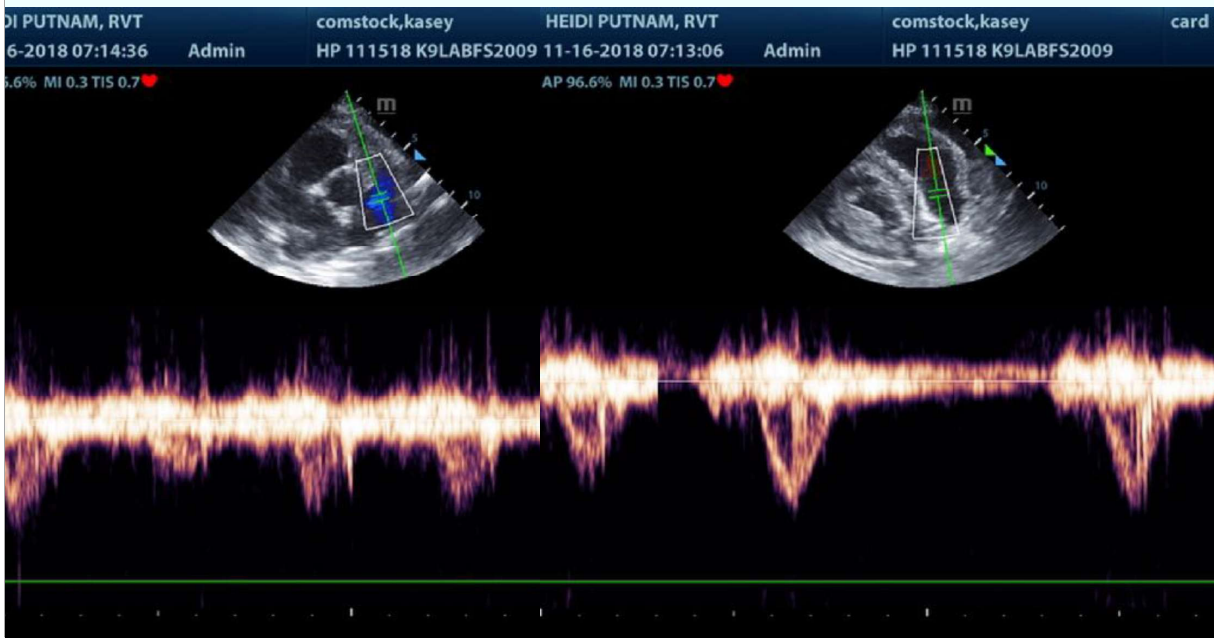
Doppler Gate Positions

Prior to valve: Insufficiency
After valve: Outflow Velocity
Deep PA Bifurcation: PDA



Doppler Quality

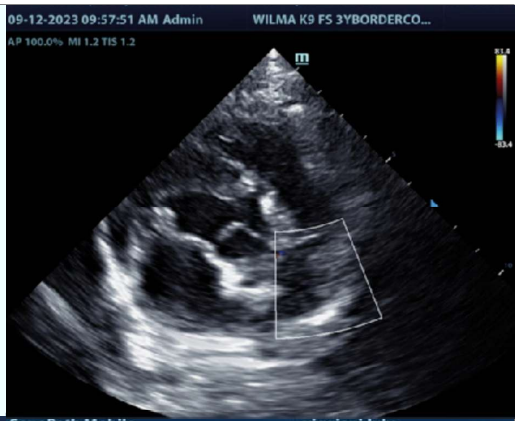
Weak Signal vs. Solid Signal = Mushy vs Clean Wave
Own Your Near Field First ! Then Doppler…

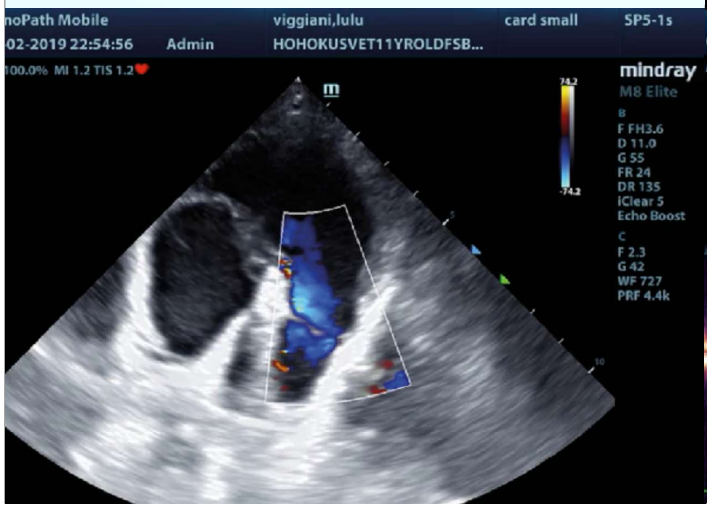


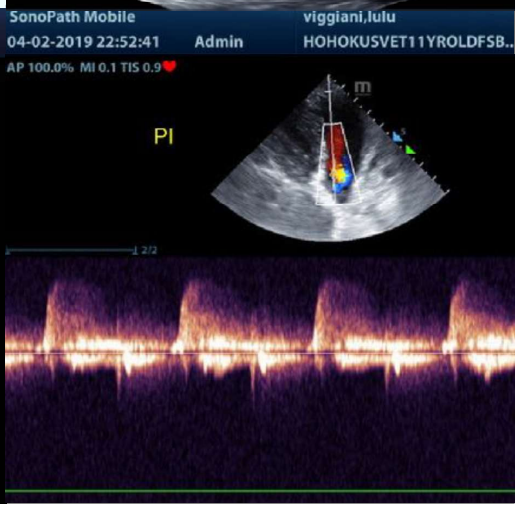
Pulmonic Insufficiency

NORMAL CF =
BLUE AWAY FROM PROBE

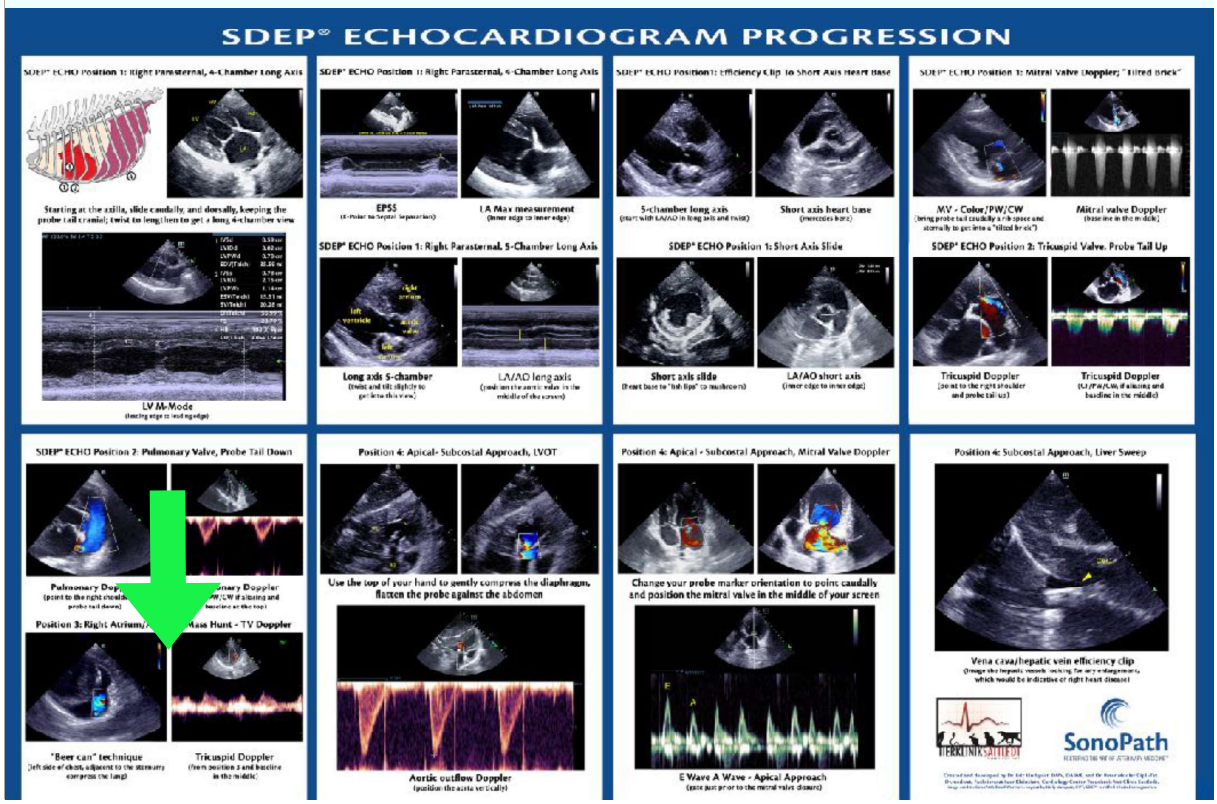
RED JET TOWARD PROBE = PI







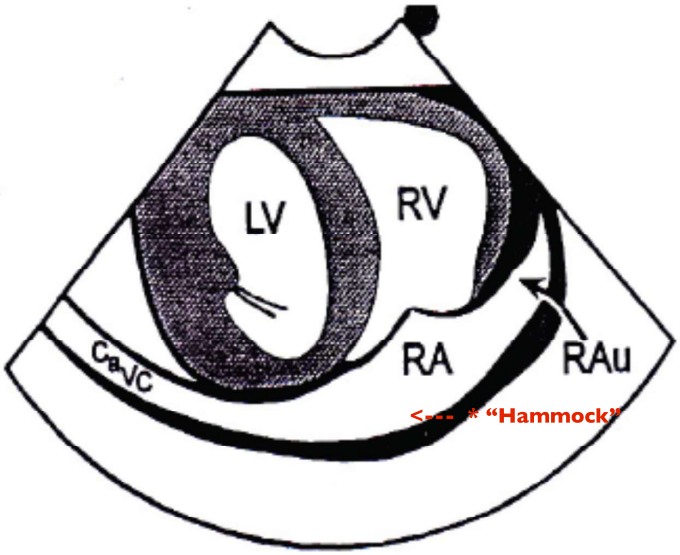
Poster Box 5B. SDEP 3. RA/TV



Position 3:

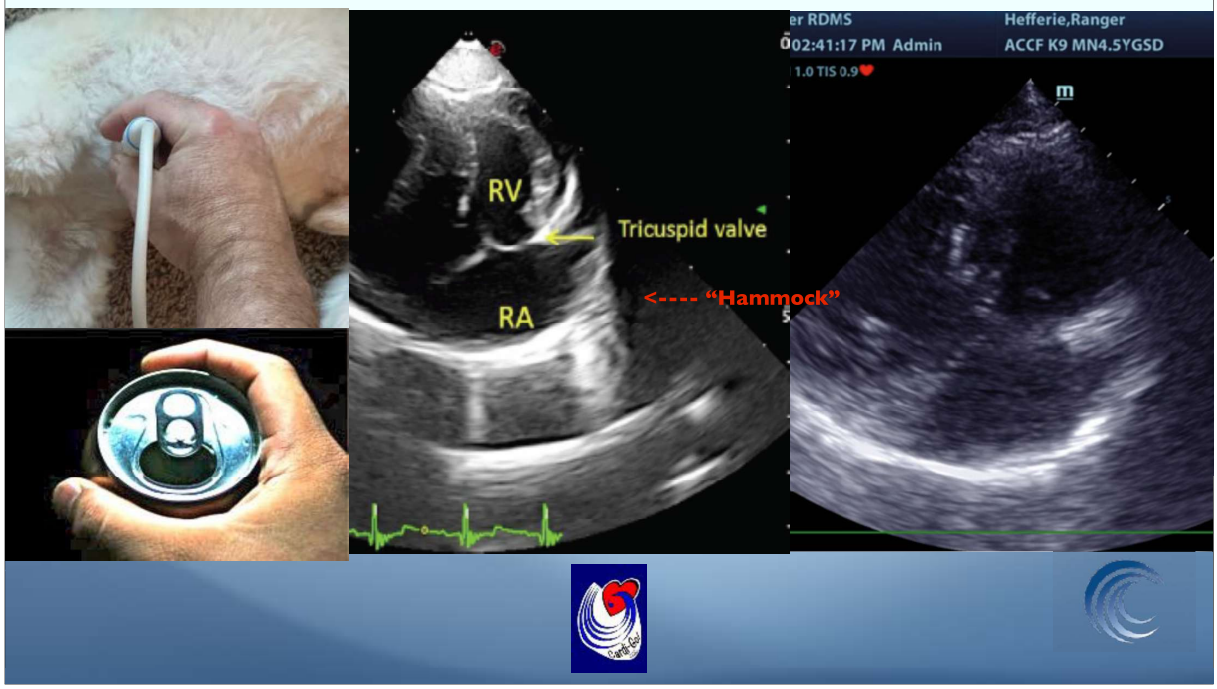
Right atrium/auricle-mass hunt.
"Beer Can View"

Searching for right auricular masses +/- pericardial effusion.

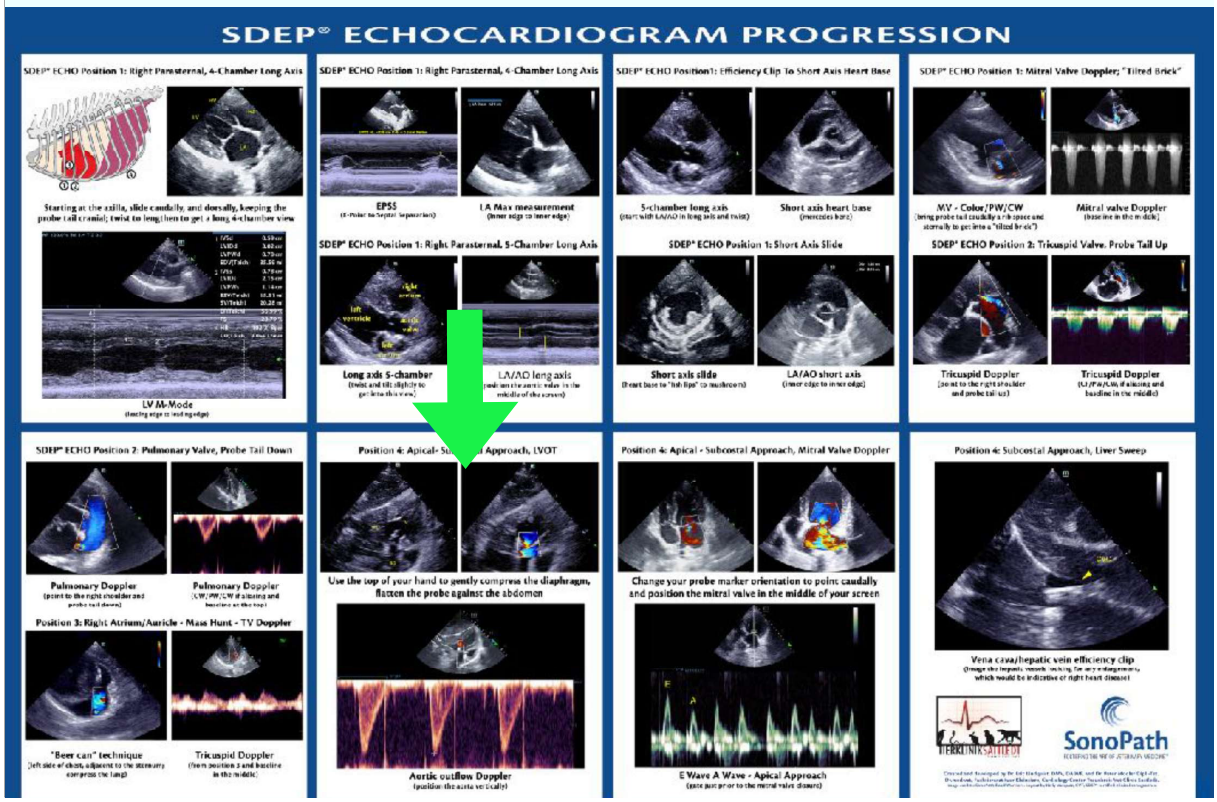


Position 3

"Beer Can" technique, right off of the sternum, push down on the lung, keeping the probe marker cranial.



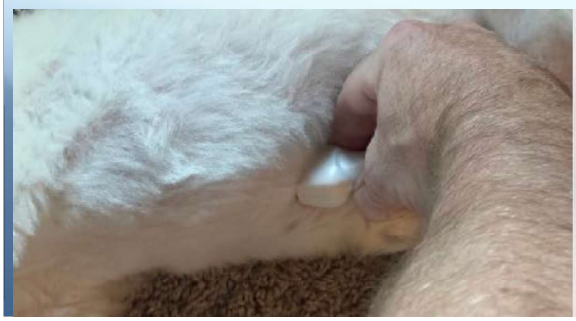
Poster Box 6. SDEP 4. Apical AO

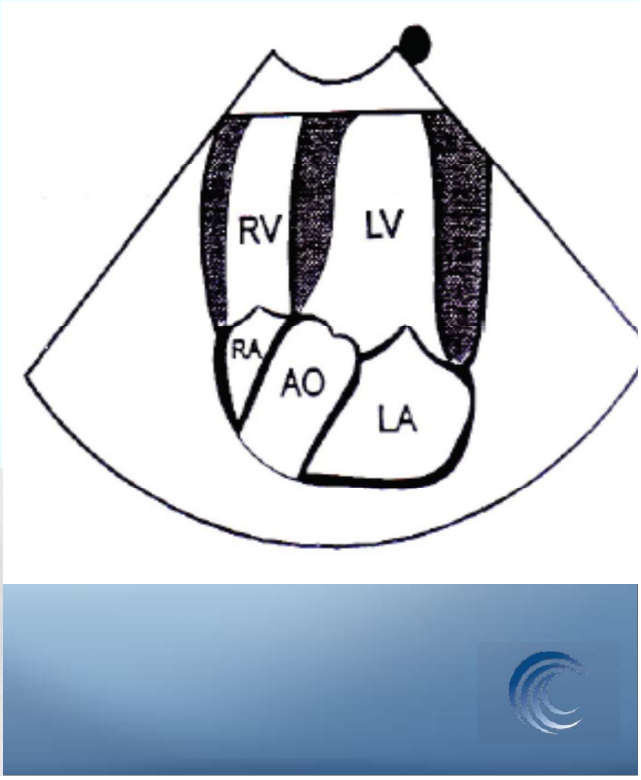


Position 4:

Apical View:
4 & 5 Chamber Views.
MV inflow,
& Liver Sweep

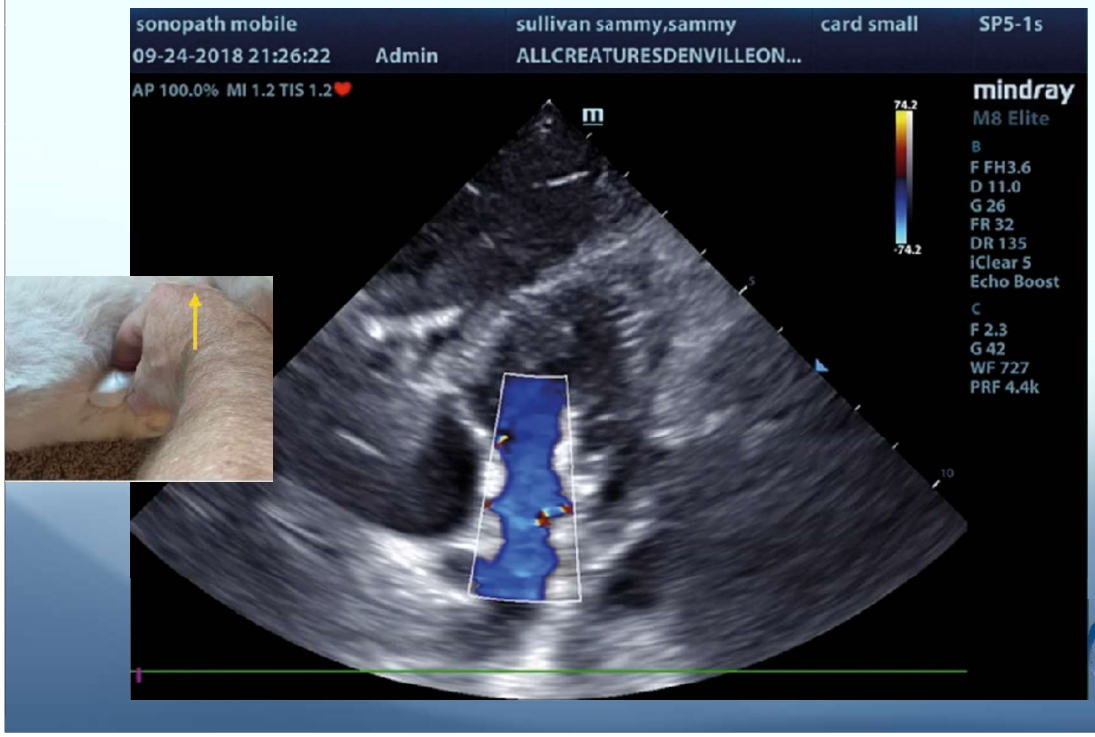
Transdiaphramatic apical view
(subxiphoid parasternal)





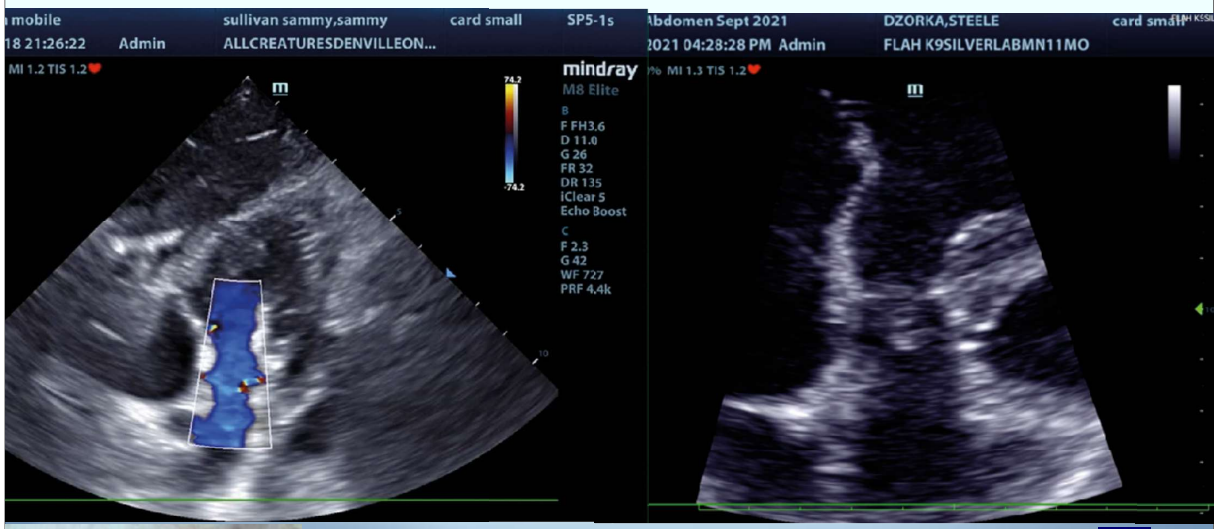
SDEP 4

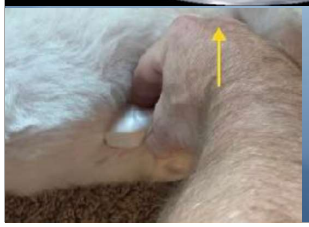
Apical With CF.
Sector Position: 1/3 before the AV, 2/3 after the AV, width of AO



SDEP 4

Apical View - Zoom



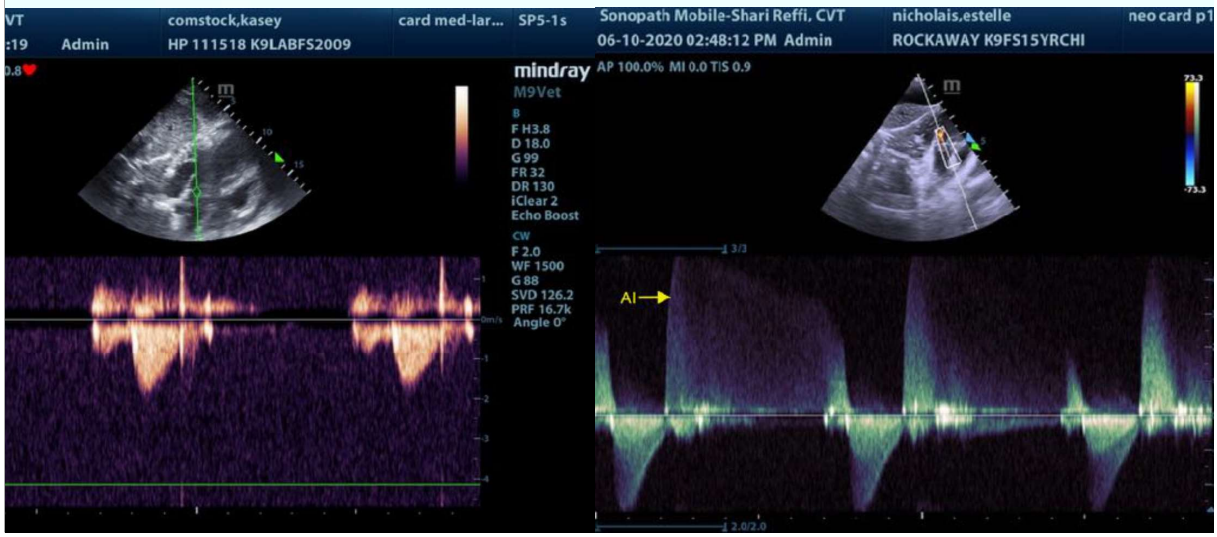


Flatten The Probe Against The Midline

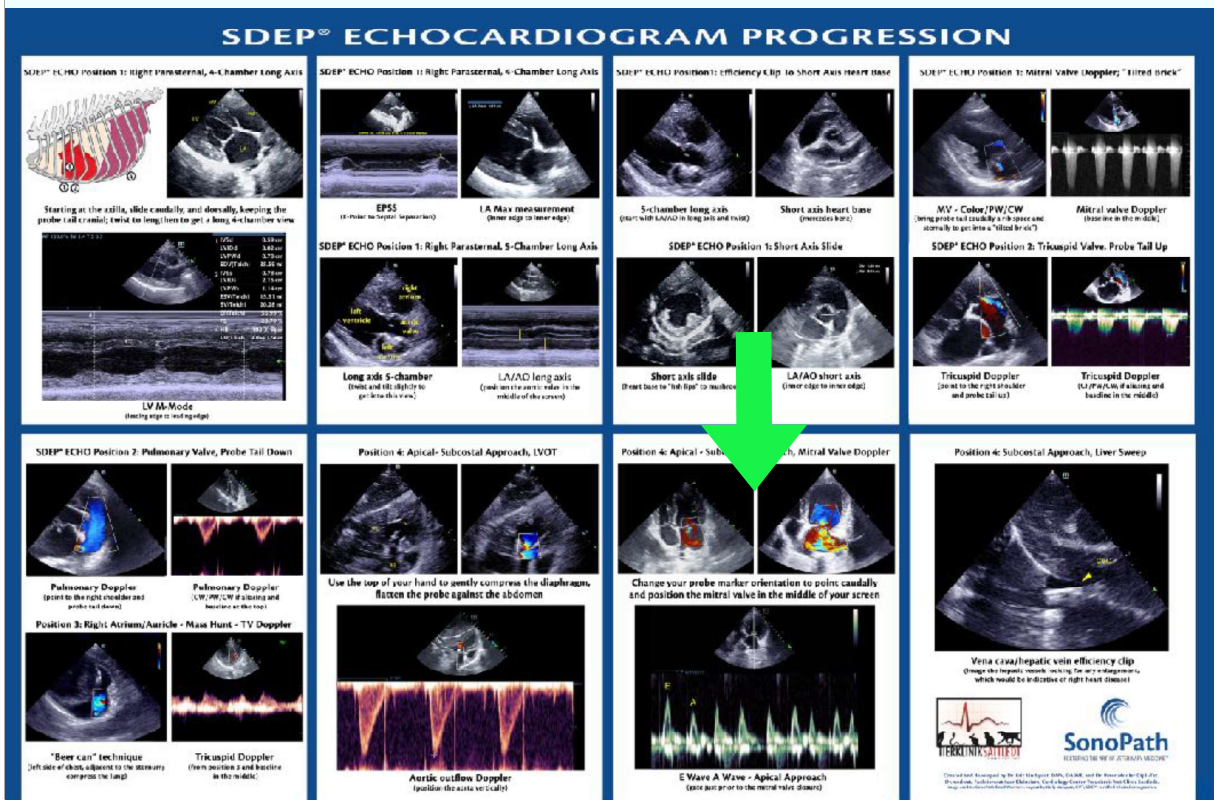
Get Your Clean Wave.
Own The Doppler!

Post AV = Outflow Velocity

Pre AV = Aortic Insufficiency

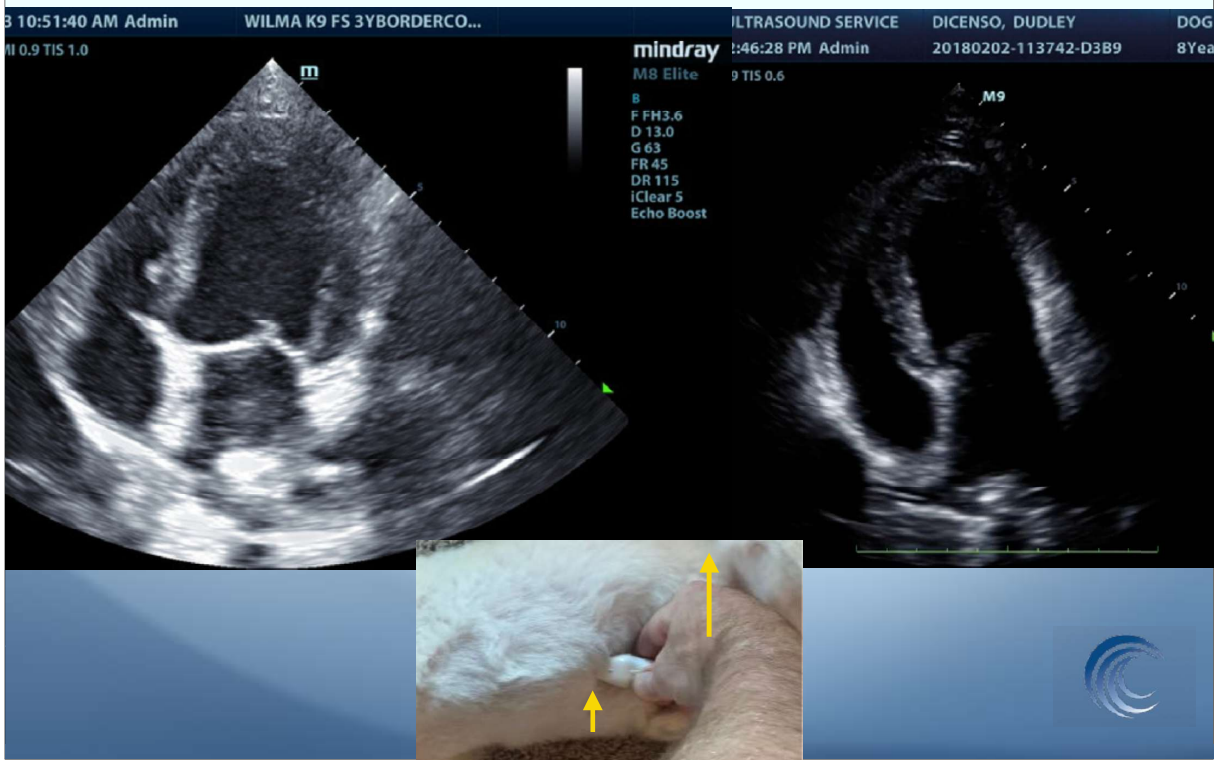


Poster Box 7. SDEP 4 Apical MV



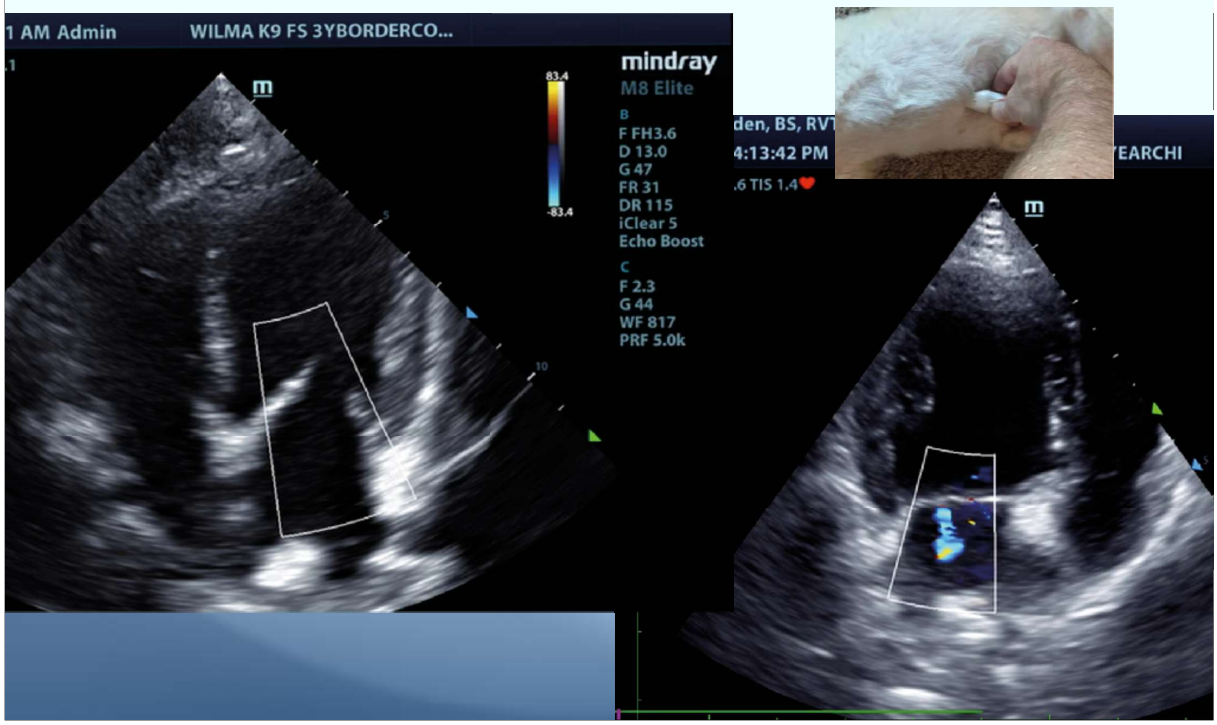
Position 4

Apical 4-Chamber MV, *Slight Probe Twist*

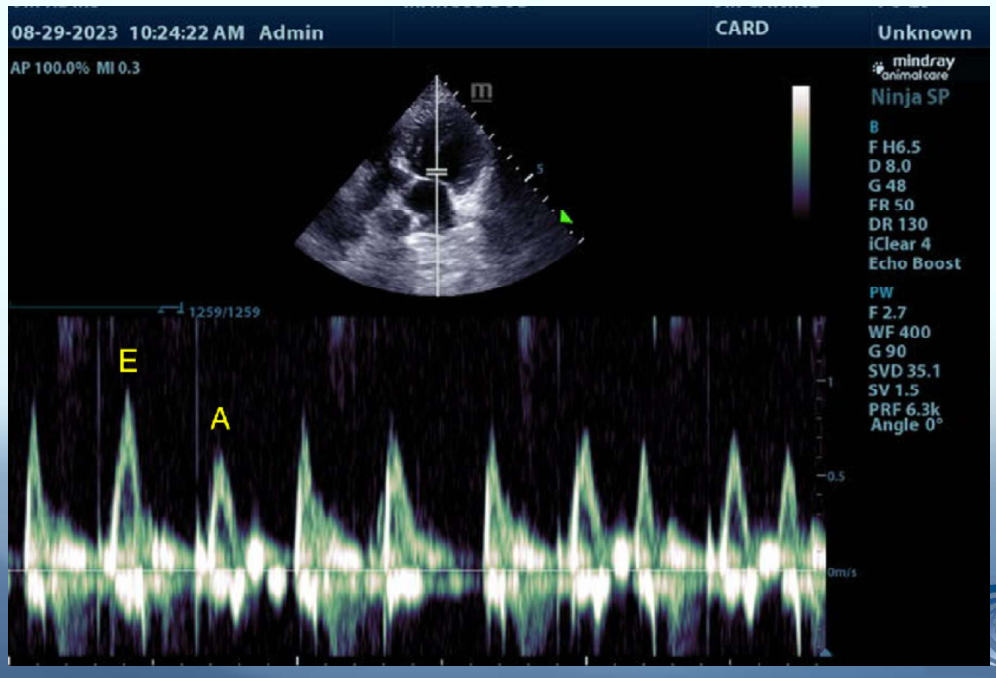


Position 4

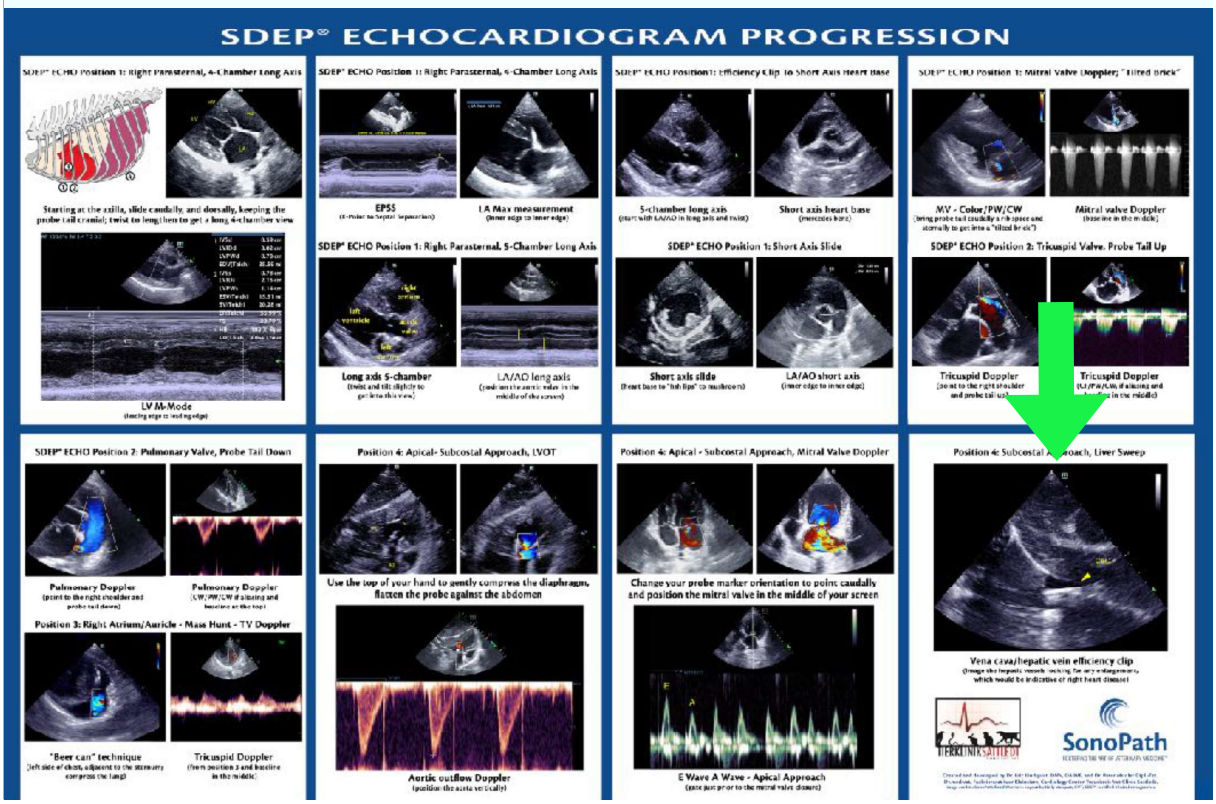
Apical 4 Chamber CF for Central MR Jet
CF Sector Position: 1/3 before, 2/3 after the MV



E/A Wave - Apical



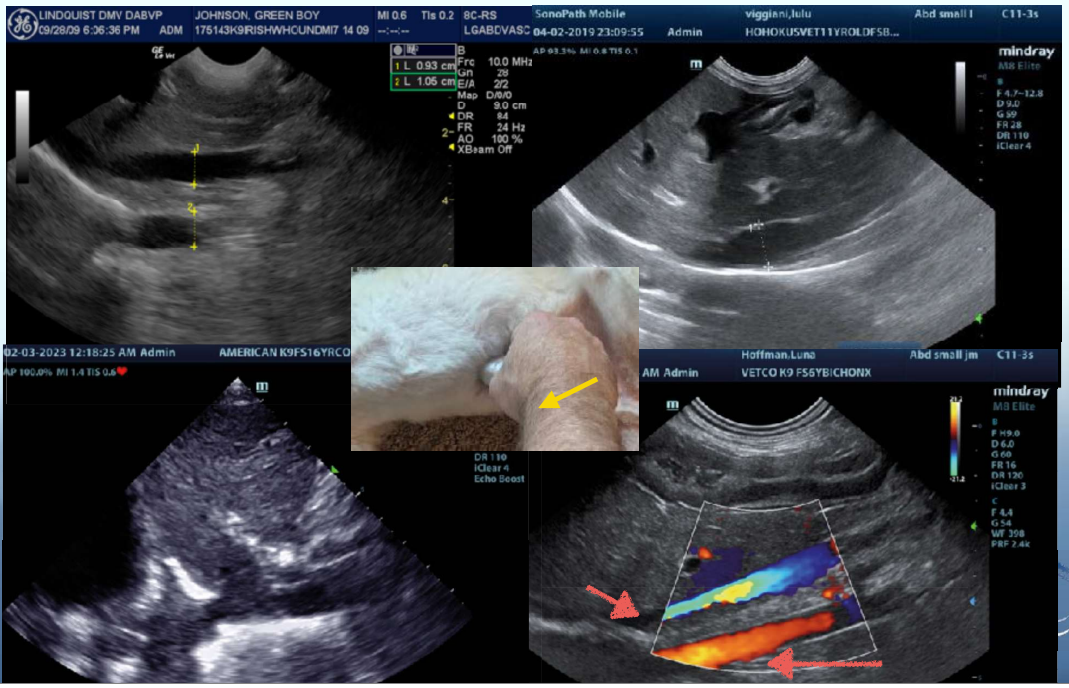
Poster Box 8. CVC & Liver Sweep



SDEP 4 LIVER

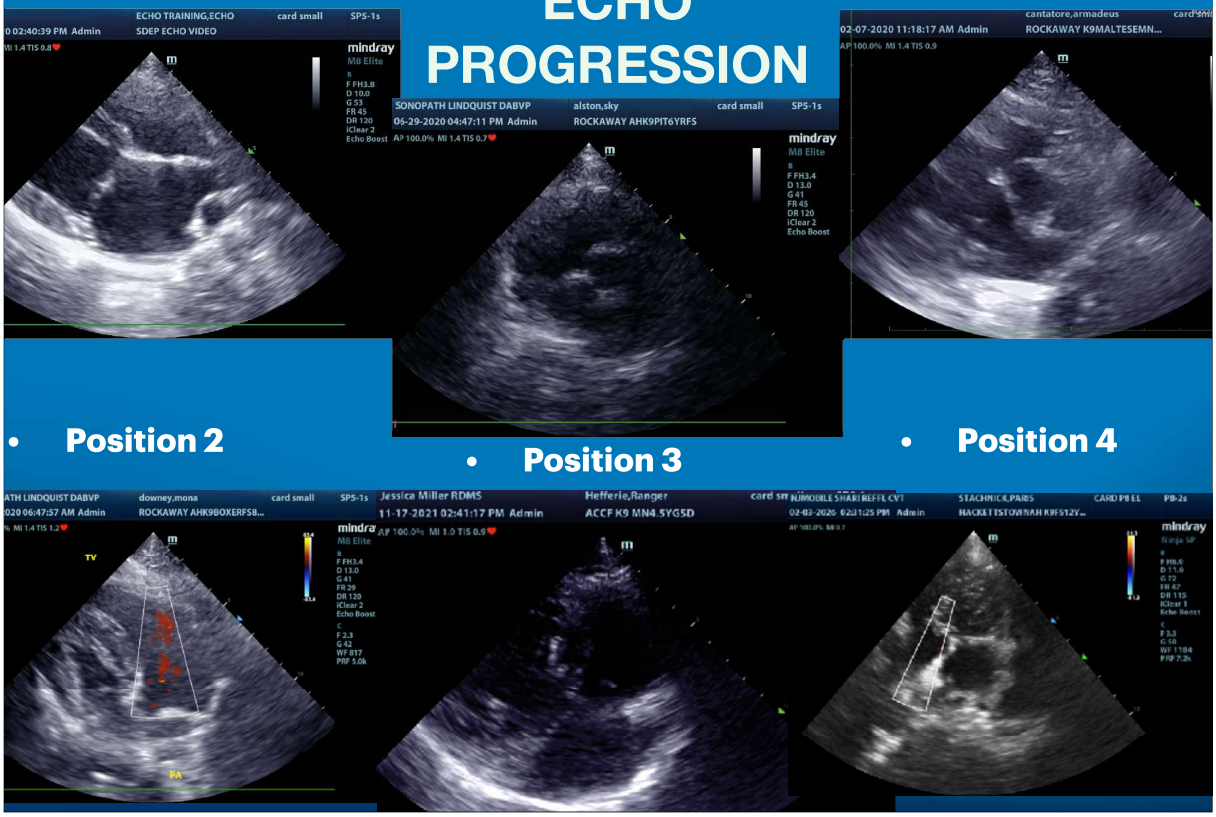
Raise The Probe Tail

Assess Passive Congestion (Domitor mimics this).
Normal CVC:AO ratio +/- 1:1 & HV:PV RATIO 1:1



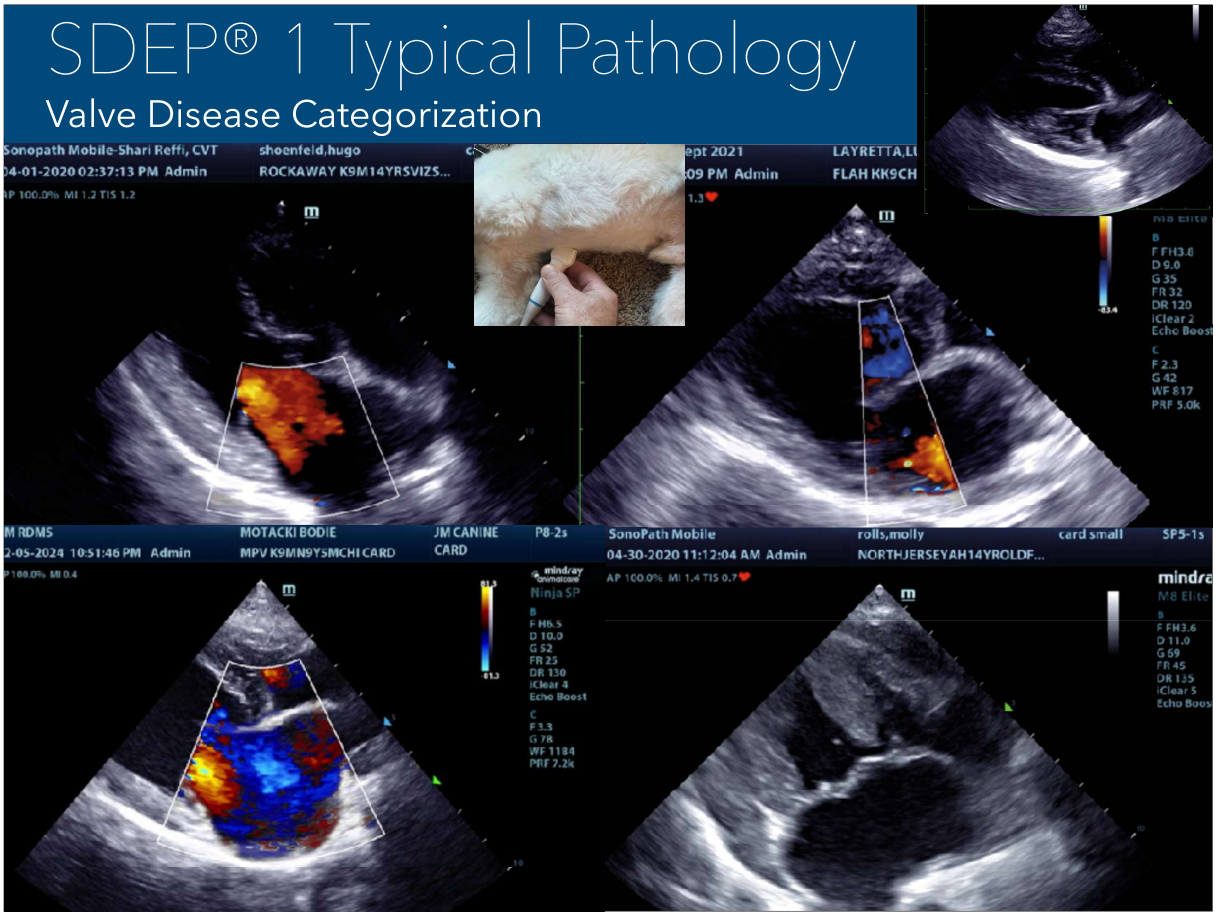
THE SDEP® ECHO PROGRESSION

- Position 1 - Long-Axis
- Position 1 - Short Axis
- Position 2
- Position 3
- Position 4



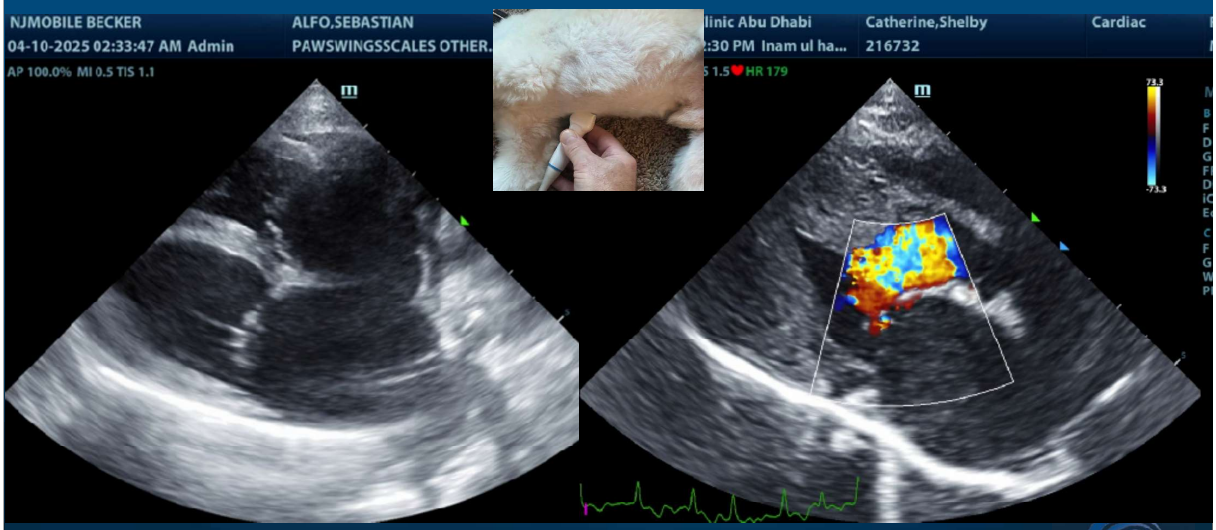
SDEP® 1 Typical Pathology

Valve Disease Categorization



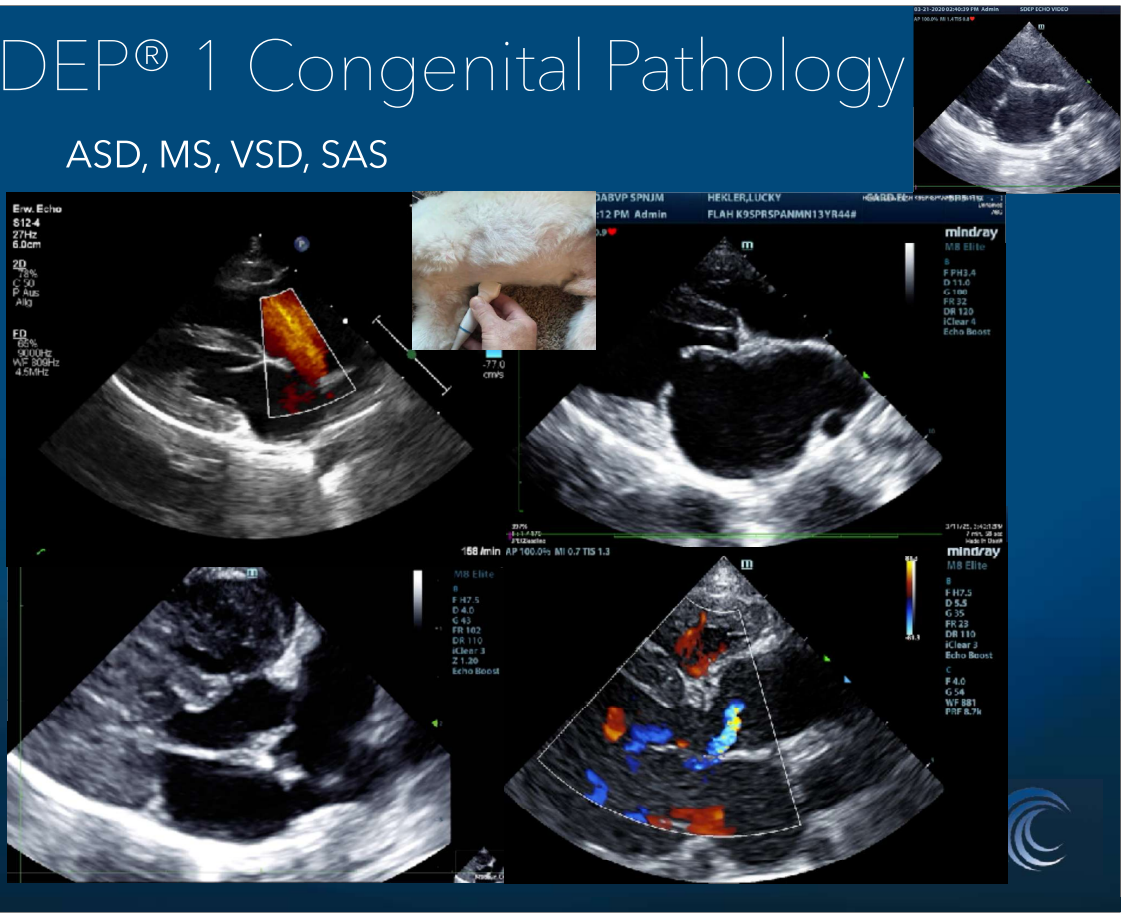
SDEP® 1 Typical Pathology

DCM, HCM-Phenotype



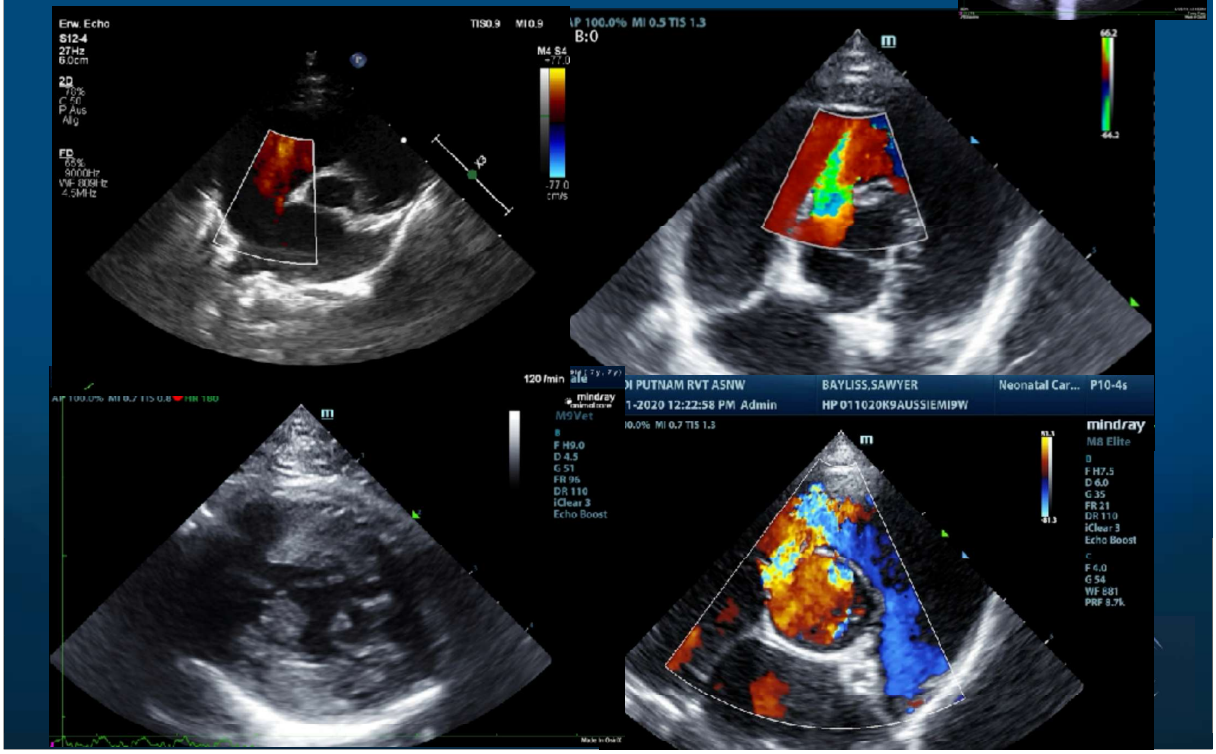
SDEP® 1 Congenital Pathology

ASD, MS, VSD, SAS

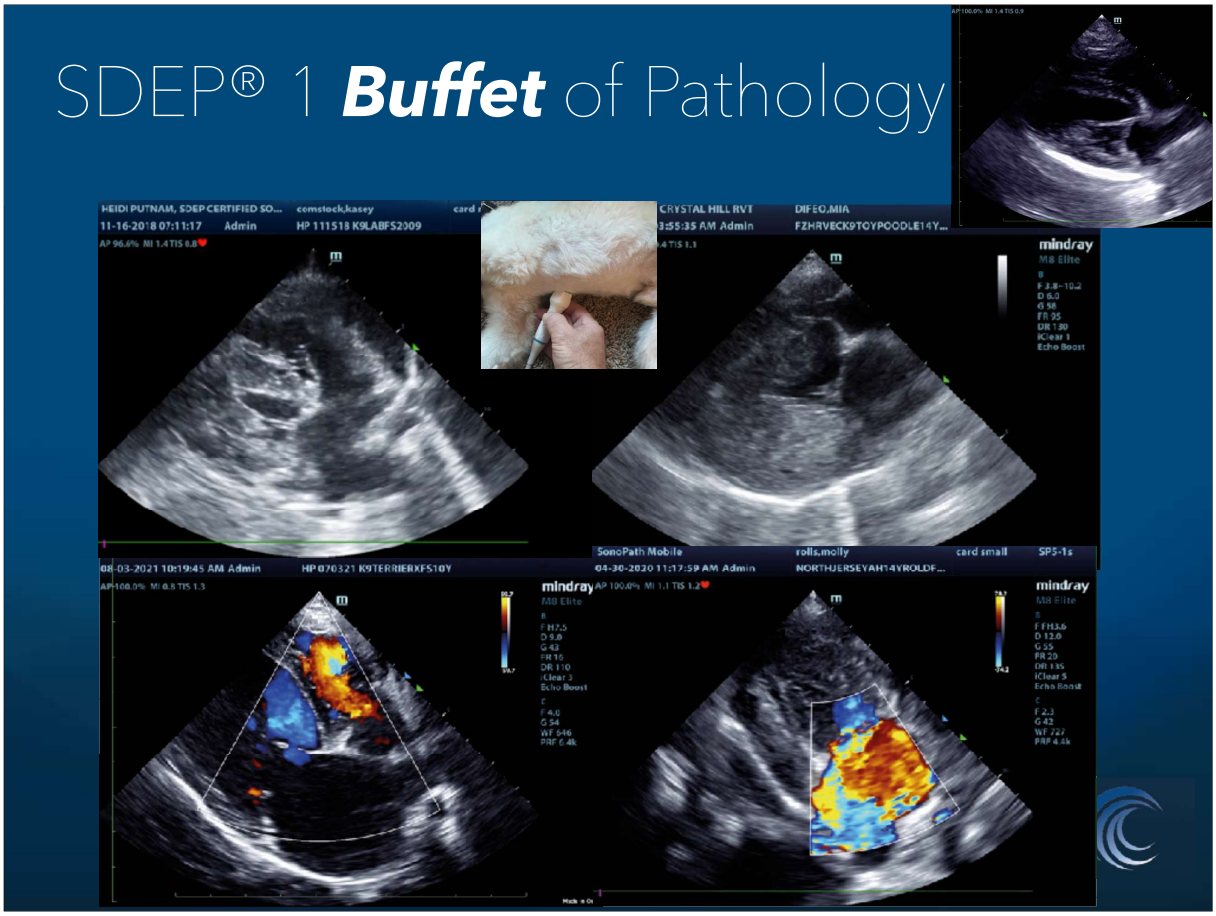


SDEP® 1 Typical Pathology

Short Axis

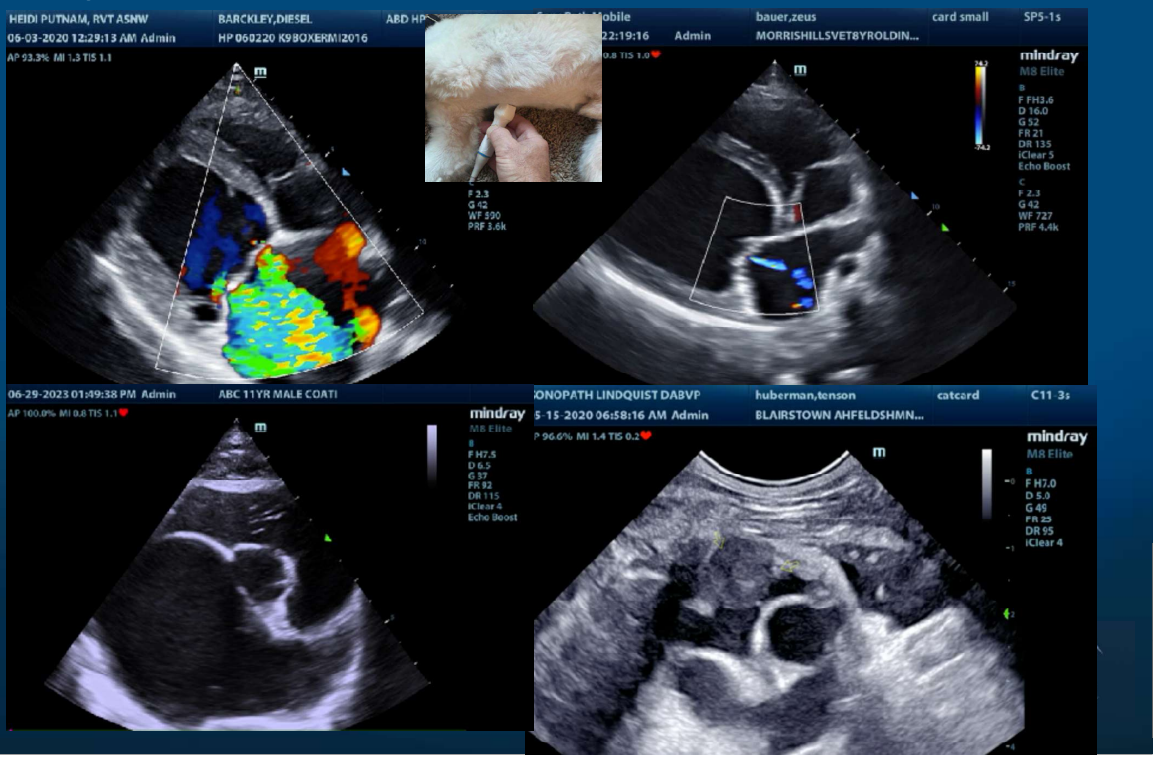


SDEP® 1 **Buffet** of Pathology



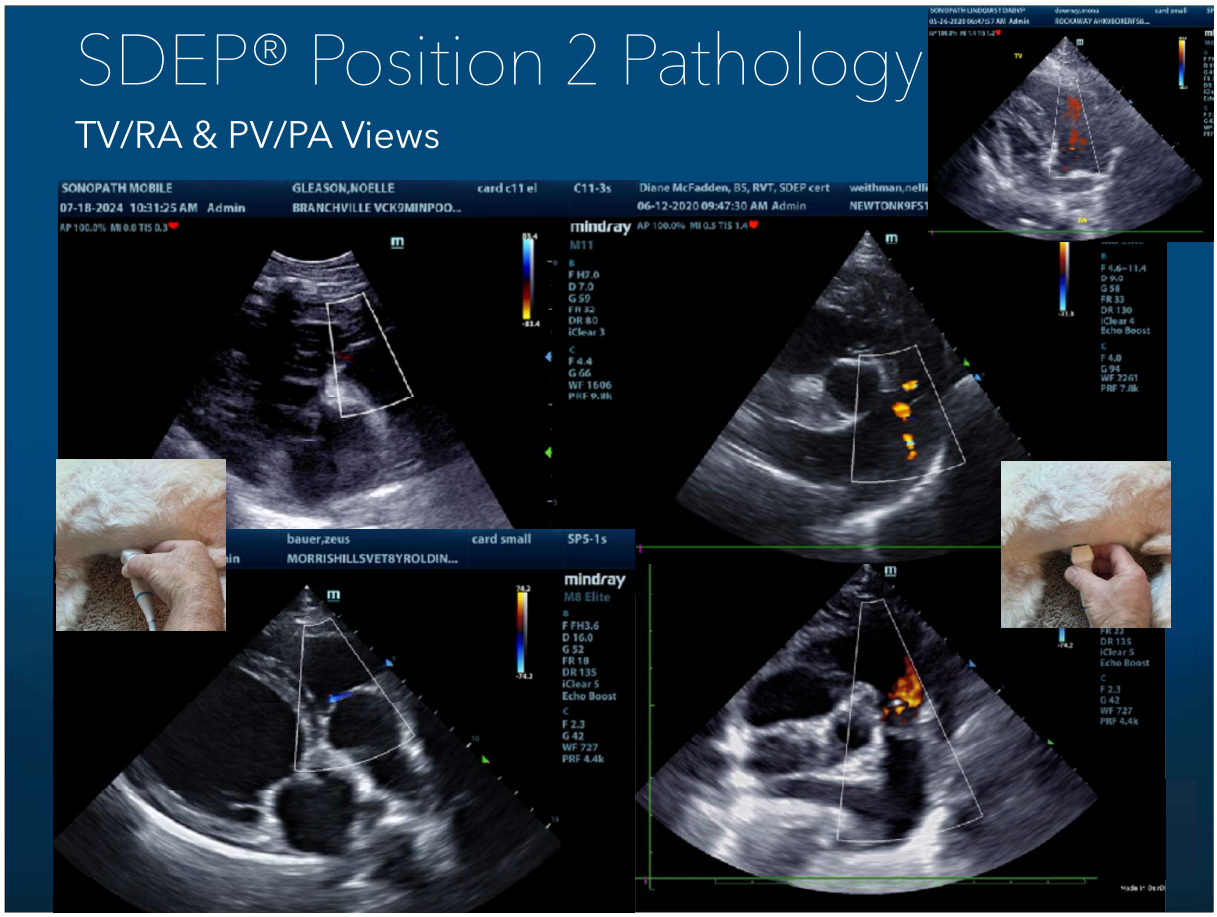
SDEP® 1 Typical Pathology

Long & Short Axis



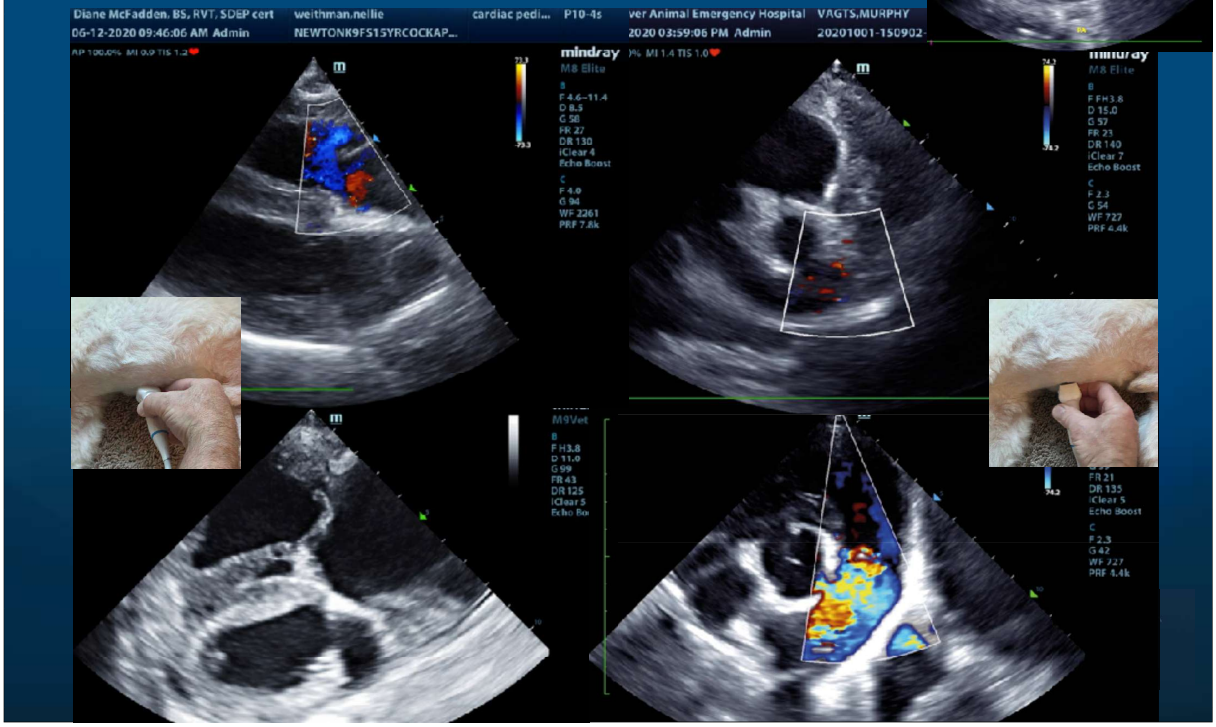
SDEP® Position 2 Pathology

TV/RA & PV/PA Views



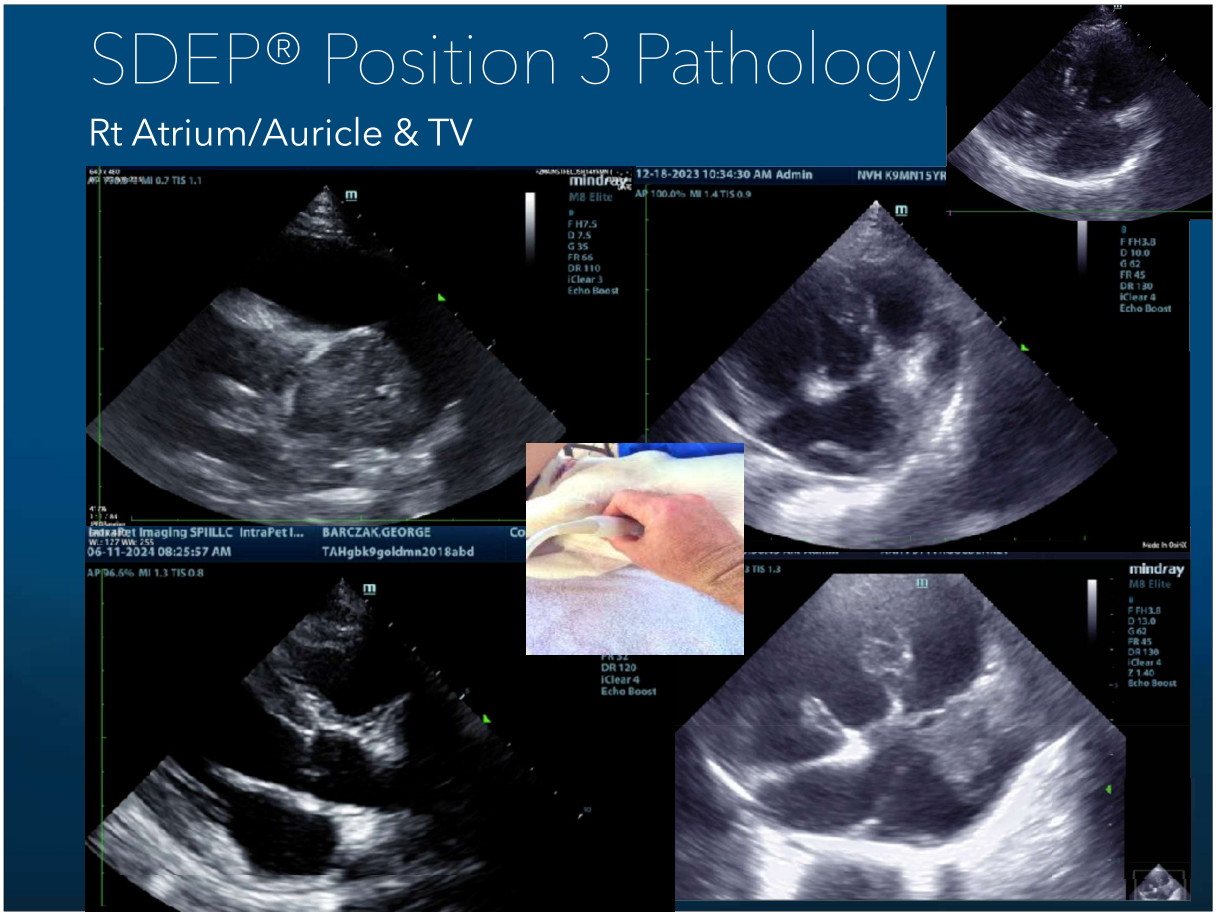
SDEP® Position 2 Pathology

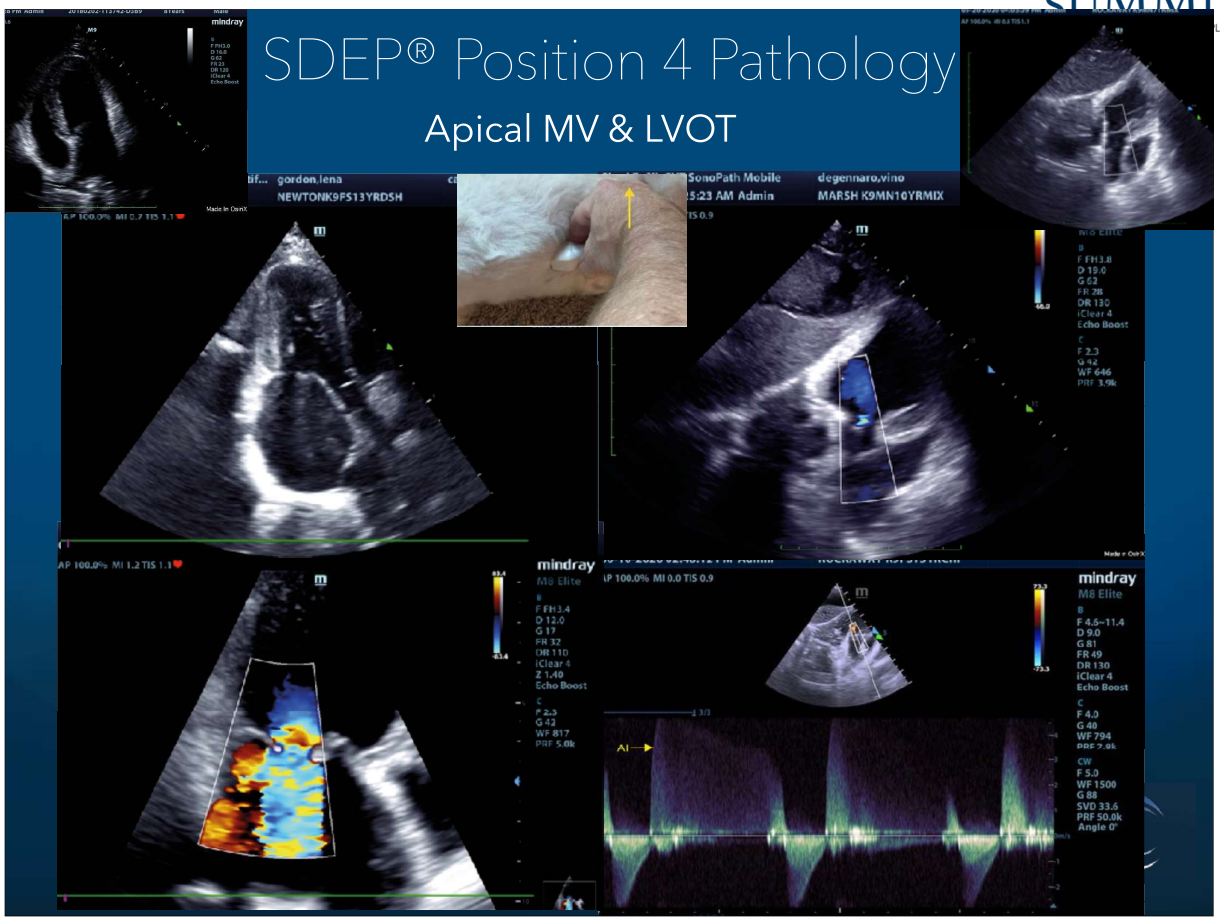
TV/RA & PV/PA Views

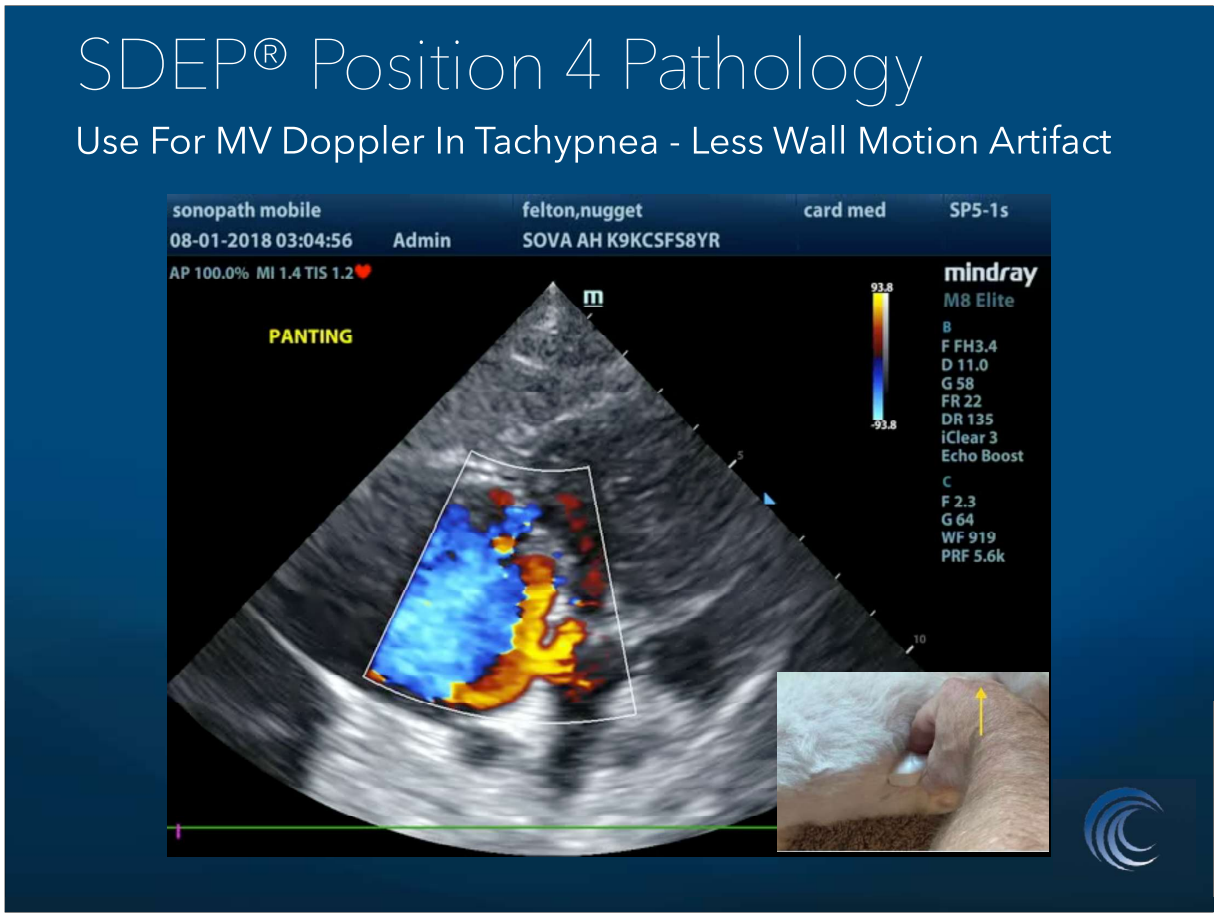


SDEP® Position 3 Pathology

Rt Atrium/Auricle & TV

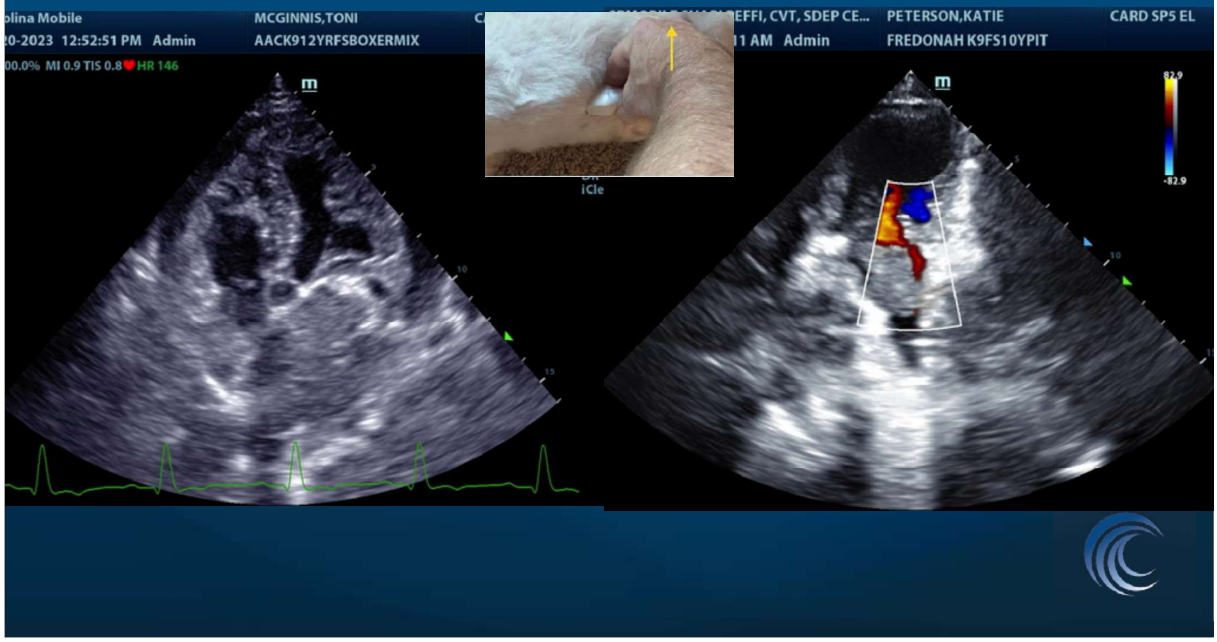



SDEP® Position 4 Pathology
Apical MV & LVOT
mindray
M8 Elite


SDEP® Position 4 Pathology
Use For MV Doppler In Tachypnea - Less Wall Motion Artifact
sonopath mobile
08-01-2018 03:04:56
Admin
felton,nugget
SOVA AH K9KCSFS8YR
card med
SP5-1s
AP 100.0% MI 1.4 TIS 1.2
PANTING
mindray
M8 Elite
F FH3.4
D 11.0
G 58
FR 22
DR 135
iClear 3
Echo Boost
F 2.3
G 64
WF 919
PRF 5.6k

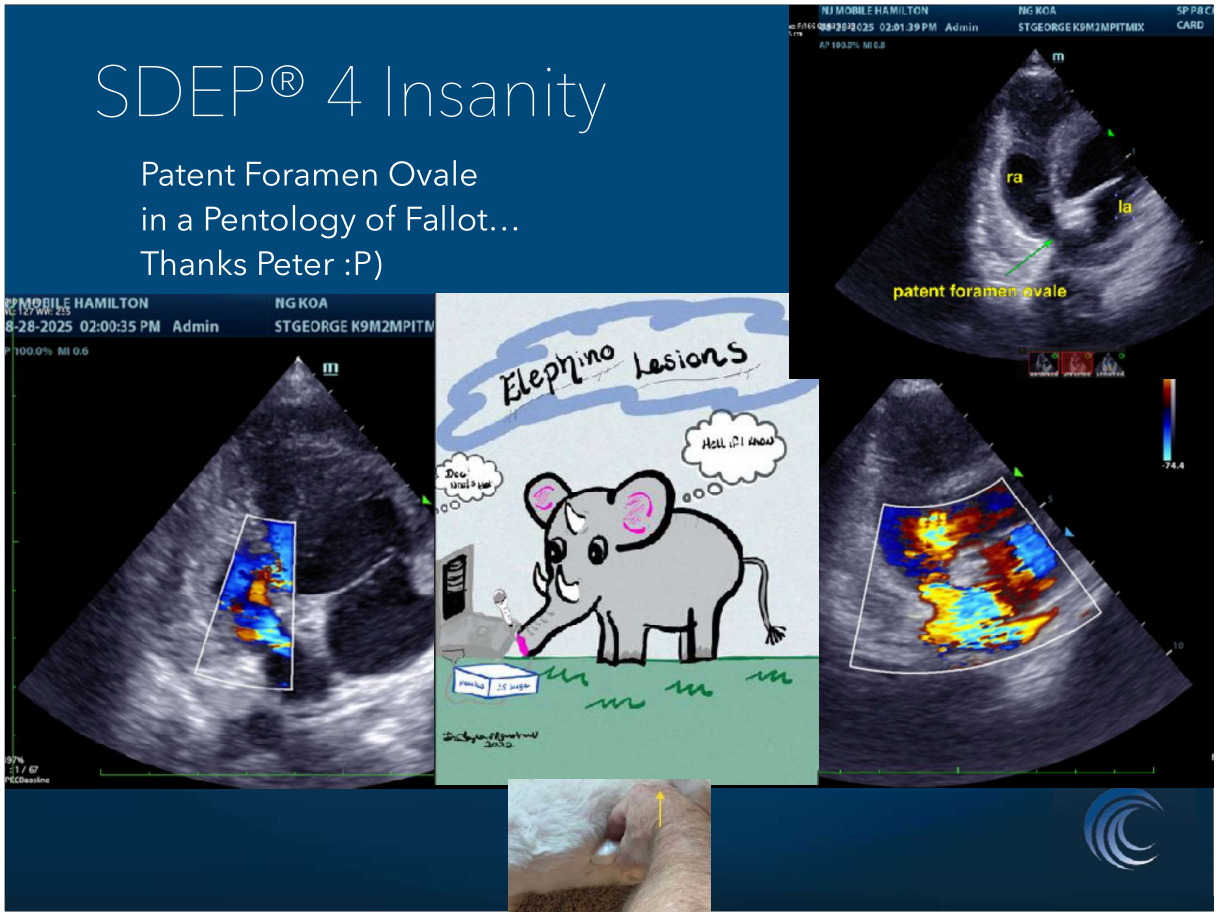
SDEP® Position 4 Pathology

Apical MV & LVOT



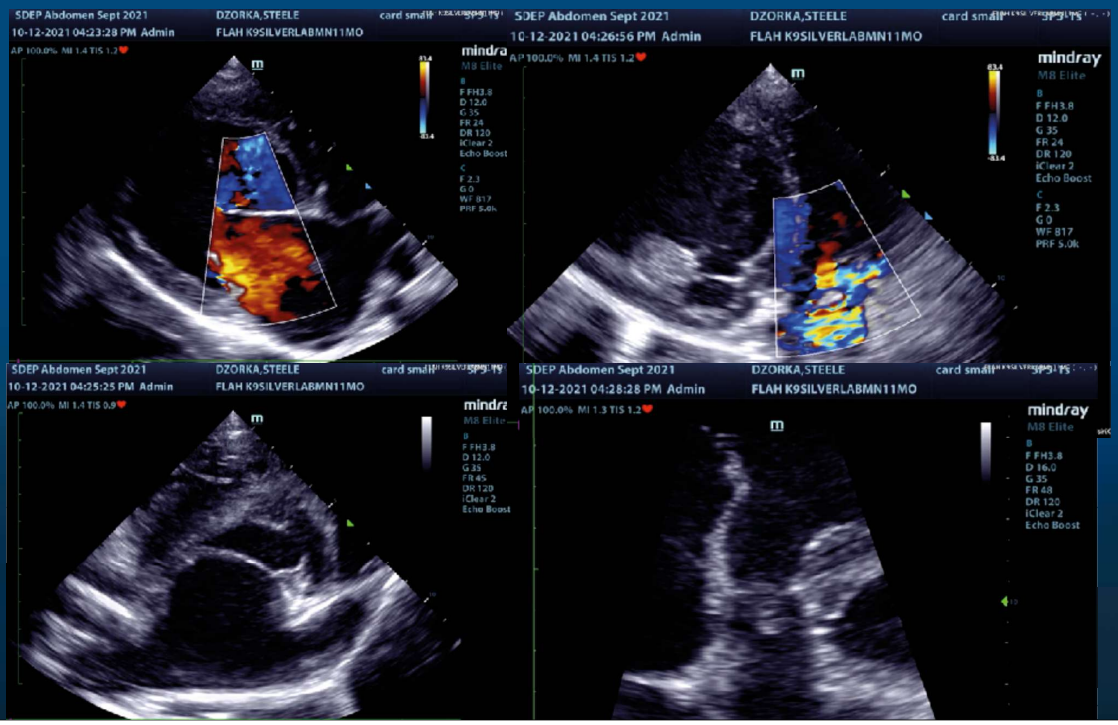
SDEP® 4 Insanity

Patent Foramen Ovale
in a Pentology of Fallot…
Thanks Peter :P)



11 Mo FS K9 Silver Labrador
Small Gene Pool Heart With An "Odd Murmur"

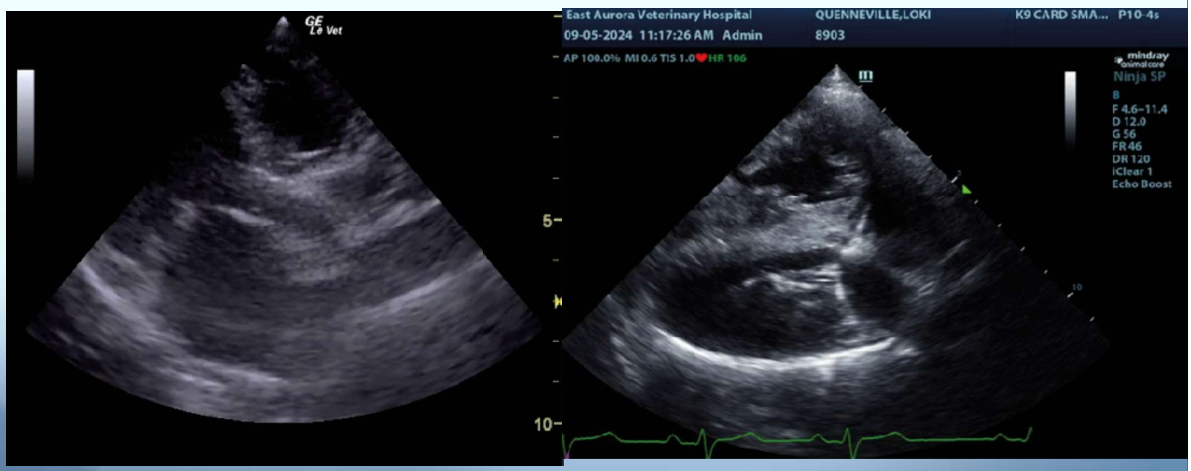
SDEP® *Buffet*… PDA, PS & SAS

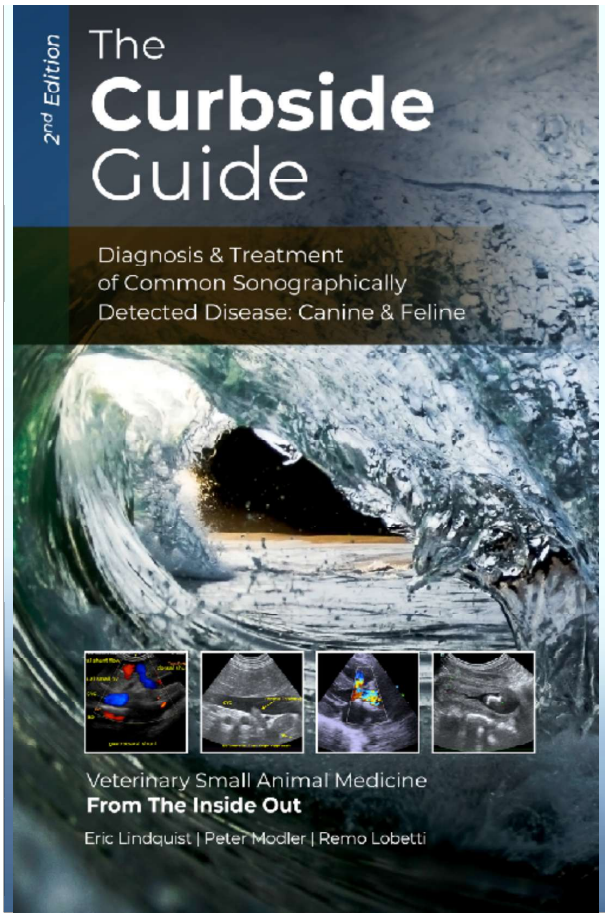


Volume Overload?

Slide to spine
if left overload

Slide to sternum
if right overload





Ride The Curbside Guide

SenoPath
SUMMIT
FOSTERING THE ART OF VETERINARY MEDICINE
SEE YOU IN
Nova Scotia
July 2027

May 2026

Dr. Eric Lindquist, DMV (Italy), DABVP, Cert. IVUSS, Founder & CEO of SonoPath

THE SONOGRAPHIC DIAGNOSTIC EFFICIENCY PROTOCOL (SDEP®): Abdomen & Echo

A structured approach to abdominal & echo ultrasound for small animal imaging

Standardized protocols are fundamental to the advancement of diagnostic ultrasound, providing consistency, reproducibility, and a framework for accurate interpretation. Within this context, the SDEP® Abdomen and SDEP® Echo progressions represent structured approaches designed to address the inherent variability of freehand sonography. Each protocol emphasizes systematic image acquisition, reliable landmarks, and incorporation of clinically accepted views, thereby establishing a methodology that is both efficient and transferable across practitioners. By uniting abdominal and cardiac imaging under the same principles of standardization, these protocols not only enhance diagnostic confidence but also support effective communication between general practitioners, instructors, and specialists.

THE SDEP® ABDOMEN 17-POINT PROGRESSION FOR SMALL ANIMAL IMAGING

The SDEP® Abdomen progression is a 17-point protocol that uses a three-second cine loop approach with a defining fanning maneuver to produce a complete, edge-to-edge organ system evaluation. The SDEP® Abdomen is the first published protocol in veterinary medicine. *(Lindquist, E., Lobetti, R., & McFadden, D. (2019). Proposed standardized procedure for abdominal sonograms in dogs and cats: Sonographic diagnostic efficiency protocol (SDEP™). Abstracts of the European Veterinary Diagnostic Imaging (EVDI) Congress, Basel, Switzerland, August 21–24, 2019.)*

The hallmarks of SDEP® Abdomen.

- SDEP® Abdomen is built for thoroughness and efficiency
- Standardized video clip protocol (as opposed to image sets with limited information) to maximize the amount of information present for the interpretation
- Wide-spread manual pressure to optimize the acoustic window
- A 20–30% reduction in probe-to-target distance compared to traditional techniques
- Redundant imaging angles to provide multiple views of each organ system and reduce the risk of missed lesions
- Numbered, referenceable points that strengthen communication between instructor, sonographer, and specialist
- Standardization that shortens the learning curve and supports efficient, complete, and reproducible diagnostic scans, especially for novice sonographers

- Manual probe-hand control that minimizes patient discomfort and enhances image consistency by minimizing probe-organ distance and compressing tissue
- A consistent methodology that is reliable and consistent in routine examinations and adaptable to emergency situations with practice

SDEP® Abdomen: timing and adaptability

The SDEP® is highly adaptable, allowing for rapid trauma assessment while maintaining a broad diagnostic scope. It identifies both solid organ injury as well as ascites, evaluates localized and retroperitoneal structures, and is equally effective in trauma and nontrauma imaging. The protocol integrates seamlessly into trauma, triage, and monitoring systems, and it can be applied efficiently within the general practice setting.

Notes:

- Cine loop-based protocol
- Animal positioned in right lateral recumbency
- Recommended image count: 35-45 images, plus pathology
- Image capture: three-second cine loop, complete fan through parenchyma
- Stills, labels, and measurements of long axis kidneys and adrenals required
- Optional: Measurements of masses and nodules”

“SDEP® ABDOMEN PROGRESSION POSITIONS”

- **Position 1:** Urinary Bladder: long and short axis
- **Position 2:** Cystourethral junction - long axis
- **Position 3:** Pelvic urethra - 2-5 cm length
- **Position 4: “Iliac trifurcation and long aorta”**
  - Add color
  - Add multiple angular approaches if the stomach is repleted
- **Position 5:** Left adrenal
  - Dogs: Cranial to left renal artery
  - Cats: Region of celiac and cranial mesenteric arteries
- **Position 6:** Left kidney – long and short axis
  - Include long axis power Doppler or color Doppler
  - Image caudal to left kidney for ovary if intact
- **Position 7:** Spleen
  - “Paintbrush”-type fanning, caudal to cranial poles
  - Power Doppler splenic hilus

    - 2–3 cines at different angles fanning to open and follow spleen
- **Position 8a:** Left pancreatic limb
    - Image region medial to spleen – stomach on left, colon on right
    - Wide "motorcycle throttle" fanning technique to image the left limb body and right limb of the pancreas and adjacent GI structures
- **Position 8b:** gastric fundus/pylorus/gastroesophageal inlet
    - Wide "motorcycle throttle" fanning technique pylorus to gastroesophageal inlet
- **Position 9:** Left liver and diaphragm
    - (Lower third of thorax) – Move sternally for additional liver
- **Position 10:** Left liver
    - Move sternally for additional liver
- **Position 11:** Liver/gallbladder
    - Subxiphoid long and short axis
- **Position 12:** Right intercostal liver
    - "Beer can" technique – sweet spot fan for right intercostal liver, gallbladder, and diaphragm
- **Position 13:** Pylorus
    - Wide "motorcycle throttle" fanning technique to diaphragm
    - Slide towards the sternum for pylorus/duodenum/right pancreatic base
    - Slide towards the spine for portal hilus and common bile duct
- **Position 14a:** Right kidney – long axis
    - Include long axis power Doppler
    - If intact, image caudal to right kidney for ovary
- **Position 14b:** Right adrenal
    - Dogs: Medial to long CVC
    - Cats: Follow long CVC from right kidney to liver, slight fan, adrenal tucked under CVC
- **Position 14c:** C-Loop (shunt view, GES, and the liver/CVC junction)
    - Follow the diaphragm in a C-shaped maneuver from right kidney or right adrenal to the portal hylus, then gallbladder, then C-curve to pylorus and right pancreatic base
- **Positions 15–17:** "Bears in the Forest"
    - Light "paintbrush" maneuvers for complete GI imaging
- **Position 15:** Right side pylorus/stomach to urinary bladder
- **Position 16:** Left side from bladder to stomach
- **Position 17:** Midline from stomach to bladder

Standard additional views:

- Right auricle, SDEP® Echo Position 3 (only if there is a splenic mass/nodules)
- Pathology: Cine loop imaging of at least four different angles including power Doppler and color Doppler of any abnormal structure or region of clinical interest. Organ-associated masses are followed to organ of origin
- Enhance image optimization (higher frequency, additional zoom approaches and angles) on clinically pertinent organs with additional cine loops

THE SDEP® ECHO FOUR-POINT PROGRESSION FOR SMALL ANIMAL IMAGING

The SDEP® Echo progression is a four-position protocol using three-second cine with M-mode, color, and spectral Doppler to optimize and evaluate every region of the heart. It provides a repeatable, reliable method for assessing both normal cardiac anatomy and typical acquired cardiac disease, and incorporates the standard views required and accepted by cardiologists.

The hallmarks of SDEP® Echo

- Optimal, complete, and efficient protocol for normal cardiac presentation, acquired disease, and congenital pathology
- All structures are imaged from multiple angles in video clip protocol and still images for measurement modes
- Evaluation of cardiac function, chamber size, pressures, and flow velocities
- Three separate measurements of the left atrium for accuracy and reproducibility
- Acquisition of all standard Doppler velocities
- Visualization of heart base masses using alternative views of the right atrium and auricle
- Numbered, referenceable positions that reinforce and enhance communication between instructor, sonographer, and specialist

“SDEP® Echo: timing and adaptability

The SDEP® Echo protocol is typically completed in 10–15 minutes, depending on the experience and training of the sonographer. It can be readily adapted for a complete examination in five minutes or less in emergency situations. With additional training, the protocol can also be extended to include the views necessary for evaluation of congenital cardiac disease.

Notes:

- B-mode cine loop/still and M-mode-based protocol
- The animal is imaged in right lateral recumbency for the entire scan, unless additional left-sided views are required. In middle-aged to elderly cats, a left- apical approach is preferred over the subxiphoid approach
- Redundant imaging of abnormal structures or areas of particular clinical interest with four different views and angles on the same structure
- Recommended image count: 30–40 images, plus pathology
- Image capture: three-second cines, M-mode and spectral Doppler stills
- SDEP® standard views (as described in the positions below) can be adapted for congenital presentations with additional training
    - Congenital views will increase the number of images by 5–10
    - Focus on all four valves and IVS in Position 1 – long and short axis, and deep PA for PDA
- Standard color flow and spectral Doppler applications

SDEP® ECHO PROGRESSION POSITIONS

**Optional views are presented to give options for the best Doppler velocity angle*

Position 1:

- 4-chamber long axis – still of LA Max with measurement
- Obtain LV M-mode, EPSS, LA/AO M-mode; 3 stills with measurements
- MV-Color: cine; MV PW/CW Doppler: still (from tilted LA/LV)
- 4-chamber to 5-chamber long axis – cine
- 5-chamber long axis – cine – color on aorta – cine
- 5-chamber long axis twist to short axis heart base (“Mercedes”) – cine
- Short axis heart base – cine
- LA/AO heart base – still with measurement
- Short axis sweep: Heart base “fish lips” (mitral valve) – “mushroom” (left ventricle with papillary mm at 4 & 6 o’clock) – cine loop
- PW/CW Doppler of tricuspid and PA from heart base view – still of each
- Optional*: LV M-mode from “mushroom” – still with measurement

Position 2:

- Pulmonary artery to right atrium – cine loop
- Tricuspid – Color cine; PW/CW Doppler – still (probe tail up)
- Pulmonary – Color cine; PW/CW Doppler – still (probe tail down)

Position 3:

- Right atrium/auricle – cine loops
- Optional*: Color on tricuspid – 1 cine loop; PW/CW Doppler – still

Position 4:

- Apical transdiaphragmatic approach, 4-chamber to 5-chamber – cine loops
- Aortic valve color – cine loop; CW/PW Doppler – stills with LVOT measurement
- MV color and PW/CW Doppler
- Cats: left apical view for aortic velocity (LVOT)
- Optional*: Left apical view for dogs for MV and tricuspid velocities
- To assess right-sided liver failure: Subxiphoid liver views to image vena cava, aorta, hepatic veins – cine loops
- Mitral valve inflow view E/A wave

SDEP® REFERENCE SUMMARY

The SDEP® Abdomen and Echo progressions provide structured, repeatable approaches that enhance diagnostic accuracy and standardize image acquisition. Their adaptability allows efficient use in both routine and emergency cases. Within this text, certain images will reference the numbered SDEP® position, reinforcing the protocols described within this section. Note: SDEP® Abdomen was originally presented at EVDI 2019, Basel, Switzerland.

May 2026

Dr. Eric Lindquist, DMV (Italy), DABVP, Cert. IVUSS, Founder & CEO of SonoPath

SDEP® Abdominal Ultrasound Pathology

Description:

We have adopted the utilization of ultrasound in the initial workup of any patient by essentially employing ultrasound at any time we think there is need for a CBC, chemistry panel, urinalysis, and/or radiographs. This has allowed us to be much more diagnostically efficient in finding and ruling out pathologies. We live by the "12-hour rule": the rule that any clinically sick patient should have an ultrasound within the first 12 hours to either give a direct diagnosis or a clinical direction for the patient - "if it's sick, it needs a probe". We have found that this approach has led to vast improvement in clinical efficiency to arrive at a clinical diagnosis and prepare the animal for adequate therapy in the shortest amount of time.

Explore the most common and easily missed pathologies seen during abdominal ultrasound position by position. This focused session walks you through each SDEP® scan point, starting with normal anatomy and building toward the frequent and occasional pathologies you're most likely to encounter in practice. Learn how to recognize subtle changes, improve image optimization, and avoid overlooking key findings.

Learning Outcomes:

- Develop a sharp eye for pathology by mastering what "normal" looks like—so you can spot abnormalities faster and with greater accuracy.
- Learn what to look for in real-world presentations of urinary, adrenal, GI, pancreatic, hepatic, splenic, and ascitic pathology—plus how to handle unexpected findings with confidence.
- Discover how SDEP® repetition improves your diagnostic precision and helps you catch what others miss.
- Gain practical techniques to scan around foreign bodies, masses, or challenging anatomy using alternate views, intercostal approaches, and patient repositioning.