Providing the best quality care and service for the patient, the client, and the referring veterinarian.

Case Studies in Cardiology

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Case 1

- 8 year old male neutered Pomeranian
- Acute onset dyspnea/tachypnea

Physical examination

- Grade 4/6 right apical systolic heart murmur
- Split S2 heart sound
- Tachycardia – HR 180
- RR 80
- Respiratory effort increased

Problem list

- Heart murmur, split S2
- Tachycardia
- Tachypnea
- Dyspnea
Heart murmur
- endocardiosis of the tricuspid/mitral valves (AV valves)
- tricuspid valve insufficiency 2nd to pulmonary hypertension (PHT)
- AV valve insufficiency 2nd to myocardial failure, endocarditis or dysplasia
- Split S2 – pulmonic valve closes pathologically later than aortic valve
- PHT
- RBBB, RV pacing
- Tachypnea, dyspnea
  - left-sided congestive heart failure (CHF)
  - primary respiratory disease
- Tachycardia
  - sinus tachycardia
  - supraventricular/ventricular tachycardia

Differentials

ECG
- Sinus rhythm with right axis shift
  - negative leads I, II, III & AVF

Diagnostic plan

- ECG
- Thoracic radiographs
- CBC, chemistry, urinalysis
- Echocardiogram

Thoracic radiographs

Sinus rhythm with right axis shift
- negative leads I, II, III & AVF
Echocardiogram

Pulmonary hypertension (PHT)
- Pre-capillary PHT (pulmonary arterial)
  - Pulmonary thromboembolic disease
  - Chronic pulmonary disease
  - Heartworm disease
- Increased pulmonary blood flow
  - Overcirculation (L to R shunt… PDA, VSD)
- Post-capillary PHT (pulmonary venous)
  - Left-sided CHF (mitral valve disease, DCM, mitral stenosis)

Treatment
- Anticoagulants
- Phosphodiesterase-5 inhibitors (PDE-5)
- Diuretics, digoxin, pimobendan, oxygen
- Calcium channel blockers
- Endothelin-receptor antagonists (ERAs)
- Prostacyclin analogues
Anticoagulants

- Clopidogrel (Plavix)
  - ¼ of 75 mg tablet (18.75 mg) PO q 24 h in cats
  - 1 mg/kg PO q 24 h in dogs
- Aspirin
- Low molecular weight heparin

Phosphodiesterase 5 inhibitors

- Sildenafil
  - 1 - 2 mg/kg PO q 8 - 12 h
  - Can titrate to 3 mg/kg PO q 8 h
- Tadalafil

Diuretics, positive inotropes, oxygen

- Furosemide
- Hydrochlorothiazide/spironolactone
- Pimobendan
  - 0.2 - 0.4 mg/kg PO q 12 h
- Digoxin

Calcium channel blockers (CCBs)

- Diltiazem
- Amlodipine
- For patients that are vasoreactive
  - Tested with invasive cardiac catheterization
  - Reduction of mean right atrial pressure (MRAP) of 10 mmHg or more
  - Achieve MRAP of < 40 mmHg with normal cardiac output
  - Tx with CCBs in patients with negative response is contraindicated
Prostacyclin analogues & ERAs

- Synthetic prostacyclin & analogues
  - IV epoprostenol
  - SQ or IV treprostinil
  - PO beraprost
  - Inhaled or IV iloprost

- Endothelin-receptor antagonists (ERAs)
  - PO bosentan (active endothelin receptors A & B)
    - expensive
  - Sitaxsentan or ambrisentan (ETA only)

Current recommendations

- Humans: early IV epoprostenol with PDE-5 inhibitor and/or ERA
- Veterinary: ???, treatment of underlying cause, sildenafil, oxygen, anticoagulants
- Oral bosentan still cost prohibitive

Case 2

- 5 year old male neutered Persian
- Presented for acute dyspnea
- History of lethargy & anorexia for 2 days

Physical examination

- Grade 4/6 sternal systolic heart murmur
- Dyspnea and tachypnea
Problem list & differentials

- Grade 4/6 sternal systolic heart murmur
  - DLVOTO = systolic anterior motion of mitral valve (SAM)
  - Mitral valve insufficiency
  - Tricuspid valve insufficiency
- Dyspnea and tachypnea
  - Pulmonary edema 2nd to HCM, RCM, DCM or UCM
  - Primary respiratory disease

Plan

- ECG
- Thoracic radiographs
- Echocardiogram

ECG

Sinus rhythm with left anterior fascicular block (LAFB, left axis shift)
- Lead II and AVF negative, but lead I is positive, resulting in a left axis shift

Thoracic Radiographs
Updated differentials

- Severe obstructive left ventricular concentric hypertrophy – HOCM
- DVLOTO or SAM seen on echo – cause for murmur
- Pulmonary edema second to HCM

Plan

- Hospitalize
- IV furosemide 0.5 - 2 mg/kg q 8 h (lower dose in cats!) OR CRI of 0.15 - 0.5 mg/kg/h with usual starting dose of 0.15 - 0.25 mg/kg/h
- Oxygen cage
- Monitor RR q 1 h
- Monitor urine production, temperature, HR

Next day

- Respiratory rate better – 36 bpm
- Purring
- Plan now?
  - Renal panel
  - Repeat radiographs

Renal panel

- Mild azotemia
- BUN 33
- CREA 1.6
Updated plan

- Send home
- Furosemide 0.5 - 1 mg/kg PO q 8 h for next 3 days, then 0.5 - 1 mg/kg PO q 12 h thereafter
- Benazepril 0.25 - 0.5 mg/kg PO q 24 h (or at recheck)
- NO Pimobendan!
- Atenolol ??? Maybe at recheck
- Renal panel & radiographs in one week

Case 3

- 12 year old spayed female Yorkshire terrier
- One week hx of progressive respiratory disease
- Coughing, tachypnea, dyspnea
- Heart murmur for years
Physical examination

- Grade 5/6 left apical systolic heart murmur
- Tachycardia – HR 190
- RR 80
- Respiratory effort increased

Problem list

- Heart murmur
- Tachycardia
- Tachypnea
- Dyspnea

Differentials

- Heart murmur
  - endocardiosis of mitral valve
  - mitral valve insufficiency 2nd myocardial failure
  - mitral valve insufficiency 2nd to endocarditis or dysplasia
- Tachypnea, dyspnea
  - left-sided CHF
  - primary respiratory disease
- Tachycardia
  - sinus tachycardia
  - supraventricular/ventricular tachycardia

Diagnostic plan

- ECG
- Thoracic radiographs
- CBC, Chemistry, Urinalysis
- Echocardiogram
Sinus tachycardia with increased R wave amplitude

Bloodwork & urinalysis

- CBC – mild neutrophilia, PCV 49, TS 7.2
- Chemistry – BUN 56, creatinine 2.1
- Urinalysis – USG 1048

Thoracic radiographs
Plan

- Hospitalization
- Oxygen
- Diuretics
- ACE inhibitors?
- Positive inotropes?
- Heart rate control?

Preload reduction (venous)

- Furosemide
  - IV bolus 2 - 4 mg/kg initially, repeat
  - IV CRI at 0.1 - 1 mg/kg/h (0.5 - 1 when severe)
  - IV > IM if possible for prostaglandin release
- Nitroglycerin
- Other diuretics
  - Hydrochlorothiazide: 0.25 - 1 mg/kg PO q 24 h
  - Spironolactone: 0.5 - 2 mg/kg PO q 24 h
- (Nitroprusside)

*All doses are canine only unless indicated otherwise.
Afterload reduction (arterial)

- **Nitroprusside**
  - Immediate acting IV hypotensive agent (preload and afterload reduction) independent of autonomic innervation via vascular SM relaxation
  - IV CRI at 0.5 - 1 mcg/kg/min carefully titrated to effect by increasing by 1 mcg/kg/min increments every 15 minutes as long as BP remains stable (usually 2 - 5 mcg/kg/min with upper limit of 8 - 10 mcg/kg/min)
  - Concurrent use of dobutamine
  - Acidosis then cyanide poisoning > 3 days

- **Amlodipine**
  - Ca+2 channel blocker
  - 0.1 mg/kg q 12 - 24 h initially; titrate up as needed to 0.25 mg/kg PO q 12 - 24 h

- **Hydralazine**
  - Afterload>>>preload
  - 0.5 - 1 mg/kg PO q 12 h in patients administered ACE inhibitors
  - 0.5 - 3 mg/kg PO q 12 h without ACE inhibitors
  - Reflex tachycardia & increase RAAS response

*All doses are canine only unless indicated otherwise.

Positive inotropy

- **Dobutamine**
  - IV CRI 2.5 - 7 mcg/kg/min
  - Beta receptors downregulated after 72 hours -> not effective long term

- **Pimobendan**
  - PO dosage: 0.2 - 4 mg/kg PO q 8 - 12 h. Can go up to 0.5 mg/kg PO q 8 h in refractory CHF

*All doses are canine only unless indicated otherwise.

Other considerations

- Oral medications can be too stressful: temporarily DC ACE inhibitors, spironolactone, etc.
- Watch electrolytes with profound diuresis
- Cautious of hyponatremic CHF – poor prognosis and keeping up with salt loss
- Blood pressure monitoring
The next morning

- HR 140, RR 30
- More comfortable, less RE
- Eating

New plan

- Repeat renal panel
- Repeat thoracic radiographs
- Medications to go home?

Renal panel

- BUN 44, Creatinine 1.7
- Why improvement?
Homeward bound

- Furosemide 2 mg/kg PO q 8 h for 3 days, then 2 mg/kg PO q 12 h thereafter
- Enalapril 0.25 mg/kg PO q 12 h
- Pimobendan 0.25 mg/kg PO q 12 h
- Recheck renal panel & thoracic radiographs in 1 - 2 weeks

Case 4

- 12 week old male intact English bulldog
- Presented for grade 5/6 left basilar systolic heart murmur
- Exercise intolerance

Physical examination

- Grade 5/6 left basilar systolic heart murmur
- Normal pulses
- Upper airway noises
Problem list & differentials

- Grade 5/6 left basilar systolic heart murmur
  - Pulmonic stenosis
  - Aortic stenosis
  - VSD
- Exercise intolerance
  - Airway disease
  - Heart disease
- Upper airway noises
  - Brachycephalic syndrome

Plan

- ECG
- Thoracic radiographs
- Echocardiogram

ECG

Sinus arrhythmia with right axis shift
- negative leads I, II, III & AVF

Thoracic radiographs
Updated differentials & plan

- Severe valvular pulmonic stenosis
- Balloon valvuloplasty indicated

But wait, English bulldogs are predisposed to coronary anomaly contributing to PS – balloon can cause death!!!

Left heart coronary catheterization before right heart catheterization for balloon valvuloplasty

Left heart cath

- Cut down over femoral artery
- Seldinger technique to place catheter/introducer set in femoral artery
- Angiogram catheter placed through introducer to aortic root
- Contrast injected

Coronary angiogram

- Single right coronary artery with R2A vessel wrapping around main pulmonary artery
Abort procedure
Balloon dilation can result in rupture of anomalous coronary vessel → death
Continue beta blockers (atenolol) – prolong diastole, decrease contractility, allow better perfusion of myocardium
If PS so severe that will shorten lifespan, balloon can be attempted with caution

Now what???

14 week old male intact pit bull
Grade 4/6 left basilar systolic heart murmur
Normal femoral pulses

Case 4 – part 2

ECG
Thoracic Radiographs
Echocardiogram
Skipping through….
Pulmonic stenosis again
Balloon valvuloplasty again

Problem list & differentials
4/6 left basilar systolic heart murmur
- Pulmonic stenosis
- Aortic stenosis
- VSD

Plan
**Balloon valvuloplasty**

- Right heart catheterization
- Access through femoral vein or jugular vein
- Catheter/introducer in vein
- Direct pressures measured through balloon wedge pressure catheter in RA, RV and PA
- Wire placed through balloon wedge
- Exchange made over wire for balloon inflation catheter for valvuloplasty – balloon inflated

**Post op**

- Patient recovered well in ICU
- Small incision over jugular vein
- Recheck echocardiogram to measure pressure gradient across RV outflow tract
- Successful surgery is 50-75% reduction
- Recheck in 3 months

**Case 5**

- 4 month old female intact boxer puppy
- Grade 5/6 left basilar systolic heart murmur
- Murmur radiates up carotid arteries
- Weak femoral pulses
- Exercise intolerance
### Problem list & differentials

- 5/6 basilar systolic heart murmur
  - Aortic stenosis
  - Pulmonic stenosis
  - VSD
- Exercise intolerance
  - Aortic stenosis
  - Pulmonic stenosis
- Weak pulses
  - Aortic stenosis

### Plan

- ECG
- Thoracic radiographs
- Echocardiogram

### ECG

- Sinus arrhythmia with tall R waves & ST segment depression
- Increased R wave amplitude – LV hypertrophy
- ST segment depression – myocardial hypoxia

### Thoracic radiographs
Subvalvular aortic stenosis
- Beta blockers (atenolol) – prolong diastole, decrease contractility, allow better perfusion of myocardium
- Possible high pressure & cutting balloon – long term outcome unknown
- Holter monitor
- Risk for sudden death
Case 6

- 12 week old male intact Maltese
- Grade 4/6 left basilar continuous heart murmur
- Bounding femoral pulses

Problem list & differentials

- Continuous basilar systolic heart murmur
  - Patent ductus arteriosus (PDA)
  - VSD with aortic insufficiency
  - Aortic stenosis with aortic insufficiency
  - AV fistula
  - Aortic pulmonary window

Plan

- ECG
- Thoracic radiographs
- Echocardiogram

ECG

Sinus arrhythmia with tall R waves due to LV hypertrophy
Thoracic radiographs

Echocardiogram

Echocardiogram
**Updated differentials**

- Patent ductus arteriosus (PDA) with mild left sided congestive heart failure

**Plan**

- Furosemide 2 mg/kg PO q 12 h
- Surgical ligation dogs < 1.3 kgs
- Transcatheter occlusion in one week
  - Coil occlusion through femoral artery or carotid artery for dogs 1.3 kgs or larger
  - Amplatz canine ductal occluder (ACDO) for dogs 3 - 4 kgs or larger through femoral artery only
  - Ductal plug – overlaps ACDO so ACDO usually chosen depending on PDA shape
- TEE and fluoroscopic guidance

**PDA occlusion with ACDO**

**Post operatively**

- With transcatheter occlusion
  - Go home next day
- With surgical ligation
  - Go home in few days when pain managed
Case 7
- 7 year old male neutered Boxer presented for syncope
- 3 episodes of syncope yesterday
- Otherwise healthy

Physical examination
- Rapid regular heart rhythm – HR 250 bpm
- Grade 2/6 left apical systolic heart murmur

Problem list & differentials
- HR 250 bpm
  - ventricular tachycardia
  - supraventricular tachycardia
- Syncope
  - 2nd to tachyarrhythmia – arrhythmogenic cardiomyopathy (AC)
- Grade 2/6 left apical systolic heart murmur
  - mitral valve insufficiency

Plan
- ECG!!!!
- Thoracic radiographs
- Echocardiogram
- NIBP
- Holter monitor
ECG

Ventricular tachycardia with HR of 250 bpm!!!

Hold on the radiographs

- Let’s treat the arrhythmia
- IV lidocaine bolus 2 mg/kg quickly with ECG attached
- Two doses later, normal sinus rhythm

NIBP

- 120 mmHg systolic during normal sinus rhythm

Echocardiogram
Echocardiogram

Oh no – VT is back!
Should have started a lidocaine CRI

Now what

- Back to the ICU
- Administer IV bolus of lidocaine again – but wait, ECG is changing:

VENTRICULAR FIBRILLATION
Tx: DEFIBRILLATION

Defibrillation

- Biphasic defibrillator: 2 - 3 J/kg
- Disorganized (fine) VF more difficult to defibrillate than organized (coarse)VF
- Influence of transthoracic impedance on success rate
  - Chest conformation
  - Chest to paddle size ratio (Adult paddles if >10kg)
- Inadequate energy
  - Too low: increases post-shock dispersion of refractoriness
  - Too high: membrane disruption by electroporation

ECG post defibrillation

Junctional escape with massive ST segment depression – myocardial hypoxia
What if he survived...

- **Sotalol**
  - 1 - 2 mg/kg PO q 12 h
  - Some beta blocking properties
- **Mexiletine**
  - 3 - 8 mg/kg PO q 8 h
  - Give with FOOD (GIT upset)

1 OR 1 + 2

*All doses are canine only unless indicated otherwise*

Questions

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