Degenerative Valve Disease

Degenerative valve disease affects mainly the mitral and tricuspid valves. It is also called myxomatous valve disease due to the pathology and "endocardiosis" although this later term has fallen out of favor as it does not help describe the disease. It is the leading cause of heart disease being responsible for 75% of all cases of heart disease seen in general practice and may affect up to 5 - 7 million dogs in the US. It is most prevalent in small breed dogs and the cavalier King Charles spaniel is particularly prone, developing the disease at a young age with 50% of all cavaliers developing a murmur by 6 years. In this breed, a genetic predisposition has been documented.
As the mitral valve is most commonly affected, the disease has a reliable biomarker, the presence of a left apical systolic murmur. Typically this is quiet, grade 1 or 2, with little evidence of cardiac remodeling, but as the disease progresses, the murmur becomes louder often radiating to the right. In a third of cases, the tricuspid valve is also affected and a right apical systolic murmur can be appreciated. Rarely, only the tricuspid valve is affected. The strength of the apical beat can also be helpful in assessing severity

Blood samples: In asymptomatic dogs, these are usually normal but with the onset of heart failure mild elevation of renal parameters is often seen due to the pre-renal renal failure caused by the poor cardiac output. Biomarkers such as ANP and BNP rise in the few months prior to heart failure and in the dyspneic dog, a high level of BNP is strongly suggestive of heart failure. There is no evidence that tracking BNP levels should guide treatment decisions

ECG findings: These are usually non-specific. A tall or wide R wave can represent left ventricular enlargement and a wide P wave can suggest left atrial enlargement. Arrhythmias are not uncommon. Atrial or supraventricular premature complexes (SVPC) are seen and atrial fibrillation (AF) is occasionally found especially in larger dogs secondary to the left atrial dilation. Ventricular arrhythmias can be found but isolated ventricular premature complexes (VPC) are more common than runs of ventricular tachycardia (VT).

Radiographs are very helpful to confirm the presence of congestive heart failure. In asymptomatic dogs, the heart and lungs can be normal in class B1. The pulmonary vasculature should also be normal. Once cardiac remodeling develops, dogs enter class B2 and left atrial and ventricular enlargement can be seen on the radiographs due to the volume overload of the regurgitation. This is typically observed with tracheal elevation which suggests left ventricular enlargement and a triangular soft tissue density on the caudodorsal margin of the cardiac silhouette on the lateral radiographs. On the DV radiograph, a bulge at the 2 – 3 'o' clock position suggests enlargement of the left auricle. It is important to use breed normals for the VHS. As left atrial pressures start to rise, the pulmonary vein dilates and this can be used as a sign that heart failure is imminent. Once heart failure develops, an interstitial/alveolar pattern develops in the right caudodorsal lung field first, obscuring the outline of the left atrium.

Echocardiography can be used to confirm the etiology of the murmur. The thickened mitral valve leaflets can be seen and volume overload of the left ventricle and left atrium can be assessed. The left atrium to aorta ratio is a reliable way to document left atrial enlargement as the disease progresses. The disease affects the chordae tendineae and if these rupture, valve prolapse or a flail leaflet may be seen. Color flow with variance mapping will show the turbulent jet of mitral regurgitation and mitral regurgitation can been seen on echocardiography before a murmur is audible. The size of this jet can be used to roughly assess severity. As the blood is pumped back into the low pressure left atrium, most echocardiographic parameters for systolic function are elevated as they are affected by the low afterload. For example the fractional shortening is usually 25 -30%, but in advanced mitral valve disease when 50 – 75% of the output of the left ventricle returns to the left atrium, the fractional shortening may be as high as 40 – 50%. However, this does not mean that systolic function is normal and dogs with advanced disease may benefit from inotropic support.
There are few differential diagnoses for a left apical systolic murmur and in an older small breed dog, degenerative valve disease is the likely cause. In younger animals, mitral valve dysplasia is seen particularly in the bull terrier breed. Co-morbidities are mainly those of an aging dog. Renal failure presents a significant problem as it may reduce the dosage of diuretic that can be used.

Therapy

In the asymptomatic dog with cardiomegaly, pimobendan has been shown to delay the onset of heasrt failure by 15 months. Trials involving angiotensin converting enzyme inhibitors (ACEi) and beta blocker have failed to show any improvement. It would be prudent to avoid a high sodium diet and the use of omega 3 fatty acids. The recommended dose of DHE and EPA are 25 mg/kg and 40 mg/kg respectively.

If heart failure develops, treatment is with i/v furosemide and pimobendan. ACE inhibitors are usually started after the patient is discharged and eating well. Sprionolactone can be added as there is evidence it slows progression of the disease by reducing myocardial fibrosis

Once heart failure is controlled and the patient returns home, heart failure can recur after a period for a number of reasons:

1. **Rupture of a chordae tendinae** – this is probably the most common cause and can result in acute death. It can be visualized with echocardiography. The patient is treated as for acute congestive heart failure although the dose of diuretics especially will need to be increased. The sudden increase in left atrial pressure causes the return of heart failure and it may take several days for the left atrium to dilate and adapt to the increased pressure.
2. **Development of an arrhythmia usually AF**. When AF develops, the dogs lose the atrial component of left ventricular filling and the heart rate increases, decreasing diastolic filling. Rate control is usually sufficient to bring the failure under control.
3. **Left atrial tear** – the mitral regurgitant jet produces fibrous scars on the left atrial wall, so called "jet lesions" and can eventually puncture the left atrial wall causing a hemopericardium. These are difficult to treat as the pericardium should not be drained unless the cardiac tamponade is life threatening. Then a small volume is withdrawn. The pressure in the pericardium helps reduce the leak which, in some cases, can heal. Cage rest and drugs to reduce blood pressure to 90 - 100 mmHg are used to reduce the afterload and hence regurgitant fraction and left atrial pressures. Recurrence is not uncommon.
4. Increasing systolic dysfunction – the volume loaded left ventricle becomes unable to eject blood into the circulation without elevated filling pressures and pulmonary edema. This may be seen with a gradual increase in breathing rate necessitating changes in medications. For patients that have recurrence of heart failure with none of the previous 3 causes, treatment is continued as:
    a. Optimize medications: Ensure the drugs are given correctly, e.g. every 12 hours for twice daily medication, ensure spironolactone is given with food which enhances its absorption and pimobendan is given on an empty stomach. The dose of pimobendan should be increased to closer to 0. 3 mg/kg to ensure its effect. Some cardiologists increase the dose of pimobendan to three times daily although there is no evidence this is beneficial. Furosemide should be given at least 3 times daily to control failure and a thiazide diuretic can be added such as hydrochlorthiazide for sequential nephron blockade.
    b. Change medications: Consider switching to a more potent loop diuretic such a torsemide. The starting dose of torsemide is typically 1/10 of the total daily dose of furosemide. That dose is halved and given twice daily. For example if a dog is receiving 10 mg furosemide three times daily, the starting dose of torsemide would be 1.5 mg twice daily. Again electrolyte depletion and dehydration are common side effects and may necessitate dose reduction.

Low sodium diets rich in omega 3 fatty acids have been advocated but there is little evidence in veterinary literature regarding their benefit. Moderate sodium restriction would be prudent and a calorie dense diet will help mitigate cardiac cachexia. Often, if the dog is eating a good quality diet, it should continue on this rather than try to change diet to one that may be less palatable.

Prognosis is variable with degenerative mitral valve disease making prediction of survival time difficult. Some dogs with mild disease never develop congestive failure, while others have a more rapid progression of their disease. Patients with class B1 disease can be monitored with an annual echocardiogram or radiograph to assess cardiac size. Patients in class B2 warrant closer monitoring with a review every 6 months. It is helpful to actively enroll the owner in monitoring their pet. Counting their resting respiratory rate has been shown to be one of the most effective ways of detecting the onset of heart failure. Rates less than 30 breath/minute are normal while rates over 40 require further investigation. When patients are in the compensated stage of congestive heart failure (class C) continuing to monitor breathing rate is a useful way of monitoring the effectiveness of diuretics and guide dose adjustments.

Once heart failure develops, the mean survival time is 9 – 12 months. However as chordal rupture, for example, may cause acute decompensation at any time, predicting the lifespan of an individual dog is impossible. There are certain parameters that are associated with poorer prognosis such as larger LA:Ao ratio, high E wave velocities of mitral inflow or larger LV but ultimately they suggest that the more advanced the disease, the poorer the prognosis.

Degenerative valve disease: Advanced treatment options

Once heart failure develops, average survival is limited with a mean survival of 9 months (QUEST), although some dogs have a slower progression with 15% still alive at 2 years. More recently other treatment options have become available to try to manage these patients.
Medical treatment remains with the main options as listed previously. Othe treatments options include:

- Mitral valve repair surgery under cardiopulmonary bypass
- Mitral clip – V Clamp
- Atrial septostomy

Mitral valve repair surgery

This is only available at a small number of specialist centres and requires an experienced team for good results. The cost reflects the expertise and complexity of the procedure.
Successful outcomes were first reported by Dr Uechi who remains the most experienced with the best outcomes – over 97% survive surgery to discharge. Generally, those that survive the surgery tend to die from another old age disease, not heart failure. Extensive pre-operative investigations are needed including clotting times, abdominal ultrasound, blood typing and CRP. There is a long wating list for this procedure at most institutions with good outcomes.
Under general anaesthesia, the left carotid artery and left jugular vein cannulated and connected to the bypass machine. A left thoracotomy is used to approach the left atrium and aorta. The aorta is cathetised so cardioplegic solution can be administered. Once the heart is stopped, the left atrium is opened and the valve examined. The chordae tendineae are replaced – usually 4 in the anterior leaflet and 2 in the posterior. An annuloplasty sutured is placed and tightened to approximately the diameter of the aorta. Air is expelled and the incisions closed. Once the heart has started beating, the bypass can be stopped and the cannulas removed.
The first 48 hours are critical and the patient is usually hospitalised for a further 5 – 7 days before discharge. Inflammation such as pancreatitis is common. Antithomobitic agents usually clopidogrel are continued for 3 months. The heart remodels over the next 6 months and if regurgitation is minimal, cardiac medications can be stopped.

Mitral V clamp

This is a relatively new procedure so long term follow up is not available. The idea is to clip the mitral leaflets together turning the large valve orifice into 2 smaller ones with less regurgitation.
Under general anaesthesia, a minithorocotomy allows an approach to the apex of the heart. Simultaneous 3D echocardiography is needed to guide the procedure and fluoroscopy is also helpful. A blunt instrument is used to identify the left ventricular apex and a large bore catheter introduced. This is advanced under guidance into the left atrium. The mitral valve leaflets are assessed and measured. The device is then introduced into the left atrium and the four wings should be open. It is then pulled back towards the left ventricle until the lower wings are in the left ventricle. It is advanced again so that the lower wings can be seen moving with the leaflets. Once correct position on the valve has been confirmed, the device is closed brining the wings together. The leaflets are measured again to make sure adequate leaflet has been captured before release. The pre-placed purse string suture in the LV apex is closed and incisions closed. Anticoagulants are continued for 3 months.
Although the University of Colorado are achieving good success with this, many find it difficult to position correctly and deploy. Long term results should be available in the next few years. It is clear that many dogs remain with significant regurgitation. However it is unclear if this progresses or not.

Atrial septotomy

It became apparent that for dogs with advanced mitral valve disease, those who developed a spontaneous atrial septal defect due to an anterior directed jet, had a better prognosis than those who did not. The theory is that the ASD allows blood to flow from the high pressure left atrium into the lower pressure right atrium reducing left atrial pressures and hence pulmonary edema.

Under general anaesthesia, the right jugular vein is catheterised and a catheter advanced into the right atrium. Both fluoroscopy and 3D echocardiography are needed for this procedure. Contrast is used to outline the left atrial wall and the catheter advanced interatrial septum ideally the thin fossa ovalis. While a septotomy needle and guide can be used, a stiff wire will often penetrate the interatrial septum. The catheter is then advanced into the left atrium and contrast used to confirm position. There are several techniques for creating a larger hole:

- Inflate an BWP catheter in the left atrium and pull back into the right atrium, tearing a hole
- Inflate a balloon across the septum (8 – 10 mm) to enlarge the hole. There is a risk that this just stretches the interatrial hole and it rapidly reduces once the catheters are withdrawn
- Use a balloon expandable stent to maintain an open communication

There is little data as to which technique is better. There is a risk that the needle can be advanced into the aorta, not the left atrium but the use of 3D echocardiography minimises that. There is also a risk that the needle is passed through the free wall of the right atrium.

This technique is not recommended in patients with pulmonary hypertension and significant tricuspid regurgitation. The left to right flow will cause a volume load to the right heart and pulmonary vasculature. However, the volume is relatively small and progression to right heart failure is uncommon especially as this is usually performed in patients with very advanced often unstable mitral valve disease.

Postoperatively, the diuretic dose can often be reduced as the risk of pulmonary oedema has reduced. Long term, the ASD may close and this is often accompanied by a recurrence of clinical signs.

Mitral valve replacement

There were hopes that this could be achieved by an apical approach with the device deployed through catheters avoiding the requirement for cardiopulmonary bypass. Unfortunately, none of the available devices or those developed for dogs resulted in success. The device seems to be very inflammatory and clotting seems to be a much larger problem in dogs than people.

As a result, these devices are not currently used.

Congenital heart disease in dogs: Diagnosis

Auscultation of puppies is a good screening test for the presence of congenital heart disease as almost all affected dogs have a murmur. The 3 commonest congenital heart diseases, patent ductus arteriosus, (PDA), subaortic stenosis (SAS) and pulmonic stenosis (PS) have either a systolic or continuous machinery murmur. Generally, the louder the murmur is, the more severe the disease. The exception is the ventricular septal defect (VSD) where a loud murmur suggests the maintenance of a high pressure gradient from the left to right ventricle and a small VSD. Larger VSDs allow equalisation of the pressure and a lower pressure gradient hence velocity and murmur grade. VSD is the most common congenital heart defect in cats. The murmur of the PDA is continual and machinery like, peaking in systole and heard over the left base cranially whereas the murmurs of SAS and PS are systolic left basilar. The SAS murmur tends to radiate cranially up the carotid arteries whereas the murmur of PS radiates dorsally on the chest wall. Dogs with a PDA can also develop a left apical systolic murmur due to dilation of the mitral annulus by the volume overload.

Diagnosis

Definitive diagnosis and assessment of severity rely on echocardiographic assessment. Early diagnosis and treatment is important for the PDA and PS as up to 70% of affected dogs may not live beyond 12 months. However, ECG and radiographs can be helpful:

ECG: In dogs with PDAs, an ECG is rarely helpful unless there is an arrhythmia such as atrial fibrillation secondary to atrial enlargement. However, in dogs with stenosis, SAS causes a left axis deviation and broad QRS/tall R wave pattern consistent with left ventricular enlargement whereas PS causes a right axis deviation with large negative S waves on leads I, II, III and aVF.

Radiography: As the PDA causes volume overload of the left side, cardiomegaly suggests that the PDA is significant and warrants closure. Classically 3 knuckles are seen on the DV although this is only recognised in about ¼ of cases. The first knuckle at 12 -1 'o' clock is the aorta, the second at 1-2 is the main pulmonary artery and the last at 2-3 is the left auricular appendage. Pulmonary overcirculation can also be seen with wide pulmonary arteries and veins although this may manifest as the vessels being persistently visible into the periphery of the lung fields. PS and SAS cause pressure overload and hence concentric hypertrophy. In these circumstances, radiography is often unhelpful as the hypertrophy is

concentric and the finding of a normal cardiac silhouette in a boxer with a loud systolic murmur does not preclude a diagnosis of severe SAS. In PS, a knuckle may be visualised on the DV radiograph at the 1 – 2 o'clock position due to a post stenotic dilation of the main pulmonary artery.

Echocardiography

PDA

The left atrium and left ventricle are usually dilated due to the volume overload caused by the left to right shunt. There may be secondary mitral regurgitation. The pulmonary artery is dilated and color flow reveals continual turbulent blood flow beyond the pulmonic valve. The flow from the ductus is usually visualised coming towards the transducer as a plume in the pulmonary artery. The left cranial view is the best image plane to try to visualise the ductus itself. The most common shape is a finger like projection tapering at the pulmonary entrance – the ampulla. This diameter is important to assess for sizing closure devices. Systolic function may appear reduced due to dilation but this has no long term consequence.

Pulmonic Stenosis

This is usually valvular and has been described as type A and type B (Locatelli et al 2013). Type A has a normal pulmonary artery diameter and thin fused leaflets which dome during systole. These respond well to balloon dilatation. Type B often have a degree of pulmonary artery hypoplasia and thick, dysplastic leaflets which respond less well to balloon dilatation. Depending on the degree of severity, right ventricular hypertrophy may be seen as well as secondary tricuspid regurgitation. A post stenotic dilatation of the pulmonary artery can be seen in more severely affected cases. Alignment with blood flow is critically important as the peak velocity is used to grade severity. The velocity is translated into a pressure gradient based on the modified Bernoulli equation:

Pressure gradient (mmHg) = 4 x Velocity^2 (m/s)
Hence:

Mild	20 – 50 mmHg
Moderate	50 -80 mmHg
Severe	Over 80 mmHg

Dogs with severe stenosis progress and die prematurely.

Sub-Aortic Stenosis

In these dogs, a fibrous subvalvular ridge or ring causes the obstruction, and hence left ventricular hypertrophy. Aortic regurgitation is often present and is a marker for this disease. Again alignment with flow is important to assess the maximal systolic velocity and, for this reason, the subcostal view is obtained as well at the left apical view although the left apical view usually yields slightly lower velocities. This is also important for breed screening where velocities under 2.25 m/s are considered normal although this does vary among different countries. The velocity does change slightly with the stress of the dog. Left ventricular hypertrophy and papillary muscle fibrosis may also be apparent.
Grading of severity is similar to pulmonic stenosis and dogs with severe disease will die prematurely.

Treatment

PDA

If untreated, dogs can die from CHF or they can develop reactive changes in the pulmonary arteries and pulmonary hypertension. If pulmonary hypertension and right to left shunting develops, the PDA should not be closed as it acts as a pressure releasing valve for the pulmonary artery. Instead cases need to be managed for the resulting polycythemia with repeated phlebotomies or hydroxyurea. However, early treatment of a left to right shunting PDA before the onset of heart failure should result in a normal life expectancy (Saunders et al 2014). There are two techniques for closing a PDA:

1. **Surgical closure** via a left thoracotomy usually at the 4th intercostal space. In the hands of an experience surgeon 90-95% of dogs should survive. Rupture of the ductus during dissection is the most common and usually fatal complication.

2. **Transcatheter occlusion** of the ductus. There are a variety of devices used for this. Initially coils were deployed in the ductus. These are thrombogenic and result in occlusion over time. Use of the Flipper type or clasping with a bioptome allows controlled release and retrieval if they are not felt to be correctly

positioned. The most common complication is embolization into the pulmonary artery tree. Fortunately, they do not cause significant problems there. The Amplatz canine duct occluder (ACDO) requires a larger catheter but seem more reliable. They have a double umbrella shape and are sized from the minimal ductal diameter. In smaller dogs, Amplatz vascular plugs can be used. These come in 2 shapes; the standard plug which is barrel shaped: and the type 2 which has a more complex structure. The outcomes for transcatheter occlusion are similar to surgery although the ACDO can embolize and lodging in the main pulmonary artery can be fatal. Tubular ducti or large ducti in small dogs may mean that surgery is the preferred option.

PS

For patients that are not candidates for balloon dilatation, beta blockade, usually atenolol, is used long term. For those that are going to undergo the procedure, beta blockade is indicated for at least 2 weeks to reduce the risk of arrhythmias during the procedure and to minimise dynamic obstruction. The dose is titrated upwards over the first week to 0.5 mg/kg twice daily. Catheterization of the right heart via the jugular or femoral vein allows a balloon to be advanced into the right ventricular outflow tract and inflated. Sizing of the balloon is achieved during echocardiography where the pulmonic annulus at the level of the valve is measured and during angiography. Typically a balloon 1.2 to 1.5 times the diameter of the pulmonary annulus is chosen. For larger dogs, a double balloon technique may be used. In dogs with dysplastic valves, or who have failed balloon valvuloplasty, stenting should be considered.
Brachycephalic breeds especially English bulldogs can have an aberrant coronary artery arrangement, the R2A anomaly with an absent left coronary artery. The single right coronary artery has a branch that encircles the main pulmonary artery to supply the left ventricle. Balloon dilatation of this could result in tearing of the coronary artery and death. However ,a conservative balloon technique has been described where a multiplication factor of 1 is used to select the balloon size. Stenting may be a better option.

SAS

Both surgery and conventional balloon dilatation have been used to treat SAS. Unfortunately, neither has resulted in increased life expectancy compared to those treated with beta blockade (Orton et al 2000 and Meurs et al 2005). The use of, usually, atenolol results in a reduction of sudden death in these patients with severe disease and instead they may live to 5-8 years before developing systolic failure. A recent study suggests that atenolol does not result in increased longevity compared to placebo (Eason et al, 2014). In addition dogs with very severe gradients had much poorer survival (over 130 mmHg, less than 3 years)
More recently, a cutting balloon technique has been described where a balloon with blades hidden in its folds is inflated in the outflow tract to cut the fibrous ring before using a high pressure balloon to dilate the stenosis. Although the gradient reduced in the short term, long term and survival results are disappointing (Kleman et al 2012).

Other Congenital Cardiac Disease

Septal Defects
VSDs are usually detected in the perimembraneous area. Involvement of the aortic valve with aortic regurgitation is a bad prognostic sign. Although closure with a transcatheter approach is described it is uncommon. Dogs with restrictive VSDs should have normal life expectancies but may be at increased risk of infective endocarditis. Atrial septal defects present with volume overload of the right side. Murmurs are usually quiet or absent. Again, catheter occlusion has been described but may be necessary in only a few cases.

Tetralogy of Fallot
This is a combination of 4 problems:

1. Pulmonic stenosis
2. Right ventricular hypertrophy
3. VSD
4. Over-riding aorta

The clinical signs depend on the relative severities of the VSD and pulmonic stenosis. Balloon dilation may be beneficial as well as treatment for polcythemia.

Atrioventricular Valve Dysplasia
These are characterised by short chordae tendineae, thickened leaflets and regurgitation. The papillary muscle may insert directly on the valve leaflet and the valve may be tethered. Stenosis can also be seen.
Apical displacement of the tricuspid valve is recognised in Ebstein's anomaly and in the Labrador retriever, this is often associated with a splintered QRS wave.
As surgical repair is rarely available, treatment is aimed at controlling congestive heart failure when it develops.

Other more complex anomalies are also recognised as in humans.

Dilated Cardiomyopathy

Cardiomyopathies refer to the primary heart muscle diseases suffered by dogs and cats. As a result, all secondary causes must be ruled out to make the diagnosis. Secondary causes include:

- Hyperthyroidism especially cats
- Tachycardiomyopathy where a sustained fast heart rate can lead to a dilated poorly contractile ventricle e.g. supraventricular tachycardia.
- Drug toxicity such as doxorubicin
- Infections e.g. trypanosomiasis
- Nutritional deficiencies. Both taurine and carnitine deficiencies have been report in dogs as a cause of heart disease with a DCM phenotype. American cocker spaniels and Newfoundlands may be predisposed but taurine levels should be assayed in any unusual breeds with a DCM phenotype as supplementation can be curative. Blood carnitine levels reflect poorly myocardial levels so supplementation can be attempted with an improvement in systolic function expected in 2 – 3 months. There is significant interest in grain free diets and a DCM phenotype so at UF we recommend a change of diet if the patient is on a grain free diet.

In dilated cardiomyopathy (DCM), the ventricle (mainly left) becomes dilated and poorly contractile and on histology the myofibers have a wavy appearance. Certain breeds such as the Doberman and Irish wolfhound are predisposed. Boxers have a variant with mainly right ventricular origin VPCs called arrhythmogenic right ventricular cardiomyopathy (ARVC) recently changed to arrhythmogenic cardiomyopathy as all chambers are affected. On histology both the left and right ventricles have a fibrofatty infiltration similar to the human disease. Cats can also suffer from DCM although this is rare since feline diets are now supplemented with taurine.

Diagnosis
Dogs have a long asymptomatic period where echocardiographic changes are evident although in some breeds such as the boxer and Doberman, a Holter analysis of the heart rhythm over 24 hours can be more helpful. Over 500 VPCs in 24 hours or the presence of ventricular couplets is suggestive of the disease although other causes of VPCs such as abdominal disease may have to be ruled out.

Blood samples: As for degenerative valve disease, serum biochemistry is usually in the reference range in asymptomatic patients although renal parameters rise with heart failure. ANP and BNP values rise at or just prior to heart failure. Troponin may be elevated especially in patients with frequent ventricular arrhythmias and may have prognostic utility as patients with higher troponin have a poorer prognosis.

ECG findings: These can be variable with some dogs having a normal rhythm but may show the wide P wave and tall R wave suggestive of left atrial and ventricular enlargement respectively. In others atrial and ventricular premature complexes can be seen and the later can vary from isolated complexes to bigeminy to runs of ventricular tachycardia. Atrial fibrillation is not uncommon and often precipitates the onset of heart failure with the reduced diastolic filling and loss of the atrial component of LV filling. Irish wolfhounds may develop slow atrial fibrillation without concurrent myocardial disease, so called lone atrial fibrillation although many go on to develop DCM later in life. Holter monitoring may be the most sensitive and specific way to diagnose this disease is some breeds.

Radiographs: In the asymptomatic stage, the cardiac silhouette maybe enlarged although this can be difficult to document especially in breeds such as the Doberman. Once heart failure develops, an interstitial/alveolar pattern is seen in the caudodorsal lung lobes, especially the right due to the presence of pulmonary edema. The pulmonary veins are usually distended. In some dogs, a pleural effusion is also seen. If right sided heart failure

is also present, a ground glass appearance to the abdomen suggests ascites and this will obscure the hepatomegaly. A distended caudal vena cava would support this.

Echocardiography: The presence of a dilated thin walled poorly contractile left ventricle and dilated left atrium are seen in advanced cases and in those with heart failure. In dogs with asymptomatic disease, the changes are more subtle and reference to breed standards or an allometric sacling system such as Cornell may be needed. The right ventricle and right atrium may also be affected especially in ARVC in boxers. In clinical cases the various measures of systolic function would be expected to be depressed. These include fractional shortening, ejection fraction, systolic time intervals and E point septal separation as well as tissue Doppler parameters. On color flow Doppler, a small jet of mitral regurgitation is often seen which explains the soft left apical systolic murmur. This is caused by dilation of the mitral annulus which drags the leaflet tips apart, leading to incompetence.

Therapeutics: Acute, chronic and expected outcome
Both pimobendan and ACE inhibitors have been shown to be beneficial in the asymptomatic case delaying the onset of heart failure. Asymptomatic dogs with frequent arrhythmias may be given anti-arrhythmic medication especially if the coupling interval is very short (R on T phenomenon) which may suggest ventricular fibrillation is likely. However, there is no evidence that drug therapy makes sudden death less likely. However it may reduce syncopal episodes. Once a dog is started on anti-arrhythmic medication, the Holter monitor should be repeated after one month to assess response, as all anti-arrhythmic drugs have the potential to be pro-arrhythmic. Once stable, the Holter monitor is usually repeated every 6 months and again one month after any drug change.
Treatment for acute heart failure is as previously described. Some patient with poor myocardial function may have low blood pressure and require positive inotropic support with dobutamine. Patients with atrial fibrillation require careful reduction of their heart rate as they may be relying on this elevated heart rate to maintain output. Often resolving their heart failure will reduce heart rate as it reduces the sympathetic drive. At discharge, dogs are typically discharged on a diuretic, furosemide, and pimobendan. ACE inhibitors are started a home one the patient is eating well. Finally at the first recheck a week later, spironolactone is introduced.
Atrial fibrillation requires drugs to slow the heart rate as the underlying mechanism for its development is atrial enlargement which cannot be addressed. As a result, the beneficial effects of cardioversion to sinus rhythm are likely to be short lived. Digoxin, calcium channel blockers (diltiazem) and beta blockers (usually atenolol) can all be used to slow heart rate. Beta blockers tend to have more negative inotropic effects which are usually dose related so are less frequently used. Diltiazem also has some negative inotropic effects but this is less severe. Digoxin acts centrally via vagal centres to slow heart rates. A combination of digoxin and diltiazem has been shown to provide better rate control than either drug alone and presumably this will translate into longer survival. The optimum heart rate for patients with atrial fibrillation has yet to be determined but rates of 140 -160 bpm in the clinic and 120 – 140 bpm on Holter monitor have been suggested.

Longer term management
Dose escalation of diuretics and pimobendan is seen with progressing disease. The owner should be advised that many dogs with DCM are at risk of sudden death especially if they have frequent VPCS or runs of ventricular tachycardia. Options for patients who are diuretic resistant include:

- More frequent administration of furosemide – 3 to 4 times daily
- Parenteral administration of furosemide
- Addition of a thiazide diuretic
- Switching to the more potent loop diuretic, torsemide, as described previously

Right heart failure can contribute to the development of cardiac cachexia. Severe weight loss is not uncommon in dogs with chronic disease. This can be caused by increased catabolism (heart failure is an inflammatory disease), poor nutritional intake with poor appetite, poor absorption and poor metabolism from the under-perfused liver. Poor appetite can be due to:

- Advancing renal failure
- Altered taste sensations with medications
- Digoxin toxicity

Use of a calorie dense food can help to mitigate weight loss. Supplementation with omega 3 fatty acids has been shown to be beneficial in human patients with cardiac cachexia and the same is likely to be true in dogs. The dose of omega 3 fatty acids is as described previously.
Balancing diuretic requirements between controlling heart failure and not exacerbating renal failure is an act that will ultimately be lost with advancing renal failure in the face of increased diuretic requirements. Stopping the ACE inhibitors may help renal function in these cases. Sudden cardiac death is always a possibility.

Treatment of the dyspnoeic dog

Dyspnoea can be caused by heart failure, respiratory disease or pleural disease. We are going to concentrate on cardiac causes.
Heart failure is a clinical syndrome in which heart disease through functional impairment of the myocardium, the heart valves, the pericardium, or an increased resistance to ejection, reduces cardiac output, increases venous pressure and causes progressive deterioration of the heart muscle.
A simple way to classify hemodynamic abnormalities is to define reduced ejection of blood into the aorta and pulmonary artery as forward heart failure and reduced return of blood from the veins into the heart as backward heart failure. The abnormality can involve mainly the left or the right ventricle.
However, both sides of the heart operate in series, so when blood backs up behind one ventricle it impairs ejection by the other ventricle and when less blood is pumped out of one ventricle, less returns to the other. Also as filling alternates with ejection, if ejection is reduced, the increased blood remaining in the ventricle will impair filling of the ventricle, conversely when filling is reduced the heart cannot eject a normal stroke volume. The clinical picture of most patients in heart failure is dominated by the signs of impaired left ventricular function. They present as either congestive (backward) or low output (forward) heart failure.
The hallmark of congestive heart failure is the presence of oedema or effusion. Forward heart failure presents with weakness, syncope, hypotension and poor perfusion.
Right sided heart failure results in increased filling pressures and this increased systemic venous pressure results in hepatic and GI congestion and fluid weeping from the surface of the liver into the abdomen. On the left side, a similar situation develops and the elevated pulmonary venous pressures cause pulmonary oedema and dyspnoea.
Heart failure is clearly not the same as heart disease. Many animals have a normal life expectancy with mild heart disease but once heart failure develops, their prognosis is guarded if the underlying disease cannot be corrected.

Diagnosis

ECG: ECGs are not helpful in the diagnosis of congestive heart failure. However, if there is an arrhythmia present, an ECG should be recorded to further characterize it especially if it may be contributing to the failure e.g. atrial fibrillation or ventricular tachycardia

Radiography: As the PDA causes volume overload of the left side, cardiomegaly suggests that the PDA is significant and warrants closure. Classically 3 knuckles are seen on the DV although this is only recognised in about ¼ of cases. The first knuckle at 12 -1 'o' clock is the aorta, the second at 1-2 is the main pulmonary artery and the last at 2-3 is the left auricular appendage. Pulmonary overcirculation can also be seen with wide pulmonary arteries and veins although this may manifest as the vessels being persistently visible into the periphery of the lung fields. PS and SAS cause pressure overload and hence concentric hypertrophy. In these circumstances, radiography is often unhelpful as the hypertrophy is concentric and the finding of a normal cardiac silhouette in a boxer with a loud systolic murmur does not preclude a diagnosis of severe SAS. In PS, a knuckle may be visualised on the DV radiograph at the 1 – 2 o'clock position due to a post stenotic dilation of the main pulmonary artery.

Echocardiography: While an echocardiogram may be helpful in establishing the underlying heart disease, it CANNOT confirm the diagnosis of congestive heart failure. A TFAST may show B lines which can suggest fluid in the lungs. In cats with heart failure, a pleural effusion may develop

Treatment:
In cats with pleural effusion, the effusion must be drained. Usually, this can be achieved under sedation and results in a dramatic immediate improvement. Pulmonary oedema takes long to improve.
Dyspnoea is defined as a sensation of difficult or laboured breathing and as a result is hard to confirm in veterinary medicine. However, observation of our patients having difficulty breathing allows us to use the term. Dyspnoea is a common emergency presentation and differentiating respiratory from cardiac causes is an important step as these require different treatment regimes. It can be caused by an increase in the partial pressure of carbon dioxide, a decrease in the partial pressure of oxygen or increased work of breathing. Hypercarbia (P_aCO_2 over 46 mmHg) is the primary drive for respiration while hypoxemia can drive respiration when the P_aO_2 is less than 60 mmHg.

The presence of other signs of heart disease such as a murmur or gallop rhythm can be helpful but as murmurs can be very common in small breed older dogs which also suffer from small airway disease, they can also be misleading. It is vitally important to correctly diagnose and treat congestive heart failure as inappropriate treatment could be life threatening.
Equally important, if a patient has a respiratory cause of its dyspnoea, it will not respond to treatment for congestive heart failure. It is not uncommon in referral practice to see cases referred that have been treated often for prolonged periods for congestive heart failure with escalating doses of diuretics. The doses of heart medication should be discontinued in these cases and appropriate medications for respiratory disease started.
Obstructive respiratory patterns can be recognized and these include:

- Upper airway disease: The respiratory pattern may be one of inspiratory dyspnea as see with laryngeal paralysis
- Lower airway disease: This tends to cause increased effort during expiration and the abdominal muscles may be recruited for this
- Restrictive pattern: With decreased lung compliance, the respiratory rate increases but the breaths remain shallow
- Paradoxical respiration: This can be seen in patients with flail chest where the affected segment moves inwards during inspiration and out during expiration in contrast to the rest of the chest wall. It can also be seen in severe respiratory muscle fatigue where the chest wall is draw inwards as the diaphragm contracts during inspiration.

There are certain key features that can help differentiate patients that are likely to have cardiac causes v. respiratory cases. These include:

	Cardiac Cause	**Respiratory Causes**
Heart rate	Usually elevated due to high sympathetic tone	Usually normal often with respiratory sinus arrhythmia due to high vagal tone
Body condition	Normal to low due to cardiac cachexia	Normal to high – Pickwickian syndrome may contribute to the clinical signs
Heart sounds	Murmur or gallop sounds	Other heart sounds usually not present
Chronicity	Usually acute	Often chronic with a history of week to months
Cough	May have history of cough	Usually coughing
Pulses	Weak +/- pulse deficits	Usually normal

When investigating patients with acute dyspnea, it is important to balance the benefits of the further investigations against the risks of these procedures in a potentially unstable patient. While a full echocardiogram can be helpful, if the patient does not survive the echo, the information is not helpful. Often for critical patients, minimal investigations and initial treatment is indicated. Chest radiographs can be very helpful but restraint can be an issue. In addition, thoracic ultrasound/brief echocardiogram can also be very informative. A pleural effusion can be readily diagnosed and help guide treatment. Also the size of the left atrium can be assessed. It is rare for small animals to develop left sided congestive heart failure without having left atrial enlargement.
If there is a strong suspicion that heart failure is present, cage rest with oxygen and treatment with diuretics is indicated. Loop, high ceiling diuretics should be given preferably intravenously but if catheterization is too stressful, the intramuscular route can be used although the speed of onset is slower. In addition, furosemide has a pulmonary vasodilating action which can help to reduce preload of the left atrium.

Monitoring response is vital to assess progress. The most important parameter to assess is the resting respiratory rate. This should be assessed 30 to 60 minutes after starting medication. Production of a large volume of dilute urine is a good sign that the diuretic is effective. If the heart failure is secondary to degenerative mitral valve disease or dilated cardiomyopathy, a positive inotrope such as pimobendan should be administered. While this is currently only available orally, intravenous preparations are available in some part of the world.

For respiratory cases, oxygen and cage rest is also indicated. Oxygen is a potent pulmonary vasodilator. Oxygen can be administered by an oxygen cage but facemasks and nasal oxygen are can also be used. Transtracheal oxygen is possible using an through the needle catheter. Further treatment depends on the exact diagnosis. While thoracic radiographs and CT can be helpful, bronchoscopy may also be needed. However, there can be

significant risks associated with this procedure. Ultimately, some diseases may lung biopsy for a final diagnosis which is often not possible.

Pericardial effusion in dogs and cats

As fluid accumulates in the pericardium accumulates, the pressure rises. Initially there are no clinical signs until the pressure starts to exceed the pressure in the lowest pressure chamber, the right atrium. Cardiac tamponade describes the clinical syndrome of right heart failure secondary to a pericardial effusion and is associated with diastolic collapse of the right atrium and ventricle.
While heart failure is usually treated with diuretics, this is the exception as diuretics will decrease systemic venous pressure which is responsible for filling the right heart. In the short term, intravenous fluids may be used to augment cardiac output although unless the patient is critical, these are often not needed.

Causes:

- Idiopathic: Seen in younger dogs especially St Bernards
- Neoplastic: Hemangiosarcomas are common in older dogs especially golden retrievers and German shepherd dogs, Heart base tumors (chemodectomas) are seen in brachycephalic breed such as boxers. Other tumors are occasionally recognized including mesothelioma, ectopic thyroid carcinomas and lymphoma
- Left atrial tear secondary to chronic degenerative mitral valve disease
- Infectious causes and secondary causes such as hypoalbuminemia

Pericardial effusions in cats are usually incidental findings and are frequently noted in patients with heart failure. They rarely require drainage.

Clinical findings: Muffled heart sounds with a weak rapid pulse may be detected. If right heart failure is present, a distended abdomen with a fluid thrill may be seen with tachycardia and weak pulses. Pulsus paradoxus is present in some cases: the pulse disappears during inspiration but returns during expiration. This is an example of ventricular interdependence.

ECG: Small complexes are seen due to the fluid. In some cases, electrical alternans may be present with alternating heights of the R waves due to changing mean electrical axis as the heart swings in the fluid.

Radiographs: A round globoid "still" cardiac silhouette is seen. The caudal vena cava is enlarged especially if ascites is detected.

Echocardiography: This is the diagnostic test of choice. Not only can it confirm the diagnosis showing the dark ring fluid around the heart and the cardiac tamponade with collapse of the right atrial wall but it can also guide treatment and help detect an underlying cause. Common places for neoplasia include the right auricle and right AV junction for hemangiosarcoma and the base of the great vessels for chemodectomas. Masses are most easily visualized when some fluid is present. But it should be noted that echocardiography is not a good guide to identify tumor type. Echocardiography can also be used to guide treatment indicating optimal area for pericardiocentesis.

Therapy
Acute drainage of the pericardium usually causes rapid resolution of clinical signs. In the short term, intravenous fluid should be given at a high rate to maintain systemic venous pressures and hence right atrial filling. In critical patients, the effusion may need to be drained before a detailed echocardiogram can be performed but in less severely affected dogs, an echocardiographic search for a neoplastic cause should be completed.

Pericardiocentesis is usually preformed from the right side with the patient in left lateral recumbency under mild sedation. Echocardiography is used to image a window such that the depth of fluid is maximized and the needle is likely to impinge on the pericardium at 90° hence there is less chance it will glance off into the surrounding lung tissue. The needle is then advanced along the same line and angle as the echocardiographic probe while negative pressure is applied to the syringe. A variety of pericardiocentesis catheters are available but many use 14 G catheters with extra holes created. An ECG should be attached to document any arrhythmias that may indicate the right ventricle has been touched with the needle. Once fluid starts to return, the catheter is advanced off the needle and a drainage system attached. The fluid should be retained as it does not usually clot

unless the hemorrhage is acute. In addition, the supernatent will differ from serum if spun down in a centrifuge. Once the drainage starts to decrease, echocardiography should be performed. The right heart should re-expand and the pericardial effusion be reduced significantly. The pericardiocentesis needle may lacerate the pericardium allowing fluid to leak into the pleural cavity. In these cases a surprisingly small volume is drained but repeat echo shows the development of a pleural effusion. The volume of the pericardial effusion can vary up to 2 liters depending on the size of the patient and speed of development. The ascites usually resolves in 24 – 48 hours and diuretics are not needed although the ascites will resolve faster if they are used.

Although the pericardial effusion should be submitted for cytology, it is rarely helpful. It is rarely possible to differentiate reactive mesothelial cells from mesothelioma. However, on occasions, the fluid is not a modified transudate or lymphoma cells are seen. The common neoplasia do not exfoliate.

Re-evaluation depends on the underlying cause. For idiopathic effusion, they can re-effuse after very variable intervals so repeat echocardiography may not be helpful. Instead, the owner should be vigilant for the clinical signs and return if they recur. Owners should be warned that there is a 50% chance of recurrence. However, if the effusion recurs, the owner should be advised that pericardectomy should be performed as repeated drainage increases the risk of constrictive pericardial disease. Pericardectomy should be curative in these cases. Neoplastic causes are likely to have more rapid recurrence of clinical signs but again, treatment would only be performed if the effusion was causing clinical signs. Pericardectomy may be offered for control although this depends on tumor type. For chemodectomas which are relatively benign and slow growing, pericardectomy with radiotherapy can offer prolonged survival times of up to 3 years. Surgical resection of the tumor is not usually possible. Hemangiosarcomas have a poorer prognosis and surgical resection may not prolong life although survival times of 7 -8 months with resection and chemotherapy have been reported. The owner should be warned that an acute bleed into the pleural cavity after pericardectomy may result in sudden death. In cases of mesothelioma, pericardiocentesis will cause tumor cells to spread to the pleural cavity allowing a pleural effusion to develop. Chemotherapy may improve survival time up to 10 months.

Pericardectomy: Sub-total pericardectomy may be performed with a lateral or sternal thoracotomy. While the sternal approach allows better visualization to look for any masses, recovery is slower with more complications. This is the treatment of choice in constrictive pericardial disease but the surgery is associated with high morbidity and mortality as the thickened fibrotic pericardium is stripped from the heart with significant hemorrhage. Thorascopic pericardectomy can be performed but this often results in a window being cut in the pericardium which may seal with time causing recurrence of clinical signs. Balloon dilation of the pericardium to tear a window has been described but is not widely performed.

Many dogs can be managed with repeated drainage of their pericardium. However, if the frequency increases, there needs to be consideration as to whether the periods that are symptom free justify continued treatment. For patients with neoplastic effusion, sudden death can occur or a pleural effusion may prompt a discussion regarding quality of life.