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# CARDIOMYOPATHIES

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**Learning Objectives:**

1. Be able to differentiate hypertrophic, dilated, restrictive, and arrhythmogenic right ventricular cardiomyopathy. Know which form of cardiomyopathy is common in each species. Be able to describe clinical findings in Boxers with ARVC.

2. Given a set of historical, physical examination, ECG, radiographic, and/or echocardiographic findings, be able to make the diagnosis of cardiomyopathy.

3. Be able to counsel owners regarding treatment options, prognosis, and possible outcomes of cardiomyopathy.

## Primary Myocardial Disease – Cardiomyopathy

**Cardiomyopathy can be defined as diseases of myocardial structure or function that are independent of valvular disease, congenital heart disease, pericardial disease, and pulmonary or systemic hypertensive disorders.** In original usage, the term cardiomyopathy suggested that the underlying cause for the myocardial disease was unknown. Some authors use the term cardiomyopathy to describe any myocardial dysfunction, regardless of whether the cause is known or unknown.

One way to classify the cardiomyopathies is based on anatomic or functional abnormalities, and another way to classify them is based on pathogenesis or etiology. If the etiology is unknown, the cardiomyopathy is classified as primary (e.g. idiopathic dilated cardiomyopathy). If the cause can be determined (i.e. toxic as in doxorubicin, inflammatory as post-viral myocarditis, endocrine, or ischemic) then the disease is classified as secondary cardiomyopathy (doxorubicin cardiomyopathy = doxorubicin-induced cardiotoxicity).

Primary cardiomyopathies are usually classified into certain categories based on the appearance or hemodynamic abnormality. Dilated cardiomyopathy, hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and restrictive cardiomyopathy are the descriptive terms that are derived based on anatomical and suspected or known functional abnormalities. Some cats with cardiomyopathy have characteristics of more than one of the above categories; these are usually described as having either restrictive cardiomyopathy or unclassified cardiomyopathy.

## PATHOPHYSIOLOGIC CLASSIFICATION OF THE CARDIOMYOPATHIES

Systolic Pump Failure
- Dilated cardiomyopathy (most also have diastolic dysfunction once CHF is present)

Diastolic Failure
- Hypertrophic cardiomyopathy (some have concurrent systolic failure)

Restrictive Cardiomyopathy
- Restrictive cardiomyopathy
- Endocardial fibroelastosis (congenital vs acquired)
- Excessive L.V. moderator band syndrome
- Endomyocardial fibrosis

Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)
Arrhythmia is first sign of disease
Myocardial failure may be apparent later in disease

Cardiomyopathies are the most important type of cardiac disease in the cat, and the second most common cause of congestive heart failure in the dog. Cardiomyopathies are also reported in ferrets, horses, cattle and many other species. The primary cardiomyopathies are common causes of cardiac disability and death in the dog and cat. They can be an issue with breeding implications in cattle. Although congestive heart failure is the most commonly recognized complication of their effects on cardiac performance; cardiac arrhythmias, episodic weakness, syncopal episodes, thromboembolism and sudden death are other commonly recognized clinical manifestations. While the incidence of these various complications may vary to some extent in the different recognized forms of idiopathic cardiomyopathy, all are possible for each form.

**Dilated cardiomyopathy** results in severe left and right ventricular enlargement and biatrial enlargement (dilation of all 4 chambers) with modest thinning of the ventricular free walls and septum. The papillary muscles appear flattened, and the AV valve circumference increases due to cardiac dilation. Microscopic findings include mild endocardial fibrosis, mild interstitial fibrosis and edema, and focal areas of myocytolysis sometimes with a mild mononuclear infiltrate.

The disease results in myocardial systolic dysfunction and is almost certainly due to a variety of different etiologies. Similar findings can be seen in a variety of other known causes of heart diseases in their advanced or late stages. Thus, the failure of systolic contraction can be viewed as the end result of many causes of myocardial cell damage or dysfunction. Taurine deficiency is a proven cause in the cat and carnitine and taurine deficiency are postulated as causes (or more likely contributors) in some dogs. The final pathways leading to these similar phenotypical end result of dilated cardiomyopathy are likely diseases of diverse etiology. Dilated cardiomyopathy, therefore, becomes a diagnosis of exclusion, and is considered when findings characteristic of the known causes of heart disease are absent.

1. Dog, cat, ferret commonly affected, also observed in the horse, cattle, and camelids.

2. Genetically determined in an inbred line of Syrian hamsters, several mouse models.

3. **Canine Dilated Cardiomyopathy** - Giant breed dogs such as I. Wolfhound, Great Dane, St Bernard, German Shepherd, Doberman and Boxer are predisposed; Males predominate; Age - 0.5-14 years (4-6 years average).

    a. Historical complaints: Dyspnea, coughing, syncope, lethargy or exercise intolerance, abdominal distention, anorexia, weight loss; clinical signs may appear acutely.
    b. Physical examination: Dyspnea, pulmonary crackles, jugular vein distention, hepatosplenomegaly, ascites, weight loss, diminished heart and/or lung sounds if pericardial and/or pleural effusion from CHF. Murmur of mitral or tricuspid valve regurgitation from AV valve dilation, gallop (usually S3). Cardiac arrhythmias with pulse deficits, mucous membrane pallor, weak pulses.
    c. ECG: Left ventricular enlargement pattern, left atrial enlargement pattern (P-mitrale), conduction disturbances, arrhythmias common, especially atrial fibrillation. Ventricular arrhythmias also common.
    d. Thoracic radiographs: Generalized cardiomegaly most common, pulmonary venous distention and interstitial or alveolar pulmonary edema with left heart failure; pleural effusion or ascites with right or biventricular failure.

e. Clinical pathology: Elevated BUN or creatinine (prerenal azotemia due to inadequate cardiac output, possibly diuretic induced following initiation of therapy), elevated liver enzymes (chronic passive hepatic congestion), mild hypoproteinemia, hypokalemia (diuretic therapy). Increased NT-proBNP; +/- increased cardiac troponin I.
f. Echocardiography: Left ventricular dilation, markedly diminished contractility, reduced thickening of the septum and the LV free wall, left atrial enlargement, increased E point to septal separation on M-mode, reduced aortic root motion, RV and RA dilation.
g. Treatment: Pimobendan, diuretics (furosemide), ACE inhibitors (lisinopril, benazepril, enalapril), low salt diet, exercise restriction, anti-arrhythmic medications as needed. Dobermans and others in cardiogenic shock may benefit from dobutamine ± in combination with sodium nitroprusside by continuous infusion for 2-3 days.

4. **Canine Cardiomyopathy Syndromes** - While all dogs with cardiomyopathy share some clinical findings, it appears that the disease in some breeds of dogs have specific clinical syndromes. This likely follows from the suspicion that a different gene mutation is likely accounting for the cardiomyopathy in each breed.

   a. Giant breed cardiomyopathy - Those previously mentioned giant breeds typically have left or biventricular heart failure and one of the most common rhythm diagnoses is atrial fibrillation. Sudden death may also occur. Prognosis usually 6 months or less if CHF, possible 1-2 years if discovered and treated early or if arrhythmia is the primary presenting problem.
   b. Doberman cardiomyopathy: Age; 2.5-15 years (6.5 average). Radiographs may have only left atrial and left ventricular enlargement, severe and sometimes acute pulmonary edema, pleural effusion slightly less common. ECG less frequently when present poor prognostic sign. Frequently sinus rhythm, LV or biventricular enlargement pattern common, ventricular arrhythmias are often present and typically have a RBBB pattern (negative QRS in Lead II). Cardiogenic shock may be observed with pulmonary edema. Dobermans usually have a poor prognosis after the onset of clinical signs, most live less than 8-10 weeks. Sudden death common, presumably related to ventricular arrhythmias. Up to 50-65% of Dobermans > 4 years old will develop the disease. Some markers for Dobermans with occult cardiomyopathy exist, including ventricular arrhythmias and dilation of the LV cavity, which allows for screening in asymptomatic dogs. A genetic mutation has been identified to screen for dogs that might develop the disease.
   c. **Arrhythmogenic Right Ventricular Cardiomyopathy** = Boxer cardiomyopathy - Age 0.5 to 15 years (8 years average). Male to female ratio nearly equal. Also seen in English bulldogs. Ventricular arrhythmias common and are often refractory to antiarrhythmic therapy, VPCs frequently have LBBB pattern (positive QRS in Lead II). Radiographs and echocardiograms may be normal in early stages of the disease. Boxers are more likely to have ventricular arrhythmias that lead to syncope than other breeds. There appears to be three clinical categories that offer some prognostic information.

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| Category I | Asymptomatic with arrhythmias | 2 year or longer survival |
| Category II | Arrhythmias and syncope | 1-2 yr survival |
| Category III | CHF with arrhythmias | 2-10 month survival |

   Sudden death possible. Histologic lesions may include myocarditis, but the predominant findings are loss of myocytes in the right ventricle, and replacement of those myocytes with fat and fibrous tissue. Based on an analogous disease in people, the disease is best classified as arrhythmogenic right ventricular cardiomyopathy (ARVC), and this is currently the preferred term to describe the disease in Boxers. English Bulldogs can also get the disease. Holter monitor recordings can be done to assist in screening of asymptomatic individuals. One family of dogs was described with carnitine deficiency

and carnitine supplementation can be offered as an additional treatment. The disease often starts out with severe arrhythmias with relatively preserved myocardial function, although some dogs are first identified based on myocardial failure and the development of congestive heart failure. Cats can also get arrhythmogenic right ventricular cardiomyopathy, but the disease is uncommon in this species. A genetic mutation has been described to screen for Boxers that might develop the disease.

d. English and American Cocker Spaniel Cardiomyopathy - Age 10 months to 12 years (average 5-9 years), +/- male predisposition. ECG: R wave > 3.0 mV commonly, APCs common. Generalized cardiomegaly with pulmonary edema. Endocardiosis may accompany myocardial disease, some live asymptomatic for long periods of time. Some have low taurine levels, and following supplementation with Taurine and carnitine, some individuals live longer survival times (more than 6 months) and have attendant improvements in cardiac function and size.
e. Myocardial carnitine deficiency has been described in some dogs with dilated cardiomyopathy. As some humans develop myocardial carnitine deficiency with severe CHF, it is unclear whether this finding represents a significant deficiency or is an end result of CHF with myocardial failure, although in the dogs, myocardial carnitine levels can be increased with oral supplementation. In general, dogs with dilated cardiomyopathy and myocardial carnitine deficiency do not revert back to normal after supplementation with carnitine. Some of these affected dogs appear to demonstrate clinical improvement, but not cure, with oral carnitine supplementation. Taurine supplementation has also been proposed and attempted with minimal clinical improvement, although some dogs with DCM (cocker spaniels, golden retrievers, Newfoundland dogs) clearly have low plasma taurine concentrations and at least a partial clinical response is noted in most cases, and some cases have a reduced need for cardiac medications after taurine supplementation.

5. **Feline Dilated Cardiomyopathy** - Used to compromise approximately 40% of feline myocardial diseases, current incidence is unknown but much lower than 40%, maybe 3 to 5% of all feline heart diseases. The discovery of dietary taurine deficiency and subsequent dietary supplementation has markedly reduced (but not totally eliminated) the occurrence of DCM in the cat.

   a. Predisposed animals: Age is 5 months to 16 years (average - 7-8 years), Siamese, Burmese and Abyssinian cats may be predisposed, some studies suggest sex (male or female predominance).
   b. Historical complaint: Often acute (1 to 3 day) development of clinical disease, may be vague, anorexia, vomition, lethargy, dyspnea, or lameness from arterial embolization.
   c. Physical examination: Hypothermia is common, cats often very depressed. Dyspnea, soft murmur or cardiac gallop (S3 usually), pulmonary crackles, heart and/or lung sounds may be muffled from pericardial and/or pleural effusion (common). Weak apex beat and weak femoral pulses, hepatomegaly possible, ascites less frequent than in dogs. Evidence of thromboembolism, usually aortic trifurcation. Cats may present in cardiogenic shock
   d. ECG: Normal sinus rhythm or bradycardia (esp. if hypothermic), left ventricular enlargement in 25 to 50%, various arrhythmias possible, esp. VPCs.
   e. Thoracic radiographs: Generalized cardiomegaly and rounding of cardiac apex, cardiac silhouette is frequently difficult to see due to pleural effusion. Pulmonary venous distention or pulmonary edema also possible, as is hepatomegaly.
   f. Clinical pathology: Azotemia is common, usually pre-renal in origin. Elevated liver enzymes AST and ALT (hepatic congestion). Cats with thromboembolic disease frequently have coagulation abnormalities, some compatible with DIC. Low plasma taurine levels (less than 20 nM/ml) if taurine deficient.

g. Echocardiography: Similar to as described for the dog, generalized cardiomegaly with markedly increased end-diastolic and end-systolic LV dimensions, diminished shortening fraction, poor aortic root motion, walls appear thin, left atrial and right ventricular dilation.
h. Treatment: Pimobendan, furosemide, ACE inhibitor (e.g. enalapril). Nitroglycerin may be useful for acute pulmonary edema. Dobutamine has not been dramatically successful, many side effects. Supplemental taurine (250 to 500 mg/day).
I. The discovery of dietary taurine deficiency as a cause of feline dilated cardiomyopathy in 1987 was a landmark finding. It has greatly reduced the incidence of this disease that previously had such a poor prognosis (most cases never left the hospital). Taurine deficiency may be the cause of DCM in only 10-15% of cats today; the cats without taurine deficiency may not respond to supplemental taurine and their prognosis is generally very guarded to poor.

6. **Equine Dilated Cardiomyopathy**

a. Atrial fibrillation in some
b. May see peripheral edema if CHF
c. May result from monensin toxicity
d. Rarely do well with therapy. Treatment of CHF in horses is often limited to furosemide and digoxin due to the expense of many other cardiac medications. Hydralazine has also been used. There is mixed information regarding the effectiveness of ACE inhibitors in horses

## HYPERTROPHIC CARDIOMYOPATHY

The myocardial hypertrophy occurs primarily rather than secondarily to any apparent increase in cardiac work load. The excessive amount of ventricular muscle that develops (usually left ventricular free wall and interventricular septum) results in a loss of the normal ventricular filling properties (the ventricle becomes "stiff") and is responsible for diastolic failure. The diastolic size of the left ventricular chamber is reduced, while during systole it may become virtually nonexistent. Obstruction to outflow from the left ventricle may be another feature of hypertrophic cardiomyopathy when there is either pronounced hypertrophy of both the interventricular septum and the left ventricular free wall or severe localized hypertrophy of the interventricular septum alone. The disease is rare in dogs, common in cats, and may be accompanied by thromboembolism in the cat. Hypertrophic cardiomyopathy has also been reported in alpaca, ferret and cattle. A male predominance is reported in both cats and dogs. A genetic cause resulting from abnormal DNA coding of myocardial proteins has been documented in the majority of human patients and is being researched in cats; one genetic mutation has been proved in Maine Coon cats (myosin binding protein C), as well as Ragdoll cats, and a heritable genetic alteration of the sarcomeric proteins is suspected in most other cats diagnosed with the disease. This has important implications for counseling owners and breeders.

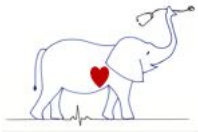
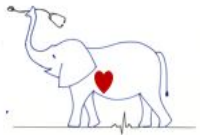
### Clinical signs/findings

1. Dogs - very rare in dogs, less than 50 dogs have been described and most of those were only recognized at the time on necropsy.

a. Predominates in large breed dogs, German shepherd breed and German Short Haired Pointer most common. Inherited in German short hair pointer. May also be seen in Shi tzu dogs and a variety of other breeds.
b. Conduction abnormalities possible, including first - third degree AV block
c. Congestive heart failure (CHF), sudden death

2. Cats - Hypertrophic cardiomyopathy is now the most common form of myocardial disease in the cat. The etiology in Maine Coon cats is a genetic mutation of myosin binding protein C, and while the exact mutation remains unknown for most other breeds of cats, a sarcomeric mutation seems the most likely explanation. Like DCM, it is possible that HCM is not a single disorder but a number of morphologically similar diseases.

    a. Predominates in young and middle-aged (mean age 6-9 yrs. range 5 months to 17 years).
    b. May be genetically determined in the Persian breed, American shorthair, as well as Maine Coon cat; males predisposed to developing clinical signs.
    c. Historical complaint: Acute onset of dyspnea is common, evidence of thromboembolism, anorexia, vomition, and sudden death are possible. A stressful initiating event is identified in some cases (anesthesia, surgery, steroids, fluids, and change in household).
    d. Physical examination: Animals with pulmonary edema are severely dyspneic and have increased lung sounds (crackles); a diastolic gallop (S4), soft murmur, or both are common findings. The left apical impulse may be hyperdynamic. Thromboembolism will result in expected findings (lack of femoral pulses, etc.). Some cats may have left and right heart failure (pulmonary edema is most common), pleural and/or pericardial effusion may cause muffled lung and/or heart sounds.
    e. ECG: The ECG may be normal, conduction disturbances, esp. left axis shift or left anterior fascicular block (LAFB) are the most frequent findings. LAFB is an insensitive sign of concentric LV hypertrophy. Left ventricular enlargement patterns and arrhythmias (VPCs) may be observed. Atrial fibrillation occurs in cats with marked left atrial enlargement.
    f. Thoracic radiographs: Mild to moderate left ventricular enlargement with moderate to severe left atrial enlargement, valentine-shaped heart frequently observed on the dorsoventral view. Pulmonary venous distention and evidence of pulmonary edema (often interstitial or fluffy alveolar in cats) is common. Pleural effusion may be observed. Longstanding HCM may result in biventricular failure with the additional findings of marked pleural effusion, pericardial effusion, hepatomegaly, and dilation of the caudal vena cava.
    g. Clinical pathology: Azotemia and elevated hepatic enzymes are less frequent than with dilated cardiomyopathy. Cats with hypertrophic cardiomyopathy should be evaluated for hyperthyroidism and systemic hypertension resulting from primary renal disease or other endocrine diseases.
    h. Echocardiography: Hypertrophy of the interventricular free wall and interventricular septum are present, although affected individuals may have values that overlap with the normal population. Left atrial enlargement may be marked, shortening fraction is usually normal or increased. Severe or advanced disease may lead to right ventricular enlargement or pericardial effusion. Systolic anterior motion of the mitral valve may be present. Doppler studies may show turbulent flow in the aortic outflow track and mitral regurgitation; spectral Doppler studies can document diastolic filling abnormalities.
    i. Treatment: The aim of therapy for cats with HCM who do not yet have clinical signs is to reduce the heart's ability to respond to stressful situations with an increase in heart rate causing elevated left ventricular end diastolic pressure. ß-adrenergic blocking drugs (atenolol or propranolol) and calcium channel blockers (Diltiazem) are commonly used. Long acting diltiazem (Dilacor – 30 mg PO SID) are useful due to short t ½ to allow SID (vs TID) dosing. ACE inhibitors, Furosemide, and with severe dyspnea, nitroglycerin are given for pulmonary edema. Antithrombotics are often administered to prevent thromboembolism (los dose since cats are sensitive to aspirin).

Cats diagnosed with hypertrophic cardiomyopathy on the basis of clinical or echocardiographic findings may have left ventricular hypertrophy from potentially reversible causes such as hyperthyroidism, systemic hypertension, renal failure, acromegaly or other endocrine diseases. These causes of cardiac hypertrophy should be explored in each animal.

**Restrictive cardiomyopathy** describes a group of cardiac diseases which have in common left ventricular endocardial abnormalities or restrictive myocardial filling abnormalities. In primary restrictive cardiomyopathy ventricular filling is impaired. The ventricle(s) is unable to distend adequately in diastole despite high filling pressures, due to restrictions imposed by endocardial thickening and both endocardial and subendocardial fibrosis. This is accompanied by a relative reduction in the force and degree of myofiber shortening during systole. Whether the impairment of ventricular contraction is inherent in the disease or simply a reflection of impaired diastolic distension is unknown. In some cats the endocardium appears normal and a myocardial restrictive disorder is suspected, although the histopathologic variations and cause have not been proved; some people classify these cats as having unclassified cardiomyopathy instead. Three other cardiac conditions have been identified in domestic animals that appear to fulfill the criteria for a restrictive type of myocardial disorder.

1. **Endocardial fibroelastosis**

    a. A congenital anomaly characterized by thickening and opacity of the endocardium and by a subendothelial layer of collagenous and elastic fibers. Marked left ventricular and left atrial dilatation is also present at post mortem.
    b. Reported in the cat, dog and man; In cats reported in Burmese and Siamese breeds
    c. Onset of clinical signs at a young age - usually 4 weeks to 4 months. Congestive heart failure and sudden death are common.
    d. This disease in the cat is (to my knowledge) virtually unrecognized since additional supplementation of taurine to feline diets.

2. **Excessive left ventricular moderator bands (accessory chords)**

    a. This condition may represent a congenital anomaly in cats characterized by excessive moderator bands (or accessory chordae tendinae) within the left ventricle, usually extending from the LV free wall or papillary muscles to the interventricular septum.
    b. Recognized in young to middle-aged cats
    c. Conduction abnormalities possible (bundle branch block or AV block)
    d. Clinical signs indistinguishable from those found in the various forms of feline cardiomyopathy.
    e. May not be a cause of pathology/pathophysiology and may accompany intermediate, dilated or other forms of cardiomyopathy. Might just be a feline variation of normal in some cats.

3. **Idiopathic restrictive cardiomyopathy**

    a Restrictive cardiomyopathy is characterized by endocardial or subendocardial thickening due to fibrosis or infiltrative disease. Post mortem findings include focal areas of endocardial fibrosis in the left ventricle, papillary muscle fibrosis, multifocal myocardial necrosis and fibrosis and left atrial enlargement. Recognized only in the cat and man. Some recognize endomyocardial fibrosis and endocardial form of restrictive cardiomyopathy as separate entities in cats; others classify them as the same disease.
    b. Male predominance, middle and old-aged cats.
    c. Historical complaint: Clinical signs are inconsistent, clinical signs similarly to cats with DCM or HCM. Cats with RCM may have a higher incidence of thromboembolism.

d. ECG: Left atrial and left ventricular enlargement patterns common, arrhythmias possible.
e. Thoracic radiographs: Left atrial enlargement may be dramatic; other findings may include left ventricular enlargement, pericardial or pleural effusion, pulmonary edema and pulmonary venous distention.
f. Echocardiography: Left ventricular and interventricular septal hypertrophy possible, marked left atrial dilation. Shortening fraction may be normal or slightly depressed. Left ventricular internal dimension may be reduced and cavernous areas or regions of increased endocardial echodensity (from fibrosis) may be present.
g. Treatment: Treatment is similar to other forms of cardiomyopathy.

**Unclassified Cardiomyopathy**

1. Have characteristics of more than one type of myocardial change. For example, LV hypertrophy and dilation. Typically have a restrictive filling pattern based on spectral Doppler studies if they have CHF.

2. Treatment based on predominant clinical signs.

The predominant clinical signs in feline cardiomyopathy are related to congestive heart failure and peripheral arterial occlusion due to thromboembolic disease. Cardiac arrhythmias may also play a role, resulting in syncopal episodes or even sudden death. Thromboembolic disease is common and the usual site of thrombus formation is the left atrium. Disruption of the endocardium owing to underlying myocardial disease may serve as the initiating nidus, with stasis of blood flow secondary to atrial dilatation and prothrombotic state contributing to thrombus formation.

**REFERENCES**


1. Current Veterinary Therapy XiV, Bonagura JD Twedt DC (eds), Saunders Elsevier 2009
   Calvert CA, Meurs KM. Cardiomyopathy in Doberman pinschers
   Hogan DF, Green HW. Dilated cardiomyopathy in dogs
   Meurs KM, Spier AW. Cardiomyopathy in Boxer dogs
   Fuentes VL. Management of myocardial disease in cats

2. Textbook of Veterinary Internal Medicine. Ettinger SJ, Feldman EC (eds). Saunders Elsevier 2010 Meurs KW. Myocardial disease: Canine.
   MacDonald K. Myocardial disease: Feline

3. Fox PR et al. Spontaneously occurring arrhythmogenic right ventricular cardiomyopathy in the domestic cat. Circulation 102:1863, 2000