MANAGEMENT OF HEART FAILURE

John D. Bonagura DVM, MS, DACVIM (Cardiology, Internal Medicine)
Veterinary Clinical Sciences, The Ohio State University

OVERVIEW of CANINE & FELINE HEART FAILURE

Congestive heart failure (CHF) is a clinical syndrome characterized by a cardiac lesion that limits cardiac output, causing arterial under-filling and evoking maladaptive compensations to restore blood pressure (BP). Most compensatory responses triggered in heart failure, including activation of the sympathetic nervous system, renin-angiotensin-aldosterone system, and pro-inflammatory cytokines, ultimately injure heart muscle and blood vessels. Furthermore, CHF is characterized by renal sodium retention that promotes elevated venous pressures behind the failing side(s) of the heart. Effective management controls these compensations with multifaceted medical therapy.

Various staging systems of heart disease/failure have been developed including the NY Heart Association (NYHA) functional Class I to IV classification; the International Small Animal Cardiac Health Council (ISACHC) system (Classes I, II, III), and the recent ACVIM-Consensus Panel adaptation of the American Heart Association/American College of Cardiology Staging A-B-C-D system for canine heart disease. Class A indicates a risk of heart disease; Class B includes asymptomatic dogs, Class C is established CHF receiving standard therapy, and Class D includes cases of refractory CHF or that requiring non-standard dosages or additional medications. Both prognosis and therapy are linked to these schemes, which are considered in more detail below.

Causes of Heart Disease – Dogs

The most common heart diseases leading to CHF in dogs are valvular endocardiosis, dilated cardiomyopathy, pulmonary hypertension, and pericardial effusion. Various congenital malformations (including patent ductus arteriosus, pulmonic stenosis, subaortic stenosis, atrioventricular valve dysplasia) are important causes of heart disease and heart failure young animals.

Valvular endocardiosis (myxomatous disease) is characterized by progressive mitral/tricuspid valvular degeneration and apical systolic murmurs typical of mitral regurgitation (MR) and tricuspid regurgitation (TR). Atrial arrhythmias, left mainstem bronchus compression, PH, and rarely atrial tearing may complicate the clinical picture. Systemic hypertension from renal or Cushing’s disease increases the regurgitant fraction and represents a comorbid condition. In contrast to endocardiosis, infective endocarditis is a multisystemic inflammatory disorder originating from a cardiac infection and is a relatively rare cause of CHF in dogs. The conditions should not be confused.

Dilated cardiomyopathy (DCM) is a primary myocardial disorder caused by an inexplicable loss of myocardial contractility. This idiopathic/genetic disease is often associated with cardiac arrhythmias, such as atrial fibrillation (AF) and ventricular tachycardia (VT). Occult or preclinical DCM refers to the echocardiographic finding of reduced left ventricular (LV) ejection fraction in the absence of CHF. Left- and right-sided CHF as well as sudden cardiac death are common outcomes of DCM. In some breeds such as Doberman pinschers, development of ventricular or atrial arrhythmias may predate the development of DCM. Right ventricular arrhythmogenic cardiomyopathy (ARVC), is especially common in boxers and English bulldogs.
Pulmonary hypertension (PH) stems most often from three disorders: chronic left sided heart failure; dirofilariasis; and severe interstitial lung disease. This disorder also can be idiopathic (primary) in dogs. PH is very common in dogs with chronic mitral regurgitation (MR) and typically leads to a progressively louder murmur of tricuspid regurgitation, signs of low cardiac output, right sided failure (including ascites and exertional syncope). With the exception of heartworm disease, PH due to primary lung disease infrequently leads to heart failure.

Pericardial effusion is a frequent cause of heart failure in dogs but often is misdiagnosed. Acute effusions can provoke collapse related to hypotension. Right-sided CHF, including pleural effusions, can develop in chronic cardiac tamponade. In younger dogs (and some older ones) idiopathic pericardial hemorrhage is the underlying cause and carries a very good prognosis with proper management. In dogs >7 years of age there is often a cardiac-related neoplasia involved with the effusion (hemangiosarcoma, chemodectoma, mesothelioma, ectopic thyroid neoplasia). Treatment of pericardial disorders does not involve drugs, but instead, pericardiocentesis often followed by form of surgical or endoscopic procedure.

Cardiac arrhythmias often complicate the atrial and ventricular remodeling observed in structural heart diseases. Heart rhythm disturbances can precede the development of heart failure in some disorders, especially in forms of cardiomyopathy. Tachyarrhythmias, if relentless (as with atrial flutter, atrial fibrillation, reentrant supraventricular tachycardia, or sustained ventricular tachycardia) induce a potentially-reversible decrease in ventricular function called tachycardia-induced cardiomyopathy. This impairment of cardiac output is additive to any preexisting structural heart disease. Bradyarrhythmias such as sinus arrest and atrioventricular blocks are more often related to primary disease (degeneration) of the conduction system in dogs and can lead to collapse, syncope, or CHF. Management approaches for arrhythmias may involve directed follow-ups (with no therapy), antiarrhythmic drugs, cardiac pacing, or catheter based interventions.

Causes of Heart Disease – Cats

Genetic and idiopathic myocardial diseases are often termed ‘primary’ cardiomyopathies. These include hypertrophic, dilated, restrictive, right ventricular, and unclassified cardiomyopathies, as well as myocarditis. Myocardial infarction is a poorly characterized disorder in cats that causes regional or global ventricular dysfunction. Of these conditions, hypertrophic cardiomyopathy (HCM) is most common. Secondary myocardial diseases develop from defined disorders such as systemic hypertension, hyperthyroidism, taurine deficiency, and growth hormone excess (acromegaly). Echocardiographic findings do overlap between primary and secondary myocardial disorders, however, these conditions should be distinguished as patient management and long-term prognoses can differ.

Other causes of feline heart disease must be considered in the differential diagnosis of feline cardiomyopathies. Congenital malformations of the heart and great vessels are observed regularly in cats. Mitral valve malformation, ventricular septal defects, and atrial septal defects are encountered most often, but other lesions, including peritoneopericardial diaphragmatic hernia and patent ductus arteriosus must be considered. Although cardiac malformations usually are considered problems of kittens and young cats, these defects may go unrecognized until maturity. Moderate to severe anemia is an under-recognized reason for cardiac enlargement. Cats with diabetes mellitus may exhibit myocardial heart disease, in some cases related to growth hormone excess. Additionally, severe respiratory
diseases in cats can induce pulmonary hypertension and cor pulmonale, sometimes resulting in marked enlargement of the right heart. In contrast to other species, both degenerative valvular disease and infective endocarditis are very rare in cats. Pericardial effusions in cats are generally caused by congestive heart failure (CHF) and often resolve with effective treatment of the underlying condition. Moderate to severe anemia is an under-recognized reason for cardiac enlargement. Cats with diabetes mellitus may myocardial heart disease, in some cases related to growth hormone excess.

Cardiac rhythm disturbances requiring treatment seem less common in cats when compared to dogs. However, atrial and ventricular ectopic rhythms do develop in association with cardiomyopathies, cardiomegaly, myocardial fibrosis, myocarditis, ischemia, infarction, increased sympathetic activity, electrolyte disturbances, hyperthyroidism, and cardiac or systemic neoplasia. Some persistent rhythm disturbances, including atrial fibrillation, can be idiopathic in cats. Atrioventricular blocks are observed most often in older cats.

**Hypertrophic Cardiomyopathy** – Feline HCM is characterized by thickening of the left ventricular walls and papillary muscles unexplained by congenital disease, hypertension, or endocrinopathy. Considering the prominence of HCM in the feline population and prevalence in certain breeds, it is not surprising that genetic mutations have been identified in some affected cats (including a mutation of myosin binding protein C). Some limited genetic testing is available currently; but this is mainly of value to breeders. Male cats are predisposed to HCM in some studies; however, there is no reported evidence of a sex-linked mode of inheritance. Some specific breeds at risk for HCM include the Maine coon, Persian, Ragdoll, Bengal, Sphinx, American and British short-hair cats, and Norwegian Forest cat.

The variable pattern of ventricular hypertrophy in this disease, ranging from concentric to focal (segmental) thickening, can be demonstrated at necropsy or by 2D echocardiography. The pattern of segmental or regional hypertrophy can influence the prognosis. For example, asymmetric free wall hypertrophy is often associated with significant LV dysfunction and progressive left atrial (LA) dilation. Conversely, focal subaortic, focal mid-septal, or isolated papillary muscle hypertrophy are often well-tolerated forms of HCM. However, these lesions progress in some cats and thus warrant follow-up. A specific variant of HCM in older cats is a subaortic septal thickening associated with a dilated aorta. Whether this is a genetic HCM, or a degenerative aortic dilation (aortoannular ectasia) in which altered flow stimulates focal hypertrophy is undetermined. In most cases, this form is benign.

The key histologic findings of HCM are hypertrophy of cardiomyocytes with fiber disarray and interstitial fibrosis. Intramural coronary arteries are narrowed with foci of myocardial infarctions or replacement fibrosis observed. Some cats with HCM progress to a form of RCM or a type of DCM termed “burned out HCM”. In each of these conditions, extensive myocardial fibrosis is evident histologically.

Systolic ventricular function in most cats with HCM is hyperdynamic, but there can be regional or focal reductions that may require advanced echo studies to identify and systolic function may slowly decrease over time. When HCM evolves to a “burned out” form, the entire ventricle may be dilated and hypokinetic. RCM with severe biatrial dilatation also can evolve as a late phase of HCM. Should atrial fibrillation develop, ventricular function is further impaired and this can precipitate severe CHF or ATE.

Dynamic and labile pressure gradients between the LV and aorta are found frequently and confer the title of “obstructive” to HCM. These gradients stem from the combinations of
septal and papillary muscle hypertrophy and systolic anterior motion (SAM) of the mitral valve. The latter is likely related to abnormalities of the papillary muscles or the valve itself. The major differential diagnosis is a primary mitral valve malformation.

The presumptive cause of CHF in feline HCM is diastolic LV dysfunction, which means that elevated left atrial and venous pressures are required to fill the ventricle. These abnormalities (discussed in the previous section) can be documented by advanced Doppler studies and generally evolve gradually, often over years. However, sudden sympathetic stress or abrupt impairment of myocardial perfusion can lead to rapidly-developing or “flash” pulmonary edema in cats with HCM with a need for emergent treatment. In some cases, diastolic function seems to improve with elimination of the stress, allowing a reduction in therapy over time.

Most cats with HCM are asymptomatic and recognized when a heart murmur or gallop sound is discovered during a routine examination. As described previously, there are no unique clinical findings of HCM, and symptomatic cats can present with any combination signs. Similarly, other than the echocardiographic examination (or results of genetic testing), ECG, clinical laboratory, and ancillary studies do not sufficiently distinguish HCM from other forms of cardiomyopathy. Thus, a careful clinical workup including high quality cardiac ultrasound is required for definitive diagnosis. LV hypertrophy, including papillary muscle thickening, is the requirement for diagnosis. The presence of significant SAM is invariably associated with an eccentric jet of mitral regurgitation (MR), and may represent an indication for beta-adrenergic blockade. Intraventricular or midcavitary obstructions often develop between the ventricular septum and papillary muscles and can be identified by Doppler studies.

Early diastolic dysfunction for the clinician is heralded by an atrial (S₄) gallop. Progressive disease leads to decreased LV compliance, high venous pressures, a loud ventricular (S₃) or summation gallop, and CHF. Progressive atrial dilatation and dysfunction go hand and hand with progressive loss of ventricular function. Thus, atrial size as observed by echocardiography or thoracic radiography stands as one of the best indicators of disease severity and short-term prognosis.

The natural history of feline HCM can be benign or lethal; relatively brief or protracted; and some cats remain asymptomatic for many years before succumbing (if ever) to the disease. Even severely affected cats may be asymptomatic when first diagnosed. When present, severe LVOT obstruct may lead to syncope or sudden cardiac death, but the incidence of this is largely unknown. As in humans, there are seemingly different stages of HCM that range from 1) “occult” disease (with genetic mutations and subtle myocardial changes that are near or below thresholds of clinical detection); 2) established hypertrophic cardiomyopathy that is easy to diagnose by Echo but largely well-tolerated, with no overt clinical signs and an overall low risk of sudden death, ATE, or CHF; and 3) progressive HCM characterized by ventricular remodeling (including “burned out HCM”), progressive LA dilatation, impaired LV systolic function, and higher risks for CHF and ATE. These are generalities of course because some cats with mild disease will experience bouts of thromboembolism or CHF. When clinical signs do develop with HCM, these are explained mainly by left-sided CHF, complications of ATE, outflow tract obstruction, or arrhythmias. Left atrial size and left auricular function are probably the most important risk factors predicting ATE or CHF. Therapy of these complications is discussed below.

Restrictive Cardiomyopathy – Feline RCM represents a heterogeneous disorder, and some latitude is used in placing cats within this group as opposed to the “unclassified” category of feline cardiomyopathy, although most are probably “end-stage” or “burned-out”
forms of hypertrophic cardiomyopathy complicated by myocardial failure, ischemia, and fibrosis. The key pathologic feature of RCM is myocardial fibrosis of uncertain pathogenesis. Antecedent myocarditis may be a cause, but in some cats RCM clearly represents a late stage of HCM. Burmese cats may have a predisposition to this disorder.

Post-mortem lesions in cats with clinical features of RCM are dominated by fibrosis that may be patchy, multifocal, or diffuse. The LV cavity is generally normal to reduced in size with variable but generally unimpressive hypertrophy, sometimes interspersed with regions of thinning or overt infarction. The latter changes are most evident in the LV free wall or apex. Prominent endocardial or papillary muscle fibrosis may be evident with extreme endocardial fibrotic scarring in some cases. Large moderator bands may be observed (and are classified by some as a congenital malformation or a separate form of cardiomyopathy). A consistent feature of RCM is striking left atrial or biatrial dilation. Histologic lesions include endocardial thickening, endomyocardial fibrosis, myocardial interstitial fibrosis, myocyte hypertrophy, focal myocytolysis and necrosis and arteriosclerosis. Systemic thromboemboli are common and LA and ventricular mural thrombi may be observed.

The clinical pathophysiology of RCM is compatible with a combined diastolic and systolic dysfunction syndrome. Increases of venous and atrial pressures, combined with ventricular dysfunction, atrial stiffness, and renal sodium retention, lead to CHF. Most cats with RCM are presented with overt clinical signs caused by CHF or ATE. Murmurs may not be evident, but loud gallop sounds are the rule, often punctuated by heart rhythm disturbances. The ECG is typically abnormal with wide P-waves, ventricular conduction disturbances, and ectopic complexes common.

Echocardiography and Doppler studies generally demonstrate the following: mild systolic dysfunction; regional LV wall dysfunction; mild mitral or tricuspid valvular insufficiency; elevated LA pressures; and impaired LV distensibility with a “restrictive” filling pattern. Pulmonary edema, pleural effusion, jugular venous distention, and hepatic congestion are commonly identified through physical examination and diagnostic imaging. The ECG is often abnormal and atrial and ventricular rhythm disturbances may be observed. Stasis of blood in a dilated left atrium places affected cats at high risk for atrial thrombi and ATE.

Management of RCM is based on control of CHF and prevention or treatment of ATE as discussed below. In cats with atrial fibrillation, diltiazem may provide the best control of ventricular heart rate. In the odd case that is diagnosed prior to onset of CHF, empirical use of an ACE-inhibitor and anti-platelet drug seems warranted. Treatment of these disorders is considered at the end of these notes.

Dilated Cardiomyopathy – This disorder is uncommon today. Taurine deficiency can cause DCM in cats, and this is still observed in cats eating off-brand or some “natural” diets, but most cases are idiopathic or related to diffuse myocarditis. The main postmortem lesions of DCM are left-sided or four-chamber dilatation, generally with necropsy findings of CHF and with no demonstrable congenital, coronary, or valvular heart disease. Histological findings include myocyte loss, prominent interstitial fibrosis, and variable degrees of hypertrophy and myocytolysis or apoptosis. Some cases are characterized by diffuse myocarditis.

The clinical features of DCM in cats are indistinguishable from those of other cardiomyopathies. Heart sounds may be soft owing to impaired contractility or pleural effusion. The principle functional disturbance as shown by echocardiography is marked reduction of LV ejection and shortening fractions, often with mitral and tricuspid regurgitation caused by ventricular dilation and dysfunction. While some cats are detected
in the asymptomatic phase, cardiogenic shock, left-sided CHF, or biventricular CHF are the most common presentations. These may be complicated by ATE. Prognosis is poor unless the condition is related to taurine deficiency. Oral taurine supplementation should be administered while awaiting results of a blood taurine test or at a minimum for 2 to 3 months following diagnosis. Management is discussed below.

**Right ventricular cardiomyopathy** – This condition, sometimes referred to as arrhythmogenic right ventricular cardiomyopathy, has been observed in cats, and the necropsy features have been described (Fox et al, 2000). The right ventricle is replaced by fat and fibrous tissue with the consequences of right-sided myocardial failure and right-sided dilatation with tricuspid regurgitation. Right Ventricular Cardiomyopathy is characterized in most cases by right sided CHF. Atrial standstill or atrial fibrillation may be apparent on the ECG. Ventricular ectopic rhythms are common as well. These cats generally present for clinical signs of pleural effusion, sometimes with concurrent ascites, owing to right-sided CHF. Chylothorax may be evident. Sudden death can occur. Early cases may demonstrate only atrial or ventricular arrhythmias. Diagnosis hinges on echocardiography and exclusion of other predominately right-sided diseases such as atrial septal defect and cor pulmonale. Treatment involves control of CHF and possibly antiarrhythmic therapy (see below).

**Other Acquired Myocardial Diseases** – A number of other cardiomyopathies are encountered in cats. Some of the key features of these are summarized below.

The term “Unclassified Cardiomyopathy” describes a myocardial disease of unknown etiology that does not readily fit into one of the above categorizations. Findings of RCM and UCM are often very similar, and undoubtedly, what one cardiologist might call RCM is classified as UCM by another. Myocardial infarctions and primary atrial diseases may also lead to this diagnosis. Occasionally cats with left atrial dilation, impaired LV diastolic function, but no overt LV myocardial disease are identified (these may be a form of HCM without hypertrophy, a condition recognized in people). The assessment and management of the feline patient with unclassified cardiomyopathy can be "simplified" by describing completely the clinical, imaging, ECG, and biochemical findings evident in the patient and then directing treatments towards managing these abnormalities. Practically, most cases of unclassified cardiomyopathy present with CHF or ATE and are treated for these problems (see below).

**Non-suppurative myocarditis** occurs sporadically in cats. The cause is unknown and definitive diagnosis requires microscopic examination of the tissues. There is a tendency for cats with myocarditis to be young. Some are presented for ventricular arrhythmias, while others develop fulminant heart failure, ATE or RCM. Death during anesthesia is another common scenario. The clinical diagnosis is based on suspicion and exclusion of other diseases. Blood cTnI is generally elevated, but this is not a specific finding for myocarditis, and there is no “gold standard” short of myocardial histology to confirm the diagnosis. Myocarditis can also be associated with infectious diseases including toxoplasmosis, so this should be a consideration before anti-inflammatory therapies are considered. No therapies have been shown to be effective in treating myocarditis and patient management is generally supportive, related to identifiable clinical problems.

**Hyperthyroid Heart Disease** – Thyrotoxicosis causes cardiac hypertrophy related to a hypermetabolic state, peripheral vasodilation, and increased demands for cardiac output. Increased sympathetic nervous system activity and elevated thyroid hormone levels may stimulate myocardial hypertrophy. In chronic cases of hyperthyroidism, the LV becomes thickened, and concurrent systemic hypertension probably contributes to this in many
cases. Echocardiography typically shows LV hypertrophy, often indistinguishable from idiopathic HCM. In advanced cases associated with fluid retention there may be bi-atrial dilatation with normal or even reduced LV ejection fraction. These cats are at risk for CHF which is often precipitated by the administration of sodium containing fluids.

**Diagnosis of Heart Disease & Heart Failure**

The diagnosis of heart disease and the recognition of CHF require a careful history and clinical examination. There is clearly epidemiologic risk for cardiac disease related to species, age, breed, and sometimes sex. These predispositions are learned with experience or can be identified by consulting reference textbooks. The historical findings of cardiac disease are not specific. Exercise intolerance often can be identified and respiratory signs are common in patients with heart failure.

Physical diagnosis may identify objective signs of CV disease. Auscultation may indicate a heart murmur, arrhythmia, or gallop sound. Unfortunately, many cats with CHF do not have an obvious heart murmur or gallop sound. The lungs may be abnormal to auscultation if there is pulmonary edema or cor pulmonale. Blood pressure in heart failure may be normal (from cardiac, autonomic, endocrine, and renal compensations); low in profound CHF (cardiogenic shock); or surprisingly high, indicating the co-morbid condition of systemic hypertension. Remember that in cats cardiogenic shock is often accompanied by the triad of hypothermia, hypotension, and bradycardia.

Echocardiography is the noninvasive gold standard for diagnosis of heart disease and is helpful in confirming the cause in cases of suspected CHF. This topic is discussed in more detail elsewhere in these proceedings (See “Echocardiography”). While not necessary in all cases, Echo studies are pivotal for confirmation of cardiomyopathies, pericardial diseases, endocarditis, and pulmonary hypertension (as well as for the diagnosis of congenital heart defects). Echo is especially important in cats as myocardial disease is the main cause of failure.

Thoracic radiography is useful for evaluating heart size and following the progression of cardiomegaly. Thoracic ultrasound also can be helpful to identify pleural effusions or lung rockets that might indicate intrapulmonary fluid. Radiographs are also essential in the differential diagnosis of respiratory signs. Many dogs with compensated heart disease are symptomatic because of a primary respiratory, pleural, or thoracic disorder, not CHF. When CHF is suspected, chest radiographs obtained before and after diuretic treatment can support the clinical diagnosis because radiographic findings of acute or severe CHF are significantly “improved” following successful therapy.

The electrocardiogram (EKG, ECG) in advanced heart disease may delineate cardiac-enlargement patterns (wide or tall P-waves or QRS complexes), conduction disturbances, or arrhythmias. Unfortunately the 6- or 9-lead ECG is too often within normal limits or equivocal and therefore cannot be relied on for establishing a diagnosis of heart disease. Simply stated, the EKG has low diagnostic sensitivity for heart disease in many dogs. Of course, the EKG is the test of choice for delineating heart rhythm disturbances.

Confirmation of the diagnosis of left-sided CHF requires integration of history, physical examination, and radiography; echocardiography can also be instructive when performed by an experienced examiner. Most CHF patients have some cardiac abnormality on auscultation, but it may be subtle, such as soft heart sounds (pericardial disease, DCM) or a gallop sound. Resting tachycardia is common but not always evident, especially in cats with cardiogenic shock. Key radiographic findings of left sided heart failure include left atrial and ventricular enlargement; pulmonary venous congestion or distension (this is variable);
and pulmonary infiltrates compatible with cardiogenic edema. In cats both arteries and veins are often engorged with CHF. Lung infiltrates are typically bilateral, caudo-dorsal interstitial and alveolar infiltrates when heart failure is severe. There may be a slight, right-sided preponderance to the infiltrates. Diffuse edema is not uncommon in acute CHF in dogs, including involvement of craniocaudal lung lobes. In cats with left-sided CHF a more caudoventral appearance around the vena cava is also very common. Radiographic signs of cardiogenic pulmonary edema should improve within 24 to 48 hours of diuretic therapy, and will often be accompanied by reduction in overall heart size, indicating reduced venous pressures and cardiac filling. Pleural effusions also may be evident in biventricular CHF and especially in cats with chronic cardiomyopathies or in dogs with pericardial disease or end-stage CHF complicated by atrial fibrillation.

The **diagnosis of right-sided CHF** is usually suspected from physical examination (resting tachycardia, jugular venous distention, abnormal jugular pulses, abdominal distension from hepatomegaly and ascites, and abnormal cardiac auscultation). Confirmation requires identification of cardiomegaly or pericardial effusion by radiography and often with echocardiography (to establish the exact type of heart disease).

**Clinical laboratory tests** may be contributory in canine patients with heart disease. Elevated blood *troponin* (cTnI) indicates heart muscle injury and is likely to be high in cases of myocarditis or acute ischemic injury. High circulating *BNP* (brain natriuretic peptide) or part of the prohormone (*NT pro-BNP*) suggests structural heart disease and volume overload, with or without overt CHF. There are emerging data regarding the use of this biomarker for both diagnosis and prognosis in feline (better) and canine heart disease, but the test should not be assessed in isolation (as it may be high in some dogs with primary respiratory disease, compensated disease, and noncardiac conditions). Serum biochemistries, especially renal function tests and electrolytes, should be evaluated in CHF patients. These can be abnormal owing to pre-existing disease or drug therapy. *Anemia* and *hyperthyroidism* (from excess or inappropriate supplementation) increase demands for cardiac output and should also be ruled out in cardiac patients. *Thyroid function tests* (including free T4 and TSH) are indicated in dogs with inappropriate sinus bradycardia or when serum cholesterol is significantly elevated. In older cats hyperthyroidism is a cause of secondary cardiomyopathy and should be considered as a cause of heart disease and potentially heart failure. A *heartworm antigen test* should be obtained from dogs living in or arriving from geographic regions endemic for dirofilariasis.

**Stages of Heart Disease**

The ACC/AHA classification of human heart disease (Stages A-B-C-D) can be applied to dogs and to cats with heart disease/failure. Treatment approaches can be based on these modified ACC/AHA stages, especially when considering chronic home management of heart disease. The classification has been modified by an ACVIM panel for DOGS with chronic mitral valve disease, as follows:

**Stage A** includes dogs at high risk for development of heart disease/failure, but currently without signs of structural disease. Examples include the Doberman pinscher (risk for DCM) and the Cavalier King Charles spaniel (risk for chronic MR). No therapy is indicated, but monitoring by auscultation or other methods (e.g. echocardiography or perhaps biomarkers line NT proBNP) may be appropriate in some cases.

**Stage B** includes dogs with a structural heart abnormality (e.g. murmur of MR or echo findings compatible with "occult" DCM) but never showing signs of heart failure. Subclass **B1 includes dogs with a normal-sized heart** and subclass **B2 includes dogs with remodeling**
(cardiomegaly). There is some tendency to consider treatment in dogs in subclass B2 (see below).

Stage C includes those dogs with current or previously-treated heart failure. Once in stage C, the patient can never return to stage B. Dogs in this stage are prescribed *life-long cardiac therapy*. Some Stage D includes dogs with clinical signs of CHF that are refractory to “standard therapy” (defined by a consensus panel as “standard dosages of furosemide, spironolactone, ACE-inhibitor, and pimobendan”). These dogs require more aggressive treatment and may benefit from referral to a cardiologist.

Dogs with acute CHF requiring hospital stabilization are somewhat difficult to classify in this system. Some dogs may never have received therapy before and with hospital stabilization will reside in stage C. Other dogs with long-standing CHF will clearly fall into Stage D.

**DRUGS USED IN THERAPY OF HEART FAILURE**

A large number of drugs can alter heart and vascular functions. Some treatments for congestive heart failure (CHF) affect ventricular pumping (inotropes), while others reduce venous pressures and ventricular preload (diuretics and venodilators), improving or preventing CHF. Drugs with arterial vasodilator effects will most likely decrease blood pressure, ventricular afterload, and mitral regurgitant volume, with a consequence of increasing stroke volume from the ventricle.

Some drugs, demonstrate very rapid hemodynamic effects (IV diuretics and inotropes), while others modulate chronically-activated neurohormonal or inflammatory mediators of CHF (offering “cardiac protection”). The clinician should be mindful of the clinical pharmacology of these agents and also appreciate that many drugs used in veterinary practice are prescribed in an extra-label manner. For example, all of the antiarrhythmic drugs are human drugs used empirically in an unapproved manner based on current “standards of care”. The following is a summary of “bullet points” related to commonly-used cardiovascular drugs in dogs.

**Diuretics** – Furosemide and other diuretics are administered to cardiac patients initially for mobilization of edema and chronically to prevent fluid retention. Low doses also may be useful (combined with an angiotensin converting enzyme (ACE) inhibitor for management of cough related to left bronchial compression is stage B2 chronic valvular heart disease). Diuretics should be used with progressive degrees of sodium restriction. Dietary therapy is discussed elsewhere in these proceedings.

**Furosemide** *(canine dose: 2–4 mg/kg IV, IM, SQ, PO in dogs; feline dosages are about 50% of canine dosages)* is a potent loop diuretic that blocks the 2-chloride transporter and increases urinary losses of chloride, sodium, potassium and water. A relatively high initial furosemide dose (2–4 mg/kg, IV) is administered in cases of severe canine CHF as renal blood flow and drug delivery may be reduced. Once diuresis begins, the dose can be reduced to 2 mg/kg q6–12h, IV, IM, or SQ depending on severity and response. In life-threatening pulmonary edema, a constant rate infusion of furosemide should be considered (after one or two IV boluses, a constant rate infusion 0.5 to 2 mg/kg/hour can be administered over the next 6 hours until diuresis begins). Oral maintenance dosages of furosemide typically range from 2 to 4 mg/kg two to three times daily but can be increased to 12 mg/kg daily in refractory cases of heart failure;
alternatively, intermittent subcutaneous dosing (2 mg/kg) can be helpful (replacing three weekly oral doses with a subcutaneous injection of 2 mg/kg). Torsemide is another alternative substituted at about 1/8 to 1/10 of the furosemide dose. This loop diuretic may have better bioavailability and longer duration of effect.

**Spironolactone** (canine dose: 2 mg/kg PO daily in one or two divided doses; limit feline dosage to 1.5 to 2 mg/kg/day) is a weak, cardioprotective, potassium-sparring diuretic. It also may normalize baroreceptor function. There is some evidence—though it is not definitive—for a survival benefit in canine heart failure. Spironolactone is prescribed as chronic co-therapy with furosemide for management of CHF. Some also use this drug empirically in preclinical DCM for potential cardioprotection.

When fluid retention becomes refractory (Class D heart failure) other options should be considered. The use of **torsemide**, another loop diuretic, may be considered at approximately one-tenth to one-twelfth of the daily furosemide mg dose (divided into two treatments) for dogs with refractory ascites or edema. It can be combined with or substituted for furosemide. This drug is better absorbed in humans; canine studies are still needed but preliminary reports by Oyama and colleagues are encouraging.

**Hydrochlorothiazide** (HCT) is occasionally used in combination with furosemide for management of refractory fluid retention. This drug blocks the sodium transporter and inhibits sodium, chloride and water reabsorption in the distal tubule and the connecting segment. When used in combination with furosemide, HCT prevents some of the distal sodium reabsorption that escapes the effects of the loop diuretics (sequential nephron blockade). HCT is often formulated with spironolactone (25 mg of each in the 50-mg tablet) to increase the diuretic effect. Usual dose is 2-4 mg/kg of the combined product once daily, provided the drug can be tolerated. To prevent rapid volume depletion and electrolyte disturbances, when HCT is added to furosemide, the drug is given once, every other day, starting at the lower end of the dosage range. Profound hypokalemia and hypochloremia may develop with HCT, regardless of treatment with spironolactone or an ACE inhibitor. If renal function and electrolytes remain stable, increase the frequency of dosing to daily if beneficial.

**Adverse effects** of diuretics include polydipsia, polyuria, reduction in blood pressure, azotemia, electrolyte depletion, and elevated blood potassium (with spironolactone). Monotherapy will activate the renin-angiotensin-aldosterone system so chronic diuretic use should include an ACE-inhibitor as part of the treatment plan. Clients should be instructed not to administer the drug at bedtime and should not restrict water except in rare circumstances. Mild azotemia is not a reason to discontinue diuretic therapy, but moderate to severe azotemia should prompt a dosage reduction. Potassium supplements are rarely needed in dogs receiving combined therapy of furosemide, spironolactone, and enalapril as the latter two drugs “spare” potassium, reducing urinary losses.

**Diet & Nutraceuticals** – Diuretics therapy is usually discussed in conjunction with control of sodium intake in dogs. Reduced sodium intake is difficult to enforce in cats. There is also interest by many clients and veterinarians in holistic treatments with demonstrated cardiovascular effects. There is some evidence supporting the use of sodium restricted diets for reduction of plasma volume and heart size in heart failure. Conceivably this diet would also reduce daily diuretic dosages. Restriction of salt must be balanced with issues of palatability and protein/caloric intake, which can be insufficient in dogs with CHF and cardiac cachexia. Rigid sodium restriction is generally considered to be about 12 mg sodium/kg bodyweight/day, but this is rarely achieved. Freeman has recommended
moderate restriction of 50 to 80 mg sodium/100 kcal of dietary energy as a starting point for dogs. Both prescription diets (Cardiac Support diet, h/d – Heart Diet, and CV Diet) and over the counter senior diets restrict sodium to varying degrees. Perhaps as important as a special diet is simple avoidance of high-sodium treats (processed meats, hot dogs, sausages, some cheeses, etc.) that clients may use to entice pill-taking. Lower sodium treats can be identified including carrots, apple slices, and a number of dog biscuits (read the labels).

A number of potential nutraceuticals have been discussed for the cardiac patient, but in terms of evidence, only the use of fish oils (omega-3 fatty acids like EPA at 40 mg/kg/day and DHA at 25 mg/kg/day) have been shown to help prevent cardiac cachexia in dogs. L-arginine supplementation (250 to 500 mg PO three times daily) is used by the author when severe PH is documented and a PDE-5 inhibitor like sildenafil has been prescribed (this amino acid is the precursor of nitric oxide, the endothelial vasodilator maintained in an active state by phosphodiesterase-V inhibitors).

Other supplements have minimal to no evidence for their use, except in very specific situations. These nutraceuticals also can be very costly! Among this group are the supplements L-carnitine (50 to 100 mg/kg every 8 hours) and taurine (500 to 1000 mg daily). L-carnitine is considered for some boxers with DCM as a familial deficiency may be present. Taurine is considered for treating dogs eating exclusive lamb-rice diets, restricted-protein diets, or “off-brand” (home-made) diets; it is also considered in spaniel breeds, golden retrievers, and Newfoundland dogs with DCM. While there is hypothetical value to coenzyme Q10 supplementation, there is no evidence this costly compound should be used; the author never prescribes it.

Angiotensin Converting-Enzyme Inhibitors & Other Vasodilators – The ACE-inhibitors and vasodilators are mainstays of CHF therapy. Venodilation pools blood in systemic veins and reduces venous pressures, while arterial dilation reduces arterial blood pressure (BP) and ventricular afterload. Mitral regurgitation is usually reduced by lowering diastolic blood pressure, a potential benefit of ACE-inhibitors and especially more potent arterial vasodilators such as amlodipine or hydralazine. The ACE-inhibitors are widely used in treatment of mild systemic hypertension, somewhat controversially for advanced (stage B2) preclinical mitral valve disease, and as a standard of care for management of CHF.

The ACE-Inhibitors, including benazepril, enalapril, and ramipril, inhibit the renin-angiotensin-aldosterone system by blocking the converting enzyme (a kininase) leading to decreased plasma angiotensin-II and delayed degradation of vasodilating kinins. Reducing serum aldosterone concentration limits sodium retention and potassium loss in the urine. Additionally, ACE-inhibitors protect cardiac muscle, renal tissues, and blood vessels from RAAS induced injury while also down-regulating the sympathetic nervous system. Vasodilation is not as abrupt as with direct-acting drugs and overall is very modest when compared to agents such as the calcium channel blockers, especially when treating high BP. The usual canine dosage of enalapril and benazepril in North America is 0.25 mg/kg twice daily; the dose is often increased to 0.5 mg/kg twice daily at the time of first reevaluation if BP and renal function are acceptable. The feline dose is 50 to 100% of the full canine dosage.

Different direct acting vasodilators used for acute, life-threatening pulmonary edema. These include hydralazine (an arterial dilator) and the nitrovasodilators. Topical 2% nitroglycerine ointment (15 mg/inch; dosed in dogs between ¼ inch (small dogs and cats) to one inch cutaneously, q12h for 24 to 36h. The ointment is wiped off after ~6 hours to
allow a nitrate free interval). In dogs with severe MR the use of sodium nitroprusside (infused at 0.5 to 5.0 micrograms/kg/minute IV to achieve the systolic BP to approximately 85–90 mm Hg) can be used as a hospital treatment used in acute CHF. Evidence for benefit of nitrates in managing acute CHF is lacking, but nitroglycerine ointment is commonly used in part due to simple application and theoretical benefits. Many cardiologists view sodium nitroprusside as a life-saving drug for dogs with fulminating pulmonary edema from ruptured chordae tendineae. Hydralazine is not often used but can be an effective arterial vasodilator in acute situations, reducing LV afterload and the volume of mitral regurgitation. With increasing cost of nitroprusside, hydralazine is a good alternative for dogs with severe, life-threatening MR. Chronic use activates the RAAS.

The phosphodiesterase-5 inhibitors such as sildenafil (Viagra®, usual dose: 1–3 mg/kg PO q12h but as often as q8h) and related compounds like tadalafil are reserved for treatment of severe, symptomatic pulmonary hypertension. These drugs demonstrate relatively selective pulmonary arterial vasodilation and thereby lower pulmonary vascular resistance to blood flow. Some dogs respond significantly to this therapy with a reduction in collapsing or syncopal attacks and improved exercise capacity.

The dihydropyridine calcium channel blockers such as amlodipine are used mainly for control of systemic hypertension (where amlodipine is the drug of choice). Another use is as a load reducer in end-stage Class D, left-sided CHF. The initial dose of amlodipine for CHF patients is 0.05–0.1 mg/kg PO q12h; however, much higher doses (usually 0.2 to 0.4 mg/kg PO q12 to 24h) are needed to treat most dogs with systemic hypertension. Cats with hypertension rarely develop CHF, but if present, the usual starting dose in cats is 0.625 mg PO once daily. The drug has a long elimination half-life (about a day), so it may take a number of days before dosage changes are manifest.

The main adverse effects of vasodilator drugs are systemic hypotension (causing weakness or lethargy) and impairment of renal function. Some drugs, including amlodipine and hydralazine (1–3 mg/kg PO q12h), cause reflex neurohormonal activation and potentially sinus tachycardia. Hyperkalemia is a risk with the ACE-inhibitors, especially when combined with spironolactone (mild Hyperkalemia is ignored).

Inotropic Drugs – The positive inotropic drugs include catecholamines (dobutamine, dopamine), the glycoside digoxin, and the inodilator pimobendan (Vetmedin®).

Catecholamines are used only in the hospital setting. Dobutamine (2.5–20 micrograms/kg/minute constant rate infusion) is reserved for dogs and cats with cardiogenic shock (defined clinically as: CHF accompanied by systolic BP <80 mm Hg + hypothermia + impaired peripheral perfusion + elevated blood lactate). Many cats are also bradycardic when in cardiogenic shock. Dobutamine is infused for 24 to 48 hours and is often an effective bridge to oral medications. The dose is titrated to effect with adjustments made every 15 to 30 minutes until the cardiovascular status is more stable. Tachycardia and ectopic complexes are signs of overdose. Weaning can usually be accomplished by cutting the dose in ½ every 2 to 4 hours and measuring BP to insure it can be maintained.

Digoxin (0.005–0.0075 mg/kg PO q12h in dogs with normal renal function) is a modest positive inotropic drug that also slows heart rate by sensitizing baroreceptor function and altering autonomic neural tone to the CV system. The main indications for digoxin today are refractory CHF or CHF with AF. The drug is rarely if ever used in cats. In the latter situation the drug’s vagal-stimulating effect helps to slow AV nodal conduction and heart rate. Contraindications to use include complex ventricular arrhythmias, bradycardia, and moderate to severe renal dysfunction. The adverse effects of digoxin – anorexia,
vomiting, diarrhea, depression, and cardiac arrhythmias (sinus node and AV nodal depression; PVCs) – are best avoided by monitoring therapy with a serum digoxin level.

**Pimobendan** or Vetmedin® (0.2–0.3 mg/kg PO q12h) is a potent, orally administered inotropic drug with vasodilator properties labeled for **canine use.** It can be administered extra-label to cats at approximately 1.25 mg per cat twice daily in cases of DCM, end-stage HCM, or RVCJ. Pimobendan is classified as a calcium sensitizer with phosphodiesterase-3 (and possibly PDE-5) inhibitory properties. Pimobendan is useful in both acute and chronic heart failure of dogs. When used chronically it is combined with furosemide, an ACE-inhibitor, and spironolactone; this represents the current standard of care for management of chronic CHF due to chronic valvular disease or cardiomyopathy. Another indication based on recent study is for delaying heart failure in dogs (in particular, the Doberman pinscher) with well-defined, preclinical dilated cardiomyopathy (PROTECT trial). The value of this drug in advanced but preclinical mitral disease is under study (EPIC trial). Adverse effects are uncommon. Extralabel usage three times daily may be considered for end-stage heart failure (Stage D).

**Beta-adrenergic Blockers** – The beta-blockers, particularly carvedilol (0.1 to 0.6 mg/kg q12h PO), metoprolol (long acting), bisoprolol, and atenolol (0.25 to 1 mg/kg q12h PO) are sometimes prescribed to protect the heart muscle in dogs based on the standard of care for humans. The hope is that with chronic use, myocardium at risk will be protected from neurohormonal assault and demand ischemia; heart rate will be controlled; and LV ejection fraction will improve (as observed in human patients). In canine model studies, beta-blockers are cardioprotective, but this effect has *not* been proven in preliminary clinical studies of dogs with DCM or chronic mitral regurgitation. Dogs with advanced heart disease but not yet in CHF (e.g. “occult” or preclinical DCM) tolerate beta-blockade reasonably well. Atenolol is often used in cats with obstructive HCM, but is not prescribed in the setting of CHF. When it is prescribed previously to a cat that later develops CHF, the dosage is either reduced by 50% or the drug is discontinued.

Importantly, while beta-blockers are prescribed empirically by many cardiologists for treatment of preclinical dilated cardiomyopathy in dogs and cats, mainly for cardioprotection and as anti-arrhythmic, unlike the case in humans, these agents are *not* considered a standard of care for chronic CHF in dogs or in cats.

The dog with normal ventricular function and a healthy conduction system can generally tolerate high dosages of beta-blockers with little apparent difficulties. This is also the case in most cats with HCM. However, beta-blockers should never be used in uncontrolled CHF, and *gradual dose up-titration* is most appropriate when prescribed to dogs with systolic ventricular dysfunction or following stabilization of CHF. Concurrent use of pimobendan seems to offset some of the negative inotropic effects of beta-blockers in dogs with heart failure. Anticipated adverse effects of these drugs include weakness, hypotension, bradycardia, and worsening of edema or effusions.

**Antiarrhythmic Drugs**

In *atrial fibrillation* (AF) of dogs, heart rate control is usually gained by the combination of digoxin plus the calcium channel blocker diltiazem (starting dose of 0.5 mg/kg PO q8h uptitrated every 8 hours to as high as 2.5 mg/kg PO q8h for standard diltiazem; an alternative is long-acting diltiazem at a dosage range of 0.5 to 3.5 mg/kg q12h). Hypotension and bradycardia are adverse effects of over-dosage. Target in-hospital heart rate response for dogs with AF is about 120–160/minute, and an ambulatory ECG (Holter)
monitoring can be done to objectively assess rate control. Cats with AF can be treated with diltiazem, typically starting with 15 mg of the long acting drug, compounded, twice daily. Alternative dosing is ½ of a 60 mg Dilacor® tablet once a day.

Treatment of severe ventricular arrhythmias in the setting of CHF is difficult because most drugs depress ventricular function and represent yet another “pill” for clients to administer. In dogs, IV lidocaine (2–4 mg/kg IV boluses to 8 mg/kg; 50 microgram/kg/minute constant rate infusion) can be used in the hospital in dogs with rapid or dangerous-morphology ventricular. While useful for short term treatment only, it does not significantly depress heart function or heart rate. A related compound, mexiletine (5–8 mg/kg PO q8h) may be effective chronically if adverse effects are not an issue and the client can tolerate t.i.d. dosing. Side effects of both drugs include anorexia, vomiting, tremors, and seizures. Mexiletine is NOT used in cats and the feline dose of lidocaine is lower than for dogs, typically starting at 0.5 mg/kg IV slow bolus.

The class 3 (potassium-channel blocking) antiarrhythmic drug sotalol (canine and feline dosage: 1–2 mg/kg PO q12h) is generally effective well tolerated, but since this drug exhibits beta-blocking properties as well it can depress heart rate and myocardial contractility and is therefore best avoided in CHF until heart failure has been stabilized. It can then be used cautiously.

The sodium channel blocker flecainide has not been studied sufficiently in dogs, but can be administered at an initial dosage of 1-2 mg/kg PO, q8-12h for ventricular arrhythmias. It is not used in cats. Unfortunately, it is more likely to be proarrhythmic, worsening ventricular ectopy, in the setting of a failing heart.

Amiodarone is a complex drug that is sometimes used for rhythm control after electrical or drug-induced cardioversion of AF. It also can be used for suppression of malignant ventricular arrhythmias and may be highly effective (canine dose: 8 to 10 mg/kg PO once daily for one to two weeks; thereafter 4–6 mg/kg PO once daily; there is no feline dose). However, owing to liver toxicity, liver enzymes/function tests (as well as thyroid function and a CBC) must be followed. Dogs who become ill from amiodarone may take days to recover owing to the very long elimination half-life. IV amiodarone is also very effective in dogs but the preservative-free product must be used to avoid anaphylaxis.

MANAGEMENT OF HEART FAILURE

A number of standard treatment approaches that have proven useful for management of established CHF in dogs (please see above sections for drug dosages).

Acute CHF in Dogs

Acute Pulmonary Edema from Left-Sided CHF – The combination of furosemide, oxygen, nitroglycerine (or sodium nitroprusside) & sedation with butorphanol (0.25 mg/kg IM, repeated in 30 to 60 minutes if needed) closely followed by oral administration of pimobendan (0.25 to 0.3 mg/kg q12h) represents the initial treatment plan applicable to most cases of CHF regardless of cause. This can be remembered by the mnemonic “FONs Plus”. With this protocol, diuresis is initiated; oxygen saturation is increased; ventricular loading is reduced; the tendency towards pulmonary edema is decreased; anxiety is relieved; and myocardial contractility is supported. If patients are heavily sedated, the torso is positioned in sternal recumbency, the chin supported with a towel or soft pad, and nasal oxygen prongs are inserted for better oxygenation. After an initial IV or IM bolus of 2 to 4 mg/kg, the dosage, route, and frequency of furosemide can be adjusted to the clinical
response (respiratory rate, anxiety, auscultation). In life-threatening pulmonary edema due to mitral disease, a constant rate infusion of furosemide along with aggressive afterload reduction with sodium nitroprusside should also be considered. Less-potent and less controllable alternatives to sodium nitroprusside include oral hydralazine or an ACE-inhibitor.

The inodilator pimobendan is generally considered a drug for chronic CHF in dogs, but it also exhibits effects acutely and is therefore helpful in the acute treatment of heart failure. This drug functions as a preload and afterload reducer as well as a potent inotrope and can be started as soon as the dog is capable of swallowing, typically within an hour of starting other treatments.

**Cardiogenic Shock** – The findings of cardiogenic pulmonary edema or pleural effusion with severe hypotension (BP <80 mm Hg), along with other indicators of low cardiac output (pallor, hypothermia, depression, elevated blood lactate) are highly suggestive of cardiogenic shock. Dogs with dilated cardiomyopathy (often Doberman pinschers) represent the typical case of cardiogenic shock. Other potential causes of cardiogenic shock include myocardial infarction and massive pulmonary embolus as might occur following treatment for adult heartworms or after a spontaneous pulmonary embolism. Initial treatment is the same as discussed above with Furosemide-Oxygen-Nitrate-Pimobendan.

As these patients are hypotensive and often very depressed, sedation is infrequently needed and diuretics alone may further depress BP, so that more aggressive therapy is needed. The clinician should determine if centesis is necessary, as dogs with cardiogenic shock can have both pulmonary edema and large cavity effusions. Volume infusion (i.e. fluid therapy) is *not* appropriate to raise BP in this setting, as it will only worsen edema. In most cases, there is a need to stimulate myocardial contractility to improve pump function and facilitate diuresis. Dobutamine (or dopamine) is administered as a constant rate intravenous infusion, starting at 2.5 micrograms/kg per minute and increasing the infusion by 1-2 micrograms/kg/minute every 15 to 30 minutes until systolic BP is 90 mm Hg. This end-point is generally reached at an infusion of 5–10 micrograms/kg/minute, though higher infusion rates may be needed. Once the BP is stable (systolic BP in the 90 to 100 mm Hg range), other vasoactive drugs, such as nitroprusside or an ACE-inhibitor, can be added later to unload the left ventricle. Otherwise, the approach to the patient with cardiogenic shock, aside from the addition of a catecholamine, is similar to that discussed in the previous section. The main difference is the requirement to address BP and tissue perfusion aggressively and to avoid drugs that depress BP until it is supported by a catecholamine. While less effective than a catecholamine, pimobendan can be administered as co-therapy since it has a potent inotropic effect (but is also a vasodilator). After 24 to 48 hours of dobutamine therapy, the dobutamine rate is reduced by 50% every 2–4 hours, and once the dose has been lowered to ~1.25 micrograms/kg for 2-4 hours, the infusion is discontinued. By that time the dog should be taking oral drugs for CHF.

**Arrhythmias in Acute CHF** – Drugs used for management of heart rhythm disturbances were summarized previously (see “Drugs Used in Therapy of Heart Failure”). Atrial fibrillation can precipitate CHF in previously stable canine patients. This problem is usually managed with heart rate control as opposed to cardioversion (to normal rhythm). Rate control involves initiation of oral digoxin followed within 24 hours by up-titration of oral diltiazem. Diltiazem is titrated to a hospital heart rate of 120 to 160/min and is optimally evaluated later by a 24-hour (Holter) ECG. Effective treatment of CHF is also useful as it
allows for some withdrawal of sympathetic tone with reduction of ventricular rate response. Electrical cardioversion from AF to sinus rhythm has been used by some in managing this arrhythmia, but our experience is that dogs in CHF usually revert back to AF in short time, so we mainly recommend rate control in our practice.

Isolated premature ventricular complexes (PVCs) are not treated in CHF cases. However, sustained runs of rapid ventricular tachycardia require treatment to maintain BP and are managed with boluses of lidocaine followed by a constant rate infusion of lidocaine if required. As previously discussed, mexiletine, low-dose sotalol, flecainide, and amiodarone are all potentially useful for suppression of life-threatening ventricular tachycardia but each drug carries serious adverse effects.

**Acute CHF in Cats**

Management of the cat with acute or severe CHF begins with gentle handling. Thoracocentesis is the treatment of choice for moderate to large pleural effusions. This is most safely done using a small butterfly catheter or needle, with the cat in sternal recumbency and receiving supplemental oxygen by face mask, after sedation. For bilateral pleural effusions it is safest to tap on the right side to avoid puncturing a bulging left auricle.

Cats with pulmonary edema from CHF are managed by the author using “SO-FINE” approach: sedation, oxygen, furosemide, oxygen, nitroglycerine, and “extra” therapy as needed. Oxygen (40 – 50%) is delivered by cage oxygenator in most cases. Sedation is typically administered (butorphanol – 0.25 mg/kg IM; this can be mixed with acepromazine – 0.025 to 0.05 mg/kg, provided rectal temperature >100 degrees F and blood pressure >100 mm Hg). Furosemide is administered (2–4 mg/kg IV or IM; repeated in 2 to 4 hours if necessary). Once diuresis occurs and symptoms improve, the dose is reduced to 1-2 mg/kg IV, IM, or SQ q8 to 12h). For life-threatening, poorly-responsive lung edema, initial boluses can be followed by a constant IV infusion of furosemide of 4 to 6 mg/kg given over 24h. Nitroglycerin (2%) ointment is administered for venodilation (¼ inch cutaneously, q12h) for 24 hours with the hope of reducing ventricular preload.

Extra treatments may be necessary. Thoracocentesis is performed for moderate to large pleural effusions. In cats with minimal pulmonary edema, thoracocentesis may be the most life-saving procedure. The cat with cardiogenic shock (hypothermia often with bradycardia, systolic BP <70 mm Hg) is treated with passive warming and IV dobutamine infusion for 24 to 48 hours (regardless of type of cardiomyopathy). Dosing is initiated at 2.5 micrograms/kg/minute and increased to a range of 5 to 10 micrograms/kg/min). The final infusion rate targets a rectal temperature of >100°, heart rate >180/minute, and systolic BP >90 mm Hg. The dose is reduced by 50% every 2-3 hours before discontinuing the drug. Furosemide or thoracocentesis are used to treat CHF as appropriate. In cats without LVOT obstruction, pimobendan (1.25 mg per cat, PO, can be considered). Cardiogenic shock carries a very guarded prognosis, but survival exceeding one year occurs in some cats following this aggressive treatment plan along with diligent home care. Unfortunately, some cats will succumb from unresponsive CHF.

**Chronic Home Management of CHF – Dogs**

**Transition** – The transition from hospital to home therapy of CHF usually begins within 48 hours of admission. During that interval, the initial diagnostic workup should have been completed. The typical transition to “Home Therapy” includes the following steps: 1) parenteral furosemide is replaced with oral furosemide; 2) oxygen is discontinued; 3)
nitrates (if used) are replaced by an ACE-inhibitor; 4) pimobendan is continued (digoxin is used only for rate control in AF); 5) spironolactone is initiated mainly for cardioprotection at release or at the time of first follow-up; and 6) the client is counseled regarding a sodium-restricted diet and pros/cons of nutraceuticals. These specific uses of these drugs (as well as dosages) have been summarized above in the section on “Drugs Used in Therapy of Heart Failure”.

**Long-term Home Therapy** – The basic home treatment of chronic CHF in the dog with Stage C heart disease can be recalled with the mnemonic: Dogs Are For Special People: Dietary sodium restriction, ACE-inhibitor, Furosemide, Spironolactone, and Pimobendan. In the dog with echocardiographic evidence of LV systolic dysfunction, beta-blockade is considered at the first or second follow up examination (assuming the dog is “dry” and very stable). As previously stated, it can be very difficult to initiate therapy with beta-blockers due to their negative effect on contractility and there is a lack of clinical evidence to support this treatment.

Additional therapy may be added for special problems as a dog progresses from stage C to stage D. In cases of severe PH with symptoms such as exertional collapse or ascites, sildenafil is considered as a relatively selective pulmonary vascular vasodilator to unload the right ventricle. Arrhythmias have been discussed previously; again, if AF complicates CHF, both digoxin and diltiazem are added to gain better heart rate control. Isolated premature ventricular complexes (PVCs, VPCs) and nonsustained runs of VT are not treated, unless the QRS morphology or timing appear “dangerous” (such as R on T; very rapid; multiform VT; or torsade de pointes): In reality, most clients are willing to assume a risk of sudden death for their dog (and most hope that will occur instead of intractable CHF or euthanasia). Sustained ventricular arrhythmias – especially when causing signs – are managed with mexiletine, amiodarone, flecainide, or sotalol.

Strategies for managing refractory edema or ascites (Stage D) include first reviewing client compliance and optimizing the dosages of currently-prescribed drugs. Pimobendan (Vetmedin®) dosage is generally increased to 0.25 mg/kg PO q8h (extra-label). Client administration of subcutaneous furosemide is suggested (begin by substituting one oral dose of furosemide for a subcutaneous injection, three times weekly then go to every other day if necessary). Alternatively, torsemide can be substituted for furosemide or a low dose of hydrochlorothiazide can be started (1-2 mg/kg daily or every other day) with monitoring of serum biochemistries within a week (or earlier). Abdominal paracentesis should be considered to reduce tense ascites. Sildenafil (Viagra®) plus L-arginine supplementation are offered when severe PH is documented by echocardiography.

Follow up evaluations for dogs with chronic CHF are scheduled initially at 7-14 days after release, then one month later, then every 3 to 4 months if possible. Drug dosing and adverse effects of treatments are discussed with the client at all stages of therapy. Emphasis for effective treatment is on quality of life (eating well, sleeping comfortably, capacity for walking/mobility, family interaction, resting respiratory rate, and clinical signs of disease or drug toxicity). Additional examinations of importance include: physical examination findings of controlled CHF; bodyweight/cachexia; BP; renal function; heart rhythm; and thoracic radiography if respiratory symptoms are still present.

**Chronic Home Management of CHF – Cats**

The home therapy of chronic CHF provided by cat owners centers on administration of furosemide (usual dosage: 1 to 2 mg/kg, PO once or twice daily), combined with an ACE-inhibitor such as enalapril or benazepril (usual dosage: 0.25 to 0.5 mg/kg, PO once or twice daily).
daily). Occasionally furosemide is given subcutaneously on a regular schedule (1 mg/kg SQ once to three times weekly in place of an oral dose) for poorly responsive pulmonary edema or pleural effusion. Spironolactone (6.25 to 12.5 mg, once daily) can be given for possible cardioprotection and potassium sparring effects (beware: anorexia, skin lesions). *Neither* atenolol nor diltiazem should be administered to cats with recent onset CHF (such therapy was not beneficial in an unpublished multi-center study reported by Fox).

A common situation is development of CHF in a cat with HCM that is already receiving chronic atenolol or diltiazem therapy. Options here include stopping the drugs or reducing the doses (by at least 50%). These drugs should definitely be stopped if the cat exhibits cardiogenic shock. In cats with well-defined dynamic LV tract outflow obstruction, continuing a lower dose of atenolol (25 to 50% of the usual dose may be possible) with cautious up-titration once the cat is completely stable. Alternatively, diltiazem may be added if it is deemed useful for ventricular diastolic function.

Additional treatments may improve CHF in some cats. The extralabel use of the inodilator pimobendan (~0.25 mg/kg PO q12h or 1.25 mg per cat PO q12h) provides an additional treatment approach for cats with chronic CHF. In the author’s opinion, pimobendan should be prescribed immediately for cats with CHF due to DCM, RCM, UCM, or right ventricular cardiomyopathy. In contrast, pimobendan is not recommended for the cat with well-defined HCM until CHF becomes progressive or unresponsive to furosemide and an ACE-inhibitor. Today, digoxin is rarely used in cats. Routine (250 mg q12h) is prescribed when there is chylothorax associated with CHF. Famotidine (2.5 to 5 mg once or twice daily for one to two weeks) represents an empirical treatment for cats with partial anorexia associated with CHF; this drug also can be prescribed long-term.

**Follow Up**

The overall efficacy of heart failure therapy and quality of life can be gauged using practical means. The client interview should ascertain activity level, resting respiratory rate and depth, appetite, and interaction with the family/housemates/environment. Objective measures of CHF control and adverse drug effects can be obtained through a physical examination, measurement of blood pressure, evaluation of serum chemistries, inspection of thoracic radiographs, and perhaps by echocardiography. The timing of specific examinations depends on clinical circumstances and economic considerations, but initially should occur within the first 7 to 10 days from the first diagnosis of CHF, and continue every one to two weeks until the CHF is controlled and renal function and blood pressure are stable. Thereafter, the interval is extended to every one to three months, depending on the patient’s progress. In general, progressive azotemia indicates the effects of diuretics plus an ACE-inhibitor, and when possible, the dosages should be reduced, so long as cat is free of edema or effusions. In some cats with HCM, the heart stabilizes, allowing diuretic therapy to cease. In other cases, there is a clear need to tolerate azotemia to prevent discomforting pleural effusion or pulmonary edema. Life-long therapy is anticipated for most cats with CHF.
Additional Reading - Dogs


Additional Reading - Cats


© 2014 - John D. Bonagura, DVM

NOTES