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FELINE HEART FAILURE: CURRENT CONCEPTS/STRENGTHS AND WEAKNESSES

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INTRODUCTION
Cardiomyopathies are a significant cause of morbidity and mortality in the feline population. Cardiomyopathy refers to a group of diseases where the predominant feature is a structural and functional impairment of the heart muscle. Primary cardiomyopathy is diagnosed when an underlying cause cannot be identified. Secondary cardiomyopathy is a change in the morphology or function of the heart muscle secondary to an underlying metabolic, systemic or nutritional disorder. Examples of conditions resulting in secondary cardiomyopathy include systemic hypertension, hyperthyroidism, and taurine deficiency.

Classification of cardiomyopathies has been difficult due to the overlapping nature of many cases that do not fit into one of the major groups. The major morphologic classifications include hypertrophic, restrictive, dilated, and right ventricular cardiomyopathy. A more recent classification of "intermediate" or "unclassified" cardiomyopathy refers to those cases with overlapping characteristic changes of one or more groups. Despite the popularity of the morphologic descriptions in clinical practice, an attempt to identify the underlying physiologic consequences should be made.

The heart has two basic functional components: diastole and systole. Morphologic myocardial changes result in alterations of systolic function, diastolic function, or both. An understanding of the physiologic implications of the disease will ultimately allow for more focused therapy. Improving echocardiographic techniques in feline cardiology will allow for earlier and more accurate determination of the physiologic alteration present.

THERAPEUTIC APPROACH TO HEART FAILURE
Medication regimes should be tailored for each individual animal based on data obtained from physical examination, echocardiography, electrocardiography, and radiography. Knowledge of the medications including mechanism of action, physiologic effects, dosages, and side effects is essential. Therapeutic goals can include a reduction in heart rate thereby improving left ventricular filling, relieving a left ventricular outflow tract obstruction by decreasing heart rate and contractility, controlling arrhythmias, blunting the neurohormonal responses to the presence of cardiac disease, or relieving congestive heart failure. In many cases, several different treatment strategies may be used to address any of the above goals. The medication used will depend on frequency of administration (owner compliance), personal experience, available formulation, and response to treatment. Monitoring the response to therapy for the particular goal determined at the onset of therapy is imperative. The medication should be titrated to achieve the desired clinical effect within the dosing limits for that medication. If an appropriate therapeutic response is not obtained re-evaluating the goals or altering the treatment strategy is recommended.

DIASTOLIC DYSFUNCTION

Hypertrophic Cardiomyopathy
Hypertrophic cardiomyopathy (HCM) is a disease characterized by abnormal concentric or asymmetric left ventricular hypertrophy. The left ventricle is non-dilated with a broad variation in phenotypic changes. The entire left ventricle can be hypertrophied or it may be isolated to a particular wall segment. The hypertrophy can be mild to severe. Systolic anterior mitral valve motion (SAM) resulting in a dynamic left ventricular outflow tract obstruction is commonly seen and is more commonly associated with interventricular septal hypertrophy.

The primary physiologic consequences of ventricular hypertrophy are an elevated left ventricular end-diastolic pressure with a normal or reduced left ventricular end-diastolic volume. These changes result from a stiff and non-compliant ventricle along with alterations in early diastolic filling or ventricular relaxation.

Restrictive Cardiomyopathy
Restrictive cardiomyopathy (RCM) has been used to morphologically describe non-hypertrophied ventricles with normal systolic function. A presumptive diagnosis of restrictive cardiomyopathy is made based on morphology but further verification of diastolic function is essential to making a more accurate diagnosis. Left ventricular chambers dimensions are usually normal or mildly reduced, systolic function is normal, and wall thickness is normal to mildly increased. Regional areas of ventricular thinning and scarring may represent myocardial atrophy or infarction. Focal or diffuse areas of hyperechoic and thickened endocardium or wall segments are associated with excessive scarring and fibrous tissue. Fibrous bands of tissue may be seen adjacent to myocardial walls, bridging areas of myocardial thinning, or in some cases bridging the septum, papillary muscles, and free wall obliterating the left ventricular apex.

The physiologic consequences of restrictive cardiomyopathy are alterations in the diastolic filling properties of the left ventricle. Changes in ventricular relaxation and chamber compliance are the primary alterations. Elevation in left ventricular end-diastolic pressure with normal or mildly elevated end systolic volumes result in progressive increases in left atrial pressure. Characteristic mitral inflow velocity profiles have been used to implying restrictive ventricular filling. Several Doppler echocardiographic variables can be used together to determine the extent of diastolic functional impairment.

Therapeutic Approach to Diastolic Heart Failure
Acute pulmonary edema is often life threatening and rapidly progressive necessitating gentle yet aggressive therapy. The primary physiologic alteration is a reduction in the filling capacity of the ventricular myocardium. Treatment strategies include diuretics, venodilators, oxygen, and a stress free environment. Furosemide is given intravenously (1.1 – 2.2 mg/kg) q1-4 hrs until clinical signs of congestion improve. The intravenous route is preferred as peak diuresis occurs within 30 minutes of administration. The application of 1/8-1/4 inch of 2% nitroglycerin ointment to the inside of the pinna q 6 hours may hasten the resolution of the pulmonary edema. Supplemental oxygen may be administered (40 to 60 percent oxygen rich inspired gas) by placing the animal in an oxygen rich environment (incubator or oxygen cage). Large volumes of pleural effusion should be reduced via thoracocentesis. Excessive use of diuretics may result in...
electrolyte abnormalities and severe dehydration. Following resolution of the acute crisis, diuretic administration is reduced to the lowest effective dose. Laboratory evaluation of renal values, PCV, total protein and serum electrolytes should be available when the animal is stable. Further diagnostic tests should be attempted only when the animal is stable.

Chronic management is aimed to prevent congestion, prevent arterial thromboembolism, maintain or improve quality of life, prolong survival, and theoretically slow or reverse deleterious progressive cardiac remodeling. Furosemide is reduced following clinical resolution of congestion to the lowest effect oral dose (typically 6.25 – 12.5 mg per cat q 12-24 hrs). In more advanced cases of chronic congestive heart failure, additional diuretics may be indicated to overcome developing diuretic resistance. Spironolactone is commonly administered orally (1-2 mg/kg q 12-24 hrs) in addition to furosemide.

While diuretic therapy is standard for chronic management of congestive heart failure, additional medications are selected to reduce diastolic dysfunction or its sequelae. Despite this idealistic goal, there is a general lack of consensus and no data to indicate which therapy, in addition to diuretics, is optimal. Treatment therapy aimed at preventing disease progression is presently unsubstantiated. Drugs are therefore administered empirically based on clinical experiences, preferences, and theoretical bias. Common classes of medications administered include beta-adrenergic blockers, calcium channel blockers, and angiotensin converting enzyme (ACE) inhibitors.

Beta-blockers blunt the sympathetic nervous system activation initiated by congestive heart failure resulting in increased ventricular afterload, heart rate, arrhythmias, myocardial oxygen demand, and other factors which contribute to the progression of heart failure. Beta-blockers improve passive left ventricular filling and compliance by a reduction in heart rate and contractility. Beta-blockers have been shown to be more successful than other agents at reducing or abolishing dynamic left ventricular outflow tract obstruction. Atenolol is the most commonly used beta-blocker in cats. Doses are typically 6.25 – 12.5 mg orally q 12-24 hrs and titrated to a reduction in resting heart rate. Occasionally with higher doses or in those animals sensitive to the effects, lethargy or hypotension may occur. These clinical signs typically occur within one hour of administration and quickly abate when the drug is discontinued or the dose is reduced.

Calcium channel blockers are rationalized by their ability to improve diastolic function. Their physiologic benefits include a reduction in heart rate, reduction in blood pressure, mild negative inotropic effect, and a direct improvement in early diastolic left ventricular relaxation. Clinically this drug is dosed at 7.5 – 15 mg orally q 8 hrs. An extended release version (Dilacor XR) is commonly used. This drug is formulated in 240 mg capsules which contain four controlled release 60 mg tablets. Dosing is typically 30 – 60 mg orally once daily.

Neurohormonal activation is associated with congestive heart failure. The disruption of these mechanisms has been an integral component to the management of congestive heart failure and thus the rationale for the use of ACE inhibitors. In addition, activation of the renin-angiotensin system has been implicated in the regulation of myocardial hypertrophy and remodeling in heart failure. ACE inhibitors are commonly used alone or in combination with furosemide with congestive heart failure. Enalapril (0.25 – 0.5 mg/kg orally q 24hrs) or benazepril (0.25 – 0.5 mg/kg orally q 24hrs) are clinically well tolerated. ACE inhibitors are also commonly used in addition to calcium channel blockers or beta-blockers with refractory congestive heart failure or with progressive left atrial enlargement. The optimal dose and timing for ACE inhibitor administration in addition to their effects on morbidity and mortality need to be determined in cats with myocardial disease.

**SYSTOLIC DYSFUNCTION**

**Dilated Cardiomyopathy (Myocardial Failure)**

Dilated cardiomyopathy is a myocardial disease associated with a reduction in systolic function. Dilated cardiomyopathy refers to the classic description seen as dilation of all four cardiac chambers with global wall thinning and a marked reduction in fractional shortening or ejection fraction. The left ventricular end diastolic and systolic volumes are increased. Regional areas of hypokinesis are often associated with wall thinning and regional scarring.

Reduction in left ventricular systolic function leads to elevation in end-diastolic pressures due to reduced systolic emptying and increased residual end-systolic volumes. A reduction in cardiac output leads to clinical signs of pulmonary congestion, pleural and abdominal effusions, and in some cases cardiogenic shock.

**Right Ventricular Cardiomyopathy**

Right ventricular cardiomyopathy or also referred to as arrhythmogenic right ventricular cardiomyopathy is a newly recognized form of cardiomyopathy in the cat. The disease is characterized by a progressive atrophy of the right ventricular myocardium and replacement of the myocytes with fibrous tissue and/or fat. The disease is recognized clinically as dilation of the right ventricle with localized thinning of the right ventricular apex. It has been associated with a variety of conduction disturbances, supraventricular, and ventricular arrhythmias. Right sided congestive heart failure can develop as the disease advances. Mild involvement of the left ventricle may develop.

**Therapeutic Approach to Systolic Heart Failure**

Pleural effusion is more commonly associated with systolic dysfunction, and is suggested clinically by muffled heart and lung sounds. Thoracocentesis should be performed when significant pleural effusions are present. Furosemide is the recommended initial diuretic, and should be dosed at 1-2 mg/kg q 8-12 hrs. Intravenous furosemide is recommended over oral administration due to the more rapid onset of action and potential venodilating properties. Aggressive diuretic therapy may severely reduce ventricular filling resulting in azotemia, electrolyte abnormalities, reduction in forward cardiac output, and prolonged renal excretion of certain medications. Positive inotropes can be administered in cats with myocardial failure. Digoxin can be given at a dose of ¼ of a 0.125 mg tablet every other day. Digoxin should be used cautiously in cats with reduced renal perfusion or significant azotemia as this leads to intoxication. Dobutamine is preferred in those cats presenting with cardiogenic shock. Dobutamine exerts its effects through stimulation of myocardial beta-adrenergic receptors. Recommended starting doses are 2-5 ug/kg/min. Seizures can be a common complication of dobutamine therapy. If they occur, the drug should be temporarily discontinued until recovery from the seizure, and the dose of the medication should be reduced in half or discontinued. Vasodilators may
be helpful in reducing preload and afterload, but should not be used in those patients that are hypotensive or in cardiogenic shock. The application of 1/8-1/4 inch of 2% nitroglycerin ointment to the inside of the pinna q 6 hours may help improve clinical signs of congestion. Supplemental oxygen therapy should be administered. Hemodynamically or electrically unstable arrhythmias should be treated. Calcium channel blockers or digoxin can be used to slow the ventricular response to atrial fibrillation. Sustained ventricular arrhythmias can be managed with intravenous lidocaine (1-2 mg boluses or 10-20 ug/kg/min). Cats are very sensitive to the effects of lidocaine and therefore the doses are markedly reduced compared to dogs. Oral Taurine supplementation should be given to those cats with a historical non-commercial diet. In order to maintain hydration and an effort to reduce significant electrolyte depletion, nasogastric or nasoesophageal feeding tubes can be used to provide fluids and nutrition.

Chronic therapy typically involves a combination of diuretics, ACE inhibitors, and digoxin. Furosemide is reduced to the lowest effective dose to control signs of congestion (1-2 mg/kg q 12-24 hrs). Recurrent episodes of congestive heart may require higher doses of furosemide or the addition of additional diuretics. Spironolactone dosed at 1-2 mg/kg q 12-24 hours can be dosed in addition to furosemide. ACE inhibitors reduce neuroendocrine activation.

Enalapril (0.5 mg/kg q 24 hrs) is the most commonly used drug in this class. Digoxin is administered orally at a dose of ¼ of a 0.125 mg tablet every 2-3 days. Digoxin toxicity is seen as anorexia, vomiting, and lethargy. A taurine rich diet should be given. Periodic monitoring of renal values and electrolytes is recommended to help tailor the therapeutic regime.

Unclassified Cardiomyopathies
Several cases do not fit neatly into one category of morphologic changes and therefore may have features of one or more groups. Despite our desires to provide a definitive term to the disease (e.g. “unclassified cardiomyopathy” or “intermediate cardiomyopathy”), a morphologic and physiologic description should accompany this diagnosis. The description should include statements regarding wall thickness, chamber dimensions, regional scarring, endocardial changes, and regional abnormalities. In addition some statements regarding systolic and diastolic function should be made.

References are available upon request.