PATHOLOGY OF THE CARDIOVASCULAR SYSTEM

Cardiovascular pathology is the study of diseases that affect the heart and vascular structures. Diseases of the myocardium, endocardium, pericardium, and vascular structures as well as congenital cardiovascular anomalies and tumors of the cardiovascular system will be discussed.

OBJECTIVES:

1. Review normal myocardial contraction and discuss toxic and infectious disease processes which may result in myocardial disease.
2. Become able to define and discuss the primary cardiomyopathies.
3. Develop an ability to describe common congenital heart anomalies and discuss the pathological disease processes which may be associated with these abnormalities.
4. Be knowledgeable about endocardial diseases, pericardial diseases and vascular diseases.
5. Gain ability to dissect a heart and discuss specific disease processes which may affect each particular area of the heart.

REFERENCES:


HEART – INTRODUCTION

Review - (pp 559-562 Pathological Basis of Veterinary Disease)

Normal Anatomy
Normal physiology and normal blood flow (cardiac and general)
Review changes associated with right and left heart failure
Myofiber structure and function

Sectioning heart - There are as many ways to section a heart as there are pathologists! Most of the hearts which you will see have been sectioned in the echoplane sectioning – so that one can compare the gross pathological changes to the ultrasound taken in the live animal. In lab, we will review opening the heart in the more traditional manner by following the normal blood flow. Each of you will have the opportunity to open a heart in this manner. The echoplane technique will be demonstrated.
Postmortem Changes – It is important to recognize the normal from abnormal!

- Rigor mortis in heart results in contracted, rigid walls
  - The left ventricle may be empty of blood because of contraction.
  - Post mortem clots (including chicken fat clots) may be present within the atrium and right ventricle.
    - Seen in horses because of the ability of equine erythrocytes to undergo Rouleaux formation.
    - Also can be observed in septic animals
- “Fresh” hearts (before rigor mortis has set in) may appear “flabby and enlarged”.
  - This may resemble - but is NOT diagnostic for - dilative cardiomyopathy (DCM).
- Hemoglobin imbibition on endocardium and epicardium is seen with erythrocytes lyse after death – post mortem change…
- Young dogs and horses may have diffuse or patchy myocardial pallor grossly but do not have microscopic changes. One must be careful with interpretation of the gross findings and do histopathology.
- Intracardiac injections of euthanasia solution:
  - Can cause acute hemopericardium (so can other injections).
  - Can precipitate and have crystalline deposits on the endocardium or epicardium.
  - Can result in myocardial pallor at the site of injection due to the extreme toxicity of this material when injected into tissue.

DISEASES OF THE MYOCARDIUM

The myocardium is composed of cardiac muscle, (myocytes) similar to skeletal muscle, and therefore responds to injury much like skeletal muscle and vice versa. Cardiac muscle has a greater liability because of its continous activity and dependence on aerobic glycolysis. The papillary muscles of the left ventricle seem to be most sensitive believed to be due to the vascular supply of the heart.

Myocardial cells are considered to be a permanent cell population with extremely limited regenerative potential in the adult animal. Myocardial cell death results in scar formation. The thickness of the left ventricular free wall is approximately 2-4 times that of the right ventricle when measured in a transverse section across the middle of the ventricles. This results from the greater pressures in systemic circulation than in the pulmonary circuit. In newborn animals the right and left ventricles are approximately equal in thickness.

*Myocardial Reaction to Injury (pp 562-564 Pathological Basis of Veterinary Disease)

The following outline demonstrates the ability of the myocardium to undergo changes that you learned in general pathology. They are simply listed in these notes. If you have forgotten the pathological processes associated with these terms, please review last semester’s lecture notes.
• Reversible morphologic alterations of myocardium. These changes are seen as a result of workload requirement.
  o Atrophy - associated with chronic wasting diseases and malnutrition.
  o Hypertrophy
• Sublethal injuries – myofibers are still viable – but may be injured and not functioning properly.
  o Fatty degeneration
  o Lipofuscinosis
  o Vacuolar degeneration
  o Myocytolysis
  o Mineralization
• Lethal cell injury [Myocardial Cell Death]
  o Necrosis
    1. Often followed by leukocytic invasion + phagocytosis of debris.
       • This can look like myocarditis!
    2. Macrophage invasion and phagocytosis of necrotic material
    3. Fibroblasts proliferation results in fibrosis with collagen deposition
    4. End result → fibrosis
    5. Reminder: Myocardial regeneration is rare. It occurs in avian hearts and myofibers in the neonatal period. A leading area of research is in progress to develop methods to improve this regenerative capacity.
  o Apoptosis
    1. Myofibers shrink and form apoptotic bodies.
    2. No inflammation.
    3. Minimal fibrosis.
• NOTE: The normal myocardium has a 3 - 5 fold functional reserve capacity, which will eventually be lost with cardiac disease and, subsequently, will result in impaired function. However, small lesions can be important if they involve the conduction system.

Compensatory mechanisms occur with an increase demand in workload include:
Cardiac dilation  † Heart rate
Myocardial hypertrophy  † Blood volume
† Peripheral resistance    Redistribution of blood flow

Cardiac Decompensation (Failure) - (Congestive Heart Failure) (CHF)
Definition: The heart is not able to pump blood at a rate which can support the requirements of the metabolizing tissues. Cardiac output is less than venous return.
Lesions: The pathological manifestations of CHF are found in tissues other than the heart. You may want to review general pathology lecture notes if you aren’t feeling comfortable with pulmonary edema/congestion seen with left heart failure (LHF), centrilobular hepatic congestion and generalized edema resulting from increased hydrostatic pressure associated with right heart failure (RHF).
**CARDIAC HYPERTROPHY**

**Definition:** Reversible increase in the mass but not number of myocardial cells. Can be the result of normal physiology or pathology. In pathological hypertrophy, myocytes have impaired intrinsic contraction and relaxation.

**Pathophysiological Process:**
1. ↑ in size of myocardial fibers.
2. ↑ in # of myofibrils. (NOT MYOFIBERS!)
3. *Increased # of mitochondria, but mitochondria are not ↑ in # compared to the size of the myocardial fiber.*
4. ↑ in # of ribosomes.
6. ↑ in collagen (interstitial reaction).
7. *↑ Cell volume compared to vascular supply.*
8. ↑ Metabolic requirements and oxygen consumption.
9. 3 and 7 are two major reasons why a hypertrophic myocardium may fail.

**Requirements:**
1. Time
2. Adequate nutrition
3. "Healthy" myocardium
4. If 1-3 are lacking the result is a dilated ventricular chamber and heart failure.

**Types of Hypertrophy**

**Concentric Cardiac Hypertrophy (Pressure Overload Hypertrophy)**
Defined as an increase in the mass of the ventricle without accompanying increase in end diastolic volume.

- **Necropsy findings:**
  - Increased thickness of the ventricular wall and size of papillary muscles of affected chamber.
  - Ventricular chamber size may be decreased.
  - In general: ↑ in the right side of heart (RVH) makes the ♥ broader at its base; hypertrophy of the left side (LVH) increases ♥ length, bilateral hypertrophy produces a more rounded shape than normal.

- **Pathophysiology:**
  - Sarcomeres increase in number parallel to long axis of cells (wider).
- **Causes:** Pressure overloads
- **Some Examples:** Aortic stenosis (LVH), pulmonic stenosis (RVH), pulmonary hypertension (RVH), systemic hypertension (LVH), Hyperthyroidism - enhanced production of myocardial contractile proteins.

**Eccentric Cardiac Hypertrophy (Volume Overload Hypertrophy)**
- combined ventricular dilation and hypertrophy
- Defined as an increase in myocardial mass and increase in end diastolic volume resulting in an increase in ventricular volume.
Pathophysiology:
Sarcomeres increase in number in length and width.
Necropsy findings: Enlarged cardiac chamber.
- Heart tends to be globose. The ventricular walls are usually thin.
  - Papillary muscles may be attenuated.
  - Endocardium may be white due to fibrosis.
Causes: Volume overloads
- Local pathological changes
  - Valvular insufficiency (valvular endocardiosis)
  - Congenital defect with shunt (VSD)
- ↑ blood volume
- Develop in later stages of diseases that cause concentric hypertrophy.

Detection -
It is often difficult to determine whether a heart is hypertrophied, especially in eccentric hypertrophy where the walls may be thin. One good indicator is the percent heart weight relative to body weight. In the case of hypertrophy the percentage is increased. Normal heart weights vary from species to species and depend upon the amount of physical activity of the individual animal. The following normal percentages are reported: 0.75% dogs and horses, 0.3-0.8% cats, and pigs 0.4%. Remember an increased percent heart weight to body weight may be due to normal physiological hypertrophy.

Three stages of myocardial hypertrophy
1. Initiation
2. Stable hyperfunction
3. Deterioration of function associated with degeneration of hypertrophied myocytes

Cardiac Dilation
1. Reponse to an increase workload in both physiologic and pathologic states.
2. Causes - same as those of hypertrophy in the presence of a myocardium which cannot undergo hypertrophy for one or more of the following reasons:
   - Insufficient time
   - Inadequate nutrition
   - Diseases myocardium
3. Detection at necropsy – can be difficult.
4. Terminal lesion in many cardiac disease processes.
5. Maximum stretch for a sarcomere is 2.2-2.4µm.
**IDIOPATHIC PRIMARY MYOCARDIAL DISEASE**

**Synonyms:** Primary Myocardial Disease

**PRIMARY CARDIOMYOPATHY**

**Definition:** Acute, subacute, or chronic generalized disorder of heart muscle. An intrinsic disease of the myocardial fiber, the cause is usually not known. This is a primary disease process within the myocardium. In pathological terms, cardiomyopathy is diagnosed as gross or histological changes in the myocardium.

**NOTES:** “Arrhythmogenic cardiomyopathy” (ACM) is a clinical term used to refer to recurrent or persistent arrhythmia in the setting of a normal left ventricular ejection fraction. This clinical disease process often precedes pathological changes.

**Cause:** Usually etiology is unknown or obscure.

Idiopathic - speculation of immune or viral etiologies.

Carnitine and taurine have been implicated as playing a role.

**Species affected:**

**Dogs** - Possible genetic predisposition

- Great Dane – Dilated Cardiomyopathy (DCM)
- Newfoundland – DCM
- Irish wolfhound – DCM
- Saint Bernard - DCM
- English Bull Dogs -ACM
- Doberman pinscher
- Myocardium characterized by fatty infiltration and fibrosis
- English Springer Spaniels – Atrial Standstill
- Dilated thin atrium (AV muscular dystrophy)
- Portuguese water dog – Autosomal Recessive (young)
- Golden Retrievers with Muscular Dystrophy
- Incidence: male dogs > female dogs, often middle aged

Turkeys "round heart disease"

Chickens - ascites Syndrome

**Cats** - Maine Coon and American Shorthair (HCOM) - Autosomal dominant

- Rag Doll, British Shorthair, Rex, Persians, DSH
- Holstein HCOM
- Holsteins, Simmental, Red Holstein DCM
- Hereford (polled and horned) – “Tight Curled” “Wooly” Haircoat
  - Myocardial necrosis, mineralization and fibrosis, Autosomal Recessive.
- Japanese Black Calves – Autosomal Recessive young calves <30 days with myocardial degeneration and necrosis with fibrosis.
- Syrian hamsters

**Human beings**

Some forms are Autosomal Dominant with single gene mutation.
Types of Idiopathic Primary Myocardial Disease

Classification based on cardiac wall thickness measurements

*Hypertrophic (HCOM)
- Increased heart weight as a percent body weight.
  Pathophysiology: ↓ ventricular filling, ↓ compliance → diastolic Dysfunction
  “Concentric hypertrophy gone awry.”
  Primarily a left ventricular problem. But can involve both ventricles and occasionally only septal hypertrophy. This is referred to as Eccentric Hypertrophic Cardiomyopathy.
  Histologically: myocardial fibers are irregular in size. Nuclei are large. Myofibers are disorganized – so called myofiber disarray.
  Species: cat, dog, rat, pig, human beings
  Feline: Middle aged males, 10-20% posterior paralysis
 http://www.newmanveterinary.com/felhcm.html

*Congestive (dilated) (DCM)
- Progressive cardiac dilation and contractile dysfunction.
  - ↓ contractile force ↑ end diastolic volume
  - Taurine deficiency in cats and foxes
  - L-carnitine deficiency may be related to DCM
  Histo: myocardial fibers are thin and wavy. o
  Variable amounts of fibrosis may be present.
  Some adipose tissue may be seen in some dogs.
  Species: cat, dog, hamster, turkey, pig, cow, foxes

Restrictive - least common type seen in domestic animals
- Due to restriction of ventricular filling.
- Impaired diastolic filling
- Cats and humans
- Endocardial Fibrosis – endomyocarditis may initiate?

OTHER

- Arrhythmogenic Right Ventricular Fibroadipose Dysplasia - Adipose tissue and fibroblasts infiltrate and replace normal right ventricular myocardial tissue.
  - Seen most commonly in Boxer dogs.

- Excessive Moderator Bands (false tendons)
  - Reported in adult cats – may result in restriction of ventricular filling.
  - May be a congenital anomalie.
Secondary Myocardial Diseases - SECONDARY CARDIOMYOPATHIES

Definition: Any Disease of the myocardium that is the result of a metabolic, toxic, infectious, or neoplastic disease process. In other words, any myocardial disease that is not inflammatory nor an idiopathic, primary myocardial disease. May be peracute, acute, subacute, or chronic. (Many are peracute.)

Note: There are an extensive number of compounds which can result in myocardial degeneration and necrosis. For a comprehensive list – see Thomson’s Special Veterinary Pathology, page 214, Box 4-2.

Endocrine/Metabolic Diseases

** Catecholamine Toxicity

Causes:

1. CNS trauma: “Brain-Heart Syndrome” - myocardial damage secondary to release of endogenous catecholamine dump from trauma to the head and brainstem nuclei.
2. Functional pheochromocytoma - tumor of the adrenal medulla.
3. Exogenous - overzealous administration of epinephrine, etc.

Lesions

Multifocal myocardial necrosis with concentration of damage on the left ventricular subendocardium and papillary muscles. Lesions consist of necrosis with contraction bands with subsequent macrophage invasion. Excess intracellular calcium, vasoconstriction and increased heart rate all occurring together may be responsible for these lesions.

Species affected: dogs, horses, cows, sheep, pigs, goats and wildlife.

** Hyperthyroidism - Primarily seen in cats with hyperthyroidism.

- Cardiac hypertrophy due to increased production of myocardial contractile proteins under the influence of excess concentration of circulating thyroid hormones. Heart rate and cardiac output are also increased.
- Reversible upon return to euthyroidism.

Hypokalemia

Causes - potassium deficient diets
- hemodialysis

Lesions - rats, pigs, dogs
- Left ventricular free wall and septum
- Multifocal myocytolysis, myodegeneration and necrosis

Conduction Disorders

- Unexpected death in Doberman pinscher dogs and young German shepherd dogs.
  - Focal degeneration of the bundle of His.
- Syncope in pug dogs
  - Degeneration of the bundle of His
- Intermittent sinus arrest in deaf Dalmatian dogs
  - Sinus Node lesions
- Sinoatrial syncope (sick sinus syndrome)
  - Miniature Schnauzers, West Highland white terriers, Dachshunds, Springer spaniels
- Arrhythmias – dogs and horses
- Atrial fibrillation
- Heart block - Associated with myocardial lesions
Nutritional Deficiencies
**Vitamin E/Selenium deficiency**

*Discussed previously in General Pathology and Systemic Pathology – you may want to review Dr. Lopez’s notes.*

**Synonyms** for Vitamin E/Selenium deficiency
"White Muscle Disease" lambs and calves
"Mulberry Heart Disease" pigs (Vitamin E)

**Incidence:** Occurs in areas with soil deficient in Vitamin E/Selenium. Other tissues besides heart and skeletal muscle can be affected when Vit E and/or Selenium are deficient.

**Domestic animals:** (myocardial lesions) calves, lambs, pigs, turkey poults and ducklings

**Zoo animals:** Nyala antelopes, elephants, deer, baboons, camels, exotic birds

**Etiology**
- Low dietary levels of selenium, Vit E, and sulphur-containing amino acids
- High dietary concentrations of polyunsaturated fats
- Exposure to pro-oxidant compounds
  - ozone, oxygen, iron, radiation injury, doxorubicin
- Intake of selenium antagonists such as silver salts and various other metals
  - mercury, copper, cobalt, cadmium, tin, zinc

**Pathogenesis:** Vitamin E is an antioxidant that works synergistically with glutathione peroxidase to catalyze the conversion of $\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O}$. Selenium is an integral structure of glutathione peroxidase (metalloenzyme).

**Gross Lesions**

**Calves:** extensive pale areas of necrosis and mineralization in the left ventricular free wall and ventricular septum.

**Lambs:** similar areas of necrosis and mineralization but lesions are present in the subendocardial myocardium of the right ventricle.

**Pigs:** widespread epicardial and myocardial hemorrhages, with pale streaks scattered throughout the heart. The myocardial lesions are present in the walls of all chambers, but tend to be most severe within the atria than the ventricular myocardium.

**Histo Lesions**

**Calves and lambs:** Areas of myocardial damage have hyaline necrosis with or without accompanying mineralization, macrophage invasion, with eventual stromal collapse and fibrosis.

**Pigs:** Vascular lesions consist of fibrinoid necrosis in intramyocardial arteries and arterioles. Numerous fibrin microthrombi in myocardial capillaries. Myocardial hemorrhage and edema. Muscular lesions include hyaline necrosis and mineralization with macrophage invasion and later fibrosis.

**Taurine Deficiency**

Essential Amino Acid of Cats and foxes.

Modulates tissue calcium.

Results in Taurine Deficiency Myocardial Failure

Lesions – Dilated right and left ventricles with thin myocardium
Copper and/or Iron Deficiency

Synonyms - "falling disease" cattle

Lesions:
- Gross: pale, atrophic and flabby hearts
- Micro: myocardial fibrosis

Experimental disease in pigs
- Lesions: myocardial rupture = hemopericardium
  Rupture of pulmonary or coronary arteries.

Toxic Agents Producing Myocardial Disease

Gossypol Toxicity

Cause: Gossypol is a toxic alcohol found in cottonseed.
  Requires 2-3 months of continuous feeding.

Species affected:
- Pigs are more susceptible than cattle.
- Reported in dog and young ruminants.

Lesions: Dilated heart with multiple areas of degeneration and necrosis. Hepatotoxic - produces necrosis.

Poisonous Plants and Animals  [http://library.thinkquest.org/C007974/1plants.htm]

Avocado leaves – fresh leaves are toxic to sheep and goat

Cardiac Glycosides

Oleander - sudden death no lesions
Foxglove
Lily of the Valley
Toad Poisoning – Bufo toxicosis (cardiac glycoside)

Cardiotoxins

Myocardial depressants
Direct injury to myofiber
Hypersensitivity

Chemotherapeutic agents

** Doxorubicin (Adriamycin)
- Antineoplastic compound prevents synthesis of DNA, RNA and proteins
  Gross: Dose-related chronic cardiotoxicity characterized by congestive heart failure - see lesions of congestive heart failure. Pale myocardium
  Micro: Sarcoplasmic vacuolization “Adria Cells”
  Myocytolysis, hyaline necrosis
  Hydropic degeneration

** Monensin
- Coccidiostat for poultry, and growth-promoting agent for cattle
- Toxicosis reported in horses, cattle, sheep, pigs, dogs, and poultry
- Lesions: necrosis of cardiac and skeletal muscle

Furazolidone - toxicoses in poultry
- Antibacterial drug
- Congestive heart failure myocytolysis - sublethal injury, pale eosinophilic
- Turkeys slightly more sensitive than other poultry

Other agents:
Fluroacetate (1080) commercial rodenticide
Cantharidin intoxication from Blister Beetles
INFLAMMATORY DISEASES OF THE MYOCARDIUM - MYOCARDITIS

Infectious Agents

Viral
**Encephalomyocarditis virus of swine picornavirus**
**Parvovirus in the dog**
  Usually affects pups <10 weeks of age
**West Nile Virus**
*Foot and Mouth Disease - cattle*
Pseudorabies
Canine distemper in very young puppies
Bluetongue in sheep
Coxsackie virus in man and mouse
Avian encephalomyelitis, Newcastle Disease, Eastern and Western encephalitis

Human causes – Coxsackievirus, influenza, HIV, cytomegalovirus

**Note:** Viral agents may produce acute necrosis with little inflammatory response, or if the animal survives, may be infiltrated by inflammatory cells.

Bacterial
*Direct extension of pericarditis*  
  (eg. "hardware disease")
*Direct extension of endocarditis*  
  (eg. erysipelas in pigs)

*Any septicemia*
  *Borreliia burgdorferi – Lyme disease*
  *Histophilus somni - cattle*
  *Blackleg - Clostridium chauvei in cattle*
  *Listeria monocytogenes especially in sheep*
  *Actinobacillus equuli and Strep equi in horses*
  *Arcanobacterium pyogenes sheep, cattle*
  Staph aureus in sheep and goats
  *Corynebacterium kutscheri - rodents*
  *Pseudomonas aeruginosa*
  Tyzzer’s Disease - *Bacillus piliformis* in horses, rabbits, puppies and birds.
  Necrobacillosis - *Fusobacterium necrophorum*

Parasitic
**Neospora caninum**
  - Fatal fetal myocarditis, myositis and encephalitis.
  - Fetal infections may result in abortion or weak calves.

**Toxoplasma gondii**
  - Occurs in any species in contact with cat feces.
    - Public health hazard
  - Fatal fetal myocarditis can occur if infected during pregnancy.

**Trypanosoma cruzi** (Chagas’s disease) Trypanosomiasis
  - Reported in dogs and people in Texas, Louisiana and Mexico
  - Fatal infection in young dogs (6-8 months)
    - "Assassin" bug inoculates organism while feeding
- **Sarcocystis cruzi, S. bovis canis** of little significance if present within the myocardial fibers of an adult animal.
- Trichinella (usually skeletal muscle but occasionally heart)
- Cysticerca ovis (Taenia ovis)

**Fungi**  Does not commonly affect the myocardium – in fact relatively rare!

* Blastomyces dermatitidis
* Coccidioides immitis

**Miscellaneous and Interesting Myocardial Pathology**

**Porcine Stress Syndrome** - associated with stress of shipment.
- Genetic defect in the ryanodine receptor gene which results in an increase in the “open” state of this Ca^{2+} channel.
Sudden death in cattle - sometimes due to myocardial necrosis.
- etiology not known - associated with calcium containing inclusions in cardiac mitochondria - may be related to Vitamin E/Se deficiency.
Canine gastric/dilatation or volvulus → myocardial ischemia and necrosis.
Acute necrotizing pancreatitis and septic peritonitis can cause myocardial necrosis
In dogs and cats.
Senile Lipofuscinosis - aged animals and animals with severe cachexia.
  Hereditary disease in Ayrshire cattle - no clinical signs.
Glycogen storage disease.
Senile changes
- Fibrosis - (horses)
- Fatty infiltration (common in old sheep) or associated with obesity.
Anichkov Cells – “caterpillar cells”
  Origin not determined – may be macrophage or abortive attempt of myocyte regeneration.
Epithelial Inclusion Cysts - incidental finding seen in cows embryonic rests.
Primates - have bizarre myocardial cells.

<table>
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<tr>
<th>Causes of Myocardial Dysfunction - Summary</th>
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<td>Idiopathic</td>
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CONGENITAL ABNORMALITIES OF THE HEART AND LARGE VESSELS

Causes of Abnormal Cardiovascular Development

1. Genetic
   - Single or multiple gene effects
   - Most species have a low background frequency of spontaneous cardiac malformations

2. Infectious agents:
   - Parvovirus infections in cats and dogs
   - Bluetongue virus in sheep
   - BVD in cattle

3. Teratogens:
   - Deficiencies: Vitamin A, pantothenic acid, riboflavin, or zinc
   - Excesses: Vitamin A, retinoic acid, or copper
   - In utero exposure to x-irradiation or fetal hypoxia
   - Teratogenic compounds: thalidomide, ethanol, salicylates, griseofulvin, cortisone

Cardiovascular Malformations by Species and Breed

NOTE: Most Common Defects are identified with an asterisk *

**Canine**

<table>
<thead>
<tr>
<th>Defect</th>
<th>BREEDS</th>
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<tbody>
<tr>
<td>Patent Ductus Arteriosus (PDA)</td>
<td>(Poodle, Collie, Pomeranian, Chihuahua, Maltese English Springer, Bichon Friese, Cocker Spaniel German shepherd, Keeshond, Yorkshire terrier)</td>
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<tr>
<td>Pulmonic Stenosis</td>
<td>(Bulldog, Fox terrier, Beagle, Samoyed, Chihuahua, Mastiff, ChowChow, Cocker Spaniel, Labrador retriever, Terriers, Boxer, Schnauzer, Newfoundland)</td>
</tr>
<tr>
<td>Subaortic stenosis</td>
<td>(German shepherd, Golden Retriever, German shorthair pointer, bull terrier, Bulldog, Great Dane, Rottweiler, Samoyed Newfoundland)</td>
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<tr>
<td>Persistent Right Aortic Arch (PRAA)</td>
<td>(German Shepherd, Irish Setter, Great Dane)</td>
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<tr>
<td>Ventricular Septal Defect (VSD)</td>
<td>(Bull dog)</td>
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<tr>
<td>Tetralogy of Fallot</td>
<td>(Keeshond, English Bull Dog)</td>
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<tr>
<td>Atrial Septal Defect (ASD)</td>
<td>(Samoyed, Boxer, Doberman)</td>
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<tr>
<td>Tricuspid Dysplasia</td>
<td>(Labrador retriever, German shepherd, Golden Retriever Great Dane, Weimaraner)</td>
</tr>
<tr>
<td>Mitral Dysplasia</td>
<td>(Bull terrier, English bulldog, Chihuahua, German shepherd, Great Dane)</td>
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**Feline**

*Endocardial cushion defects
Mitrail Valve dysplasia 19/96
Tricuspid valve dysplasia 18/96

VSD 13/96
Aortic Stenosis 12/96
Persistent Common Atroventricular canal 11/96
PDA 7/96
Tetralogy of Fallot 6/96

**Bovine**

*Valvar hematocysts (see endocardial disease)* Tetralogy of fallot
*VSD - may be associated with microophthalmia* ASD
*Transposition of great vessels* Hypoplasia of the left ventricle
Anomalous coronary artery Persistent common truncus arteriosus

**Equine**

*VSD - not common* Aortic Stenosis
*ASD* Persistent Common Truncus Arteriosus
PDA Tetralogy of Fallot

**Porcine**

*Subaortic stenosis* Persistent ductus arteriosis
*Endocardial cushion defects*

**Ovine**

*VSD* Endocardial cushion defects
**Abnormalities of the atrial septum**

Foramen Ovale (normal)
- Functionally closes at birth
- Anatomically closes later

**Atrial Septal Defect (ASD)**
Common Atrium
Haemodynamics: ↑ flow from L to R atrium → ↑
Vol Rt ▶ → ↑ CVP (may reverse flow with pulmonary hypertension)

Dogs Breeds
Boxer
Doberman Pinscher
Samoyed

**Abnormalities of the atrioventricular canal**

Normal Development:
The endocardial cushions come together and form mitral valve, tricuspid valve, annulus pulposis and separation of four chambers.

**Persistent common atrioventricular canal - Endocardial cushion defect**
- Failure of endocardial cushions to form.
- Often associated with concomitant ASD and VSD.
- May not be fatal but there will be mixing of systemic and pulmonary blood.
- Few cases have been seen in lambs and pigs.

**Tricuspid dysplasia**
- Seen most commonly in Labrador retrievers and cats.
- Septal valve leaflets are attached to the septum.
- Chordae tendinae are short and thick.
- Downward displacement of base of the valves.

**Mitral Valvular Insufficiency**
Malformations of mitral valve complex
Relatively common in cats

**Tricuspid atresia**
a. Obliteration of the right atrioventricular orifice
b. If present, often other defects may be present and essential for in utero survival.
   These may include patent foramen ovale, ventricular septal defect, right ventricular hypoplasia and left ventricular hypertrophy.

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Abnormalities of the Interventricular Septum

Normal Development
1. Primary R and L ventricles of the embryo communicate via the primary interventricular foramen;
   -Bordered above by bulboventricular flange and below by muscular interventricular septum.
2. Primitive ventricles dilate and myocardium grows continually.
   -the medial walls of the dilating and growing ventricular myocardium fuse.
   -muscular interventricular septum.
3. Membranous portion of the interventricular septum is formed by the R and L conotruncal ridges and superior atrioventricular cushion.
4. Muscular portion grows up - membranous portion grows down.

** Interventricular Septal Defect - VSD
- Defect of membranous septum (most common).
- Occasionally the muscular part of the septum is also affected (less common).
- Sometimes associated with other anomalies of the conotruncal region (overriding aorta).
- Haemodynamics: overload RV → ↑ RV psi → RVH → RVF [blood shunts L → R but could reverse later]

Abnormalities of the truncus arteriosus and conus cordia

Normal Development
-Spiral ridges fuse to divide truncus arteriosus and conus cordis into aorta and pulmonary artery.

** Tetralogy of Fallot
Caused by unequal division of conus cordis due to anterior displacement of the conotruncal septum.
Consists of the following (4):
1. Pulmonic stenosis
2. Ventricular septal defect - membranous
3. Overriding aorta
   (rightward displacement)
4. RVH – Results from 1-3 anomalies
Haemodynamics of Tetralogy of Fallot
Pulmonic Stenosis → psi overload RV → RVH →
RHF + ↑ RV psi → blood shunts RV to LV → venous blood into systemic circulation → cyanosis.
Keeshonds – inherited as a simple autosomal locus with partial penetration in heterozygous and complete penetrance in homozygotes.
English bull dogs

** Eisenmenger’s Complex/Syndrome
Tetralogy of Fallot without pulmonic Stenosis.

** Eisenmenger’s Physiology is the result of a right to left shunt.
Persistent truncus arteriosus
- Failure of the spiral ridge to divide the truncus arteriosus and conus cordis into the pulmonary artery and aorta.
- Seen most frequently in the horse.
- Animal may survive up to a year.

Transposition of the great vessels
- Conotruncal septum fails to spiral therefore it descends straight downward.
- Aorta exits from right ventricle and pulmonary artery exits from left ventricle.
- Sometimes associated with VSD.

Abnormalities of the Semilunar Valves

**Pulmonic Stenosis (＞dogs)
Inherited: Beagles. Suspected in English bull dogs, Bull mastiffs and Chihuahua.
Seen in many dog breeds.
Partial fusion of pulmonic valve.
- Circumference of pulmonic valve ＜ aorta.
- RVH occurs 2° to 1 resistance.

Supravalvular Pulmonic Stenosis
- Fibrous narrowing above valve.
Results in Right ventricular hypertrophy (RVH).

Subvalvular Pulmonic Stenosis
- Hypertrophy of crista supraventricular muscle ridge.
- Fibrous connective tissue below valve.

Haemodynamics
Psi overload RV ＞ concentric cardiac hypertrophy ＞ RHF.

Post stenotic Dilation of Pulmonary Artery
Dilation of pulmonary artery near stenotic valve due to turbulence.
Secondary problem associated with the stenotic valve.

complete fusion = pulmonary valvular atresia
- RV fails to develop normally due to nonfunctional pulmonic valve.
- If nonfatal in utero must be associated with ASD or patent foramen ovale
  (only outlet from right heart) and PDA (only access to pulmonary circulation).
- Usually fatal at birth or shortly thereafter.

** Aortic Stenosis
- Partial fusion of aortic valve.
- Circumference of the aortic valve ＜ pulmonary valve.
- LVH occurs secondarily to increased pressure.
  Result is concentric hypertrophy.
- Most common defect in swine.
- Inherited: Newfoundland, boxer, German shepherd. Seen in many other dog breeds – including WEimeraners, Golden retrievers, and St. Bernard.
**Subvalvular Aortic Stenosis**
- Is much more common than a valvular aortic stenosis.
- May occur secondary to severe LVH.
- May occur with hypertrophy of the interventricular septum.
  - Could result from inflammatory response due to irritation of mitral valve
  - Pigs most often have this type of aortic stenosis.

Haemodynamics: \( \uparrow \) psi of LV \( \rightarrow \) concentric LVH \( \rightarrow \) LVF.
Post stenotic dilation of aorta
- Occurs due to turbulence of blood flow through stenotic valve.

Total fusion = **aortic atresia**
- Left ventricle fails to develop normally due to lack of aortic valve.
- If not fatal in utero there must be associated large PDA and usually patent foramen ovale.
- Usually fatal at or shortly after birth.

**Abnormalities of the Position of the Heart** –
Not heart anomalies but result of malformations of adjacent structures.

Ectopia cordis
1. Most frequently seen in cattle - (subcutis, neck, intra-abdominal).
2. Heart is outside of the thoracic cavity.
3. Usually secondary to sternal cleft or failure of thoracic cavity to close normally.
4. Some animals can survive for several days to months.

Dextrocardia
1. Heart is on the right side rather than the left.
2. Often associated with total or partial situs inversus (mirror image of normal left to right symmetry) - Ciliary Dyskinesia, Kartagener’s Syndrome.
   a. Dextrocardia and situs inversus.
   b. Total lack of ciliary movement.
   c. Usually fatal.

**Abnormalities of Great Vessels**
- Anomalies from failure of closure of fetal cardiovascular shunts.

Normal Development:
Fetus has two right to left shunts to bypass the lung:
1. Foramen ovale
2. Ductus arteriosus
   - In the dog there is functional closure by 9 hours and anatomic closure with formation of the ligamentum arteriosum by 15-18 days.
   - Closure in the pig by 12-14 days.
   - Closure in the guinea pig by 24 hours.
   - Ruminants - may be probe patent in "young".

Aorta develops from the left aortic arches.
Right subclavian artery arises from the brachiocephalic trunk.
Abnormal Development or Great Vessels

** Patent Ductus Arteriosus (PDA) **
1. Failure of the ductus arteriosus to close by 2 weeks normally forms ligamentum arteriosum.
2. Inverse relationship between lung expansion at birth and closure of the ductus.
3. Some cardiac malformations (see above) require a PDA for survival (eg. pulmonary atresia and aortic atresia).
4. Haemodynamics
   Blood shunts L → R (from aorta to pulmonary artery → ↑ circulation through lungs excess work load on left heart → LVH → LVF may reverse in severe, chronic cases (↑ volume).
5. Breeds affected:
   - Poodles, Collies, Pomeranians, Chihuahua, Maltese
   - Other breeds

** Persistent Right Aortic Arch (PRAA) **
A. Right 4th aortic arch remain, left arch disappears.
B. Aorta comes down the dorsum of the esophagus.
C. Ductus arteriosus attaches to the aorta behind the esophagus.
D. "Vascular ring anomaly" results due to entrapment of esophagus and trachea by (MARKED ON PHOTO BELOW):
   1. Descending aorta
   2. Ligamentum arteriosum (closed or open)
   3. Main pulmonary artery (not visible on photograph)
   4. Heart base (not visible is beneath the esophagus (E)
E. Esophageal dilatation proximal to the constriction can result in regurgitation.
F. Death most often due to aspiration pneumonia.
G. German shepherd, Great Dane, Irish setter dogs are predisposed.
   Reported in cattle.
**DISEASES OF THE PERICARDIUM**

Comments: Primary pericardial disease is rare. However, the pericardium is frequently involved secondarily by direct extension from diseases of the myocardium, pleura, lungs, or systemic disease processes. The good news is you have heard of many of the disease processes in general pathology!

The pericardial sac is basically a fibrous sac surrounding the heart, and therefore reacts to injury in a limited manner. The contents within the pericardium may provide clues relating to the pathogenesis of the disease process. The entire surface of the pericardial cavity is covered by mesothelium. Visceral pericardium is another name for the epicardium. The pericardial sac can be expanded over time.

**Non-Inflammatory Disease Processes**

**Hydropericardium**

Definition: excessive accumulation of serous fluid in the pericardial space.

Causes:

- **Hypoproteinemia (generalized edema)**
- **Congestive heart failure, (usually right heart failure)**
  - Ascites syndrome - poultry
  - Dilated cardiomyopathy - dogs and cats
  - Pulmonary Hypertension - "Brisket Disease" "high altitude disease."
- **Tumors** - both primary and secondary.
- **Systemic Diseases (may have some protein and may clot)**
  - Good site to swab for bacterial isolation.
  - Mulberry heart disease (swine)
  - Bacterial Septicemias in swine
  - Heartwater (rickettsial disease in small ruminants)

Significance of hydropericardium:

- Acute - cardiac tamponade, (acute forward heart failure – cardiogenic shock)
- Chronic - pericardium can distend/stretch to accommodate (right heart failure)
- Reversible - if 1° cause can be removed.

**Hemopericardium**

Definition: accumulation of blood in pericardial space.

Causes:

- Aortic rupture within pericardial sac (horse, turkey).
- Atrial rupture (dog).
- Rupture of the pulmonary artery.
- Iatrogenic - intracardiac injections.
- Bleeding from a tumor within pericardial sac.
- Ruptured atrium or large vessel in pigs
  - suspect Copper Deficiency

Sequela:

- Acute:
  - Produces ↓ cardiac filling and ↓ cardiac output (cardiac shock).
  - "Cardiac tamponade" terminology used for acute filling of pericardial sac.
  - Right heart more sensitive than left heart.
  - Atria collapse and are unable to fill with blood.

Chronic – pericardial sac can expand and accommodate blood.
**Idiopathic hemorrhagic pericardial effusion** of dogs
- Eti: unknown cause can occur with bleeding tumor within heart/epicardium.
- Seen most often in large breed dogs, especially Golden retriever.
- See Clinical signs of right heart failure.

**Serous atrophy of fat**
Definition: degenerative of adipose tissue with replacement by loose connective tissue.
Causes:
- Inadequate nutritional supply.
- Secondary to starvation or inanition.
- Occurs relatively rapidly in a sick cow.
Significance:
- Indicates the condition of health of the animal.
- Little effect on local function and is reversible.
- Usually seen on epicardial surface of heart near or in coronary grooves.

**Congenital and Miscellaneous Disorders**
Absence
Diaphragmatic-Pericardial Hernia (> cats, dogs)
Peritoneopericardial diaphragmatic hernia
Visceral Gout (avian and reptile) - urate deposits
Epicardial mineralization - (cardiac calcinosis)
Inbred strains of mice
( photo in *Pathological Basis of Veterinary Disease*).

**Inflammatory Diseases of the Pericardium**

**Infectious Process**
Extending outward from the myocardium.
Extending inward from the pleural space or mediastinum.

Septicemias – most common.

**Fibrinous Pericarditis** – usually hematogenous.
Lesions:

Gross: Accumulation of fluid and fibrin within pericardial space. Surfaces of epicardium and pericardial sac may be slightly opaque. Fibrinous adhesions which can be broken down (torn apart) easily are occasionally referred to as "Bread and Butter."

Micro: Usually only mild inflammation with fibrin on the surface involving the pericardial sac and epicardium in acute disease processes. Variable numbers of neutrophils and macrophages are seen.

**Causes**: (usually hematogenous infections)
Cow: Mannheimiosis, blackleg, coliform septicemias
Fetus: *Brucella sp*, *Arcanobacter pyogenes*
Pig: Glasser's disease (*Haemophilus parasuis*), Streptococcus, Mannheimiosis, *Mycoplasma hyopneumoniae*, Salmonellosis
Horses: Streptococcal infections, *Mycoplasma felis*
Birds:  Psittacosis  
Cats:  Rare in cats. Feline infectious peritonitis (FIP)  
Sheep: Pasteurella and Streptococcal infections  

Outcome:  
- Early death – often not directly related to the pericarditis, but rather due to the pathogenicity of the organism and resultant septicemia.  
- Fibrous adhesions may occur.  

**Purulent or Suppurative Pericarditis**  

Lesions:  
**Gross:** Fluid and liquefied inflammatory debris accumulated within the pericardial sac, usually very malodorous.  
**Micro:** Moderate accumulations of neutrophils and other inflammatory cells on the surface of the pericardial sac and epicardium. Fibrous connective tissue present beneath the layer of inflammatory cells, but dependent upon the time frame of the disease process.  

Cause:  
- Associated with various pyogenic bacteria.  
- Often complication of traumatic reticulopericarditis.  
- Cats and horses with pyothorax.  
- Migrating plant awns in dogs.  

Note: Either fibrinous or suppurative pericarditis may undergo organization which produces fibrous adhesions of the pericardium to the epicardium.  

**Bovine Traumatic Reticulopericarditis**  
("Hardware Disease")  
- Due to extension of a sharp object through the wall of reticulum, diaphragm and pericardium.  
- Mixture, or "garbage can" of bacteria isolated.  

**Sequela of Pericarditis**  
- Effective resolution depends on the extent of the disease and severity.  
  - **Mild fibrinous pericarditis** - May resolve completely.  
  - **Severe fibrinous pericarditis** - May resolve with only focal or diffuse thickenings of the pericardium or epicardium or focal adhesions may occur.  
  - **Suppurative pericarditis** – Seldom (probably never) resolves completely. The resolution that occurs often results in massive adhesions of pericardium to heart - leading to →  

→ **Constrictive Pericarditis**  

**Definition:** Chronic inflammatory lesion of pericardium accompanied by extensive fibrous proliferation and eventual formation of fibrous adhesions across the pericardial space.  
**Results:** Compensatory myocardial hypertrophy due to interference of cardiac filling results in eventual congestive heart failure (usually right heart).
DISEASES OF THE ENDOCARDIUM

The endocardium is the innermost layer of the heart. It lines the chambers and extends over projecting structures such as the valves, chordae tendineae, and papillary muscles. The atrial endocardium is thicker than the ventricular endocardium. Purkinje fibers are distributed throughout the ventricles in the subendocardium. Primary Endocardial Disease is not common and is defined as a non-inflammatory disease in which the exact cause is not known, eg: Endocardial fibroelastosis and endocardiosis.

*Endocardial fibroelastosis

**Cause:**
- Familial disease in the Burmese cat.
- Viral infections:
  - Parvovirus (dog)
  - Encephalomyocarditis virus (man, mouse, pig)
- Hypoxemia
- Trauma
- Extreme dilatation of ventricular chamber.

**Pathogenesis:** Progressive edema of endocardium results in fibroblast proliferation and an amount of collagen and elastin within and/or immediately beneath endocardium.

**Effects:**
- Restricted myocardial motion produces a ↓ in cardiac output and may lead to CHF
- May incarcerate subendocardial Purkinje fibers which could result in a left bundle branch block.

**NOTE:** Focal subendocardial fibrosis is occasionally seen in the atria and intima of large vessels. These changes are a reaction of the endocardium/endothelium to abnormal jets of blood or to turbulence following congenital or acquired valvular disorders. These structures are frequently termed, "jet lesions."

**Valvular Endocardiosis

**Synonyms:**
- Degenerative mitral valve disease (DMD).
- Chronic valvular fibrosis.
- Valvular mucoid degeneration.
- Myxomatous degeneration of the valves.

**Pathogenesis:** Degenerative lesion characterized by proliferations of loose, fibroblastic tissue in the spongiosa with deposition of acid mucopolysaccharides. Collagen within the fibrosa region of valve becomes degenerative. A genetic predisposition is recognized, but the mode of inheritance is unknown and complex. Inherited in Cavalier King Charles and Dachshund polygenic trait.
Lesions

**Gross** - glistening smooth, opaque, white, nodular thickenings on the valve leaflets margins and chordae tendineae which are thick and/or thin.

**Micro** - spongiosa is greatly thickened by proliferation of loose fibroblasts with an accumulation of poorly staining mucopolysaccharide material.

Incidence:
- Occurs most frequently in dogs > 5 years of age, males > females.
- Common disease of aging dogs.
- Reported to be as high as 58% in dogs 9 years and older, >75% in dogs older than 16 years.
- Cavalier King Charles >50% affected at 4 years of age 100% >10 years.
- Cocker spaniels more commonly than expected.
- German Shepherds less commonly than expected.
- Other breeds: beagle, dachshund, poodle, schnauzer, Chihuahua, fox terrier, Boston terrier, Pekinese, Wolfhound, deerhound, Doberman pinscher.
- Congenital form of disease seen young large-breed dogs.

Valves affected

<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Incidence</th>
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<tbody>
<tr>
<td>Left atrioventricular alone</td>
<td>60%</td>
</tr>
<tr>
<td>LAV and RAV</td>
<td>30%</td>
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</tbody>
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Aortic valve and pulmonic valves may be affected but not as frequent.

Sequela

- Valvular insufficiency:
  - Due to contracture of chordae tendineae resulting in volume overload ➔ LVH ➔ LVF ➔ Congestive ♥ failure.
- Rupture of chordae tendineae:
  - Acute left heart failure ➔ pulmonary edema ➔ death.
  - Chronic left heart failure ➔ pulmonary fibrosis.
- Rupture of left atrium ➔ cardiac tamponade.

Blood Cysts

**Synonyms** = Hematocyst, Valvular hematoma.

Incidence: Occurs most commonly on valves of calves and cattle, most frequently affect the AV valves. Incidental finding.. My also be seen in foals, puppies, and dogs. Seen in 11% of all slaughtered cattle.

**Lymphocyst** - Valvular cystic structures filled with clear fluid.

Both types of cysts are lined by endothelial cells.

Secondary Endocardial Disease

**Definition** = Disease of the endocardium resulting from metabolic, toxic, infectious, or neoplastic disease.

**Mineralization**

Pathogenesis: The cardiovascular system is unusually susceptible to mineralization because of its **high elastin content**. This is particularly true in the
endocardium and tunica intima of vessels, (internal elastic lamina). Mineralization is the most common degenerative change seen in the endocardium.

**Lesions:** gritty and granular plaques generally subendocardial in location.
**Gross:** White, elevated, firm.
**Micro:** Accumulations of basophilic, acellular material usually with little or no inflammation (stains positive with Von Kossa stain for calcium).

**Causes:** Any disease which will lead to an imbalance of Ca:P ratio.

- **Endocrine/Metabolic Diseases**
  - Pseudohyperparathyroidism
  - Hyperphosphatemia
  - Nutritional (excess phosphate diet)
  - Renal failure
- **Toxic Substances**
  - Vitamin D poisoning
  - Plants containing Vitamin D analogs
    - "Manchester wasting disease" Jamaica
    - "Naalehu disease" Hawaii
    - "Entique Seco" Argentina
    - Plants in the potato family
      - Solanum malacoxylon
      - Cestrum Diurnum
- **Miscellaneous Causes of endocardial mineralization.**
  - May accompany endocardial fibrosis when chambers are acutely dilated.
  - Chronic debilitating disease, ruminants.
  - Jet lesions may become mineralized.

**Endocarditis**
**Definition:** Inflammation of the endocardium. Usually bacterial in origin.

**Pathogenesis:** Usually valves are affected, (valvular endocarditis). However, occasionally valves are spared and there is involvement of the non-valvular endocardium, (mural endocarditis). The manner in which the bacteria lodge on the valves is not clear. Valves are thought to be predisposed because of their lack of blood supply. Nutrition and immune effector cells come primarily from passing blood. These areas may be predisposed because of continual trauma and/or lack of blood vessels within the valve. Bacteria tend to localize along appositional surfaces. Recurrent bacteremia is frequent. The following valves are affected most commonly:
- Mitral (LAV) > Aortic > Tricuspid (RAV) > Pulmonary
  - Except cattle where RAV commonly affected.

**Organisms**
**PIG**
- Strep suis usually LAV +/- aortic valve
- Erysipelothrix rhusiopathiae, chronic usually LAV
COW & SHEEP

*Arcanobacterium pyogenes* - (can originate from mastitis, metritis, or hepatic abscesses)
*Strep sp* - lambs with polyarthritis

**HORSE** – uncommon – may be associated with septic jugular thrombophlebitis.

*Streptococcus equi*  
*Actinobacillus equuli*  
*E. coli*  
*Pseudomonas aeruginosa*  
*Candida sp.*

**Dog and Cat** *(percents given below are for dogs)*

*Gram +* (51%)  
- β hemolytic *Streptococcus sp*, *Staph. aureus*, *Erysipelothrix rhusiopathiae*  

*Gram –* (24%)  
- *E. coli*, *Pseudomonas aeruginosa*  
- *Bartonella sp* (20%) – canine – often aortic valve

**Lesions**

**Gross**: Proliferative lesions (vegetations), which are yellow-red or yellow-gray and usually covered by a thin clot of blood, which can be easily peeled off at necropsy. The surface is friable, small lesions can be broken off leaving a granular, eroded surface on the valve. Extension into the adjacent mural endocardium is frequent.

**Micro**: Bacterial colonies are numerous. Accumulations of fibrin, neutrophils and variable amounts of granulation material dependent upon the length of time the lesion has been present.

*Sequela*: - Chronic lesions may organize by granulation from the base of the valve.  
- May undergo mineralization. Complete resolution is uncommon.

**Right Heart**

- Valvular distortion = right heart failure
- Pulmonary thrombosis and abscessation (embolic pneumonia)

**Left Heart**

- Valvular distortion = left heart failure
- Thromboemboli (kidney, spleen, myocardium, brain, joints)
- Inflammatory induced septal defects or pericarditis

**Miscellaneous Endocardial/Valvular Diseases**

- *Atrial thrombosis* may be associated with failing ventricle.  
- Dogs & cats with cardiomyopathies.
- Syrian Hamsters and certain strains of mice

- **Uremia** (usually acute): **Uremic Ulcerative Endocarditis**
  - ulcerative endocarditis of left atrium causes endocardial necrosis, mineralization, inflammation and thrombosis. Mechanism unknown.

- **Subendocardial hemorrhage**
  - Bacterial septicemias
  - Bluetongue (sheep) - hemorrhage at the base of the pulmonary artery
  - Infectious canine hepatitis
  - Toxemias - ruminants
  - Agonal findings - adult bovines

- **Strongylus vulgaris** larvae occasionally migrate aberrantly through the endocardium, eliciting an inflammatory response.

- Mycotic infections are rare
DISEASES OF BLOOD VESSELS

Degenerative Diseases

NOTE: Degenerative changes are relatively uncommon in animals compared to human beings. The following is a brief summary of disease processes seen most often in humans, but occasionally in “non-human mammals”.

Arteriosclerosis

Synonym: arteriolarsclerosis, arteriolosclerosis.
Definition: "hardening of the arteries". Includes all chronic arterial metamorphoses which consist of induration, loss of elasticity and narrowing which are the result of proliferative and degenerative (NOT inflammatory) changes of the media and intima.

Atherosclerosis

A subtype of arteriosclerosis.
Greek derivation "gruel or mush."
Definition: refers to degeneration in the wall of an artery in which lipids, (cholesterol, triglycerides, etc), are the primary components of the degenerative response.
Occurs chiefly in large elastic arteries in man:
- aorta and its branches
- coronary arteries
- cerebral arteries
- Atheromatous plaques may occlude the vessel producing ischemic necrosis of the tissue supplied by the involved artery.

Medial Necrosis (of Monckeberg)

Affects the media of medium-sized arteries
Lesions (within media)
- Hyaline degeneration
- Fatty degeneration
- Fibrinoid necrosis
- Mineralization

Arteriolosclerosis

Affects arterioles
Lesions
- Concentric
- lamellar intimal
- proliferations

Degenerative Vascular Disease in Animals

Dog
- Atherosclerosis: Lipid accumulation occurs in the intima or media of muscular arteries secondary to hypercholesterolemia usually due to hypothyroidism, diabetes mellitus.
- Medial sclerosis and amyloidosis occurs in association with endocardiosis.
- Little or no evidence that these lesions have clinical or pathologic significance.
- Renal amyloidosis and Cushing’s disease predisposes to thromboembolic phenomena, especially pulmonary artery thrombosis.
- Amyloidosis – pulmonary and coronary arteries significance unknown.

Pig
- Atherosclerosis pattern mimics that of human beings.
- Proposed as best species for experimental study.
- Little or no evidence that these lesions have any clinical or pathologic significance.

Cow
- Intimal mineralization
  - Johne’s disease
    Aortic arch
  - Vitamin D and Vitamin D analog poisoning
    Widespread mineralization
Cat
- **Medial hypertrophy of the muscular pulmonary arteries**
  - May be associated with reaction to parasites such as *Paragonimus* or *Toxocara*. Has been reported in specific pathogen free cats.

*Inflammatory Diseases of the Vasculature*

Definitions:
- Periarteritis - inflammation of the adventitia.
- Polyarteritis - inflammation of many arteries.
- Phlebitis - inflammation of a vein.
- Vasculitis - inflammation of vessels (arteries and veins).

Causes:
*Viral*
- Equine Viral Arteritis:
  - Polyarteritis affecting the media and adventitia.
  - Widespread petechiae, subcutaneous edema, hydrothorax, hydroperitoneum, hydropericardium.
- Malignant Catarhal Fever (MCF) of cattle:
  - Polyarteritis and periarteritis.
- Equine Infectious Anemia:
  - Polyarteritis and periarteritis.
- Bluetongue of sheep:
  - Polyarteritis centered around the intima.
  - See hemorrhage in at the origin (base) of pulmonary artery (intimal surface).
- Feline Infectious Peritonitis - pyogranulomatous vasculitis.
- Aleutian disease of Mink.
- Hog Cholera of pigs.

*Bacterial*
- *Salmonella sp* produces vasculitis.
- *Histophilus somni* (thromboembolic meningencephalitis, (TEM)).

*Parasitic*
*Strongylus vulgaris* in the horse.
- Fourth stage larval forms live in the intestinal arteries. Causes and intense focal inflammatory reaction in the walls of the larger arteries that results in aneurysmal dilation, thrombosis, and infarction distal to involved site (thromboembolic colic of horses).

*Dirofilaria immitis* in the dog.
- Adult worms live in the pulmonary arteries of dogs.
- Microfilaria are found throughout the circulation.
Lesions:
- villous pulmonary endoarteritis (inflammation of the intima).
- medial sclerosis and hypertrophy.
- obstruction and narrowing of the lumina produces increased pulmonary resistance causing right ventricular hypertrophy which many progress to right heart failure.

Other Parasites:
- Angiostrongylus vasorum
- Spirocerca lupi
- Schistosomiasis
- Elaeocerophorasia
- Onchocerciasis
- Aelurostrongylus sp

Fungi (infrequent) fungi disseminate via vasculature (eg. guttural pouch mycosis).

Immune Mediated Vascular Disease
- Systemic lupus erythematosis
- Rheumatoid Arthritis
- Polyarteritis nodosa
- Stapholoccal hypersensitivity

Miscellaneous Diseases

Aneurysm:
- Dilatation and attenuation of a vessel wall.
- Often only the stretched intima and adventitia remain due to rupture of the media.

Significance: May occur 2° to degenerative or inflammatory disease of a vessel wall.
- Aneurysms may rupture resulting in hemorrhage by rhexis.

Varix (varices)
Definition: An uneven, permanent dilatation of a vein.

Telangiectasia:
Definition: Marked dilatation of clusters of capillaries forming focal, red areas.
- Occurs in livers – often cattle
- Sometimes referred to as peliosis – especially in rat livers.

Post Caval Thrombosis: (Previously discussed in circulatory disturbances).
- Occurs in cattle - usually feedlot - hepatic abscess ruptures into the post cava.

*Omphalophlebitis:
Definition: Inflammation of the umbilical arteries and vein.
Lesions: Inflammation of the umbilical stump, umbilical arteries, hepatic abscesses, peritonitis, arthritis.

Post-stenotic dilation: a phenomenon that regularly occurs when a large elastic artery becomes constricted in circumference. This is a sac like dilation that forms distal to the stenotic lesion.

Jet Lesions - secondary to excessive turbulence (see congenital anomaly notes).
NEOPLASMS OF THE CARDIOVASCULAR SYSTEM

Primary

*Hemangiosarcoma

**Synonyms:** hemangioendotheliosarcoma
Angioendotheliosarcoma

**Locations:**
- Right atrium
  - German Shepherd - often see metastasis to lung.
- Spleen
  - Most common site – but may occur anywhere.

**Pronosis:** May be locally invasive and often metastasize widely.

*Hemangioma

**Synonyms:** hemangioendothelioma
angioendothelioma

Benign neoplasm arising from endothelial cells.
Most commonly found within the skin.

*Heart Base Tumour

**Synonyms:** chemodectoma, aortic body tumor.

**Incidence:** usually brachycephalic dog breeds.
(Boxer, Boston Terriers) - rare in cat.
- Arises from the chemoreceptor cells in the adventitia of the aorta, pulmonary artery or base of heart.
- Ectopic thyroid tumors are also reported at this site.

Schwannoma (Neurofibroma)
- seen in cattle
- arises from nerves of epicardium, usually multicentric

Others
- rhabdomyomas/rhabdomyosarcomas
- myxoma/myxosarcoma

Secondary Neoplasms

*Lymphosarcoma* - Most common metastatic tumor involving heart. Often occurs within the left atrium of cattle. Heart is occasionally affected in dogs and cats with lymphosarcoma.

Vascular Neoplasia

*Hemangiopericytoma* - Tumor originating from pericytes.
- Spindle cell tumour (common name), dermal or subcutis in dogs.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>ACM</th>
<th>Arrhythmogenic Cardiomyopathy</th>
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<tbody>
<tr>
<td>ASD</td>
<td>Atrial Septal Defect</td>
</tr>
<tr>
<td>CHF</td>
<td>Congestive Heart Failure</td>
</tr>
<tr>
<td>CVP</td>
<td>Central Venous Pressure</td>
</tr>
<tr>
<td>DCOM</td>
<td>Dilated Cardiomyopathy</td>
</tr>
<tr>
<td>HCOM</td>
<td>Hypertrophic Cardiomyopathy</td>
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<tr>
<td>L</td>
<td>Left</td>
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<tr>
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<td>Persistent Right Aortic Arch</td>
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<td>VSD</td>
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