Cardiac Hypertrophy and Dilation

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Compensatory Mechanisms of the Heart

Through effective compensatory mechanisms, the heart can meet increased cardiac demand up to a point. Increased cardiac demand may be purely physiological such as in athletic performance or could be to compensate cardiac abnormalities.

The compensatory mechanisms are similarly triggered in both health and disease.

The four most common compensatory mechanisms are:

- Cardiac dilation
- Cardiac hypertrophy
- Increase heart rate
- Vascular redistribution of blood

It is highly recommended to review the normal heart physiology to better understand heart pathology. See: Chapter 21 *The Heart as a Pump* in Textbook of Veterinary Physiology, 4th edition; Cunningham JC, Klein BG. Mosby.
Compensatory Mechanisms of the Myocardium

- Normal
- Myocardial hypertrophy: greater contractility and ejection force
- Cardiac Dilatation: increased stroke (blood) volume
- Increased Heart Rate (beats/min): Cardiac output = heart rate x stroke volume
Important Information

- Cardiac hypertrophy and dilation are beneficial mechanisms which help to meet increased cardiac demand, which is a good thing up to a point.

- Cardiac hypertrophy and dilation, however, can also spontaneously develop without physiological need in what is known as Hypertrophic and Dilative Cardiomyopathies, a bad thing.

- Cardiomyopathies are discussed in tutorial module 5.
Cardiac hypertrophy, an adaptive heart response, occurs when increased cardiac workload is sustained over several days or weeks.

Hypertrophy develops when the heart needs to:
- pump more blood (volume overload i.e. regurgitation) \(\rightarrow\) hypertrophy (+)
- pump at a higher pressure (pressure overload) \(\rightarrow\) hypertrophy (+++)

In hypertrophy, cardiomyocytes increase in size due to formation of new myofilaments and mitochondria. When many cardiomyocytes increase in size the overall myocardial mass/weight increases as well.

Hypertrophy is reversible if the underlying workload demand is corrected.

The distinction between cardiac hypertrophy and dilation is arbitrary and often confusing. Hypertrophy occurs in both, but in dilation increased muscle mass is not visible because the ventricles dilate. For this reason, cardiac hypertrophy is classified as:

1. **Eccentric** (dilation)
2. **Concentric** (reduced volume of the ventricular chamber)
Cardiac Hypertrophy

**Eccentric**

Note thin ventricular wall (square) and distended ventricle (arrow).

**Concentric**

Note thick ventricular wall (square) and reduced ventricular space (arrow).
Cellular stages in cardiac hypertrophy:

1. **Initiation**: Increase cell size (sarcomeres / mitochondria)
2. **Compensation**: Stable hyperfunction with no clinical signs
3. **Deterioration**: Degeneration of hypertrophied cardiomyocytes and loss of contractility followed by heart failure.
Hemodynamics in Myocardial Hypertrophy

- Normal
- Volume Overload
- Pressure Overload
### Gross Changes in Cardiac Hypertrophy and Dilation

<table>
<thead>
<tr>
<th>Heart Side</th>
<th>Gross Changes</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Right</td>
<td>Broad base</td>
<td>Pulmonic stenosis, Brisket disease</td>
</tr>
<tr>
<td>Left</td>
<td>Increased length</td>
<td>Aortic stenosis, feline hyperthyroidism</td>
</tr>
<tr>
<td>Bi-ventricular</td>
<td>Globose (rounded)</td>
<td>Hypertrophic cardiomyopathy</td>
</tr>
</tbody>
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### Images
- **Normal**
- **Right**
- **Left**
- **Bi-ventricular**
If cardiac hypertrophy and dilation become insufficient and can no longer sustain cardiac demand, clinical heart failure may ensue. Depending on the side affected, heart failure can be right sided, left sided or biventricular.

Heart failure in each side leads to specific alterations in other organs all of which cause the changes clinically observed in the live animal or the lesions found during a post-mortem examination.
Decreased contractibility of myocardial fibres (myocardial failure) is the pathophysiological hallmark of clinical heart failure.

Common causes of heart failure

<table>
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<tr>
<th>Myocardial degeneration</th>
<th>Myocarditis</th>
<th>Myocardial ischemia</th>
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<tbody>
<tr>
<td>Congenital heart diseases</td>
<td>Cardiotoxins</td>
<td>Electrolyte imbalance</td>
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</table>
Heart failure can be right sided, left sided or bilateral

Left sided
- Aortic stenosis
- Systemic hypertension
- Mitral endocardiosis
- Mitral dysplasia
- Feline hyperthyroidism

Right sided
- Pulmonic stenosis
- Pulmonary hypertension
- Brisket disease
- Hardware disease
- Pulmonary fibrosis

Biventricular
- Tetralogy of Fallot
- Hypertrophic Cardiomyopathy

Normal
Extracardial Lesions in Heart Failure

Left sided

- Pulmonary venous congestion
- Pulmonary edema
- Intra-alveolar hemorrhage
- Red cell phagocytized by alveolar macrophages
- Iron pigment in alveolar macrophages
- “Heart Failure Cells”

Right sided

- Systemic venous and portal hypertension
- Chronic passive congestion
- Edema and ascites
- Chronic passive congestion of liver
- “Nutmeg liver”
The next slides provide examples of specific animal diseases causing left and right heart failure.
Mitral insufficiency

- Passive congestion of the lung
- Pulmonary edema
- Intra-alveolar hemorrhages
- “Heart failure cells”
Example of Left Heart Failure / Mitral Endocardiosis / Dog

- Lung Congestion → Edema + hemorrhage
- RBCs in alveoli (arrows)
- Nodular thickening of mitral valve (arrows)
- Myxomatous Degeneration (Endocardiosis)
- Iron-laden macrophages
- Heart failure cells
Right sided Systemic venous and portal hypertension
Chronic passive congestion
Edema and ascites
Chronic passive congestion of liver
“Nutmeg liver”
High Altitude
- Pulmonary hypertension →
- Dilation-hypertrophy RV →
- Right heart failure →
- Ascites and subcutaneous edema

Example of Right Heart Failure / Brisket Disease
Brisket Disease in Cattle

Note swelling of the pectoral region (arrows) due to extensive subcutaneous edema (star) caused by right sided heart failure.

Liver with chronic passive congestion which translates into a zonal pattern caused by necrosis/fibrosis of the centrilobular regions. Affected livers have a hard texture.

Nutmeg
3-yr-old dog

- Ascites and suspected right heart failure
- Euthanasia
- 2.5 L of fluid in the abdomen and 400 ml in the thorax
- Notably enlarged heart wide on the base
- 20 ml of fluid in the pericardial sac
- RV concentric hypertrophy with a LV:RV thickness ratio 1:1
- Final Dx: Pulmonic valve dysplasia and stenosis
Example of Right Heart Failure / Ascitic Syndrome

Rapid growing chickens
- Pulmonary hypertension
- Dilation-hypertrophy RV
- Right heart failure
- Ascites

Distended abdomen with fluid

Fluid admixed with fibrin

Ascites
Thanks to all AVC pathologist for contributing case materials

Some images were acquired from veterinary colleges of Canada, United States and Mexico and the names of some contributing pathologists are unknown. Their valuable contribution is sincerely acknowledged.

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Module 2: Hypertrophy and Dilation

THE END

If you have any comments or criticisms about tutorials or quizzes please let me know. Also, if you find any errors or typos please let me know

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