Anatomy and Physiology of the Heart

SNM Annual Meeting
Sheila A. Knepfle BS, CNMT, NCT
I would like to extend my appreciation to the following people for their generous help in preparing this presentation:

Dan Koller
Dan Zebrowski
Dan Basso
Nancy Clifton
Donna Mars
April Mann
Objectives:

- Review cardiac anatomy
- Cardiac hemodynamics
- Review mechanical and conduction systems
- Review of heart diseases
Electrician or a Plumber?
Fun Facts

- Heart is a hollow muscular organ weighing in at approximately 9 ounces and is about the size of a clenched fist.
- Beats approx. 100,000 times a day.
- Propels 3,600 gallons of blood through 60,000 miles of blood vessels in the normal adult.
Thoracic Cavity

- Mediastinum – space between the lungs
  - Varies in geometry
  - Contains the pericardium, heart, great vessels, trachea and esophagus
- Shape and geometry of diaphragm is variable
- Anomalies
  - Effusions
  - Rotations
Cardiac Anatomy: MRI

Magnetic Resonance Imaging (MRI) Study

This coronal MRI shows a section of the descending limb of the aorta immediately adjacent to the spinal vertebrae.
Heart Layers

The heart wall is comprised of 3 layers:
- Epicardium
- Myocardium
- Endocardium

The pericardium is a fibrous sac surrounding the heart filled with a small amount of pericardial fluid.
Chambers of the Heart

Figure 1.2 Midcoronal view of the heart.
Atrioventricular Valves

- The right atrium and right ventricle are separated by the **tricuspid valve**.
- The left atrium and left ventricle are separated by the **mitral valve**.
Semilunar Valves

- **Aortic Valve** - Between the left ventricle and the aorta.
- **Pulmonary Valve** - Regulates flow between the right ventricle and the pulmonary artery.
Circulation

- Right Atrium
- Tricuspid Valve
- Right Ventricle
- Pulmonic Valve
- Pulmonary Arteries
- Pulmonic Veins
- Left Atrium
- Mitral Valve
- Left Ventricle
- Aortic Valve
- Aorta
## Ventricles

<table>
<thead>
<tr>
<th>Function</th>
<th>Right Ventricle</th>
<th>Left Ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Delivers deoxygenated blood from body to lungs</td>
<td>1. Delivers oxygenated blood from lungs to body</td>
</tr>
<tr>
<td></td>
<td>2. Ejects its volume of blood against minimum resistance - the pulmonary circulation</td>
<td>2. Ejects its volume of blood against maximum resistance - the systemic circulation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Musculature</th>
<th>Right Ventricle</th>
<th>Left Ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relatively thin walled</td>
<td>Relatively thick walled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Valves</th>
<th>Right Ventricle</th>
<th>Left Ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Atrioventricular: tricuspid</td>
<td>1. Atrioventricular: mitral</td>
</tr>
<tr>
<td></td>
<td>2. Semilunar: pulmonary</td>
<td>2. Semilunar: Aortic</td>
</tr>
</tbody>
</table>
Heart Sounds

- As the ventricles begin to contract, the atroventricular valves—the tricuspid and mitral valves—snap shut, producing a sound heard as a *lupp*.

- Ventricular Systole--the first heart sound -- S₁.

- At the conclusion of ventricular systole, when the ventricles relax to receive blood from the atria, the semilunar valves—the pulmonary and aortic valves—snap shut producing the *dupp* sound.

- Ventricular diastole-- second heart sound -- S₂.

- Interval between S₁ and S₂ : Ventricular systole,

- *Pause* : Ventricular diastole.

- Valvular disease and coronary artery disease can affect the quality or number of heart sounds.
Blood Supply to Myocardium

2 MAJOR CORONARY ARTERIES

Left Coronary

Right Coronary

Left Coronary

L. Ant. Descending

L. Circumflex

Rt. Coronary

PDA and smaller branches

Figure 1.4 Anterior view of the heart, great vessels, and coronary arteries.
Blood Supply to the Myocardium

- Right Coronary, which branches off to the Posterior Descending Artery and other small branches, supplies the right atrium and ventricle as well as the inferior portion of the left ventricle.
- Circumflex Artery supplies the lateral wall.
- Left Anterior Descending Artery supplies the anterior and interventricular septum.
Figure 1.4 Anterior view of the heart, great vessels, and coronary arteries.

Figure 1.5 Posterior view of the heart, great vessels, and coronary arteries.
Coronary Arteries

- The intimal layer is composed of a single monolayer of endothelial cells, in contact with circulating blood, that serves as a functional barrier.

- The media consists predominantly of smooth muscle cells, embedded in extracellular matrix, that regulate vascular tone.

- The adventitia harbors nutrient vessels, nerves, and dense fibroelastic tissue.
Cardiac Muscle

- longitudinal section
- intercalated disk
- capillary
- central nucleus
- cross section

www.mhhe.com/biosci/ap/histology_mh/strimusc.htm
The Cardiac Conductive System

- Synchrony: The Characteristic of a healthy heartbeat where myocardial fibers must contract and relax in a coordinated, rhythmic fashion
- Maintained by the heart's intrinsic electrical system, which originates and transmits electrical impulses through a specialized conduction pathway.
The Cardiac Conductive System

- **Pulse**: Evidence of the heart's mechanical activity
- **Electrocardiogram (ECG)**: Evidence of its electrical activity.
- **Ventricular fibrillation**: Absence of synchrony, myocardial fibers contract in a random, uncontrolled fashion.
Electrical Conduction

Five step evaluation
- Heart rate
- Rhythm
- QRS duration
- P waves present and uniform
- PR interval <0.2

ECG changes in CAD
- Ischemia
- Injury
- Infarct

Images capture from 12 Lead Tutorial
Components of an ECG
Cellular Physiology

Na-K ATPase

Na+ K+

Na+ K+

Na+ Na+ Ca++ Ca++

Na-Ca Exchange

Na+ Ca++

K+ Na+ Myofilaments

Ca++

CONTRACTILITY
Cellular Physiology

http://www.hypertensiononline.org/anima/animation.cfm
Autonomic Nervous System

- Autonomic nervous system starts in the medulla oblongata of the brain. It controls involuntary activity of the body (digestion, breathing and heart rate)
Two Pathways of the Autonomic Nervous System

- **Sympathetic nervous system**: Increases heart rate in response to stress or exercise.
- **Parasympathetic nervous system**: (vagus nerve) causes a decrease in heart rate.
Sympathetic Nervous System

- SA node discharge rate is increased.
- Excitability of all portions of the heart is increased.
- Conduction time is reduced.
- Contractile force is increased.
Parasympathetic nervous system

- SA node discharge rate is reduced.
- The excitability of AV junctional tissue is lowered, slowing transmission of the pacemaker impulse to the ventricles.
Summing Up: Electrophysiology and Cardiac Contraction

Myocardial tissue has four main characteristics that together integrate the heart’s electrical and mechanical activity:

- **Automaticity:** the ability to initiate an impulse or stimulus. The cells of the cardiac conduction system – called pacemaker cells – have this inherent capacity. They spontaneously depolarize – without external stimulation.

- **Excitability:** the ability to respond to an impulse or stimulus. Atrial and ventricular myocardial fibers respond to the impulse generated by the pacemaker cells of the cardiac conduction system by depolarization and repolarization.

- **Conductivity:** the ability to transmit impulses to other areas. Both the cells of the conduction system and the myocardial muscle fibers have this property.

- **Contractility:** the ability to respond to stimulus with mechanical action. Myocardial fibers respond mechanically to electrical stimulation by contracting. The simultaneous contraction of bands of myocardial fibers is the heart’s pumping action.
ECG Changes in CAD

- Ischemia
- Injury
- Infarction
Ischemia, Injury and Infarction

- **Ischemia:**
  - Flat or sharp ST depression
  - T wave inversion

- **Injury:**
  - 1mm + in the limb leads
  - 2mm + in the precordial leads

- **Infarction:**
  - Absent in most leads in a normal ECG
  - 0.04 sec or longer in duration
  - 1/4 height of QRS complex

Images capture from 12 Lead Tutorial
## Localization of ECG Abnormalities

<table>
<thead>
<tr>
<th>Location</th>
<th>Vascular Territory</th>
<th>Findings</th>
<th>Reciprocal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>LAD</td>
<td>$V_1 - V_4$</td>
<td>II, III, aVF</td>
</tr>
<tr>
<td>Inferior</td>
<td>RCA</td>
<td>II,III, aVF</td>
<td>I,aVL</td>
</tr>
<tr>
<td>Lateral</td>
<td>LCx</td>
<td>I, aVL,$V_5, V_6$</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>PDA</td>
<td></td>
<td>$V_1, V_2$</td>
</tr>
<tr>
<td>Septal</td>
<td>LAD</td>
<td>Loss of R wave</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Images capture from 12 Lead Tutorial
The Heart Beat

Correlation of Events in Left Side of Heart

- Electrocardiogram
- Aortic Pressure
- Left Atrial Pressure
- Left Ventricular Pressure
- Ventricular Volume

ELECTROCARDIOGRAM

PRESSURE mm Hg

VENTRICULAR VOLUME ml

D = Ventricular diastole  S = Ventricular systole

Slides are not to be reproduced without the permission of the author
Diseases of the Heart

- Electrical and Conduction Disturbances
- Valvular Disease
- Heart Failure / Edema
- Hypertension
- Coronary Artery Disease
Right to Left Shunts (cyanosis)

- Tetralogy of Fallot
- Transposition
- Truncus
- Foramen Ovale
- Ductus Arteriosus has closed
- Tricuspid Atresia with VSD
- TAPVD
Left to Right Shunts

Normal Lung T/A Curve
Left to Right
Cardiac Anatomy

Apical Short Axis View

Photographs courtesy of Dr. Grover Hutchins, Johns Hopkins University

Latex injection: LCA RCA

http://www.med.yale.edu
MPI: Orientation

Short axis view  Horizontal long axis view  Vertical long axis view

http://www.med.yale.edu
Coronary Territories

Normal Mid-ventricular VLA Anatomy

Blood Supply Key:
- LAD
- LCx
- PDA

©1991, Yale Univ.

http://www.med.yale.edu
Coronary Territories

Coronary Anatomy – Short Axis View

Blood Supply Key:
- LAD
- LCx
- PDA

Choose view angle:
- SA
- VLA
- HLA

©1991, Yale Univ.

http://www.med.yale.edu
Perfusion Patterns

Stress

Normal

Ischemia

Infarction

Rest
Ventricular Function

- Available in many cardiology offices
- Allows evaluation of valvular function and myocardial morphology

Adapted from /info.med.yale.edu/intmed/cardio/echo_atlas
Echocardiology

- Used to evaluate
  - Ventricular Function
  - Valvular Disease
  - Shunts
  - Clots
  - Masses
  - Effusions
Echocardiology

- Operator dependent
- Image quality suboptimal in significant number of patients
- Ischemic wall motion abnormalities do not persist after exercise termination
Why Review

- As professionals continue to practice, we too must practice the basics to become a stronger performer in our jobs.
- The quality of everything we do is dependent on practice.
- Strive to provide the level of care you would wish for someone who is near and dear to you.