Atlantic Health System
Morristown Medical Center
Newton Medical Center
Overlook Medical Center

Basic Dysrhythmia Course
Day 1
Chapter 1

Anatomy and Physiology
Learning Objectives

1) Identify electrophysiology of the heart.
2) Identify the electrical conduction structures and pathways of the heart.
3) Label an ECG complex identifying the waveforms and intervals for segments: PR, QRS, R-R, P-P, QT.
4) Recognize the features of normal sinus rhythm.
5) Identify atrial rhythms.
6) Identify junctional rhythms.
Location of the Heart

- Hollow muscular organ
- Lies in the space between the lungs (mediastinum) in the chest
- 2/3 lies to left of midline of sternum
Coverings of the Heart

- **Pericardium**
  - Parietal pericardium – tough outer layer
  - Serous pericardium
  - Pericardial space contains serous fluid
Layers of the Heart Wall

- **Endocardium**
  - Innermost layer
  - Lines heart’s inner chambers
  - Continuous with innermost layer of vessels
Layers of the Heart Wall

- **Myocardium**
  - Middle layer
  - Thick, muscular layer
  - Responsible for pumping action
Layers of the Heart Wall

- **Epicardium**
  - Also called visceral layer of serous pericardium
  - External layer of heart
  - Contains blood capillaries, lymph capillaries, nerve fibers, and fat
Heart Chambers

Heart is divided into four chambers

- Two upper chambers = right and left atria
- Two lower chambers = right and left ventricles
Heart Valves

- Heart contains four valves
  - Two sets of atrioventricular (AV) valves - Leaflet
  - Two sets of semilunar (SL) valves – Crescent shaped cusps

- Function
  - Ensure blood flows in one direction through heart chambers
  - Prevent backflow of blood
Skeleton of heart, including fibrous rings around valves

Left AV (mitral) valve

Pulmonary valve

Aortic valve

Right AV (tricuspid) valve

Left ventricle myocardium (cut)

Right ventricle myocardium
Atrioventricular (AV) Valves

- AV valves separate atria from ventricles
- Tricuspid valve
  - Lies between right atrium and right ventricle
  - Three separate leaflets
- Mitral (bicuspid) valve
  - Has only two leaflets
  - Lies between left atrium and left ventricle
Atrioventricular (AV) Valves

- Cusps of AV valves are attached to chordae tendineae
  - “Heart strings”
  - Attach into papillary muscles, which imbed deeply into the endocardium
  - Serve as anchors
Semilunar Valves

- Prevent backflow of blood from the vessels into the ventricles during diastole
  - Pulmonic valve
  - Aortic valve
Coronary Circulation

- **Coronary arteries**
  - Right
  - Left Main
    - Left anterior descending
    - Circumflex

- **Coronary veins**
  - Coronary sinus
Autonomic Nervous System

- Sympathetic division – fight or flight
- Parasympathetic division – rest and digest
Sympathetic Stimulation

- Impulses sent from accelerator center in medulla travel along sympathetic fibers
- Primary neurotransmitters: norepinephrine, epinephrine
Sympathetic Receptor Sites

- **Alpha-1**
  - Eyes, blood vessels, bladder, male reproductive organs

- **Alpha-2**
  - Digestive system
  - Peripheral nervous system

- **Beta-1**
  - Heart, kidneys

- **Beta-2**
  - Bronchial smooth muscle
  - Skeletal blood vessels

- **Dopamine**
  - Renal, mesenteric, and visceral blood vessels
Parasympathetic Stimulation

- Primary neurotransmitter = acetylcholine
- Main effect = slowing of heart rate
Baroreceptors

- Also called “pressoreceptors”
  - Specialized nerve tissue
  - Found in internal carotid arteries/aortic arch
  - Detect changes in blood pressure
Chemoreceptors

- Located in internal carotid arteries and aortic arch
- Detect and respond to changes in:
  - Oxygen content of blood
  - pH
  - Carbon dioxide tension
Cardiac Cycle

- **Systole**
  - Period during which the chamber is contracting and blood is being ejected

- **Diastole**
  - Period of relaxation during which the chamber is filling
Atrial Systole and Diastole

- Atrial diastole
  - Blood enters the right atrium
  - Right atrium fills and distends
    - Tricuspid valve opens and the right ventricle fills
    - Same sequence occurs a split second earlier in the left heart
  - Left atrium receives blood from pulmonary veins
    - Mitral valve opens as the left atrium fills
    - Blood flows into the left ventricle

- Atrial systole
  - Atrial kick
Ventricular Systole and Diastole

- **Ventricular systole**
  - Blood is propelled through the systemic and pulmonary circulation
  - AV valves close
  - Aortic and Pulmonic valves open

- **Ventricular diastole**
  - Ventricles begin to passively fill with blood
  - Aortic and Pulmonic valves close
  - AV valves open
Cardiac Output

- Cardiac output
  - Volume of blood pumped into the aorta each minute by the heart

- Stroke volume
  - Amount of blood ejected from a ventricle with each heartbeat
Cardiac Output

- Cardiac output (CO) equals stroke volume (SV) multiplied by heart rate (HR)
  \[ CO = SV \times HR \]

- In a healthy adult, CO at rest is about 5 L/min
Cardiac Output

- Affected by change in heart rate OR stroke volume

- Factors that influence heart rate

- Factors that affect stroke volume
Ejection Fraction

- The *percentage* of blood pumped out of a ventricle with each contraction
- Used as a measure of ventricular function
- A normal ejection fraction is between 50% and 65%
Signs and Symptoms of Decreased Cardiac Output: Your Thoughts

1. ________________________________________
2. ________________________________________
3. ________________________________________
4. ________________________________________
5. ________________________________________
Signs and Symptoms of Decreased Cardiac Output

- Acute changes in blood pressure
- Acute changes in mental status
- Cold, clammy skin
- Color changes in the skin and mucous membranes
- Crackles (rales)
- Dyspnea
- Dysrhythmias
- Fatigue
- Orthopnea
- Restlessness
Questions?
The Conduction System
The Conduction System

- Conduction system
  - Specialized electrical (pacemaker) cells
  - Arranged in a system of pathways
Electrical System of the Heart

- Sinoatrial (SA) Node
- Bachmann's Bundle
- Anterior Internodal Tract
- Left Bundle Branch
- Middle Internodal Tract
- Conduction Pathways
- Posterior Internodal Tract
- Right Bundle Branch
- Atrioventricular (AV) Node
The Conduction System

- Primary pacemaker
  - Sinoatrial (SA) node
The Conduction System

- **Atria**
  - Impulse leaves SA node to Bachmann’s Bundle (to the left atrium) to simultaneously depolarize both atria
  - Spreads from cell to cell across atrial muscle
Some abnormal heart rhythms that originate in the atria result in ineffectual atrial contraction.

What effect would this have on atrial kick?
The Conduction System

- Internodal pathways
  - Impulse is spread to AV node via internodal pathways
  - Merge gradually with cells of AV node
The Conduction System

- AV node
  - Located in floor of right atrium
    - Supplied by right coronary artery in most people
  - Delays conduction of impulse from atria to the ventricles
    - Allows time for atria to empty into ventricles
The AV node and AV bundle

- Internodal pathways
- Transitional fibers
- AV node
- Atrioventricular fibrous tissue
- Penetrating portion of AV bundle
- Distal portion of AV bundle
- Right bundle branch
- Left bundle branch
- Ventricular septum
The Conduction System

- **Bundle of His (AV bundle)**
  - Connects AV node with bundle branches
  - Pacemaker cells have an intrinsic rate of 40 to 60 bpm
  - Conducts impulse to right and left bundle branches
The Conduction System

- **Right bundle branch**

- **Left bundle branch**
  - Divides into three fascicles
    - Anterior fascicle
    - Posterior fascicle
    - Septal fascicle
The Conduction System

- **Purkinje fibers**
  - Receive impulse from bundle branches
  - Relay it to ventricular myocardium
  - Pacemaker cells have an intrinsic rate of 20 to 40 bpm
Cardiac Action Potential
Cardiac Action Potential

- Electrons
- Current
- Polarity
- Voltage
Cardiac Action Potential

- Electrolytes
- Ions
- Cell membranes
Polarization (Resting)

Polarization (resting)

Polarization (inside negative)

Potassium (K⁺)
Sodium (Na⁺)
Anions
Depolarization = Stimulation

Depolarization (stimulated)

Depolarization (inside positive)

Potassium (K⁺)
Sodium (Na⁺)
Anions
Ventricular Action Potential
Refractory Periods

- Refractoriness
  - The period of recovery that cells need after being discharged before they are able to respond to a stimulus
Refractory Periods

Absolute Refractory Period
Refractory Periods

Relative Refractory Period
The Electrocardiogram (ECG)
Sinoatrial (SA) node

Pulmonary artery

Left atrium

Right atrium

Internodal pathways

Septum

Left ventricle

Atrioventricular (AV) node

AV bundle (bundle of His)

Right ventricle

Atrial excitation

Excitation of ventricles begins (initial downward deflection is a Q wave)
The ECG

- Can provide information about:
  - The orientation of the heart in the chest
  - Conduction disturbances
  - The electrical effects of medications and electrolytes
  - The mass of cardiac muscle
  - The presence of ischemic damage
Does not provide information about the mechanical (contractile) condition of the myocardium

- Evaluated by assessment of pulse and blood pressure

The ECG
Electrodes

- Applied at specific locations on the patient's chest wall and extremities
- One end of a monitoring cable is attached to the electrode
- The other end is attached to an ECG machine
- The cable conducts current back to the cardiac monitor
EASI Lead Placement
Bipolar Leads

- A lead that consists of a positive and negative electrode
  - All ECG leads are technically bipolar leads
  - Leads I, II, and III use two distinct electrodes
Standard Limb Leads

- Leads I, II, and III

- Right arm electrode is always negative

- Left leg electrode is always positive
Einthoven’s Triangle
# Standard Limb Leads

<table>
<thead>
<tr>
<th>Lead</th>
<th>Positive Electrode</th>
<th>Negative Electrode</th>
<th>Heart Surface Viewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Left arm</td>
<td>Right arm</td>
<td>Lateral</td>
</tr>
<tr>
<td>II</td>
<td>Left leg</td>
<td>Right arm</td>
<td>Inferior</td>
</tr>
<tr>
<td>III</td>
<td>Left leg</td>
<td>Left arm</td>
<td>Inferior</td>
</tr>
</tbody>
</table>
Augmented Limb Leads

- Leads aVR, aVL, aVF
  - a = Augmented
  - V = Voltage
  - R = Right arm
  - L = Left arm
  - F = Foot (usually of the left leg)
- Lead aVR
  - Views the heart from the right shoulder
  - Does not view any wall of the heart
## Augmented Limb Leads

<table>
<thead>
<tr>
<th>Lead</th>
<th>Positive Electrode</th>
<th>Heart Surface Viewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>aVR</td>
<td>Right arm</td>
<td>None</td>
</tr>
<tr>
<td>aVL</td>
<td>Left arm</td>
<td>Lateral</td>
</tr>
<tr>
<td>aVF</td>
<td>Left leg</td>
<td>Inferior</td>
</tr>
</tbody>
</table>
Horizontal Plane Leads

- Six chest (precordial or “V”) leads view the heart in the horizontal plane

- Chest leads
  - V1
  - V2
  - V3
  - V4
  - V5
  - V6
## Chest Leads

<table>
<thead>
<tr>
<th>Lead</th>
<th>Positive Electrode Position</th>
<th>Heart Surface Viewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_1$</td>
<td>Right side of sternum, fourth intercostal space</td>
<td>Septum</td>
</tr>
<tr>
<td>$V_2$</td>
<td>Left side of sternum, fourth intercostal space</td>
<td>Septum</td>
</tr>
<tr>
<td>$V_3$</td>
<td>Midway between $V_2$ and $V_4$</td>
<td>Anterior</td>
</tr>
<tr>
<td>$V_4$</td>
<td>Left midclavicular line, fifth intercostal space</td>
<td>Anterior</td>
</tr>
<tr>
<td>$V_5$</td>
<td>Left anterior axillary line; same level as $V_4$</td>
<td>Lateral</td>
</tr>
<tr>
<td>$V_6$</td>
<td>Left midaxillary line; same level as $V_4</td>
<td>Lateral</td>
</tr>
</tbody>
</table>
**MCL₁**

- **Variation of chest lead V₁**
  - Negative electrode below left clavicle toward left shoulder
  - Positive electrode right of sternum in 4th intercostal space

- **Views ventricular septum**
ECG Paper and Systematic Rhythm Interpretation
ECG Paper
Waveforms

- P wave
- QRS complex
- T wave
- U wave
- PR interval
- QRS duration
- QT interval
ECG Paper

- ECG paper is graph paper made up of small and larger, heavy-lined squares
  - Smallest squares are 1 mm wide and 1 mm high
  - 5 small squares between the heavier black lines
  - 25 small squares within each large square
Horizontal Axis = Time

- Width of each small box = 0.04 second.

- Width of each large box (5 small boxes) = 0.20 second.
Horizontal Axis = Time

- 5 large boxes = 1 second.
- 15 large boxes = 3 seconds.
- 30 large boxes = 6 seconds.
Vertical Axis = Voltage/Amplitude

- Size or amplitude of a waveform is measured in millivolts (voltage) or millimeters (amplitude).
Waveforms

- **Terms**
  - Baseline (isoelectric line)
  - Waveform
  - Segment
  - Interval
  - Complex
P Wave: Atrial Depolarization

The ECG cannot show the electrical activity of these five structures.
Normal P Wave Characteristics

- Smooth and rounded
- No more than 2.5 mm in height
- No more than 0.11 seconds in duration
- Positive in leads I, II, aVF, and V₂ through V₆
Abnormal P Waves
Q Wave

- Normal (physiologic) Q waves
  - Less than 0.04 sec
  - Less than 1/3 the height of R wave in that lead

- Abnormal (pathologic) Q waves
  - More than 0.04 sec
  - More than 1/3 the height of the following R wave in that lead
R and S Waves

- **R wave**
  - The first positive, or upward, deflection following the P wave
  - Always positive

- **S wave**
  - A negative waveform following the R wave
  - Always negative

- **R and S waves**
  - Represent depolarization of the right and left ventricles
QRS Complex

The ECG cannot show the electrical activity of these five structures.
Normal QRS Complex

- Measure the QRS complex with the longest duration and clearest onset and end

- In adults, the normal QRS duration is 0.11 seconds or less
QRS Variations

Q wave: The first negative (−) deflection below the baseline proceeding the R wave. Not always present. (Normally seen in leads I, II, V₅, and V₆.)

R wave: The first positive (+) deflection above the baseline. (Most often thought of as the "QRS" complex; used to measure the "R to R" interval.)

S wave: The negative (−) deflection following the R wave; generally proceeds below the baseline.

R’ wave: The R’ (prime) wave represents the second positive (+) deflection above the baseline.
QRS Variations

S’ wave: The S’ (prime) wave represents the second negative (−) deflection below the baseline.

RS wave: The absence of a Q wave is noted. Many of complexes we observe in single-lead are in fact RS waveforms.

QS wave: The absence of any deflection above the baseline is termed a QS complex. (Often seen in lead MCL I).

QRS wave: The classic waveform to be observed; has all three components: a Q, R, and S wave present.
ST Segment

- Portion of the ECG tracing between QRS complex and T wave
- Represents early part of repolarization of right and left ventricles
ST Segment

A

B

C

J point

3-mm ST elevation

.08 sec

J point

3-mm ST depression

.08 sec
ST Segment Elevation
T Wave

- Represents ventricular repolarization
Abnormal T Waves

- The T wave following an abnormal QRS complex is usually opposite in direction of the QRS
PR Interval

- P wave + PR segment = PR interval
- Normally measures 0.12–0.20 sec
PR Interval

The PR interval reflects:

- Depolarization of the right and left atria (P-wave)
- Spread of the impulse through the AV node, AV bundle, right and left bundle branches, and the Purkinje fibers (PR segment)
Abnormal PR Interval

- **Long PR interval (greater than 0.20 sec)**
  - Indicates the impulse was delayed as it passed through the atria, AV node, or AV bundle

- **Short PR interval (less than 0.12 sec)**
  - May be seen when the impulse originates in the atria close to the AV node or in the AV bundle
QT Interval

- Portion of the ECG tracing from the beginning of the QRS complex to the end of the T wave
- Represents total ventricular activity
- 0.36 – 0.44 sec
QT Interval = 0.36 – 0.44 seconds
QT Rule of Thumb

- Tachycardia shortens QT intervals
- Bradycardia prolongs QT Intervals
- Congenital Prolongation of the QT interval
- Many medications can prolong the QT Interval
  - [www.azcert.org](http://www.azcert.org)
  - Quinolones, amiodarone, anti-psychotics, Zofran, Albuterol, Cipro, Haldol are just a few for example
R-R Interval

- Used to determine ventricular rate and regularity
P-P Interval

- Used to determine atrial rate and regularity
Artifact

- Distortion of an ECG tracing by electrical activity that is noncardiac in origin

- Can mimic various cardiac dysrhythmias, including ventricular fibrillation

- Patient evaluation essential before initiating any medical intervention
Artifact—Causes

- Loose electrodes
- Broken ECG cables or broken wires
- Muscle tremor
- Patient movement
- External chest compressions
- 60-cycle interference
Artifact—Loose Electrodes
Artifact—Muscle Tremor
Artifact—60-Cycle Interference
Systematic Rhythm Interpretation
Systematic Rhythm Interpretation

- Assess rhythmicity (atrial and ventricular)
- Assess rate (atrial and ventricular)
- Identify and examine waveforms
- Assess intervals (PR, QRS, and QT) and examine ST segments
- Interpret the rhythm (and assess clinical significance)
Rhythmicity

- Ventricular
  - Compare R-R intervals

- Atrial
  - Compare P-P intervals
Rhythmicity - Terminology

- Regular rhythm
- Essentially regular rhythm
- Irregular rhythm
- Regularly irregular rhythm
- Irregularly irregular rhythm
Assessing Ventricular Rhythmicity

A

B
Six-Second Method-
Can be Used in Regular or Irregular Rhythms

- Ventricular rate
  - Count the number of complete QRS complexes within a period of 6 sec
  - Multiply that number by 10 to determine the number of QRS complexes in 1 min
Large Box Method-
Only in Regular Rhythms

- Count the number of large boxes between two consecutive waveforms (R-R interval or P-P interval) and divide into 300
- Best used if the rhythm is regular
# Large Box Method

<table>
<thead>
<tr>
<th>Number of Large Boxes</th>
<th>Heart Rate (beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>43</td>
</tr>
<tr>
<td>8</td>
<td>38</td>
</tr>
<tr>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>
Sequence Method – Only in Regular Rhythms

- Select an R wave that falls on a dark vertical line
  - Number the next 6 consecutive dark vertical lines as follows:
    - 300, 150, 100, 75, 60, and 50
  - Note where the next R wave falls in relation to the 6 dark vertical lines already marked—this is the heart rate
Small Box Method – Only in Regular Rhythms

- Count the number of small boxes between two consecutive waveforms (R-R interval or P-P interval) and divide into 1500
- Time consuming, but accurate
Identify and Examine Waveforms

- Look to see if the normal waveforms (P, Q, R, S, and T) are present

- P waves
  - Present?
  - Upright?
  - Do they look alike?
  - Is there one P wave before each QRS complex?
Identify and Examine Waveforms

- **QRS**
  - Are QRS complexes present?
  - If so, does a QRS follow each P wave?
  - Do the QRS complexes look alike?

- **T waves**
  - Does a T wave follow each QRS complex?
  - Does a P wave follow the T wave?
  - Are the T waves upright and of normal height?
Assess Intervals and Examine Segments

- PR interval
- QRS duration
- QT interval
- ST segment
Interpret the Rhythm

- Interpret the rhythm
  - Specify site of origin (pacemaker site) of the rhythm (sinus)
  - Specify mechanism (bradycardia) and ventricular rate
    - For example: Sinus bradycardia at 38 beats/min

- Evaluate patient’s clinical presentation to determine how he or she is tolerating the rate and rhythm
Questions?