HEART ELECTRICAL ACTIVITY

Learning objectives

1. Describe the conduction system of the heart.
2. Explain pacemaker activity in the heart.
3. Explain the regulation of heart rate by the autonomic nervous system.
4. Explain the ECG and its correspondence to the cardiac action potential (AP)
CONDUCTION SYSTEM

PACEMAKERS:

- Sino-Atrial (SA) node fires at 100 beats/min
- Atrial-Ventricular (AV) node pauses electrical signal; fires at 40-60 beats/min
- Bundle of His and Purkinje fire at 25-45 beats/min

Repolarization occurs in reverse order!
Phase 4. slow depolarization due to
- closing of voltage gated K+ channels
- transient opening of “funny” Na+ channel
- transient opening of Ca++ (L & T) channel

Phase 0. rapid depolarization due to Ca++ influx (opening of Ca++ L type channel)

Phase 3. repolarization due to K+ efflux (opening of voltage gated K+ channel)
Sympathetic nervous system (SNS) speeds up HR by decreasing K+ efflux (phase 3) and increasing the opening of the funny Na+ channel (phase 4).

Tachycardia > 100 bpm
Parasympathetic nervous system (PNS) decreases heart rate by increasing K+ efflux (phase 3) and slowing the opening of the funny Na+ channel (phase 4).

Bradycardia $< 60 \text{ bpm}$
ELECTRICAL ACTIVITY OF WHOLE HEART

1. SA node fires leading to atrial depolarization.

2. Delay at the AV node then AV node fires.

3. His Bundle & Purkinje fibers fire leading to depolarization of septum and of ventricles.

4. Depolarization of heart wall is from inside (endocardium) to outside (epicardium).

5. Repolarization is in opposite direction.

Electrocardiogram (ECG) detects electrical activity of whole heart
Electrocardiogram

P wave is atrial depolarization
QRS = ventricular depolarization
T = ventricular repolarization

PR segment = time between SA & AV node firing.
ST segment = phase 2 of fast action potential.
R-R = heart rate

Which of segments change in running?

CARDIAC RHYTHM & ECG

• Rhythm initiated by SA node whatever its rate is termed a *sinus rhythm*.

• Certain disease conditions can permit other parts of the conduction system or even the contracting portion of the myocardium to take over pacemaker function. These are called *ectopic foci*. These can result in skipped beats, impaired filling and even ventricular fibrillation (disorganized contractions).

• Electrochemical events that accompany signal generation and conduction are observable on a clinical electrocardiogram (ECG).
ECG & PATHOLOGY

Case: Mrs. R is 80 y/o female. Her normal resting HR is 85 bpm. On Friday, she was unable to do her AM exercises. Her resting HR was 30 bpm.

ECG findings: *P waves occur independent of QRS.*

*What is her pacemaker?*
KEY CONCEPTS

1. Each heart beat (cardiac cycle) involves electrical activation of the atria and ventricles in the right & left chambers.
2. Action potentials of the pacemaker & contractile cells differ.
3. Pacemaker cells have unstable resting membrane potential.
   The SA node, the fastest pacemaker, sets the rate of beating.
4. Heart rate (HR) is determined by the autonomic system.
   Sympathetic (SNS) increases HR; parasympathetic NS (PNS) decreases HR.
5. ECG is the sum of the electrical activity of the entire heart.
   P waves depict atrial depolarization. QRS complex depicts ventricular depolarization. T wave is ventricular repolarization.
6. Disease of the electrical conduction system is manifested by change(s) in the ECG.