Circulatory System and Disorders

Course 3

Normal Electrocardiogram

Res.Ass. Fırat AKAT, PhD
akatfirat@gmail.com

Introduction

- **Electrocardiography** (ECG), is an amplified, timed recording of the electrical activity of the heart, as detected on the surface of the body.
- The graphic display of the electrical impulse recorded in an ECG is called a ***tracing (electocardiogram)***.
- The clinical utility of the ECG derives from its immediate availability as a noninvasive, inexpensive, and highly versatile test.

Scope of ECG

- By analyzing the details of these fluctuations in electrical potential, the physician gains valuable insight into;
  1. the anatomical orientation of the heart
  2. the relative sizes of its chambers;
  3. various disturbances in rhythm and conduction;
  4. the extent, location, and progress of
  5. ischemic damage to the myocardium;
  6. the effects of altered electrolyte concentrations;
  7. the influence of certain drugs (notably digitalis, antiarrhythmic agents, and calcium channel antagonists).

- ECG, however, cannot give *direct* information about the contractile performance of the heart.

Electrocardiographic Leads

- A typical ECG makes use of multiple combinations of recording locations on the limbs and chest called **ECG leads**.

- A “lead” is not a single wire connecting from the body but a combination of two electrodes to make a complete circuit between the body and the electrocardiograph.

Electrocardiographic Leads

1. Standart (Bipolar) Limb Leads
   – DI, DII, DIII

2. Augmented (Unipolar) Limb Leads
   – aVR, aVL and aVF

3. Precordial Chest (Unipolar) leads
   – V_1, V_2, V_3, V_4, V_5 and V_6

Frontal Plane

Horizontal Plane

Limb Leads

Chest (Precordial) Leads

Standart Limb Leads

Standart Limb Leads (DI, DII, DIII)

- These three limb leads roughly form an equilateral triangle (with the heart at the center), called **Einthoven triangle.**

- Whether the limb leads are attached to the end of the limb (wrists and ankles) or at the origin of the limbs (shoulder and upper thigh) makes virtually no difference in the recording.

Augmented Limb Leads

Augmented Limb Leads (aVR, aVL, aVF)

- Each of these leads has a single positive electrode that is referenced against a combination of the other limb electrodes.

- The positive (recording) electrodes for these augmented leads are located on the left arm (**aVL**), the right arm (**aVR**), and the left leg (**aVF**); the “F” stands for “foot”.

- For every lead, the other two limbs are used as negative *(indifferent)* electrode.

Precordial Chest Leads

Precordial Chest Leads (V_1, V_2, V_3, V_4, V_5, and V_6)

- These six positive electrodes are placed on the surface of the chest over the heart to in a **horizontal plane.**

- The other limb electrodes are used through resistance as a combined negative electrode called ***indifferent electrode***.

The Origin of ECG Signal

- The ECG signal is **NOT** cardiac action potential!

Heart (cardiac) dipole:

- When a portion of the myocardium becomes depolarized, its polarity is temporarily reversed, relative to the neighboring inactive tissue.

- When this reversal occurs, it temporarily creates two neighboring regions of opposite charge, or polarity, within the myocardium.

- Heart dipole is the electromagnetic force between (–) and (+). It is carried by conductive extracellular fluids to our electrodes on the skin.

The cardiac dipole is a vector which has both a direction (from the most negative to most positive regions of the heart) as well as an amplitude (voltage).

The Origin of ECG Signal

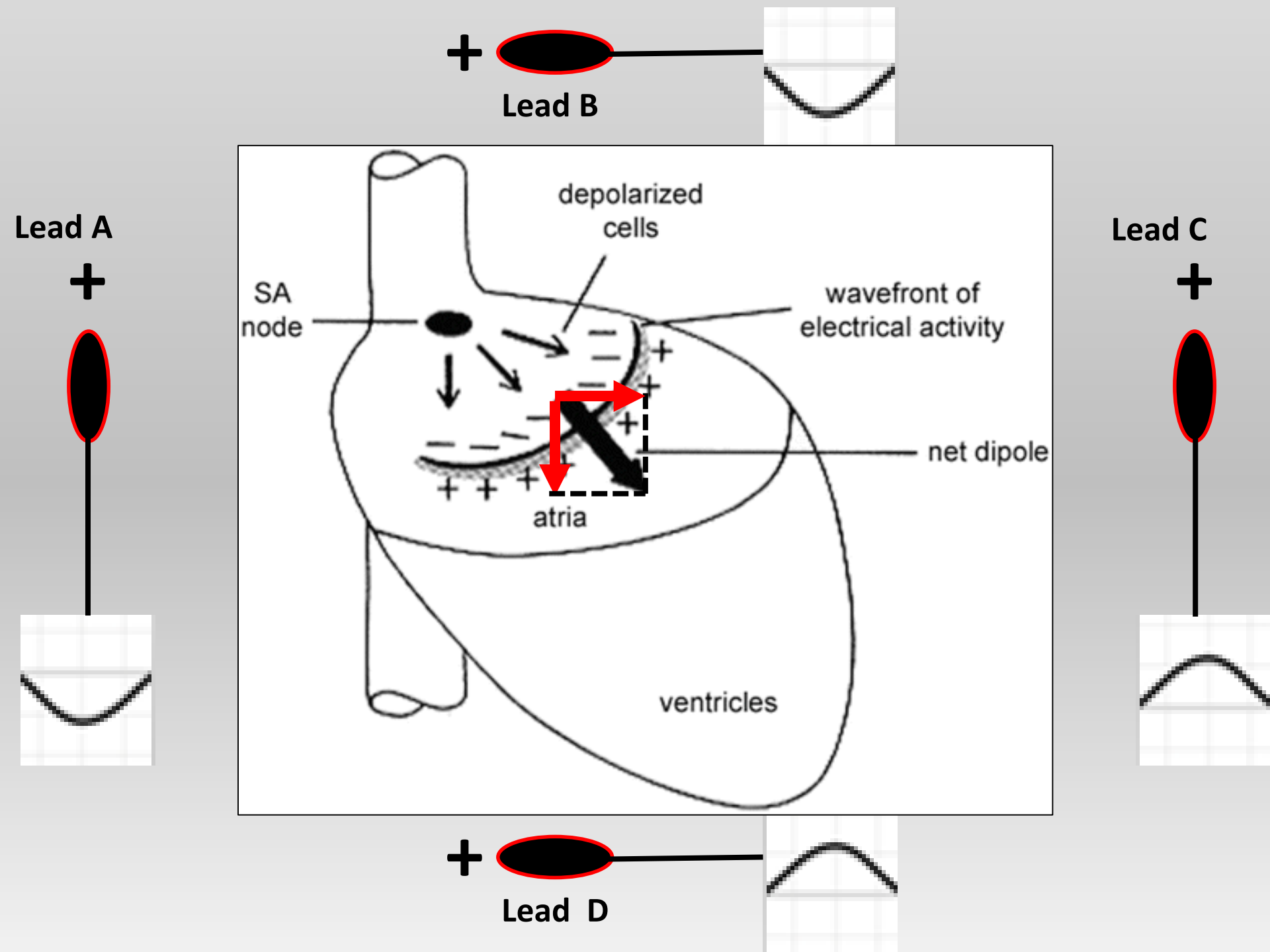
- Positive deflection ≠ Depolarization
- Negative deflection ≠ Repolarization

- If the direction of dipole is towards the positive electrode, a positive deflection is observed in tracing.

- If the direction of dipole is towards the positive electrode, a positive deflection is observed in tracing.

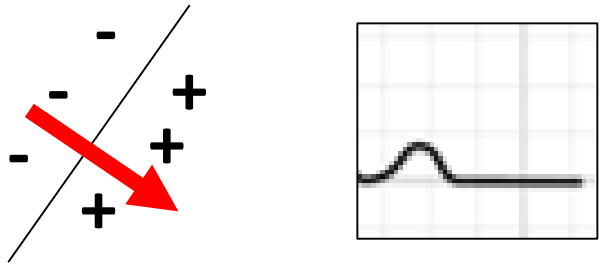
Standart ECG Waves

- The first deflection on the tracing, is the **P wave,** corresponds to current flow during **«atrial depolarization»** *(not only SA node, whole atrial depolarization)*.
- The second deflection the **QRS complex,** is the result of **«ventricular depolarization»**.
  - The QRS complex is often, but not always, three separate waves: the **Q** wave, the **R** wave, and the **S** wave.
- The final deflection, the **T wave,** is the result of **«ventricular repolarization»**.
- Atrial repolarization is usually not evident on the ECG because it occurs at the same time as the QRS complex.

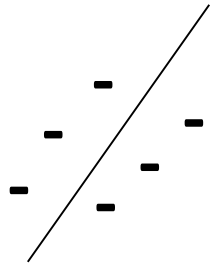

Lead B
Lead A
Lead C
depolarized cells
SA node
wavefront of electrical activity
net dipole
atria
ventricles
Lead D

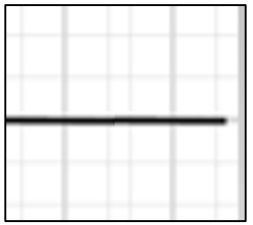
The Origin of ECG Signal

A.

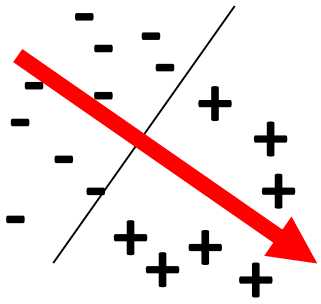


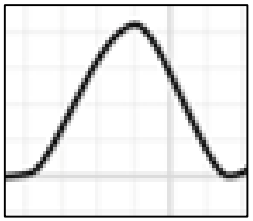
C.



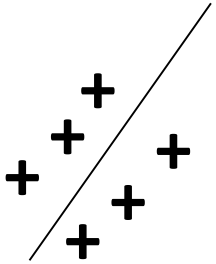


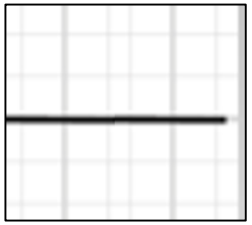
B.





D.





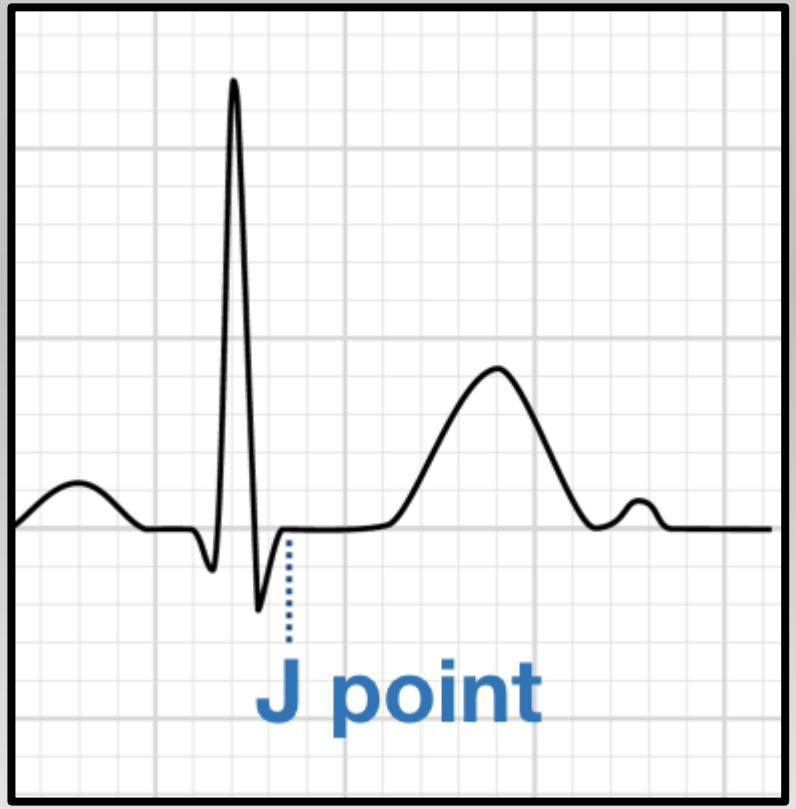
The amplitude of the wave (wavelength) is directly related to magnitude of the dipole.

The Isoelectric Line

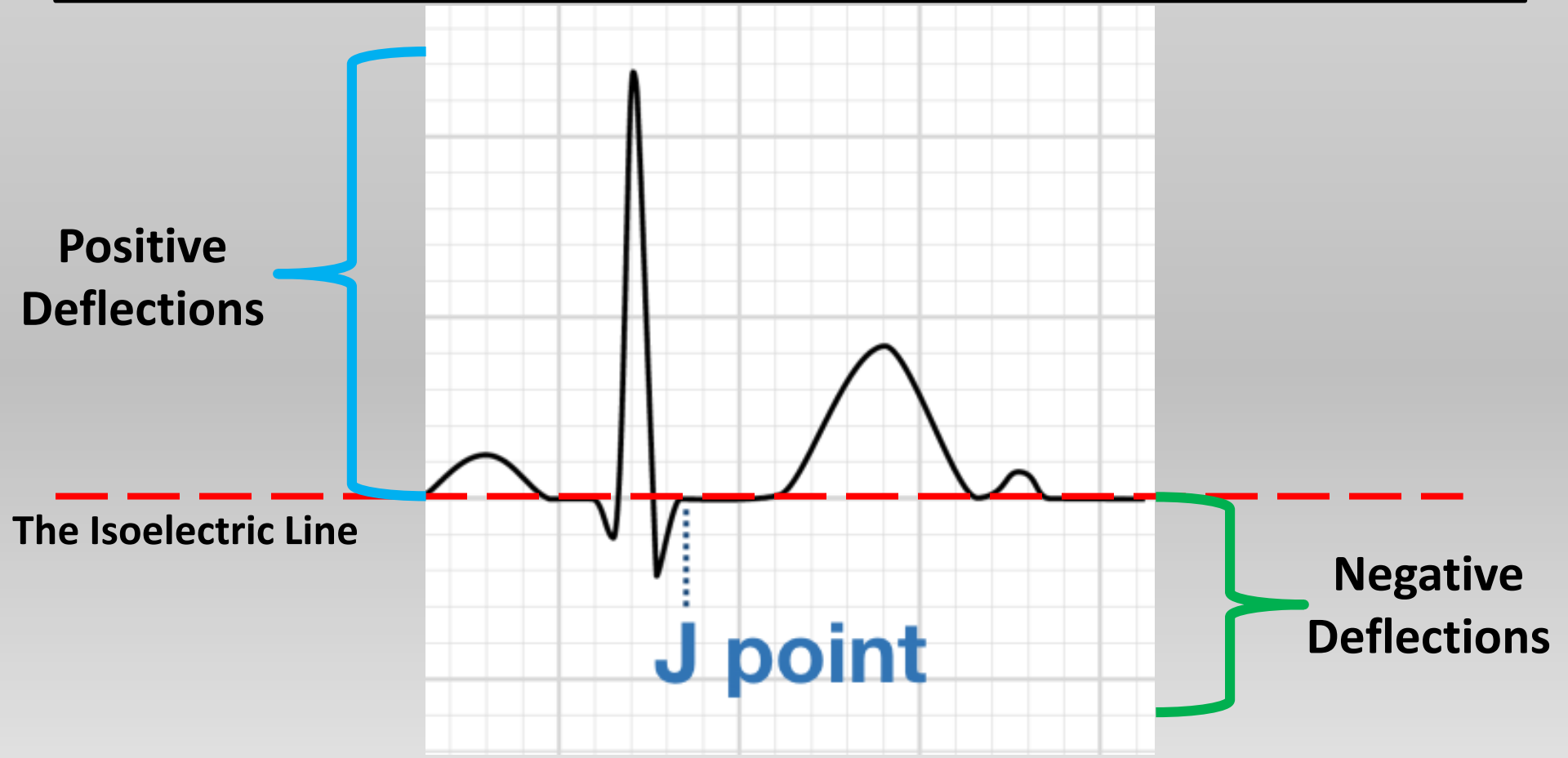
- Isoelectric line is the **«zero line»** in the ECG.
- If the tracing shows the isoelectric line that means there is **no dipole** (completely depolarized or completely repolarized) reflected to the electrode in the particular time point.
- If a deflection is below isoelectric line it is called positive deflection, if it is under isoelectic line it is called negative deflection.

The Isoelectric Line

- The **J point** is the junction between the termination of the QRS complex and the beginning of the ST segment.
- The J (**junction**) point marks the end of the QRS complex, and is often situated on **the isoelectic line**, particularly in healthy people.



The Isoelectric Line



We draw a line horizontal line crossing on J point to determine the isoelectric line.

QRS-Complex Nomenclature

Rules:

1. If a deflection is bigger than 5 mm we use capital letters (Q,R and S); if not we use lowercase (q,r and s).

2. Name of the first negative deflection is **«Q»**.

3. The complex may start with a positive deflection **«R»** (no Q). It is perfectly normal.

4. The negative deflection following the R wave is **«S».**

5. If there is an extra positive defletion after S wave it is called **«R'».**

Standart ECG Waves

- **P wave:** The first sign of electrical activity, small, rounded, upward (usually positive) deflection.
- Duration of P wave is between 0,08 – 0,10 seconds and its amplitude is lesser than 0,25 mV.
- P wave is always negative in aVR lead but usually positive in other leads.
- After a short interval, QRS complex is observed.

Standart ECG Waves

- **PR (PQ) Interval.** The time frame from the onset of atrial activation (start of P wave) to the onset of ventricular activation (start of QRS) (0.12 to 0.20 sec).

- The inhibition of conduction through the AV node (**negative dromotropy**) is often reflected as a lengthening of the PR interval.

Standart ECG Waves

- **QRS complex**, is recorded during the depolarization of ventricles.
- The duration **(QRS Interval)** is usually between 0,06 and 0,10 second.
- An abnormally prolonged QRS complex may indicate a block in the conduction pathways through the ventricles (such as a block of the left or right bundle branch). The duration of the QRS complex is roughly equivalent to the duration of the P wave.
- Q wave should be no more than ¼ of the R wave in the same lead. R wave amplitude should be lower than 25 mm, S wave amplitude should ne lower than 30 mm.

Standart ECG Waves

- **QT interval:** The time between the initiation of the QRS complex and the end of the T wave **(0,20- 0,40 sec) .**
- The QT interval measures the total duration of ventricular activation (depolarization + repolarization).
- If ventricular repolarization is delayed, the QT interval is prolonged.
- This interval is **inversely proportional** to the heart rate and is often altered by drugs or conditions that alter the rate of myocardial repolarization in phase 3 (e.g., altered K^+ conductance).
- **Corrected QT (QTc):** QT interval is corrected with heart rate by various formulas in clinic (*Bazett's, Fridericia's, Sagie's Formula*)

Standart ECG Waves

- **T wave:** Ventricular repolarization.
- Duration: 0,10-0,25 s.
- Amplitude: <6mm in limb leads, <10mm in precordial leads
- Normally, T waves are positive in all leads, except aVR.

Standart ECG Waves

- **U wave:** The 'U' wave comes after the T wave of ventricular repolarization and may not always be observed as a result of its small size.
- The exact source of the U wave remains unclear.
- The most common theory is the «repolarization of the papillary muscle».
- Prominent U wave is related to some pathological conditions.

ECG Segments

- **PR Segment:** Atria are completely depolarized, ventricles are completely repolarized. No dipole!
- **ST Segment:** Atria are completely repolarized, ventricles are completely depolarized. No dipole!
- These segments normally lie on isoelectric line.
  - Positive deviation from the isoelectic line is called «**segment elevation**» (e.g. ST elevation)»
  - Negative deviation from the isoelectic line is called «**segment depression**» (e.g. ST depression)»

Current of Injury

- Myocardial infarction, leaves a lesion (scar tissue) behind.
- This scar tissue is partially depolarized/repolarized compared to healthy myocardium.
- This difference creates an «**current of injury**» an extra dipole which doesn’t occur in healthy myocardium.

Normal Sinus Rhythm

- A **rhythm strip** is usually generated from a single ECG lead (often lead II).

Normal Sinus Rhythm Criterias:

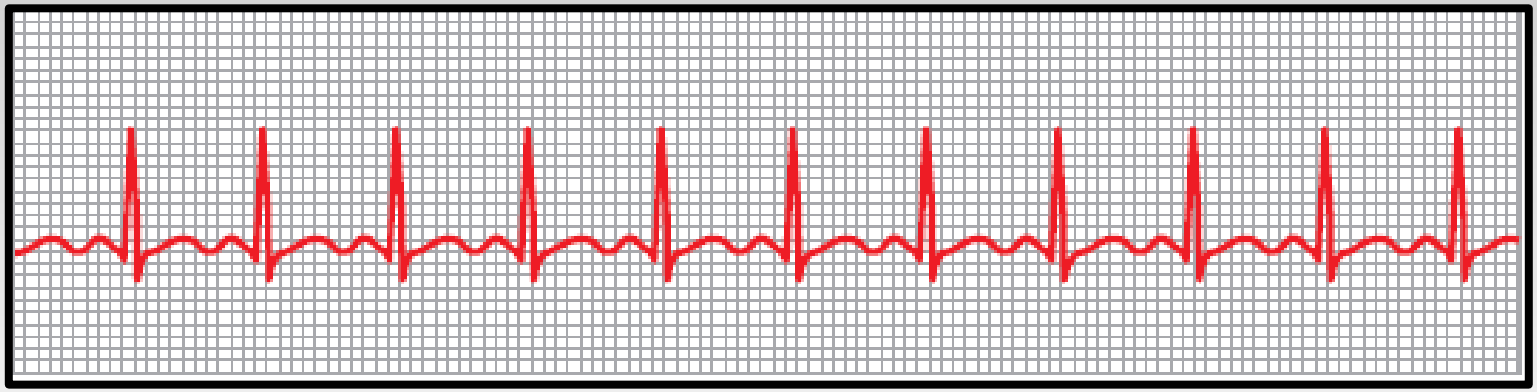
1. P wave should be positive in lead I, lead II, and aVF and negative in aVR.
2. PR interval should be 0,12 – 0,20 seconds
3. Each P wave should be followed by a QRS complex. Each QRS complex should be preceded by a P wave.
4. R-R intervals should be equal.
5. Heart rate should be between 60 – 100 bpm.

Abnormal Sinus Rhythms

Sinus Tachycardia

- The term “tachycardia” means *fast heart rate,* which usually is defined as faster than 100 beats/min in an adult.

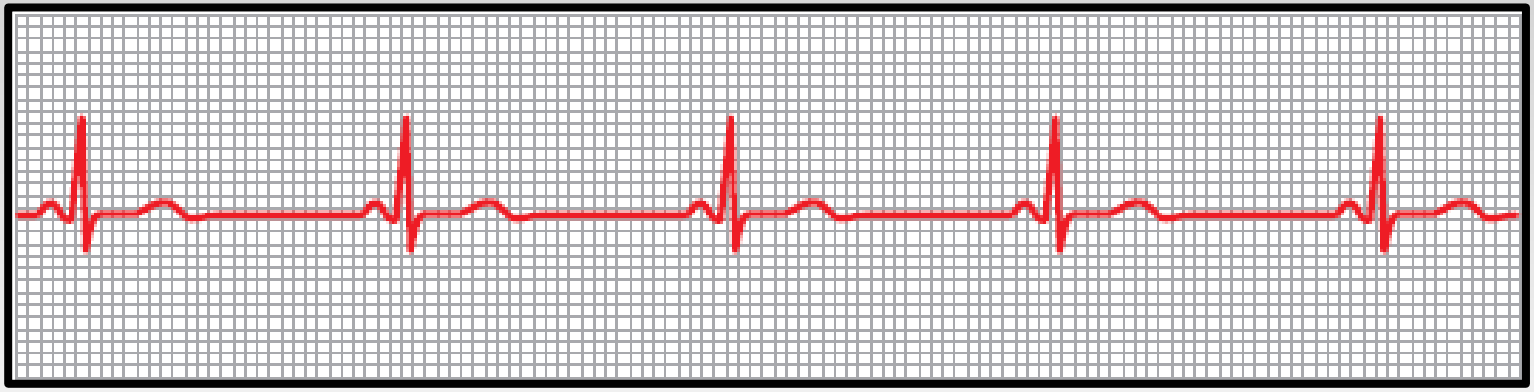
- Some causes of tachycardia:
  - Hypertermia (+18 bpm per 1°C)
  - Sympathetic stimulation
  - Cardiac Toxicity



Abnormal Sinus Rhythms

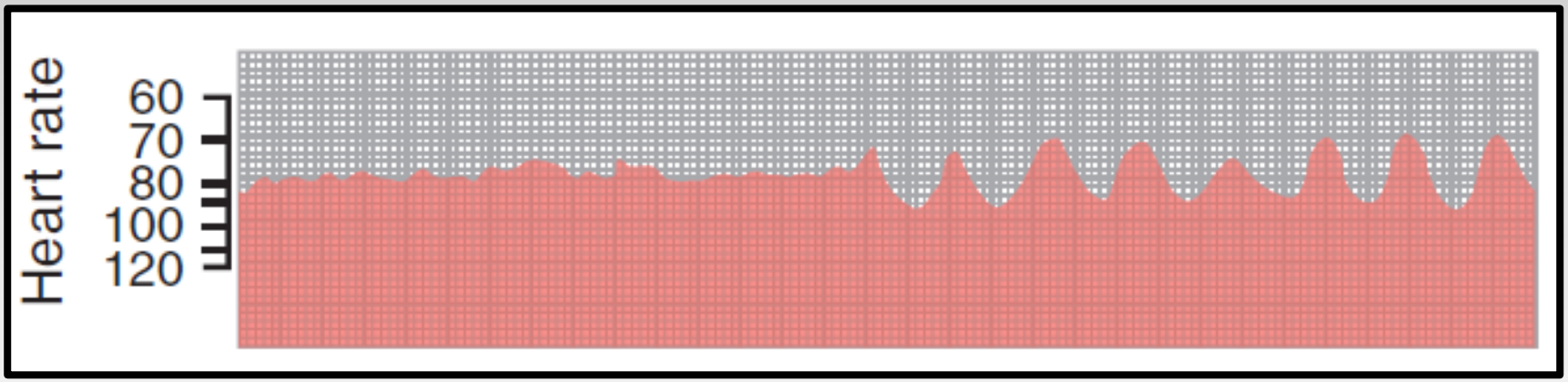
Sinus Bradycardia

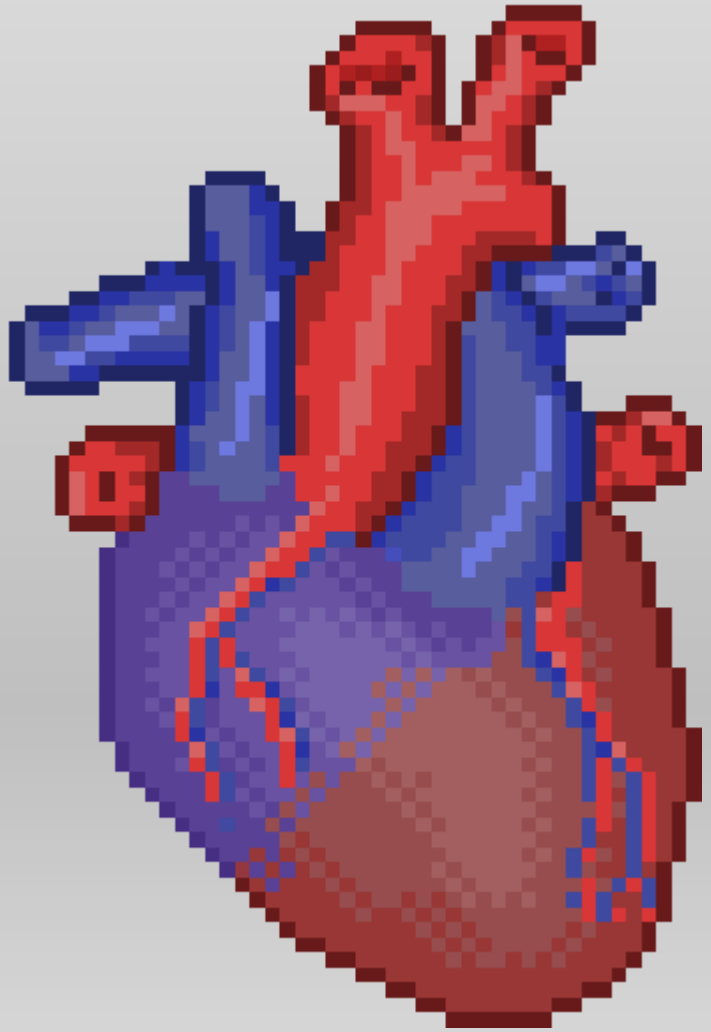
- The term “bradycardia” means a slow heart rate, usually defined as fewer than 60 beats/min
- **Athletic heart syndrome (AHS)** (Athletic bradycardia): non-pathological condition. Resting heart rate is lower than normal in professional athletes.
- Vagal (Parasympathetic) stimulation causes bradycardia.



Respiratory Sinus Arrhythmia

- Inspiration increases heart rate, expiration decreases heart rate.
  - In normal respiration ±5%, in deep respiration ±30%.
- Closely related to vagal tone. Frequently used as a noninvasive method for investigating vagal tone, in physiological, behavioral, and several clinical studies.
- The **Bainbridge reflex**, aka. the **atrial reflex**, is an increase in heart rate due to an increase in central venous pressure. Increased blood volume is detected by stretch receptors (Cardiac Receptors) located in both sides of atria at the venoatrial junctions.





REFERENCES

Hall, John E. *Guyton and Hall textbook of medical physiology e-Book*. Elsevier Health Sciences, 2010.

Koeppen, Bruce M., and Bruce A. Stanton. *Berne & Levy Physiology, Updated Edition E-Book*. Elsevier Health Sciences, 2009.

Rhoades, Rodney, and George A. Tanner, eds. *Medical physiology*. Lippincott Williams & Wilkins, 2003.

Widmaier, Eric P., et al. *Vander's Human physiology: the mechanisms of body function*. Boston: McGraw-Hill Higher Education,, 2008.

Thank you for your patience!