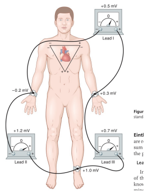
Done by Laith Alkhazaleh

ECG Interpretation Overview

1. Introduction to Electrocardiography (ECG)

- ECG is a graphical representation of the heart's electrical activity.
- It is a valuable diagnostic tool due to its sensitivity, specificity, non-invasive nature, quick results, ease of use, and affordability.
- The electrical activity of the heart is measured at the body surface, as the body is highly conductive to electricity.

This is done using a device called the Galvanometer.

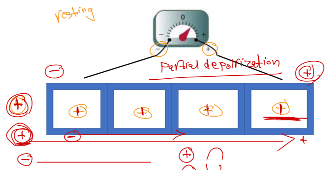


2. Understanding the Action Potential and Resting Cells

- Resting Cells: In their resting state, all cardiac muscle cells have a negative resting potential (e.g., -60mV in the SA node, -90mV in ventricular cells).
- The Galvanometer detects no potential difference between electrodes, resulting in a zero reading (isoelectric line).

3. Depolarization and ECG Deflection

- Stimulated Cells: When one side of the cell is stimulated, a difference in electrical potential is created, resulting in a positive deflection on the ECG.
- Positive deflection occurs when depolarization moves toward the positive electrode.
- Completely Depolarized Cells: Once all cells are depolarized, there is no potential difference, and the Galvanometer shows zero reading.



4. Repolarization and ECG Deflection

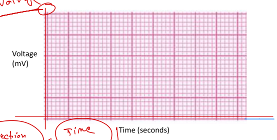
- Repolarization: As cells begin to repolarize, the difference in potential between the two electrodes causes a negative deflection on the ECG.
- Negative deflection occurs when repolarization moves toward the [illegible]e electrode.
- Complete Repolarization: The cells return to their resting potential, and once again, the ECG shows zero deflection (isoelectric line).

5. ECG Basics: Movement of Current and Deflections

- Positive deflection: When depolarization moves toward the positive electrode or repolarization moves toward the negative electrode.
- Negative deflection: When depolarization moves toward the negative electrode or repolarization moves toward the positive electrode.
- No current flow results in a straight line (isoelectric line).

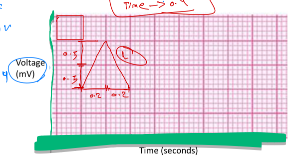
6. ECG Detection: Atria vs. Ventricles

- ECG Limitations: Small changes in the membrane potential of tissues like the SA node are not detected by the ECG due to their smaller tissue mass.
- The ECG primarily detects the electrical activity of the atria and ventricles.
- Amplitude: The deflection amplitude is influenced by the tissue mass. Larger masses, like the ventricles, produce a larger amplitude.
- Time: The speed of deflection is affected by conduction speed. Ventricular depolarization is faster than atrial depolarization.



7. Amplitude and Duration Differences

- Amplitude Differences: Ventricular waves have higher amplitude than atrial waves because of the larger muscle mass in the ventricles.
- Pathological conditions like hypertrophy can also increase the amplitude.
- Duration Differences: Waves in the ventricles take longer because conduction is slower in some fibers (e.g., Purkinje fibers have a higher conduction speed than other tissues).



8. Standard ECG Grid and Measurement

- The ECG recording uses a standard grid of large squares, each containing 25 smaller squares.
- These squares are used to measure time (in seconds) and voltage (in millivolts) for proper analysis of the heart's electrical activity.

In an ECG, the horizontal calibration represents time. Each 1 mm in the horizontal axis corresponds to 0.04 seconds (40 milliseconds), with every 5 mm (designated by a bold line) indicating 0.2 seconds. The ECG paper moves at a constant speed of 25 mm/sec, allowing for the precise representation of time intervals and waves on the ECG recording
1

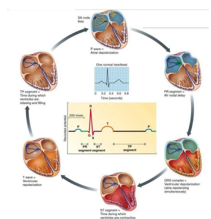
ECG Calibration

1. Horizontal Calibration (Voltage)

- The horizontal lines on the ECG represent voltage.
- Each 10 small horizontal divisions (upward or downward) corresponds to 1 millivolt (mV).
  - Each small horizontal line is approximately 0.1 mV.
  - Positive deflections are displayed upward, while negative deflections are shown downward.

2. Vertical Calibration (Time)

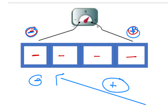
- The vertical lines on the ECG represent time.
- The ECG typically runs at a speed of 25 millimeters per second.
  - Each 25 mm in the horizontal direction equals 1 second.
  - Each 5-millimeter segment, marked by dark vertical lines, represents 0.20 seconds.
  - These 0.20-second intervals are divided into five smaller intervals, each representing 0.04 seconds.
  - Small vertical lines represent 0.04 seconds, and large vertical lines represent 0.2 seconds.
  - 5 large vertical lines equal 1 second.



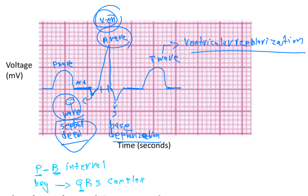
Summary

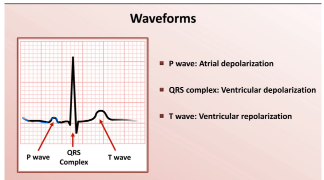
- Horizontal lines correspond to voltage.
- Vertical lines correspond to time.
- Make sure to differentiate between voltage (horizontal) and time (vertical) directions to avoid confusion during ECG analysis.

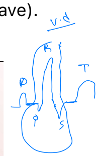
2. Cardiac Depolarization Phases

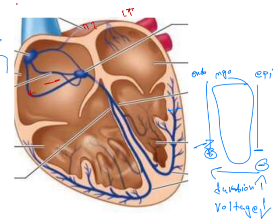


a) Atrial Depolarization (P wave)
- Depolarization begins at the SA node and spreads throughout the right and left atria.
- The direction of flow (summed vector) is down and left.
- In Lead I, the vector points toward the left, causing a positive deflection on the ECG (P wave).
- The time is moderate, and the amplitude is also moderate compared to other waves.









b) Septal Depolarization (Q wave)
- Depolarization moves from the AV node through the AV fibers and bundle branches to the septum.
- The direction of flow is up and right.
- In Lead I, the vector points right, resulting in a negative deflection (Q wave).
- The time is short, and the amplitude is small because of the small muscle mass in the septum.

d) Base Depolarization (S wave)
- The direction of flow is up and right.
- In Lead I, the vector points right, causing a negative deflection (S wave).
- The time is moderate, and the amplitude is smaller compared to other waves.

3. Ventricular Repolarization (T wave)
- Ventricular repolarization begins at the epicardial side and moves toward the endocardial side.
- Repolarization is slower than depolarization and takes longer. → +ve
- The direction of flow is up and right, resulting in a [redacted] deflection (T wave).
- The amplitude is moderate, and the duration is longer compared to depolarization.
- Atrial repolarization is masked by the larger QRS complex.

4. ECG Waves, Segments, and Intervals
- Waves:
- P wave: Atrial depolarization.
- QRS complex: Ventricular depolarization (Q, R, S waves).
- T wave: Ventricular repolarization.
- Segments:
- P-R segment: Between P wave and QRS complex (often called PQ).
- S-T segment: Between QRS complex and T wave, important for diagnosing myocardial infarction (MI).
- Intervals:
- P-R interval: Includes P wave and P-R segment (Q wave is not always visible).
- Q-T interval: Includes QRS complex, S-T segment, and T wave.

5. Summary of Key Points
- The P wave represents atrial depolarization.
- The QRS complex represents ventricular depolarization.
- The T wave represents ventricular repolarization.
- The P-R segment and S-T segment are important for detecting abnormalities such as myocardial infarction (MI).
- The P-R interval and Q-T interval include both waves and segments, offering important timing information for diagnosis.

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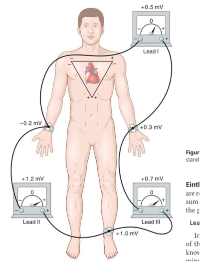
ECG Leads Overview

Standard Leads

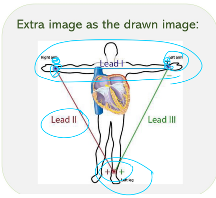
- Standard ECG: 12 leads (6 limb leads + 6 chest leads).
- Other machines: May use 3 or 6 leads, but 12 leads are standard.

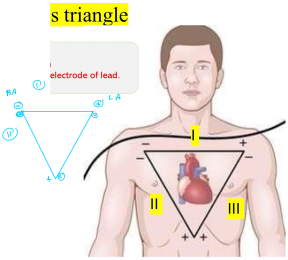
12 → 6 limb, 6 chest
6 limb → 3 unipolar, 3 bipolar

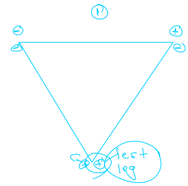


Types of Leads

1. Limb Leads (Vertical Plane):
- Bipolar Limb Leads (3): Measure between two electrodes on different sides of the heart.
- Lead I: Positive (LA), Negative (RA)
- Lead II: Positive (LL), Negative (RA)
- Lead III: Positive (LL), Negative (LA)
- Einthoven's Triangle: Formed by Leads I, II, and III.

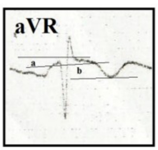


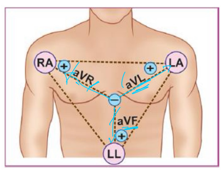




QRS
Complex
Ventricular
depolarization

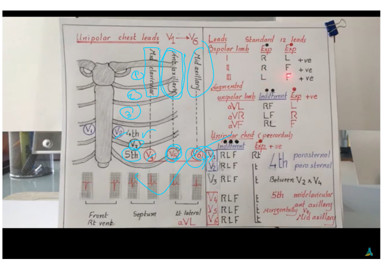
- Augmented Unipolar Limb Leads (3): Calculated using higher resistance.
- aVL: Between LA and heart
- aVR: Between RA and heart (inverted)
- aVF: Between LL and heart

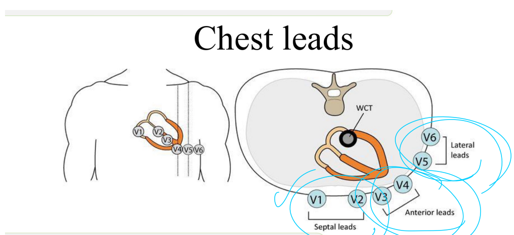




QRS recording Negative due to close to the base of the heart Than Apex.

2. Chest Leads (Horizontal Plane):
- Positioned on the Chest Wall:
- V1: Right 4th intercostal space
- V2: Left 4th intercostal space
- V3: Midway between V2 and V4
- V4: Left 5th intercostal space (mid-clavicular line)
- V5: Left 5th intercostal space (anterior axillary line)
- V6: Left 5th intercostal space (mid-axillary line)
- Chest leads provide stronger signals due to proximity to the heart, detecting minute abnormalities in the ventricles





n a horizontal plane on the chest wall arround

Einthoven's Law

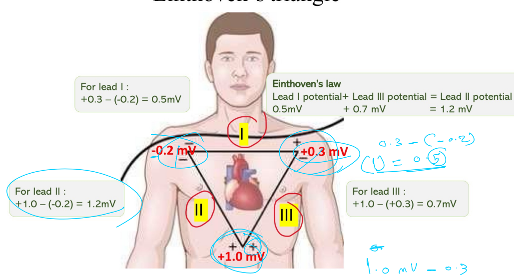
Einthoven's law states that at any given instant, the sum of the electrical potentials recorded in **Leads I and III equals** the potential recorded in **Lead II**:

Key Points:

1. **Mathematical Representation:**
- The law holds true as long as the three standard bipolar leads are recorded simultaneously.
- The correct signs (positive or negative) of the potentials must be used.

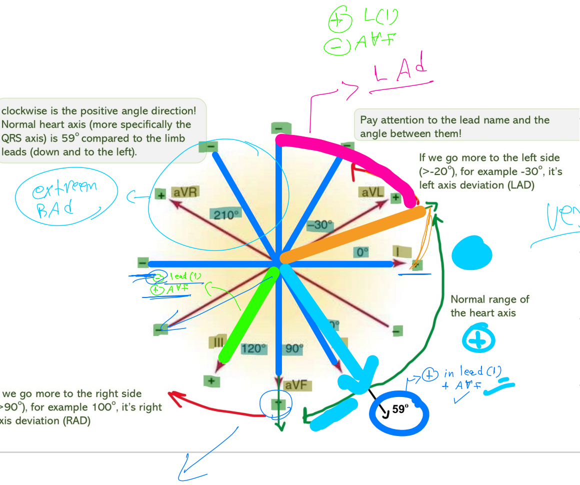
2. **Einthoven's Triangle:**
- Formed by the three limb leads (Lead I, II, and III).
- Example potentials:
- Lead I:
- Lead III:
- Lead II:
- Verification:

Einthoven's triangle



3. **ECG Measurements Using QRS Complex:**
- To calculate potentials:
- **Net Deflection** = Total positive deflection minus total negative deflection (QRS complex).
- Example:
- Lead I: 7 small squares up, 2 small squares down → →
- Lead II: 15 squares up, 3 squares down → →
- Lead III: 10 squares up, 3 squares down → →

4. **Application:**
- The exact number of squares on the ECG trace can vary, but the relationship defined by Einthoven's law remains constant.
- This principle helps validate the accuracy of ECG recordings.



Average detection of electrical activity through heart during depolarization (QRS)

vem

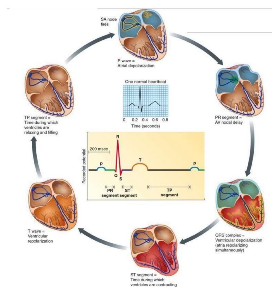
QRS vector

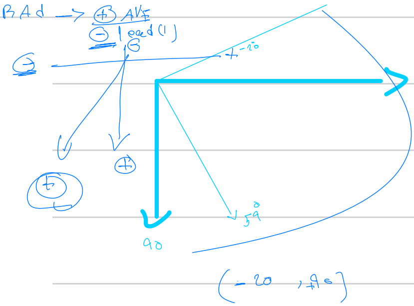
Normal ——> down to the left

LAd ⊕ lead (I)
⊖ AVF

BAd —> ⊕ AVF
⊖ lead (I)

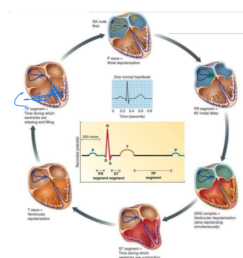
Normal axis between (-20 , +90)



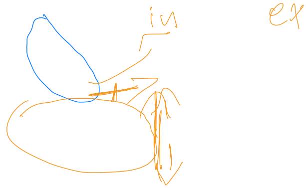


LBBB — LAd

RBBB — RAd



Causes of Axis Deviation in ECG



Left Axis Deviation (LAD)

Physiological Causes:

1. End of deep expiration.
2. Lying down (abdominal contents press upward on the diaphragm).
3. Obesity (increased visceral fat pushes the diaphragm upward).
4. Pregnancy (increased intra-abdominal pressure).

Pathological Causes:

1. **Left Ventricular Hypertrophy (LVH):**
   - More muscle on the left increases electrical potential.
   - Depolarization takes longer on the hypertrophied side.
2. **Left Bundle Branch Block (LBBB):**
   - Slower conduction on the left side shifts the axis to the left.

Right Axis Deviation (RAD)

Physiological Causes:

1. End of deep inspiration.
2. Standing up (gravitational effects on the heart).
3. Tall, thin individuals (vertical heart position).

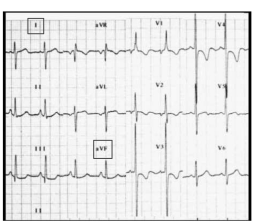
Pathological Causes:

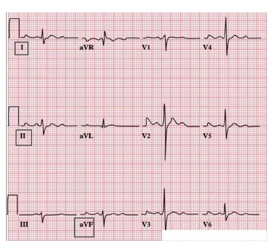
1. **Right Ventricular Hypertrophy (RVH):**
   - Similar to LVH, but affects the right side.
2. **Right Bundle Branch Block (RBBB):**
   - Slower conduction on the right side shifts the axis to the right.

Summary of Ventricular Hypertrophy:

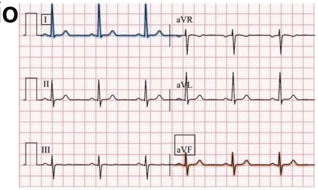
- **Hypertrophy shifts the axis toward the affected ventricle** due to:

1. Increased muscle mass generating greater electrical potential.
2. Prolonged depolarization time in the hypertrophied ventricle.





Summary of ECG Interpretation and Axis Determinatio



ECG Axis Interpretation:

1. **Step 1: Assess Lead I**
- Positive deflection: Axis likely normal or LAD.
- Negative deflection: Likely RAD.
2. **Step 2: Assess Lead aVF**
- Positive deflection: Confirms normal axis if Lead I is positive, or RAD if Lead I is negative.
- Negative deflection: Suggests LAD or possible normal axis.
3. **Step 3: Assess Lead II (if needed)**
- Negative deflection in Lead II confirms LAD.

Systematic Approach to ECG Interpretation:

1. **Standardization:** Ensure proper calibration, lead placement, and absence of artifacts.
2. **Heart Rate:**
- Calculate using the R-R interval:

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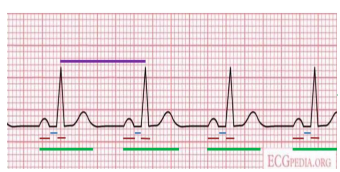
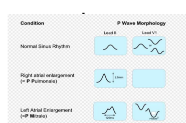
3. **Rhythm:**
- Normal rhythm characteristics:
- Each P wave followed by a QRS complex.
- PR interval within normal duration.
- Regular pattern of QRS and T wave.
4. **Waveform and Interval Analysis:**
- P wave: Morphology and consistency.
- PR interval: Duration and abnormalities.
- QRS complex: Duration, voltage, axis, and R-wave progression.
- QT interval: Duration.
- Abnormal Q wave: Assess for pathological significance.
- ST segment: Elevation or depression.
- T wave: Morphology and changes.
- U wave: Presence and clinical relevance.



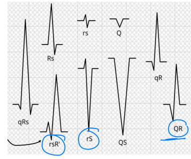
Heart Rate Variability (HRV):

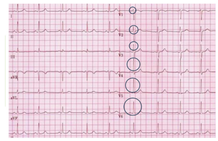
- Reflects the interplay between the sympathetic and parasympathetic systems of the autonomic nervous system (ANS).
- A healthy heart shows slight variations in R-R intervals due to environmental and physiological changes.

By following this systematic method, accurate interpretation of ECG findings is

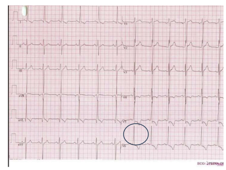


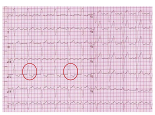
1. **R Wave and Lead-Specific Changes:**
- The **R wave** is the first upward (positive) deflection in the QRS complex, typically seen in Lead I.
- In **aVR**, due to inverted polarity, the usual positive deflection (ventricular depolarization) appears negative, so the naming changes:
- A small positive wave becomes the **r wave** (lowercase).
- A downward deflection is the **S wave**.
- A second small positive deflection is named **r′ wave**.





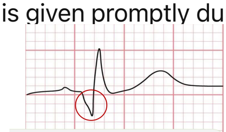
2. **R Wave Progression in Chest Leads (V1–V6):**
- The R wave amplitude increases from V1 to V6, while the S wave decreases.
- This normal progression reflects healthy depolarization and is termed **R wave propagation**.
- Abnormal high QRS amplitudes suggest **left ventricular hypertrophy** (e.g., due to hypertension).
- Low amplitudes may occur in:
- **Cardiac diseases** (e.g., amyloidosis).
- **Extracardiac causes** (e.g., pericardial effusion or emphysema).





3. **QRS Duration Abnormalities:**
- Normal QRS duration is **<3 small squares (0.12 seconds)** due to rapid conduction via Purkinje fibers.
- Prolonged QRS (e.g., **>5 small squares**) indicates conduction delay, such as a **bundle branch block (BBB)**.
- **Left Bundle Branch Block (LBBB):** Causes **Left Axis Deviation (LAD)** (positive Lead I, negative aVF, and negative Lead II).

4. **Pathological Q Waves:**
- Large Q waves may indicate previous **myocardial infarction (MI)** or current ischemia.
- Q waves can persist lifelong unless reperfusion therapy is given promptly during the MI.



5. **Ischemia vs. Infarction:**
- **Ischemia:** Temporary or partial blood flow reduction, leading to oxygen deprivation but reversible tissue damage if blood flow is restored.
- Example: **Angina** (chest pain) during heart ischemia.
- **Infarction:** Prolonged ischemia causing irreversible **tissue death** (e.g., myocardial infarction).
- Prompt reperfusion can prevent infarction.