ECG Basics: Simplified

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ECG Basics: Simplified
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Introduction

Electrocardiography (ECG) is a cornerstone of cardiovascular assessment and an invaluable diagnostic tool in clinical practice. It enables the identification of a wide array of cardiac conditions, including arrhythmias and myocardial infarctions. Additionally, it provides insights into the influence of systemic and non-cardiac disorders on the heart. Understanding the principles of ECG interpretation is crucial for accurate diagnosis and effective management of patients.

Key Components of ECG

1. **Leads and Planes:**

The 12-lead ECG comprises six limb leads (I, II, III, aVR, aVL, aVF) viewing the heart in the vertical plane, and six chest leads (V1–V6) in the horizontal plane.

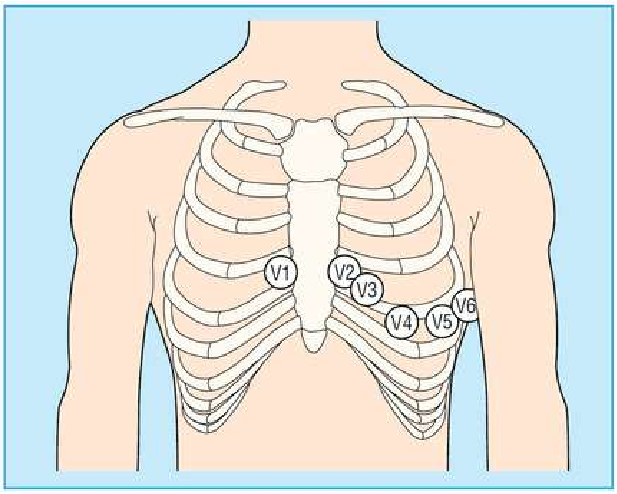
2. **Segments and Intervals:**

P wave, PR interval, QRS complex, ST segment, T wave, and QT interval offer detailed information about atrial and ventricular activity.

3. **Cardiac Axis:**

Indicates the direction of ventricular depolarization, assisting in diagnosing conditions like bundle branch blocks or ventricular hypertrophy.

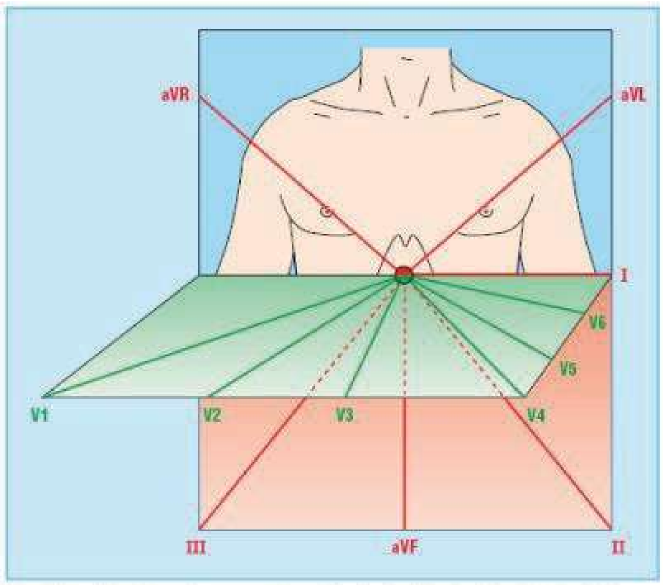
Where to place ECG Leads?



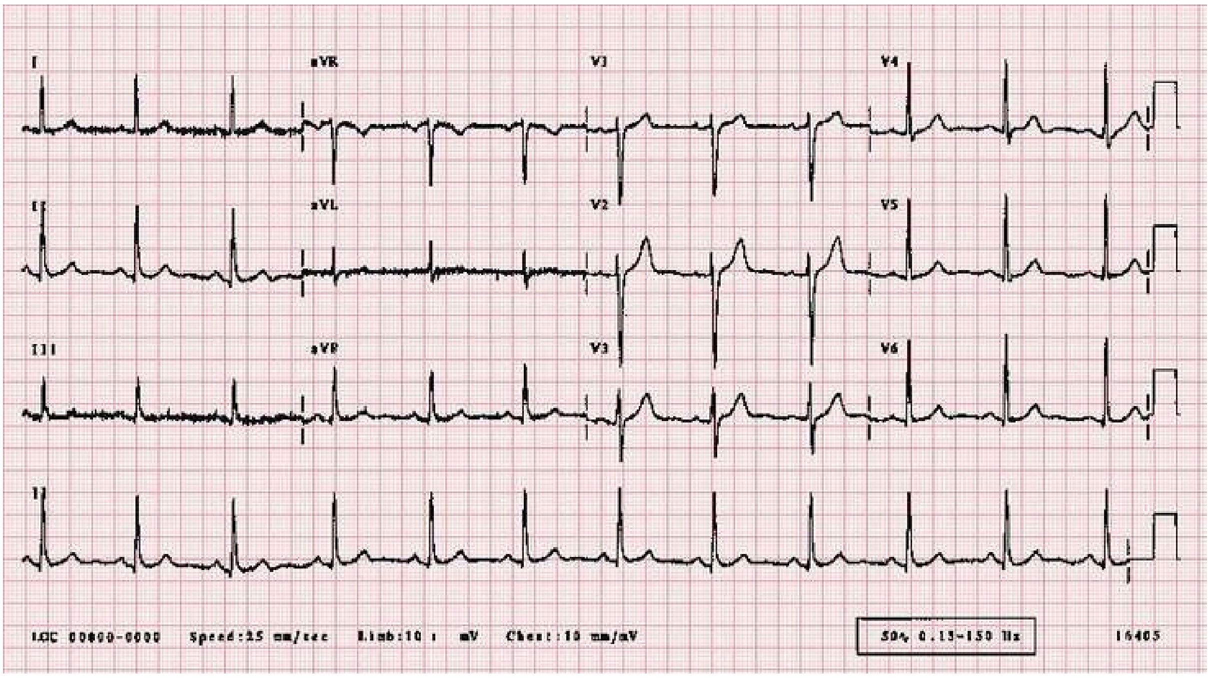
Position of the six chest electrodes for standard 12 lead electrocardiography. V1: right sternal edge, 4th intercostal space; V2: left sternal edge, 4th intercostal space; V3: between V2 and V4; V4: mid-clavicular line, 5th space; V5: anterior axillary line, horizontally in line with V4; V6: mid-axillary line, horizontally in line with V4

The six chest leads (V1 to V6) provide a view of the heart in the horizontal plane. Signals from the limb electrodes are combined to create six limb leads (I, II, III, aVR, aVL, and aVF), which offer a perspective of the heart in the vertical plane.

Together, these 12 leads form the standard electrocardiogram (ECG), offering a comprehensive assessment of the heart's electrical activity.

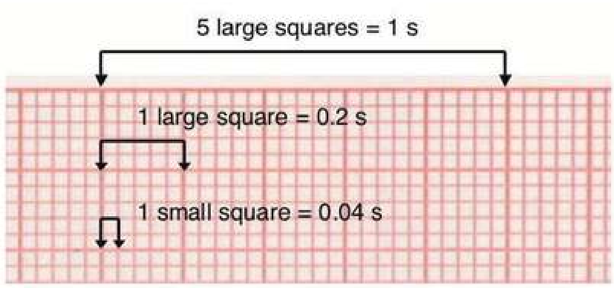


- Leads II, III, and aVF provide a view of the inferior surface of the heart.
- Leads V1 to V4 focus on the anterior surface of the heart.
- Leads I, aVL, V5, and V6 capture the lateral surface of the heart.
- Leads V1 and aVR offer a perspective through the right atrium into the heart's cavity.



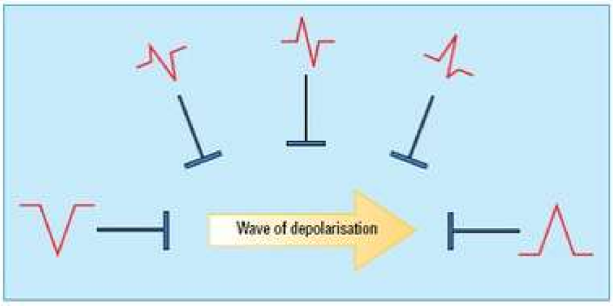
Normal ECG

The electrocardiogram (ECG) is recorded on standardized paper that moves at a speed of 25 mm per second. The paper is divided into large squares, each measuring 5 mm in width, corresponding to a time interval of 0.2 seconds. Within each large square are smaller squares, each 1 mm wide, representing a time interval of 0.04 seconds.



The amplitude of the waveform recorded on an ECG depends on several factors, such as the size of the heart muscle (myocardial mass), the direction of the electrical activity (depolarization vector), the thickness of surrounding tissues like the chest wall, and the distance between the heart and the ECG electrodes. Larger heart muscles produce higher amplitude waveforms, as seen in conditions like ventricular hypertrophy. Conversely, conditions like obesity, pericardial effusion, or emphysema, which create more resistance or increase the distance between the heart and electrodes, tend to reduce the waveform amplitude.

In cases of ventricular hypertrophy, the heart muscle is larger, which generates higher electrical activity, resulting in taller waveforms. On the other hand, conditions that increase resistance to the electrical signal, such as fluid around the heart (pericardial effusion), air-filled lung spaces (as in emphysema), or a thick chest wall (often due to obesity), result in dampened or smaller amplitude waveforms. Understanding these factors is crucial in interpreting ECGs accurately, as abnormal waveform amplitudes can provide important clues about underlying heart and systemic conditions.

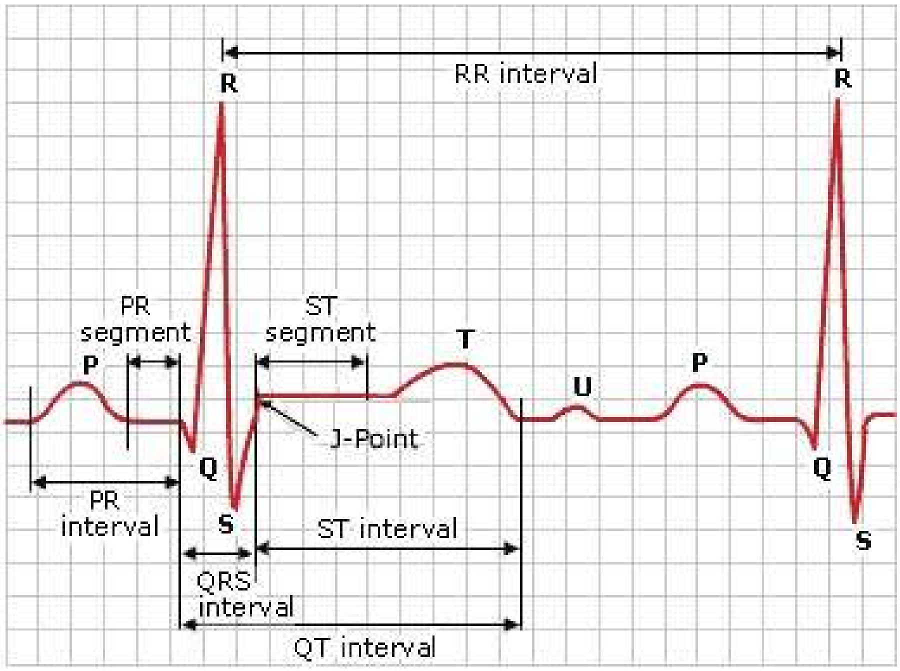


Wave of depolarisation. Shape of QRS complex in any lead depends on orientation of that lead to vector of depolarisation

Think of the heart's electrical activity like the sound of a speaker playing music. If the speaker is large and powerful (like a big heart muscle), the music will sound louder and clearer. But if there's something blocking the sound, like a thick blanket over the speaker (similar to fluid around the heart or extra fat on the chest), the music will be muffled and harder to hear. Similarly, a bigger heart muscle makes taller waves on the ECG, while conditions like fluid, air, or extra tissue around the heart make the waves smaller.

When the heart is stronger or working harder, like in a bigger speaker playing louder music, the ECG shows higher waves because the electrical signals are stronger. But if the sound has to travel through obstacles, like air, fat, or fluid, the signals weaken, and the ECG shows smaller waves. This helps us figure out if the heart is bigger than normal, surrounded by extra fluid, or if other conditions are dampening its signals.

THE BASICS



Rate

The heart has special pacemaker cells located in different areas, which generate electrical signals to maintain the heartbeat. These pacemaker cells can work independently to sustain the heart's rhythm if needed.

The natural pacemaker of the heart is the SA node (sinoatrial node), which normally generates signals at a rate of 60–100 beats per minute (bpm). If the SA node fails, other parts of the heart can take over, but at slower rates:

Atria: Less than 60 bpm
AV node (atrioventricular node): 40–60 bpm
Ventricles: 20–40 bpm

To measure the heart rate from an ECG, use the squares on the paper. The paper moves at a standard speed of 25 mm per second, with each large square representing 0.2 seconds.

This means there are five large squares per second and 300 large squares per minute. When the rhythm is regular, you can calculate the heart rate by counting the number of large squares between two consecutive R waves (peaks of the heartbeats) and dividing 300 by that number. Alternatively, you can count the small squares between two R waves and divide 1500 by that number for a more precise calculation.

Rhythm

Think of the heart's rhythm like a well-organized parade. The sinus node is the leader of the parade, sending signals to keep everyone marching in order. When the signals start at the sinus node and travel properly to the ventricles (the lower chambers of the heart), it's called a sinus rhythm.
This is the heart's "normal marching order."

To check if the parade (or rhythm) is normal, doctors often look at Lead II on an ECG, which gives the best view of the P wave (the start of the signal). For a rhythm to be sinus:

- The P wave (the start of the beat) should point upwards in Leads I and II.
- Every P wave should be followed by a QRS complex (the main heart contraction).
- The heart rate should be between 60 and 99 beats per minute—not too fast, not too slow, just like a steady marching pace.

Cardiac Axis

The cardiac axis is the overall direction of the heart's electrical activity during ventricular contraction. Imagine it as the compass pointing to where most of the heart's electrical signals are heading. **This direction is measured in the vertical plane, using a reference point based on Lead I.**

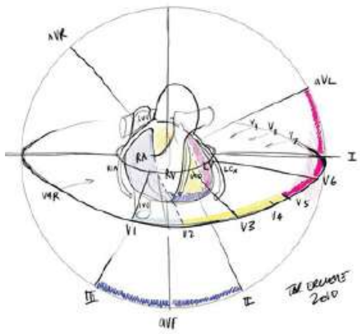
- If the electrical activity is heading above the reference line, the axis is assigned a negative value.
- If it is heading below the line, the axis has a positive value.
- The cardiac axis can range anywhere between -180° and +180°, but the normal range is between -30° and +90°.
- An axis beyond -30° is called left axis deviation.
- An axis greater than +90° is called right axis deviation.

Understanding the axis can help identify:

- Conduction defects: Like anterior hemiblock.
- Ventricular enlargement: Such as right ventricular hypertrophy.
- Broad complex tachycardia: Suggesting a ventricular origin.
- Congenital heart disease: Like atrial septal defects.
- Pre-excitation syndromes: For example, Wolff-Parkinson-White syndrome.
- The axis acts as a clue to uncover underlying cardiac conditions.

Calculating the cardiac axis

	Normal axis	Right axis deviation	Left axis deviation
Lead I	Positive	Negative	Positive
Lead II	Positive	Positive or negative	Negative
Lead III	Positive or negative	Positive	Negative



P Wave

The P wave represents the electrical activity during atrial depolarization (the heart's upper chambers contracting).

Here are its main characteristics:

- Leads I and II: The P wave is typically upright in these leads.
- Best Seen: It is most clearly observed in Leads II and V1.
- Biphasic in Lead V1: In this lead, the P wave often has two phases—an initial upward (positive) deflection followed by a downward (negative) deflection.
- Size: The width should be less than 3 small squares (0.12 seconds).
  The height (amplitude) should be less than 2.5 small squares (0.25 mV).

The P wave is directed inferiorly and to the left, making it upright in Leads I and II and inverted in Lead aVR.

Abnormalities in the P wave could be due to:

- Incorrect ECG placement (e.g., swapped left and right arm electrodes).
- Dextrocardia (heart positioned on the right side of the chest).
- Abnormal atrial rhythms.

A large biphasic P wave in Lead V1 may suggest left atrial enlargement, as seen in conditions like mitral stenosis. Slight notches in P waves are normal in some cases, but a pronounced notch (greater than 1 mm) may indicate delayed atrial conduction.

PR Interval

The PR interval measures the time it takes for the electrical impulse to travel:

Through the atrioventricular (AV) node, down the bundle of His, into the Purkinje fibers, which stimulate the ventricles. This interval starts at the onset of the P wave and ends at the beginning of the QRS complex, marking the time between atrial and ventricular depolarization. A prolonged PR interval can indicate transmission delays, such as: AV block or Other conduction system abnormalities.

Understanding these details helps identify conditions affecting atrial conduction and AV node function.

QRS Complex Overview

The QRS complex represents ventricular depolarization, which is the electrical activity that causes the ventricles to contract. The electrical wave starts at the endocardium (inner layer of the heart) at the apex of the ventricles and spreads outward to the epicardium (outer layer).

The left ventricle has a larger muscle mass than the right, so its electrical signals dominate the QRS complex on the ECG.

Nomenclature for QRS Components

Q wave: The first downward deflection after the P wave.
R wave: The first upward deflection.
S wave: The downward deflection following the R wave.

Normal Duration of the QRS Complex

The width of the QRS complex is measured in the lead with the widest QRS complex. It should not exceed 0.10 seconds (2½ small squares). A wide QRS complex (≥ 0.12 seconds) suggests a delay in ventricular conduction, such as a bundle branch block.

Septal Depolarization

The electrical impulse begins on the left side of the septum and spreads to the right. This creates:

- A small positive deflection (R wave) in Lead V1, located on the right side of the chest.
- A small “septal” Q wavein the lateral leads (I, aVL, V5, and V6). These are considered normal if:
    - They are less than 1 small square wide.
    - They are less than 2 small squares deep.
    - They are less than ¼ of the R wave's amplitude.

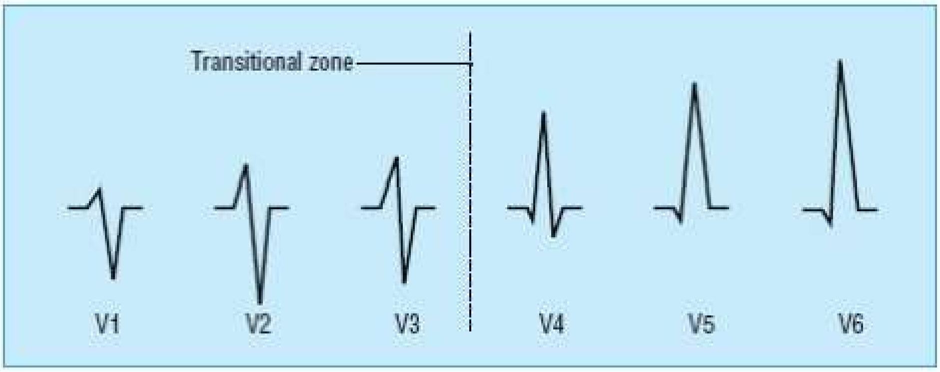
QRS Morphology in Precordial Leads

In the precordial leads, the QRS morphology changes as electrical forces move across the heart:

- In Lead V1, a small R wave is followed by a large S wave.
- The R wave gradually increases in amplitude from V1 to V6 as it reflects the larger left ventricle.

Causes of a Positive R Wave in Lead V1

Normal variation in children and young adults.; RVH; Pulmonary Embolism; Right Bundle Branch Block (RBBB); Posterior Myocardial Infarction (visible in Leads V7, V8, V9); WPW syndrome; Incorrect lead placement (e.g., V1 and V3 switched); Dextrocardia; Hypertrophic Cardiomyopathy; Muscular dystrophies, such as Myotonic or Duchenne dystrophy



R Wave Progression

The R wave, which represents ventricular depolarization, gradually increases in size from Lead V1 to V6:

- In Lead V1, the QRS complex is mostly negative (larger S wave).
- By Lead V6, the QRS complex is mostly positive (larger R wave).
- The lead where the QRS complex is equally positive and negative is called the transition zone and is typically between Leads V3 and V4.

R Wave Height

- The R wave height increases across the precordial leads, peaking in V5 and V6.
- Normally, the R wave in V6 is slightly smaller than in V5, as Lead V6 is further from the left ventricle.
- A tall R wave is defined as an R wave as tall as or taller than the S wave in the same lead.

S Wave

- The S wave (a downward deflection after the R wave) is deepest in Lead V1 and becomes smaller moving across the precordial leads.
- By Leads V5 and V6, the S wave is often absent.
- The depth of the S wave in a normal individual should not exceed 30 mm.

Low Voltage QRS

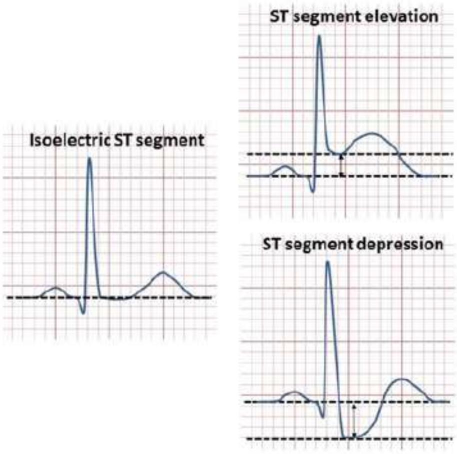
A low voltage QRS is defined as:

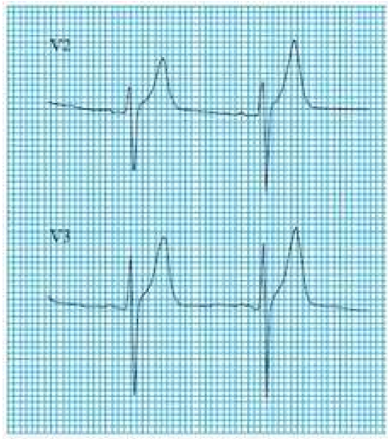
- QRS amplitudes < 5 mm in all limb leads, or
- QRS amplitudes < 10 mm in all precordial leads.

Conditions Associated with Low Voltage QRS

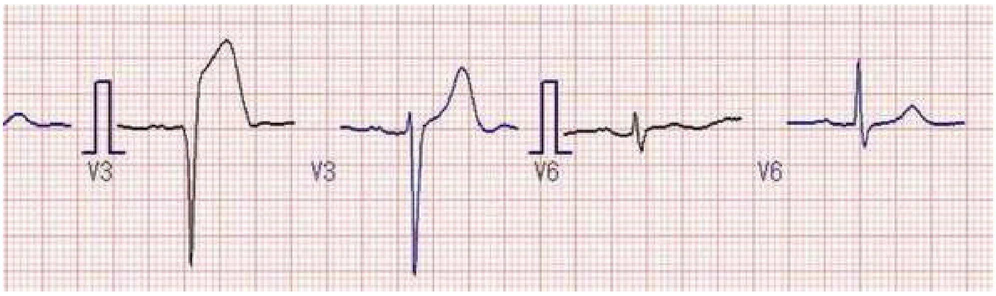
Myxedema; Large pericardial effusion; Large pleural effusion; End-stage cardiomyopathy; Chronic obstructive pulmonary disease (COPD); Severe obesity.

Myocardial diseases (e.g., scarring from prior massive MI); This gradual R wave progression and potential for low voltage provide important insights into the heart's size, position, and surrounding conditions.





Complexes in leads V2 and V3 showing high take-off



ST Segment

The ST segment lies between the J point (where the QRS complex ends) and the beginning of the T wave. It represents the time between the end of ventricular contraction (depolarization) and the start of ventricular relaxation (repolarization).

- In Leads V1 to V3, the S wave often blends with the T wave, making the J point and ST segment less distinct. This is referred to as "high take-off" and is a normal finding.
- A slight ST segment elevation can occur in certain individuals, such as young men, athletes, or people of African descent, without indicating any disease. This is called benign early repolarization.

Identifying ST Segment Changes are a 'Must-Know' and is beyond the scope of this document. Visit ECGRULER.com for ECG learning resources and quizzes.

Certain acute brain conditions can cause severe ECG changes that resemble acute myocardial infarction but are not related to heart disease. These changes are often seen in conditions like Haemorrhagic stroke, Subdural or epidural hematomas, Seizures, Subarachnoid haemorrhage.

ECG Manifestations

These conditions can lead to disturbances in the repolarization phase of the heart's electrical cycle, visible as:

- Prolonged QT interval (longer time for ventricles to reset between beats).
- Prominent, peaked T waves (tall and sharp).
- Deeply inverted, symmetric T waves (consistent abnormal downward deflection).

T Wave

The T wave represents ventricular repolarization, or the process of the ventricles relaxing and preparing for the next contraction. Key features include:

- The orientation of the T wave typically matches that of the QRS complex.
- The T wave is normally inverted in Lead aVR and can also be inverted in Lead III.

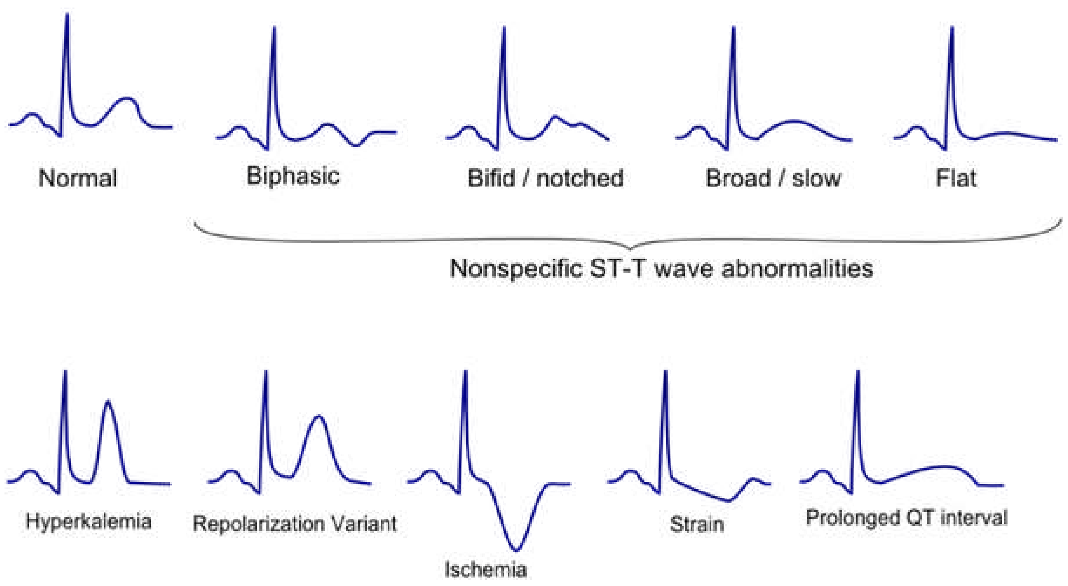
T Wave Inversions

- Lead V1: T wave inversion is common and not necessarily abnormal.
- Lead V2: Isolated T wave inversion is abnormal.
- Two or more right precordial leads (e.g., V1, V2): Persistent T wave inversion here is known as a persistent juvenile pattern, more commonly seen in people of African descent.

Shape of the T Wave

The normal T wave is asymmetrical, with the first half rising gradually and the second half descending more steeply. Symmetrical, inverted T waves are a strong indicator of myocardial ischemia (reduced blood flow to the heart). Asymmetrical, inverted T waves are often nonspecific and not always tied to a particular condition.

T Wave Morphologies

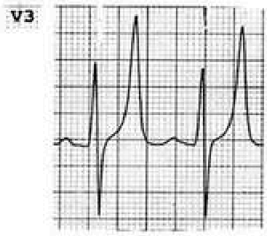


T Wave Amplitude

The size of the T wave on an ECG is closely related to the size of the preceding R wave. Some general rules for T wave amplitude include:

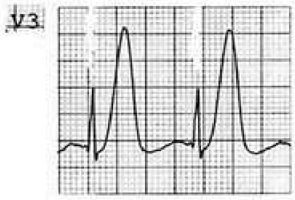
- The T wave should be at least ⅛ but less than ⅔ of the R wave's amplitude.
- The T wave rarely exceeds 10 mm in height.
- The tallest T waves are typically seen in Leads V3 and V4.

Hyperkalemia



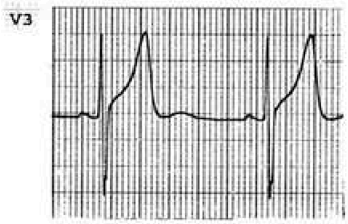
Symmetric, narrow-based, pointed, tenting

Hyperacute Ischemia



Symmetric, broad-based, not tented, not pointed
QT interval tends to be long (not in this example)

Normal Variant



Asymmetric and not narrow

Causes of Tall T Waves

- Tall T waves may occur in the following conditions:
- Hyperkalemia (high potassium levels): Produces tall, narrow, and peaked T waves.
- Acute myocardial ischemia: Early signs of ischemia often show tall and broad T waves (hyperacute T waves).
- Left ventricular hypertrophy: Increased muscle mass in the left ventricle can cause larger T waves.
- Benign early repolarization: Common in young and athletic individuals.
- Bundle branch blocks: May alter T wave morphology.
- Other syndromes: Including conditions like hypertrophic cardiomyopathy or idiopathic variations.
- Understanding these changes helps in identifying whether tall T waves are pathological or part of normal variation.

QT Interval

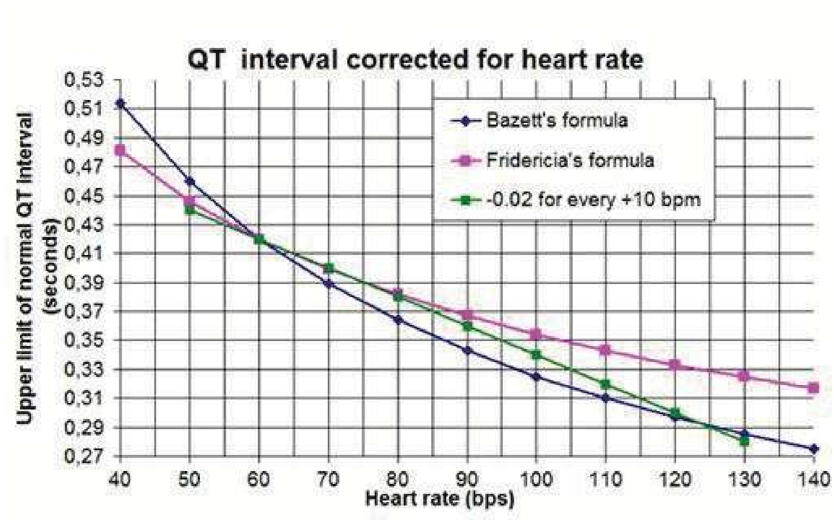
The QT interval represents the time taken for the ventricles to contract (depolarize) and then relax (repolarize). It is a critical marker for heart health.

- The QT interval is measured from the beginning of the QRS complex to the end of the T wave.
- Prominent U waves (small waves following the T wave) can sometimes be confused with the T wave, leading to an overestimation of the QT interval. To avoid this, the QT interval is often measured in Lead aVL, which typically lacks prominent U waves.

The QT interval gets longer when the heart rate slows and shorter when the heart rate increases. This is why it's important to consider the heart rate when measuring the QT interval.

General Guidelines:

- The normal QT interval ranges from 0.35 to 0.45 seconds.
- It should always be less than half of the RR interval, which is the time between two consecutive R waves.



QT Interval

The QT interval can vary based on age and gender:

- It tends to increase slightly with age.
- Women usually have a longer QT interval compared to men.

To account for heart rate, the QT interval is often corrected (QTc) using a formula like Bazett's correction:

$$\text{QTc} = \frac{\text{QT interval in seconds}}{\sqrt{\text{cardiac cycle in seconds}}} = \frac{\text{QT}}{\sqrt{\text{RR}}}$$

U Wave

The U wave is a small wave that appears after the T wave and represents the final stage of ventricular repolarization.

Key Features:

- Appearance: Generally upright, except in Lead aVR.
- Prominence: Most visible in Leads V2 to V4.
- Origin: Believed to arise from:
  - Mid-myocardial cells (cells between the inner and outer heart layers).
  - The His-Purkinje system (part of the heart's electrical conduction pathway).

Conditions Associated with Prominent U Waves:

- Athletes: Common as a normal finding.
- Hypokalemia: Low potassium levels.
- Hypercalcemia: High calcium levels.
- Torsades de Pointes: A specific type of abnormal heart rhythm.

While many ECGs do not show visible U waves, their presence can provide important diagnostic clues when prominent.

COMBINE ALL THE ABOVE AND YOU HAVE THE CLASSIC 10-STEP METHOD TO FULLY ANALYZE AN ECG

1. Rate: Measure the heart rate using the RR intervals.
2. Rhythm: Identify the heart rhythm (e.g., sinus rhythm).
3. Axis: Determine the cardiac axis to assess electrical activity direction.
4. P Waves: Evaluate P wave presence, shape, and relationship with the QRS complex.
5. PR Interval: Measure the PR interval to assess atrial conduction.
6. QRS Complex: Analyze width, amplitude, and morphology of the QRS complex.
7. ST Segment: Check for elevation, depression, or other abnormalities.
8. T Waves: Assess T wave shape, orientation, and any inversions.
9. U Waves: Look for the presence or prominence of U waves.
10. QT Interval: Measure the QT interval and correct it for heart rate (QTc).

ECG LEARNING takes a lot of patience, dedication and practice.

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