Practical guide to ECG

1. Preparation for ECG

Before performing the ECG, ensure the patient is ready and the equipment is correctly set up.

Step 1: Prepare the Patient

- **Patient Positioning:** Have the patient lie down in a comfortable position, preferably supine (on their back), with their arms at their sides.
- **Exposure:** Ensure that the patient's chest, arms, and legs are exposed to allow for electrode placement. If needed, clean the skin of any excess hair or oils with alcohol swabs to improve electrode adhesion and signal quality.
- **Comfort:** Ensure the patient is relaxed and at rest for at least 5 minutes before the test. This helps reduce artifacts caused by muscle tension or movement.

Step 2: Choose Correct Lead Placement

- **Limb Electrodes:** Place the electrodes on the patient's limbs:
  - **Right Arm (RA):** Just above the wrist.
  - **Left Arm (LA):** Just above the wrist.
  - **Right Leg (RL):** Just above the ankle (ground electrode).
  - **Left Leg (LL):** Just above the ankle.
- **Precordial Electrodes (Chest Leads):**
  - **V1:** 4th intercostal space, right of the sternum.
  - **V2:** 4th intercostal space, left of the sternum.
  - **V3:** Between V2 and V4.
  - **V4:** 5th intercostal space, midclavicular line.
  - **V5:** 5th intercostal space, anterior axillary line.
  - **V6:** 5th intercostal space, midaxillary line.

How to Locate the 4th Intercostal Space from the Suprasternal Notch

To properly locate the **4th intercostal space**, follow these steps:

- **Identify the Suprasternal Notch**:
  The **suprasternal notch** is a dip at the top of the sternum, just above the manubrium (the top portion of the sternum).
- **Locate the Sternum**:
  From the suprasternal notch, move your fingers downward along the sternum to feel the **manubrium** (the upper portion of the sternum). Then, move further down until you feel the **body of the sternum**.
- **Count the Intercostal Spaces**:
  - The **1st intercostal space** is just below the clavicle (collarbone).
  - The **2nd intercostal space** is found by feeling for the second rib directly below the clavicle. You can consider the **manubrium** to be at the level of the **2nd**

intercostal space (ICS). Once you locate this, move down two spaces to identify the **4th intercostal space**.

  - The **3rd intercostal space** is below the 3rd rib.
  - The **4th intercostal space** is located directly beneath the **4th rib**.
- **Locate the 4th Intercostal Space**:
  Once you have identified the 4th rib, the space directly below it is the **4th intercostal space**. This is the location where you will place the V1 and V2 electrodes.

Ensure the leads are attached securely and check for good contact to avoid poor signal quality.

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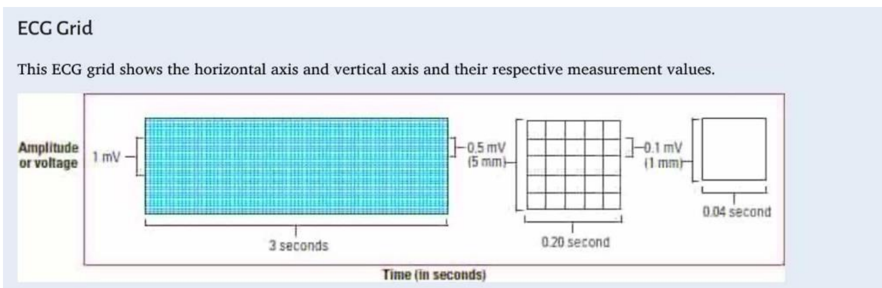
2. Standardizing the ECG

Ensuring that the ECG is standardized is crucial for accurate interpretation.



Step 1: Check Calibration

- Confirm that the **ECG machine is properly calibrated.**
- The standard calibration should show a 10 mm tall deflection for each 1 mV input signal. Check the calibration square on the ECG to verify.

Step 2: Verify Paper Speed and Sensitivity

- **Paper Speed**: Set the paper speed to **25 mm/second**.
- **Sensitivity**: Set the sensitivity to **10 mm/mV**.

ECG Strip Basics

- The **horizontal axis** of the ECG strip represents **time**:
  - Each **small block** equals **0.04 seconds**.
  - **Five small blocks** form a **large block**, which equals **0.2 seconds**.
  - **Five large blocks** equal **1 second** (5 x 0.2).
  - When measuring or calculating the heart rate, a **6-second strip** consisting of **30 large blocks** is commonly used.

- The **vertical axis** of the ECG strip measures **amplitude** in millimeters (mm) or **electrical voltage** in millivolts (mV):
    - Each **small vertical block** represents **1 mm** or **0.1 mV**.
    - Each **large vertical block** represents **5 mm** or **0.5 mV**.

Amplitude Measurement

To determine the amplitude of a wave, segment, or interval:

- Count the number of small blocks from the **baseline** to the **highest** or **lowest point** of the wave, segment, or interval.

3. Recording the ECG

Once the patient is prepared and the machine is calibrated, begin recording.

Step 1: Record the ECG

- Ask the patient to stay as still and relaxed as possible during the recording.
- Allow at least 10–15 seconds of ECG recording for a clear result, ensuring that all 12 leads are captured.
- Observe the tracing on the screen or paper for any irregularities, and make sure the signals are clear and free from artifacts.

Step 2: Confirm Full Lead Coverage

- Ensure all 12 leads are recorded (if performing a 12-lead ECG). A complete ECG includes 3 bipolar limb leads (I, II, III), 3 augmented limb leads (aVR, aVL, aVF), and 6 precordial (chest) leads (V1–V6).
- Check the quality of the trace. If there is noise, poor signal, or incorrect placement of electrodes, you may need to reposition them or recheck connections.

A look on ECG complex:

The **P wave** is the first component of a normal ECG waveform, representing **atrial depolarization**, which is the conduction of an electrical impulse through the atria.

When evaluating the **P wave**, focus on its key characteristics, including **location**, **amplitude**, **duration**, **configuration**, and **deflection**.

Normal P Wave Features:

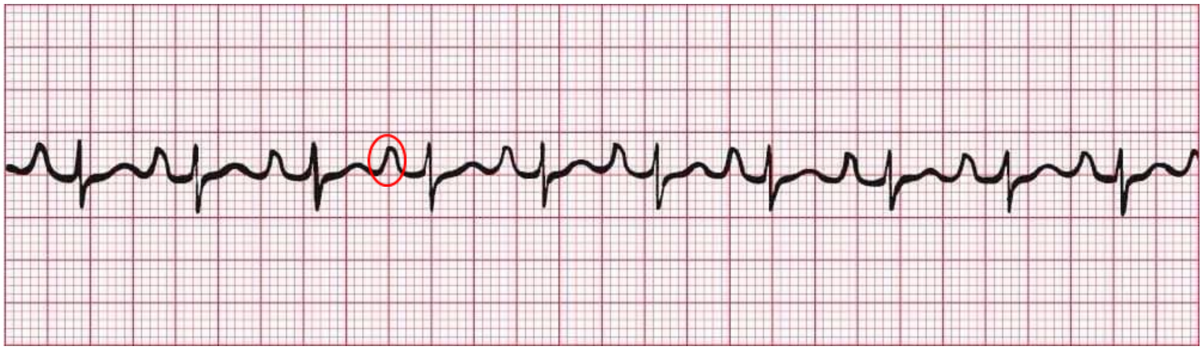
1. **Location**:
    - The **P wave** always precedes the **QRS complex**.
2. **Amplitude**:
    - **< 0.25 mV** (or **2.5 mm** or **2.5 small squares** high).
3. **Duration**:
    - **< 0.12 second** (or **3 small squares** in length, as each horizontal square represents 0.04 seconds).
4. **Configuration**:
    - The P wave is typically **rounded and upright**.
5. **Deflection**:
    - The P wave is **positive (upright)** in leads **I, II, aVF**, and **V2-V6**.
    - It is **usually positive, but can be variable** in leads **III** and **aVL**.
    - It is **negative (inverted)** in lead **aVR**.

Abnormalities of the P Wave

Two key conditions that cause significant alterations to the P wave are **right atrial hypertrophy (P pulmonale)** and **left atrial hypertrophy (P mitrale)**.

Right Atrial Hypertrophy (P Pulmonale)

- **Cause**: Conditions such as **pulmonary hypertension**, **tricuspid valve stenosis**, and other factors that increase the workload on the right atrium.
- **ECG Findings**:
    - The **P wave** becomes **peaked** or **tall** in amplitude, typically **greater than 2.5 mm in lead II**.
    - The P wave shape is **tall and narrow**, reflecting increased electrical activity in the hypertrophied right atrium.



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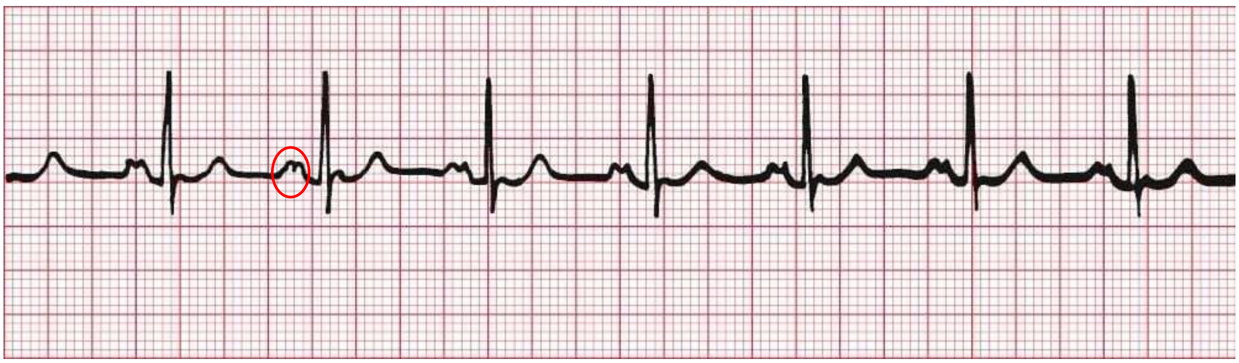
Left Atrial Hypertrophy (P Mitrale)

- **Cause**: Most commonly caused by **mitral stenosis**, but also seen in conditions that elevate left atrial pressure, such as **left heart failure** and **hypertensive heart disease**.
- **ECG Findings**:
  - The **P wave** becomes **broad** and **bifid** (notched), especially in lead II.
  - A **prolonged P wave duration** (≥ 0.12 second) indicates delayed conduction through the left atrium, a hallmark of left atrial enlargement.



PR Interval in ECG

The **PR interval** is measured on the **horizontal axis** of the ECG, from the **beginning of the P wave** to the **beginning of the adjacent QRS complex**. It reflects the time taken for the **atrial impulse** to travel through the **AV node**, the **bundle of His**, and the **right and left bundle branches**.

When evaluating the **PR interval**, the primary factor to consider is its **duration**. Changes in the PR interval may indicate alterations in impulse formation or conduction delays, such as those seen in **AV block**.

PR Interval Characteristics:

- **Location**: From the **beginning of the P wave** to the **beginning of the QRS complex**.
- **Duration**:
  - Normal PR interval: **0.12 to 0.20 seconds** (equivalent to **3 to 5 small squares** on the ECG paper; each small square is 0.04 seconds).

Abnormalities in the PR Interval:

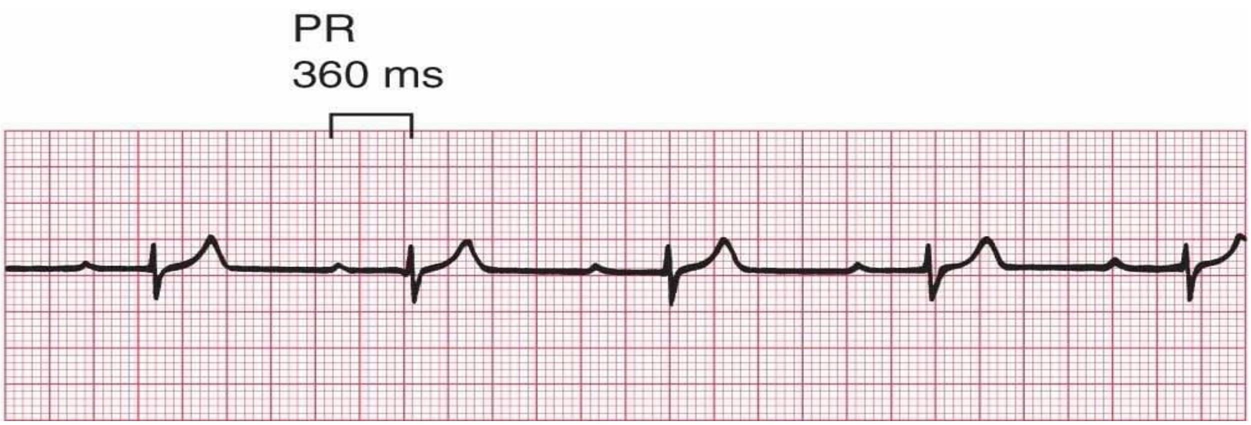
1. **Short PR Interval** (< 0.12 seconds):
    - Indicates that the impulse originated **outside the SA node**, often from an ectopic focus.
    - Associated with **pre-excitation syndromes** (e.g., **Wolff-Parkinson-White (WPW) syndrome**).
2. **Prolonged PR Interval** (> 0.20 seconds):
    - Suggests delayed conduction through the **AV node**, the **atria**, or the **AV junction**.
    - Can be seen in conditions such as:
        - **Heart block** (e.g., **first-degree AV block**).
        - **Myocardial ischemia/infarction**, where **heart injury** or **damage** causes delayed conduction.

First-Degree Heart Block

If each wave of depolarization originating from the SA node is conducted to the ventricles, but there is a delay somewhere along the conduction pathway, the PR interval becomes prolonged. This is known as **first-degree heart block**.

Fig. First-Degree Heart Block

- One P wave per QRS complex.
- PR interval is **prolonged**.



Second-Degree Heart Block

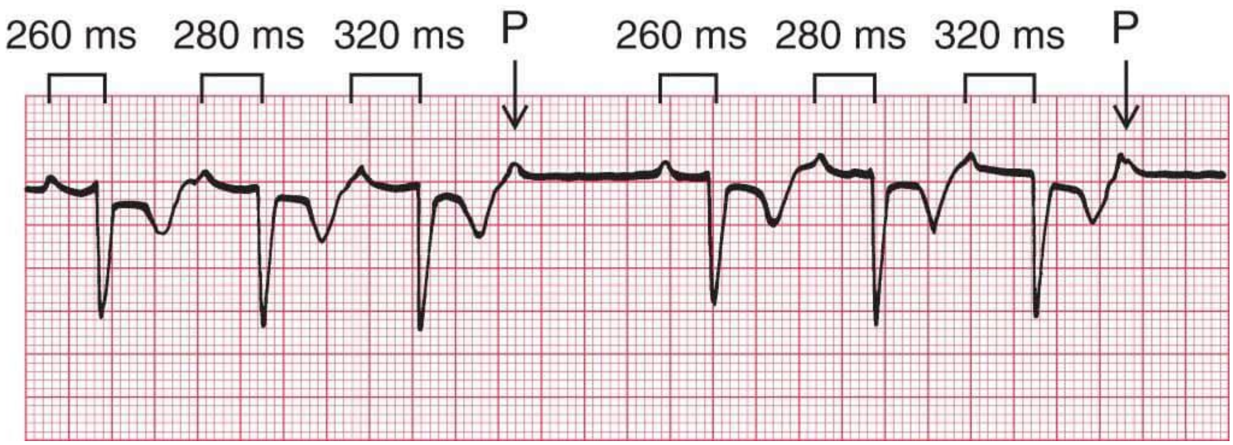
In **second-degree heart block**, excitation intermittently fails to pass through the AV node or bundle of His. This results in a partial blockage of the conduction system. There are two main types of second-degree heart block, each with its own characteristic features:

1. Wenckebach (Mobitz Type 1)

In this type, there is **progressive lengthening** of the PR interval until one atrial impulse is **not conducted** to the ventricles, followed by a conducted beat with a shorter PR interval, starting the cycle over again.

Wenckebach (Mobitz Type 1)

- **Progressive lengthening** of the PR interval.
- One **non-conducted P wave**.
- The next conducted beat has a **shorter PR interval** than the previous conducted beat.
- A **P wave** may occasionally appear as a distortion of the **T wave**.

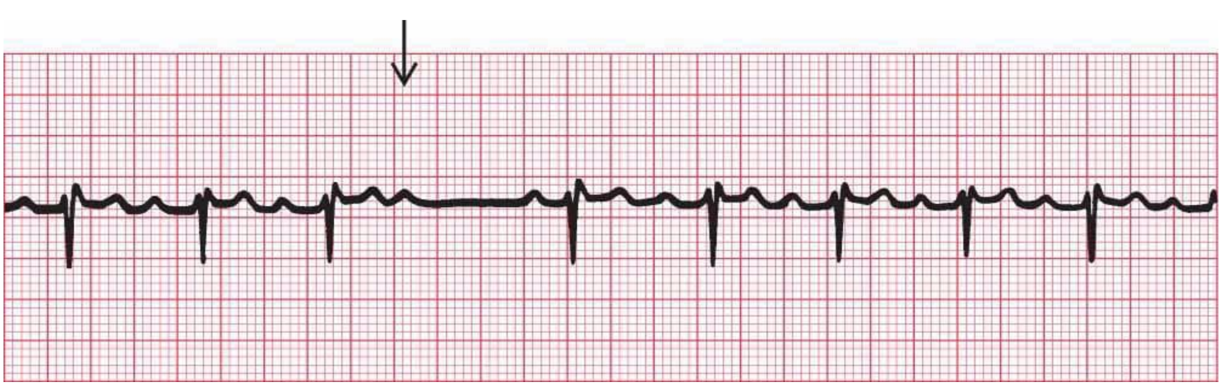


2. Mobitz Type 2

In this type, most beats are conducted with a **constant PR interval**, but occasionally an **atrial depolarization** is not followed by a **ventricular depolarization**.

Mobitz Type 2

- The **PR interval** of the conducted beats is **constant**.
- Occasionally, a **P wave** is **not followed** by a QRS complex.



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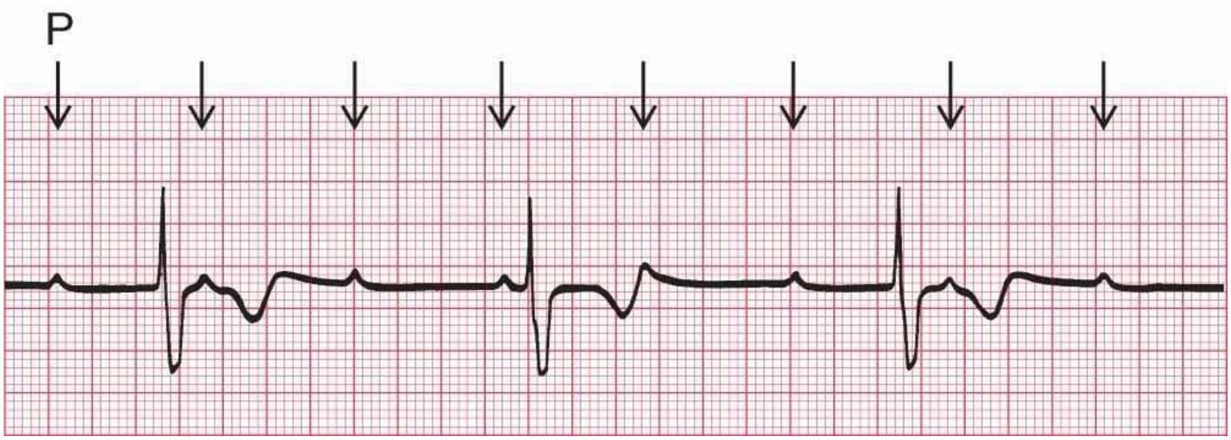
Third-Degree Heart Block

Complete heart block, also known as **third-degree heart block**, occurs when the atrial contractions are normal, but no impulses are conducted to the ventricles. In this condition, the ventricles are activated by a slow **escape mechanism** from a depolarizing focus within the ventricular muscle.

- **P wave rate**: 90 bpm (normal atrial rate).
- **No relationship** between the P waves and QRS complexes (complete dissociation).
- **QRS complex rate**: 36 bpm (ventricular rate).
- **Abnormally shaped QRS complexes** due to the abnormal spread of depolarization from the ventricular escape focus.



QRS Complex in ECG

The **QRS complex** follows the **P wave** and represents **ventricular depolarization** and contraction, also known as **ventricular systole**.

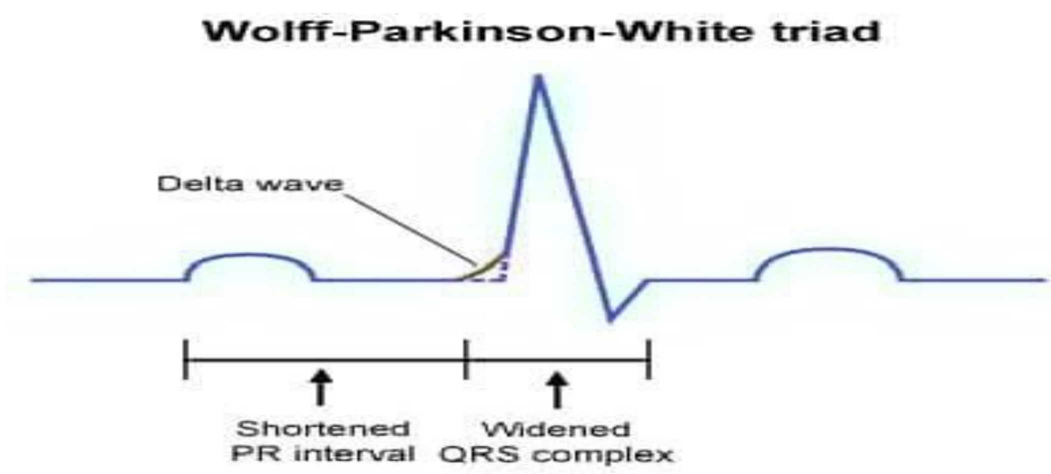
Normal QRS Complex Characteristics:

1. **Location**:
   - The QRS complex follows the **PR interval**.
2. **Amplitude**:
   - Typically ranges from **5 to 30 mV** (1 mm to 6 small squares high), though it can vary depending on the lead being used.
3. **Duration**:
   - Normal duration is **0.06 to 0.12 seconds** (or **1.5 to 3 small squares**).
   - Duration is measured from the **beginning of the Q wave** to the **end of the S wave**, or from the **beginning of the R wave** if the Q wave is absent.

4. **Configuration**:
    - The QRS complex consists of three waves:
        - **Q wave**: The first **negative deflection** after the P wave.
        - **R wave**: The first **positive deflection** after the P wave (or after the Q wave).
        - **S wave**: The first **negative deflection** after the R wave.
    - All three waves (Q, R, S) may not be visible in every lead, but the **R wave** is usually the most prominent.
5. **Appearance**:
    - The QRS complex is typically **narrow** and **sharp** because the ventricles depolarize quickly, minimizing the contact time between the stylus and the ECG paper.

- **Widened QRS Complex:** A QRS complex is considered **abnormally wide** in the following situations:

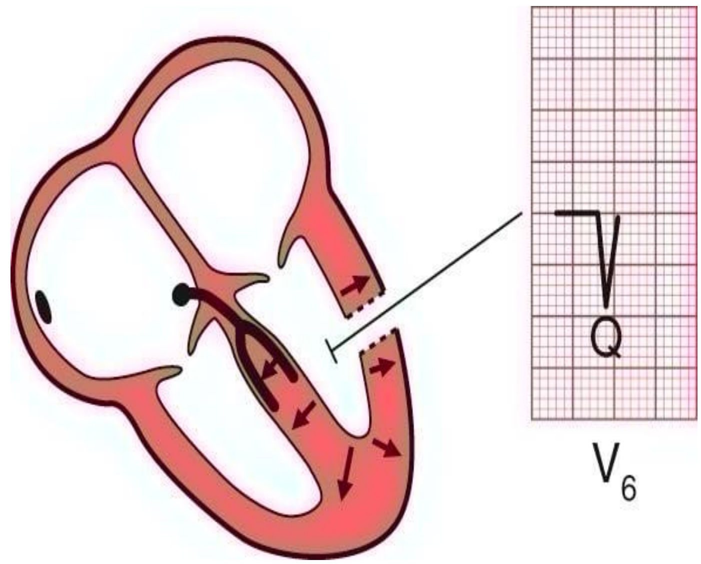
    1. **Bundle Branch Block**: bundle branch block causes a delay in the conduction of electrical impulses through the ventricles, leading to a wider QRS complex.
    2. **Ventricular origin of arrhythmia**: When depolarization originates from a focus in the ventricular muscle (such as in ventricular escape beats, ectopic beats, or ventricular tachycardia), it follows an abnormal and slower pathway through the ventricles, causing a widened QRS complex.
    3. **Wolff–Parkinson–White (WPW) Syndrome**: In WPW syndrome, a pre-excitation pathway bypasses the normal AV node conduction, leading to a shorter and wider QRS complex and a **shortened PR interval.**



- **Increased Height of the QRS Complex:** An increase in the **height of the QRS complex** may indicate **increased ventricular muscle mass**. This can be due to conditions such as **ventricular hypertrophy**, where the enlarged ventricles generate more electrical activity, resulting in a taller QRS complex.

The Origin of pathological Q Waves

- Small "Q" waves in the left ventricular leads typically represent the normal depolarization of the septum from left to right. **Q waves** that are larger—greater than 1 small square in width (40 ms) and more than 2 mm in depth—indicate a different scenario.
- Normally, the ventricles depolarize from the inside out. If an electrode is placed inside the ventricle, it will only record a **Q wave** because the depolarization waves move away from it. If a **myocardial infarction (heart attack)** causes complete damage to the heart muscle (from the inner to outer layers), it creates an "electrical window." This allows the electrode to record a **cavity potential**, or a deep Q wave, which is a sign of infarction.



ST Segment in ECG

The flat, **isoelectric** portion of the ECG that occurs from the **end of the S wave** to the **beginning of the T wave**.

The point where the **QRS complex** ends and the **ST segment** begins is called the **J point**.

Normal ST Segment Characteristics:

- **Location**:
  - Extends from the **end of the S wave** to the **beginning of the T wave**.
- **Deflection**:
  - Typically, **isoelectric** (neither positive nor negative).

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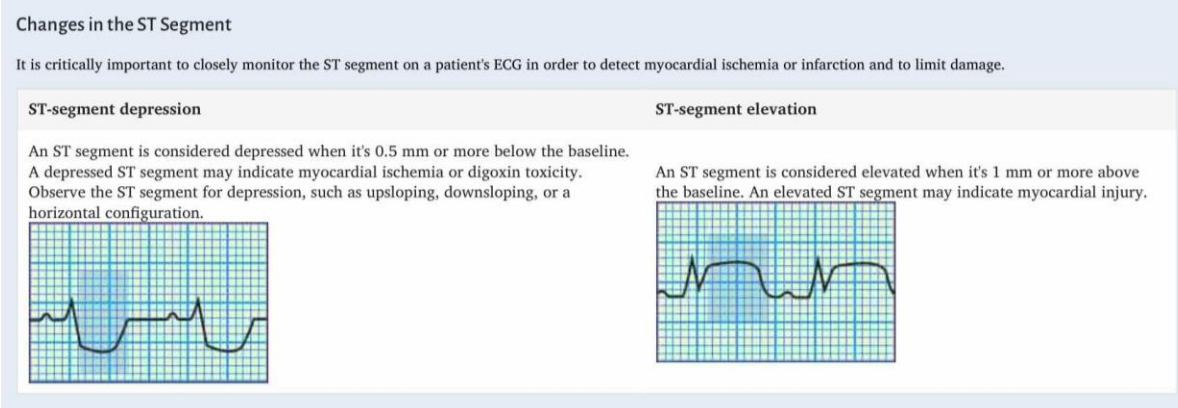
May vary slightly, usually between **-0.5 mm to +1 mm** in some **precordial leads**.

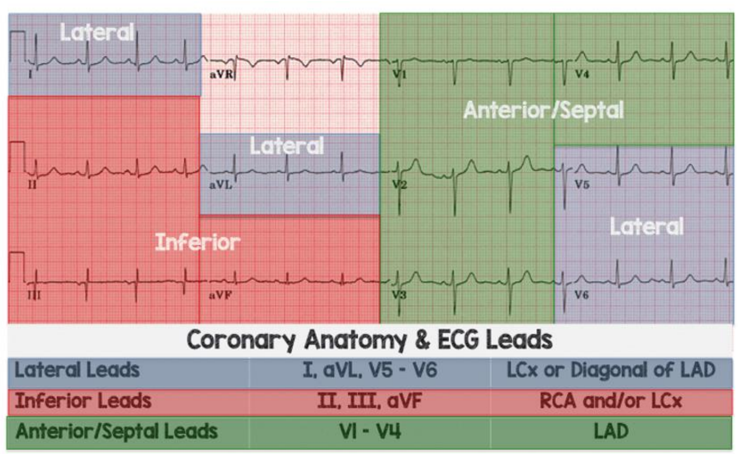


- **STEMI (ST-Elevation Myocardial Infarction** is diagnosed when:
  - There is more than **1 mm** of **ST segment elevation** in at least two contiguous **limb leads** (e.g., I and VL, or III and VF).
  - Or, there is more than **2 mm** of **ST segment elevation** in at least two contiguous **chest leads**.

A diagnosis of STEMI can also be made if there is a **new left bundle branch block (LBBB)**.

- The **ST segments** rise in the ECG leads that correspond to the area of the heart affected by the infarction. The areas and their corresponding leads are as follows:
  - **Anterior Infarction**: Leads **V1–V4**
  - **Lateral Infarction**: Leads **I, aVL, V5, V6**
  - **Inferior Infarction**: Leads **II, III, aVF**
  - **Posterior Infarction**: Leads **V7–V9** (Note: Posterior infarction is not directly visible on the standard 12-lead ECG, but can be inferred by looking for reciprocal changes in the anterior leads, especially V1–V3).

These lead groupings help localize the area of the heart that is undergoing infarction based on the ST segment elevation.



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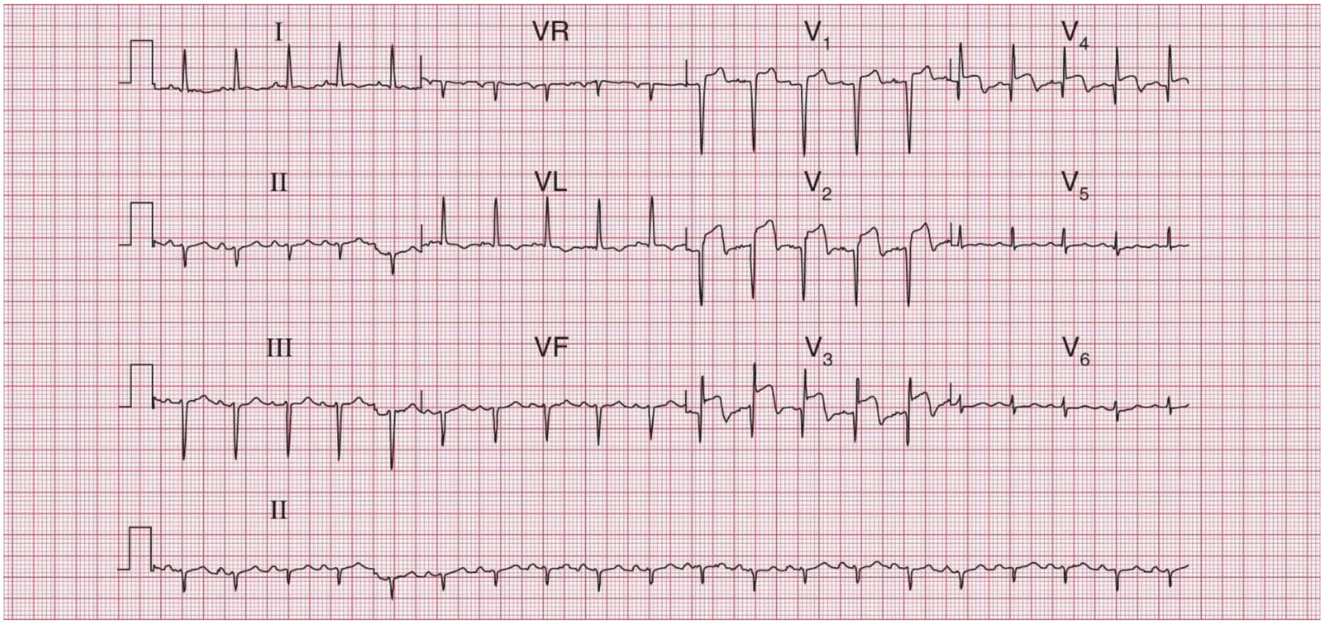

Note:

- **Rhythm**: Sinus rhythm, rate 120 bpm
- **Axis**: Left axis deviation (predominantly downward deflection in leads II and III)
- **Q Waves**: Present in leads V1–V4
- **ST Segment Elevation**: Elevated in leads V2–V4

These findings are consistent with an **acute anterior ST-segment elevation myocardial infarction (STEMI)**, where the ST elevation and Q waves indicate ongoing ischemia and myocardial damage in the anterior wall of the heart.

T Wave in ECG

The **T wave** represents **ventricular repolarization** (or recovery) following ventricular contraction.

Normal T Wave Characteristics:

- **Location**:
  - Follows the **S wave**.
- **Amplitude**:
  - Typically, **0.5 mm** in leads **I, II, and III**.
  - Up to **10 mm** in the **precordial leads**.
- **Configuration**:
  - Typically, **round** and **smooth**.
- **Deflection**:
  - **Upright** in leads **I, II, and V3 to V6**.
  - **Inverted** in lead **aVR**.
  - **Variable** in other leads.

Abnormal T Wave Characteristics:

1. **Tall, Peaked, or Tented T Waves**:
   - Suggest **myocardial ischemia** or **hyperkalemia**.
2. **Inverted T Waves**:
   - Inverted T waves in leads **I, II, or V2 through V6** may indicate **myocardial ischemia** or **ventricular strain**.

QT Interval in ECG

The **QT interval** represents the total time for **ventricular depolarization** and **repolarization**. The length of the QT interval varies with heart rate—**the faster the heart rate, the shorter the QT interval**.

When evaluating the **QT interval**, the most important factor is its **duration**.

Normal QT Interval Characteristics:

- **Location**:
  - Extends from the **beginning of the QRS complex** to the **end of the T wave**.
- **Duration**:
  - The normal QT interval varies based on factors like **age**, **sex**, and **heart rate**, but it typically lasts between **0.36 to 0.44 seconds**.
  - The **QT interval** should not exceed **half the distance between consecutive R waves** (the **R-R interval**) when the rhythm is regular.

The Importance of the QT Interval:

The **QT interval** reflects the time needed for the entire **ventricular depolarization-repolarization** cycle. Abnormalities in its duration may indicate underlying **myocardial problems**.

- **Prolonged QT Interval**:
    - A prolonged QT interval indicates that the **relative refractory period** of the ventricles is longer, which can predispose to life-threatening arrhythmias, such as **torsades de pointes**.

Interpreting a rhythm strip is a skill developed through practice. You can use several methods, as long as you employ consistent technique. Rhythm strip analysis requires a sequential and systematic approach, such as the eight steps outlined here.

Step 1: Determine the Rhythm

The first step is to determine the **atrial** and **ventricular rhythms**.

Atrial Rhythm:

- Measure the intervals between **two consecutive P waves**.
- If the intervals are consistent, the rhythm is **regular**.
- If the intervals vary, the rhythm is **irregular**.

Ventricular Rhythm:

- Measure the intervals between **two consecutive R waves** in the **QRS complexes**.
- If an R wave is not visible, use the **Q wave** of consecutive QRS complexes for measurement.
- The **R-R intervals** should be measured, and if they are consistent, the rhythm is **regular**.
- If the intervals differ significantly, the rhythm is **irregular**.

Step 2: Determine the Rate

Tachycardia is defined as a heart rate greater than 100 beats per minute (bpm), while bradycardia is defined as a heart rate less than 60 bpm. You can use one of the following methods to estimate both **atrial** and **ventricular heart rate**:

1. 1500 Method (Using Small Boxes)

This method is particularly useful for calculating heart rate when the rhythm is regular.

Steps:

- Count the **number of small boxes** between two consecutive R waves (this is the distance between the peaks of two successive QRS complexes).
- The ECG paper typically has a **small box size of 1 mm** in length, which corresponds to **0.04 seconds**.
- **Formula**:

$$\text{Heart rate (bpm)} = \frac{1500}{\text{Number of small boxes between R waves}}$$

- **Why it works: Since each small box represents 0.04 seconds, there are 1500 small boxes in one minute (60 seconds).**

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2. 300/large squares Method for Heart Rate Calculation

1. **Locate an R wave**: Find an R wave on the ECG that is easy to identify.
2. **Count the number of large squares** between two consecutive R waves:
    - Measure the number of **large squares** (each large square equals 0.2 seconds) between two consecutive R waves.
3. **Calculate the heart rate**:
    - Divide 300 by the number of large squares between two consecutive R waves.

Formula:

$$\text{Heart Rate (bpm)} = \frac{300}{\text{Number of large squares between R waves}}$$

3. 60/Duration Method (Using R-R Interval in Seconds)

This method uses the duration of the **R-R interval** (the time between two successive R waves).

Steps:

- Measure the **duration of the R-R interval** in seconds. You can use the ECG paper's time scale to determine the number of seconds between the R waves.
- **Apply the formula:**

$$\text{Heart rate (bpm)} = \frac{60}{\text{R-R interval (in seconds)}}$$

Why it works: The total duration of one cardiac cycle (R-R interval) represents the time taken for one beat. Dividing 60 by the R-R interval in seconds gives the number of heart beats per minute.

Step 3: Evaluate the P Wave

When examining the **P waves** on the rhythm strip, ask yourself the following questions:

- **Are P waves present?**
- **Do all the P waves have a normal configuration?**
- **Are the P waves consistent in size, shape, and location on the ECG?**
- **Is there one P wave preceding every QRS complex?**

Step 4: Determine the Duration of the PR Interval

To measure the **PR interval**:

1. Count the number of **small squares** between the **start of the P wave** and the **start of the QRS complex**.
2. Multiply the number of squares by **0.04 seconds** to calculate the duration.
3. Ask yourself:
    - **Is the PR interval duration normal (0.12 to 0.20 seconds)?**
    - **Is the PR interval constant across the rhythm strip.**

Step 5: Determine the Duration of the QRS Complex

To measure the **QRS complex**:

1. Measure from the **end of the PR interval** to the **end of the S wave** (not just to the peak of the S wave).
2. Count the number of **small squares** between the beginning and end of the QRS complex.
3. Multiply this number by **0.04 seconds** to calculate the duration.
4. Ask yourself:
    - **Is the QRS duration normal (0.06 to 0.12 seconds)?**
    - **Are all QRS complexes the same size and shape?** (If not, measure and describe each one individually.)
    - **Does each P wave have a corresponding QRS complex?**

Step 6: Evaluate the T Waves

When examining the **T waves**:

- **Are T waves present?**
- **Do all the T waves have a normal shape?**
- **Do all the T waves have a normal amplitude?**
- **Are all T waves consistent in amplitude?**
- **Do the T waves have the same deflection as the QRS complexes?** (i.e., if QRS is upright, T should also be upright, unless abnormal).

Step 7: Determine the Duration of the QT Interval

To measure the **QT interval**:

1. Count the number of **small squares** between the **beginning of the QRS complex** and the **end of the T wave**, where the T wave returns to the baseline.
2. Multiply the number of small squares by **0.04 seconds** to calculate the duration.
3. Ask yourself:
    - **Is the QT interval duration normal (0.36 to 0.44 seconds)?**

Correcting the QT Interval (QTc)

The **QT interval** is influenced by the **heart rate**. As the heart rate increases, the QT interval shortens, and as the heart rate decreases, the QT interval lengthens. To account for these changes and evaluate the QT interval consistently, it is corrected to a standard heart rate of **60 beats per minute**. This corrected QT interval is known as **QTc**.

Formula for Corrected QT (QTc):

The most commonly used formula for calculating **QTc**:

$$QTc = \frac{QT}{\sqrt{RR \text{ interval}}}$$

Where:

- **QT** = the measured QT interval in seconds
- **RR interval** = the time between two consecutive R waves, also in seconds

Normal QTc Values:

- For **women**, the normal QTc is generally **less than 0.45 seconds**.
- For **men**, the normal QTc is **less than 0.43 seconds**.

Abnormal QTc:

- A **QTc longer than 0.50 seconds** (in either men or women) significantly increases the risk of developing **torsades de pointes**, a potentially life-threatening arrhythmia.

Step 8: Evaluate Other Components

After analyzing the main components of the ECG, check for any additional abnormalities:

- **Ectopic Beats**: Look for premature beats originating from outside the normal conduction pathway (e.g., premature atrial or ventricular contractions).
- **ST Segment Abnormalities**: Examine the **ST segment** for any **elevation** or **depression**, which could indicate ischemia or other cardiac issues.

Method for Determining Cardiac Axis with Differential Diagnosis

The **cardiac axis** represents the average direction of depolarization through the ventricles as observed from the front. It is typically determined using the **QRS complex** in **Lead I** and **Lead aVF** with the **quadrant method**. .

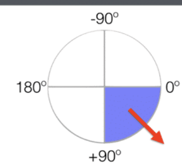
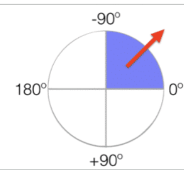
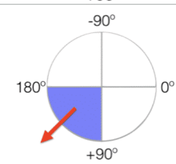
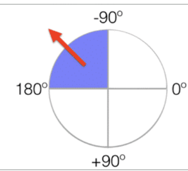
Step-by-Step Method:

1. **Positive QRS in Lead I**:
    - If the **QRS complex** is positive in **Lead I**, the axis is aligned with **Lead I**'s direction (horizontal or slightly to the left).
2. **Positive QRS in Lead aVF**:
    - If the **QRS complex** is positive in **Lead aVF**, the axis is aligned with the **Lead aVF** direction (toward the feet, positive).
3. **Quadrant Method**:
    - The combination of **Lead I** and **Lead aVF** helps to determine the axis:
        - **Normal Axis**: If both **Lead I** and **Lead aVF** are **positive**, the axis lies between **-30° and +100°** (normal axis).
4. **Axis Deviations**:
    - **QRS Positive in Lead I – QRS Negative in Lead aVF**:
        - This can indicate either a **normal axis** or **left axis deviation**.
        - To distinguish:
            - Check **Lead II**:
                - If **Lead II** is **positive**, the axis is **normal**.
                - If **Lead II** is **negative**, the axis is **left axis deviation**.
    - **QRS Negative in Lead I – QRS Positive in Lead aVF**:
        - This indicates **right axis deviation**.
    - **QRS Negative in Lead I – QRS Negative in Lead aVF**:
        - This indicates **extreme left** or **right axis deviation**.

Differential Diagnosis of Axis Deviations:

1. **Normal Axis (-30° to +100°)**:
    - **Normal physiological variation**.
    - Common in healthy individuals without significant underlying pathology.
2. **Left Axis Deviation (-30° to -90°)**:
    - **Possible causes**:
        - **Left ventricular hypertrophy (LVH)**.
        - **Inferior myocardial infarction**.
        - **Left bundle branch block (LBBB)**.

3. **Right Axis Deviation (+100° to +180°)**:
    - **Possible causes**:
        - **Right ventricular hypertrophy (RVH)**.
        - **Pulmonary hypertension**.
        - **Chronic lung disease** (COPD).
4. **Extreme Axis Deviation (–90° to +180°)**:
    - **Possible causes**:
        - **Severe ventricular hypertrophy**.
        - **Dextrocardia** (heart positioned abnormally on the right side of the chest).

Lead 1	Lead aVF	Quadrant	Axis
POSITIVE	POSITIVE		**Normal Axis** (0 to +90°)
POSITIVE	NEGATIVE		****Possible LAD** (0 to -90°)
NEGATIVE	POSITIVE		**RAD** (+90° to 180°)
NEGATIVE	NEGATIVE		**Extreme Axis** (-90° to 180°)

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Recognizing Normal Sinus Rhythm

Before identifying arrhythmias, it’s essential to first recognize **Normal Sinus Rhythm (NSR)**. NSR originates in the **sinus node** and follows the normal conduction pathway through the **atria**, **AV node**, **bundle of His**, **bundle branches**, and **Purkinje fibers** to the **ventricles**. NSR serves as the reference for comparing other rhythms.

Characteristics of Normal Sinus Rhythm

Using the 8-step method for analysis, the key features of **Normal Sinus Rhythm** are:

1. **Regular Rhythm**:
    - Both **atrial** and **ventricular rhythms** are regular.
2. **Heart Rate**:
    - The **atrial** and **ventricular rates** fall between **60 and 100 beats per minute**, which is the normal firing rate of the **SA node**.
    - All impulses are conducted to the ventricles.
3. **P Waves**:
    - The **P waves** are **rounded**, **smooth**, and **upright** in lead II, indicating that the sinus impulse has reached the atria.
4. **PR Interval**:
    - The **PR interval** is **normal** (0.12 to 0.20 seconds), reflecting normal conduction from the atria through the AV node and the His-Purkinje system.
5. **QRS Complex**:
    - The **QRS complex** has a **normal duration** (less than 0.12 seconds), indicating proper ventricular impulse conduction and recovery.
6. **T Wave**:
    - The **T wave** is **upright** in lead II, confirming normal ventricular **repolarization**.
7. **QT Interval**:
    - The **QT interval** is within normal limits (0.36 to 0.44 seconds).
8. **No Ectopic Beats**:
    - There are **no ectopic or aberrant beats**.

Rhythm Strip Interpretation Review

Normal P Wave

- **Location**: Before the QRS complex
- **Amplitude**: < 0.25 mV (high)
- **Duration**: < 0.12 seconds
- **Configuration**: Usually rounded and upright
- **Deflection**:
  - Positive or upright in leads I, II, aVf, and V4 to V6
  - Usually positive but may vary in leads III and aVL
  - Negative or inverted in lead aVR
  - Biphasic or variable in lead V1

Normal PR Interval

- **Location**: From the beginning of the P wave to the beginning of the QRS complex
- **Duration**: 0.12 to 0.20 seconds

Normal QRS Complex

- **Location**: Follows the PR interval
- **Amplitude**: 5 to 30 mV (1 mm or 6 small squares high), but may differ by lead
- **Duration**: 0.06 to 0.12 seconds (about half the PR interval)
- **Configuration**: Consists of the Q wave, R wave, and S wave
- **Deflection**:
  - Positive in leads I, II, III, aVL, aVF, and V4 to V6
  - Negative in leads aVR and V1 to V3

Normal ST Segment

- **Location**: From the end of the S wave to the beginning of the T wave
- **Deflection**: Usually isoelectric; may vary from -0.5 to +1 mm in some precordial leads

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Normal T Wave

- **Location**: After the S wave
- **Amplitude**: 0.5 mm in leads I, II, and III, and up to 10 mm in precordial leads

- **Configuration**: Typically, round and smooth
- **Deflection**:
  - Usually upright in leads I, II, and V3 to V6
  - Inverted in lead aVR
  - Variable in other leads

Normal QT Interval

- **Duration**: Varies with heart rate but typically ranges from 0.36 to 0.44 seconds

---

Normal U Wave

- **Location**: After the T wave
- **Configuration**: Typically, upright and rounded
- **Deflection**: Upright

Interpreting a Rhythm Strip: 8-Step Method

1. **Step 1**: Determine the rhythm
2. **Step 2**: Determine the rate
3. **Step 3**: Evaluate the P wave
4. **Step 4**: Measure the PR interval
5. **Step 5**: Determine the QRS complex duration
6. **Step 6**: Examine the T waves
7. **Step 7**: Measure the QT interval duration
8. **Step 8**: Check for ectopic beats and other abnormalities

---

Normal Sinus Rhythm

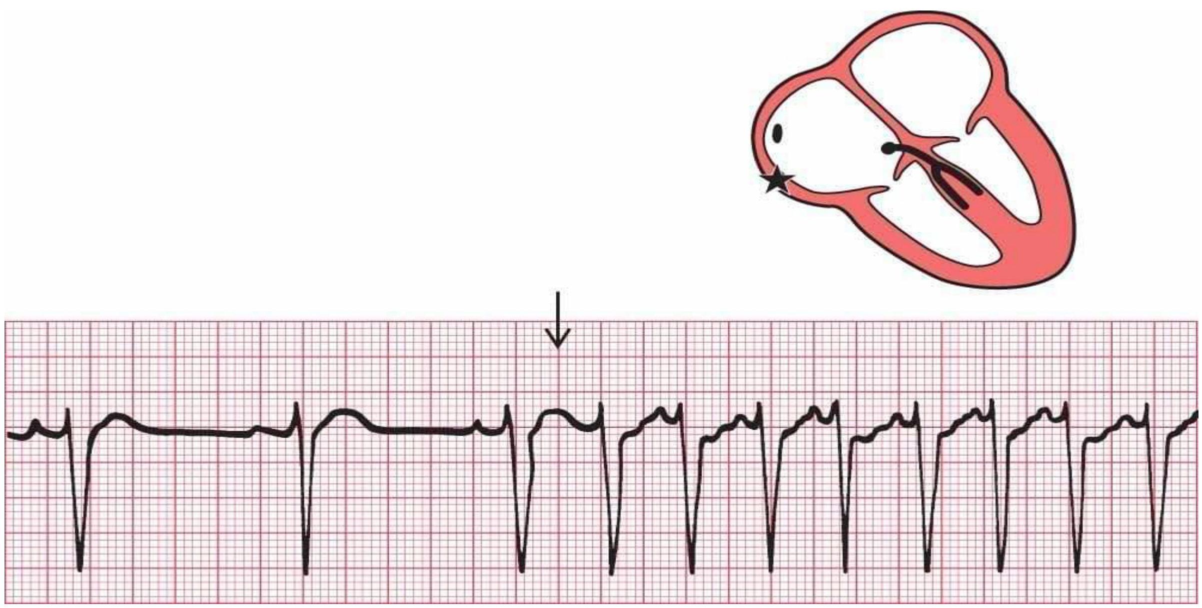
Normal sinus rhythm is the standard against which all other rhythms are compared.

Characteristics:

- Regular rhythm
- A P wave for every QRS complex; all P waves are similar in size and shape
- All QRS complexes are similar in size and shape
- Normal PR and QT intervals
- Normal T waves

Abnormal rhythms:

- **Atrial Tachycardia (Abnormal Focus in the Atrium)**
  Atrial tachycardia occurs when an abnormal focus in the atrium causes depolarization at a rate greater than 150 bpm.
- In cases where the atrial rate exceeds 200 bpm, the AV node cannot conduct all the atrial impulses, resulting in **atrioventricular block**, with some P waves not followed by QRS complexes. The AV node is still functioning properly in this scenario, preventing the ventricles from being activated too quickly and inefficiently.



Notes:

- Atrial tachycardia develops after three normal sinus beats, with a rate of 150 bpm.
- P waves may be superimposed on the T waves of the preceding beats.
- QRS complexes have the same shape as those of the sinus beats.

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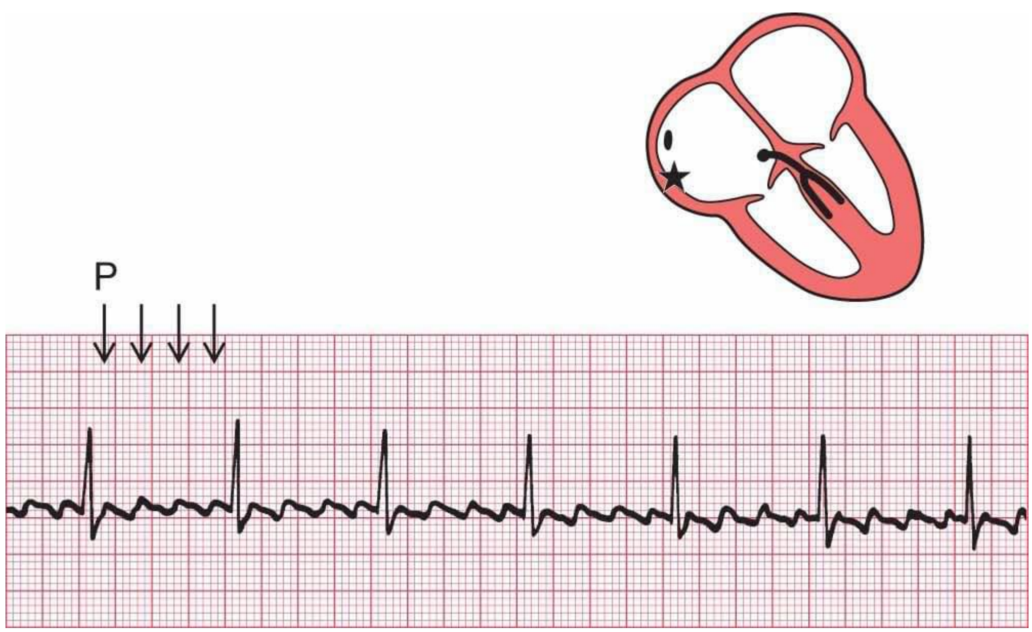
Atrial Flutter
Atrial flutter occurs when the atrial rate exceeds 250 beats per minute, leading to a rapid and regular atrial rhythm. In this condition, there is no flat baseline between the P waves, and the atrial electrical impulses are rapidly transmitted, causing a characteristic "sawtooth" pattern on the ECG.

Key Features of Atrial Flutter:

- **P Waves:** The P waves appear as distinct, regular, sawtooth waves, often at a rate of 300 bpm, giving the classic appearance.
- **Rate:** The atrial rate typically is around 300 bpm, but due to the AV node's filtering effect, not all atrial impulses are conducted to the ventricles.
- **Ventricular Rate:** The ventricular rate is usually regular but slower, often around 75 bpm, as only some of the atrial impulses pass through the AV node. The conduction ratio is often 4:1 (four atrial beats for each ventricular beat).
- **Baseline:** The baseline between P waves is not flat, and there is a consistent pattern of atrial depolarization.



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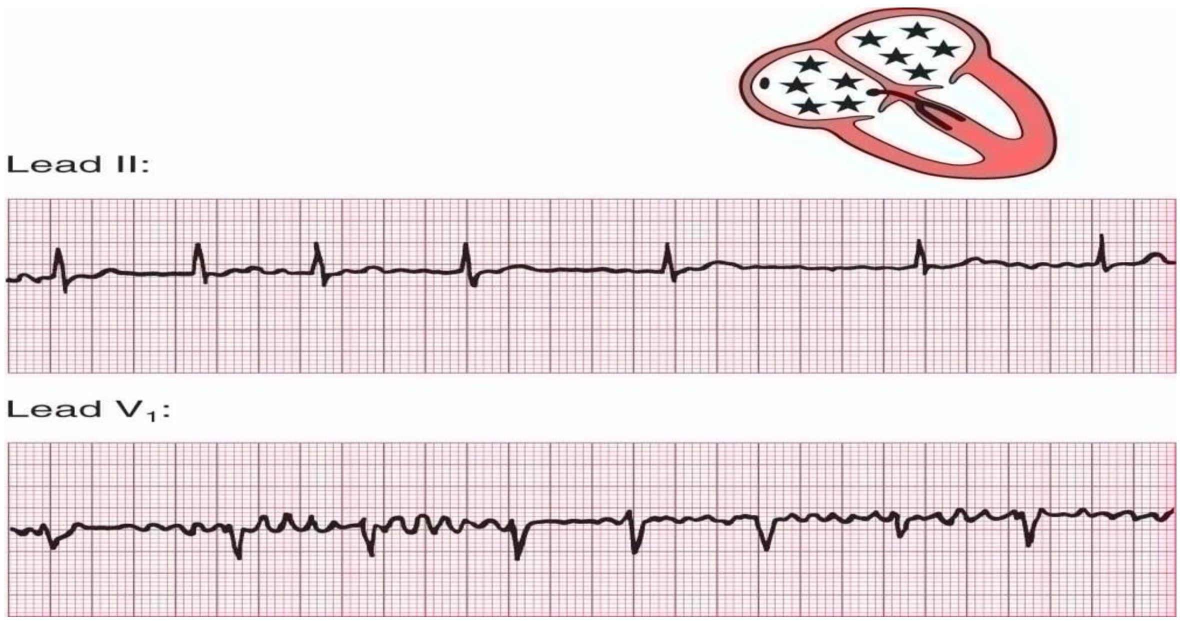
Atrial Fibrillation
Atrial fibrillation (AF) occurs when the atrial muscle fibers contract independently, leading to the absence of P waves on the ECG and an irregular baseline. The atria experience rapid, disorganized electrical activity, which bombards the AV node with depolarization waves at irregular intervals. As the AV node conducts these waves in an "all or none" fashion, the ventricular rhythm becomes irregular, but the QRS complexes remain of normal shape.



Key Features:

- **P Waves:** Absent, with no distinct P wave due to chaotic atrial activity.
- **Baseline:** Irregular, with fibrillatory waves instead of P waves.
- **QRS Complexes:** Irregularly spaced, but typically of normal shape.

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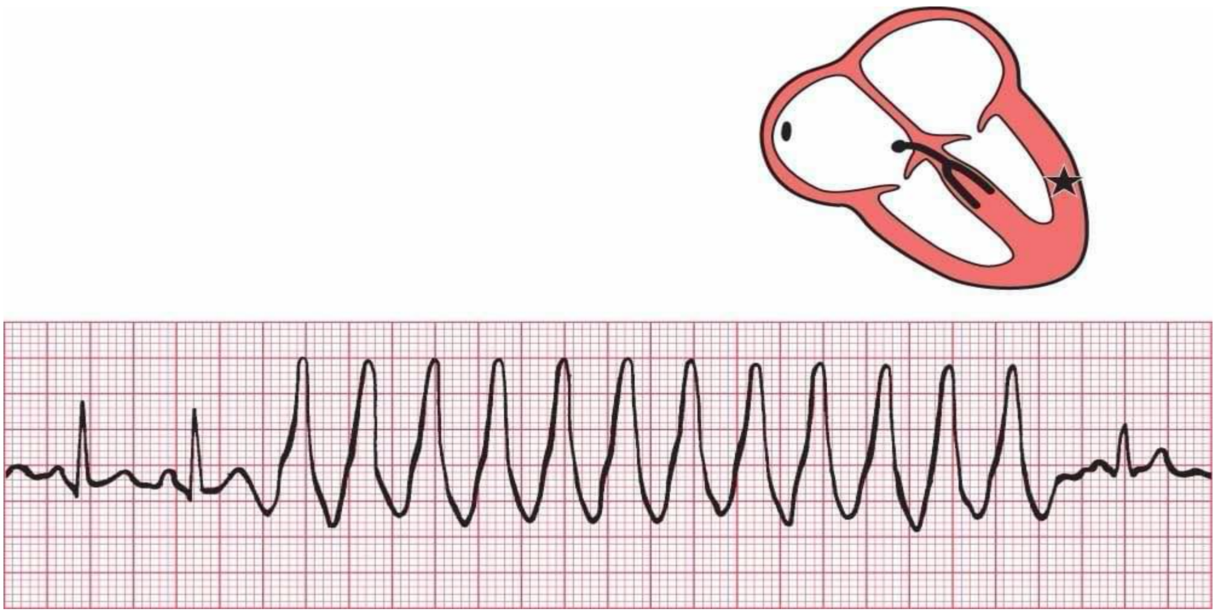
Ventricular Tachycardia

Ventricular tachycardia occurs when a focus in the ventricular muscle depolarizes at a high frequency, causing rapidly repeated ventricular extrasystoles.



Note:

- The rate increases to 200 bpm after two normal sinus beats.
- QRS complexes become broad.
- T waves become difficult to identify.
- The final beat often shows a return to sinus rhythm.

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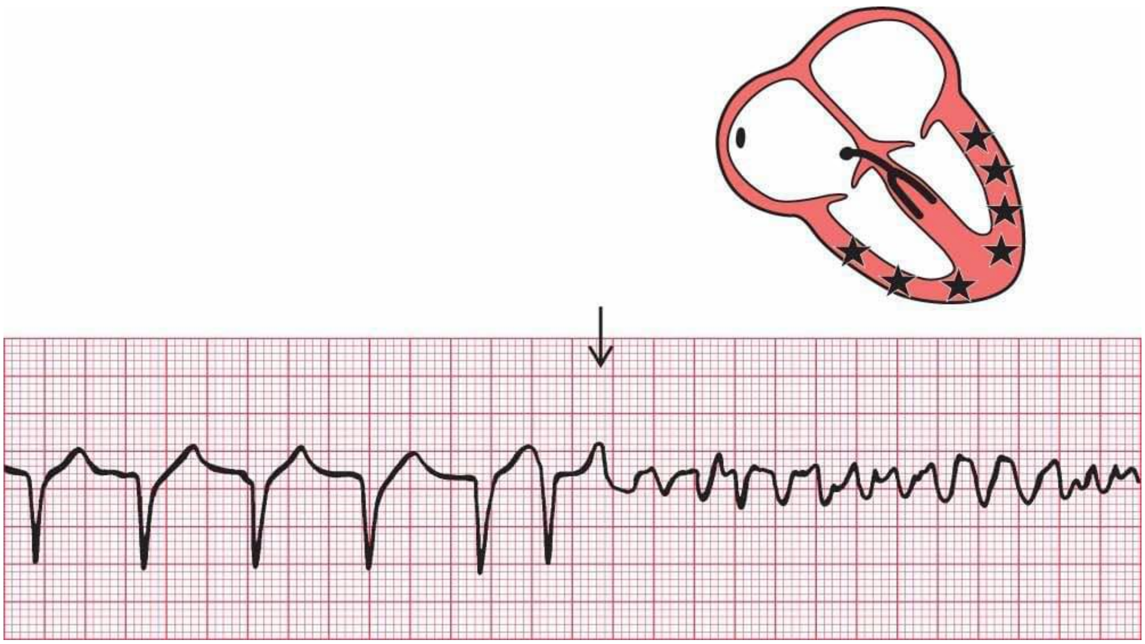
Ventricular Fibrillation

Ventricular fibrillation occurs when the ventricular muscle fibers contract independently, resulting in the absence of identifiable QRS complexes. The ECG appears completely disorganized. Since the patient is typically unconscious by the time the abnormal ECG pattern is recognized, the diagnosis is usually straightforward.



References:

- *ECG Interpretation Made incredibly Easy*
- *ECG Made Easy*
- *Sherwood Medicine*

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