How to Interpret an ECG in Seven Steps

Physicians encounter ECGs in their clinical routine every day. Additionally, ECGs are frequently the topic of exams, which is reason enough for us to provide an analysis algorithm that will aid students in interpreting an ECG. Learn the seven steps to interpret an ECG and test your knowledge by taking the ECG quiz.

**Step 1: Heart Rate**

The heart rate can be determined via paper speed and the distance between 2 R waves. There are 2 paper speeds: 25 and 50 mm/s.

With the paper speed of 50 mm/s, one minute equals a strip length of 3,000 mm or 600 large squares (1 large square equals 5 mm):

Heart rate (beats/min) = 600/number of large squares between 2 R waves.

It is easier to determine the heart rate with the aid of an ECG ruler.

<table>
<thead>
<tr>
<th>Heart rate</th>
<th>Term</th>
<th>Examples</th>
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</table>
Step 2: Heart Rhythm

When interpreting the heart rhythm, you should look for P waves, which is a sign of atrial excitation. When every P wave is followed by a QRS complex, the ECG shows sinus rhythm.
If the P waves are irregular, sinus arrhythmia is likely present. If the P waves are missing altogether, the following differential diagnoses should be considered:

- **Atrial fibrillation:** The fibrillation is characterized by low-amplitude, high-frequency atrial fibrillatory waves.

- **Atrial flutter:** The flutter waves are configured in a saw-tooth pattern.
Sinus arrest with escape rhythm: The retrograde atrial stimulation is caused by centers other than the sinus node. In this instance, bradycardia occurs with small QRS complexes but without P waves (i.e., synchronization of the QRS complexes and P waves).

Step 3: Electrical Heart Axis

The electrical heart axis is determined using the Cabrera circle, which is complex, or by examining the waves of the QRS complex (in limb leads I, II and III).

Since the 2nd method is easier, memorize the following 'rules of thumb':

- Right heart axis deviation: Leads I and II show negative deflection, whereas lead III has a positive deflection.
- **Right heart axis**: Lead I has negative deflection and leads II and III show positive deflection.
- **Vertical cardiac axis**: All leads show positive deflection, R in III > R in I.
- **Normal cardiac axis**: All leads show positive deflection, R in I > R in III.
- **Left heart axis**: Lead III has negative deflection, while leads I and II have positive deflection.
- **Left heart axis deviation**: Leads II and III show negative deflection, whereas lead I has positive deflection.

### Step 4: The PR Interval

The normal PR interval ranges between **120 and 200 ms** (0.12–0.2s). A **PR interval > 200 ms** suggests a **first-degree AV block**.

- **First-degree AV block**: When PR interval > 200 ms, each P wave is followed by a QRS complex.
- **Second-degree AV block (Mobitz I or Wenckelbach)**: The PR interval steadily increases until the impulse transmission fails (skipped heartbeat, and missing QRS complex).
- **Second-degree AV block (Mobitz II)**: A constant PR interval with sudden failure of conduction to the chambers (missing QRS complex), frequent 2:1 conduction (2 P waves followed by a single QRS complex), or 3:1 conduction (3 P waves followed by a QRS complex).
- **Third-degree AV block**: The atria and ventricles act independent of each other (AV dissociation).
Step 5: The QRS Complex

The normal QRS complex consists of a small negative Q wave (amplitude < ¼ of an R wave) as well as small R and S waves. The physiological QRS duration is **60-100 ms** (**0.06-0.1 s**).
Broad and deformed QRS complexes can occur in the case of:

- Ventricular extrasystoles (VES; no preceding P wave)
- Conduction system disorders
# Right bundle branch block (RBBB)

- Broad, frequently M-shaped QRS complexes in leads V1 and V2
  - Complete RBBB: QRS > 120 ms
  - Incomplete RBBB: QRS = 100-120 ms

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# Left bundle branch block (LBBB)

- Broad, frequently M-shaped QRS complexes in leads V5 and V6
  - Complete LBBB: QRS = 120 ms
  - Incomplete LBBB: QRS = 100-120 ms
  - Attention! Exception: hemiblocks may occur

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**Step 6: Repolarization**

Repolarization includes the ST segment and the T wave (repolarization of chambers). The standard **ST segment** is an isoelectric line. Elevations and depressions of the ST segment are, therefore, pathological abnormalities (specifically > 1 mm in the limb leads and > 2 mm in the chest leads).

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**Image:** Schematic diagram of normal sinus rhythm for a human heart as seen on ECG. By Agateller (Anthony Atkielski), License: Public Domain
The most important causes for such type of ST elevation are acute myocardial infarction (AMI) and acute pericarditis. In cases of AMI with ST-segment elevation (STEMI), the ST-segment takes off from the descending limb of the R wave, whereas in cases of pericarditis, it takes off from the ascending limb of the S wave.

Image: A 12-lead ECG showing a STEMI. Elevation of the ST segment can be seen in some leads. By James Heilman, MD, License: CC BY-SA 4.0

Note: An indication for STEMI is ST-segment elevation with poor R wave progression in at least 2 limb leads (amplitude > 0.1 mm) or 2 adjacent breast leads (amplitude > 0.2 mm). Horizontal or descending ST-segment depressions with a downward slope > 1 mm are considered pathological, and point to acute myocardial ischemia. Downsloping depressions also occur in digitalis therapy.

Repolarization abnormalities manifest as changes in T wave configuration. Possible pathological causes of repolarization abnormalities include:

- **Tent-shaped T waves** as signs of hyperkalemia, but the sensitivity of an ECG for hyperkalemia is poor.
- **Inverted T waves**: The causes for inverted T waves vary, including acute myocardial infarction and pulmonary embolism. Therefore, these findings should always be analyzed in conjunction with the remainder of the ECG as well as the patient’s other clinical signs.

N.B. Inverted T waves are not considered pathological per se. They are obligatory in lead aVR and are also found in leads III, V1 and V2, without manifesting any sign of disease.

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<th>Age (ethnicity)</th>
<th>n</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
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<tbody>
<tr>
<td><strong>Children</strong></td>
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<td><strong>Males</strong></td>
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<th>13 years–14 years</th>
<th>16 years–19 years (Whites)</th>
<th>16 years–19 years (Blacks)</th>
<th>20 years–30 years (Whites)</th>
<th>20 years–30 years (Blacks)</th>
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Step 7: The R/S Ratio

Usually, the height of the R wave in the breast leads increases, while the S wave decreases and the S wave is completely missing in V6. The R/S ratio is considered as the area where R is taller than S (usually between V2 and V3, or V3 and V4). If this is not the case, the situation is referred to as poor R wave progression, which may be an indication of myocardial infarction or left ventricular hypertrophy.

### How to Interpret an ECG: An Overview

**Interpretation of an ECG in seven easy steps**

1. Heart frequency
2. Heart rhythm
3. Electrical heart axis
4. PR interval
5. QRS complex
6. Repolarization
7. R/S ratio

While these steps represent a good start, these guidelines are not considered complete. Rather, these steps simplify the approach to reading and interpretation of an ECG in clinical practice.

### References


