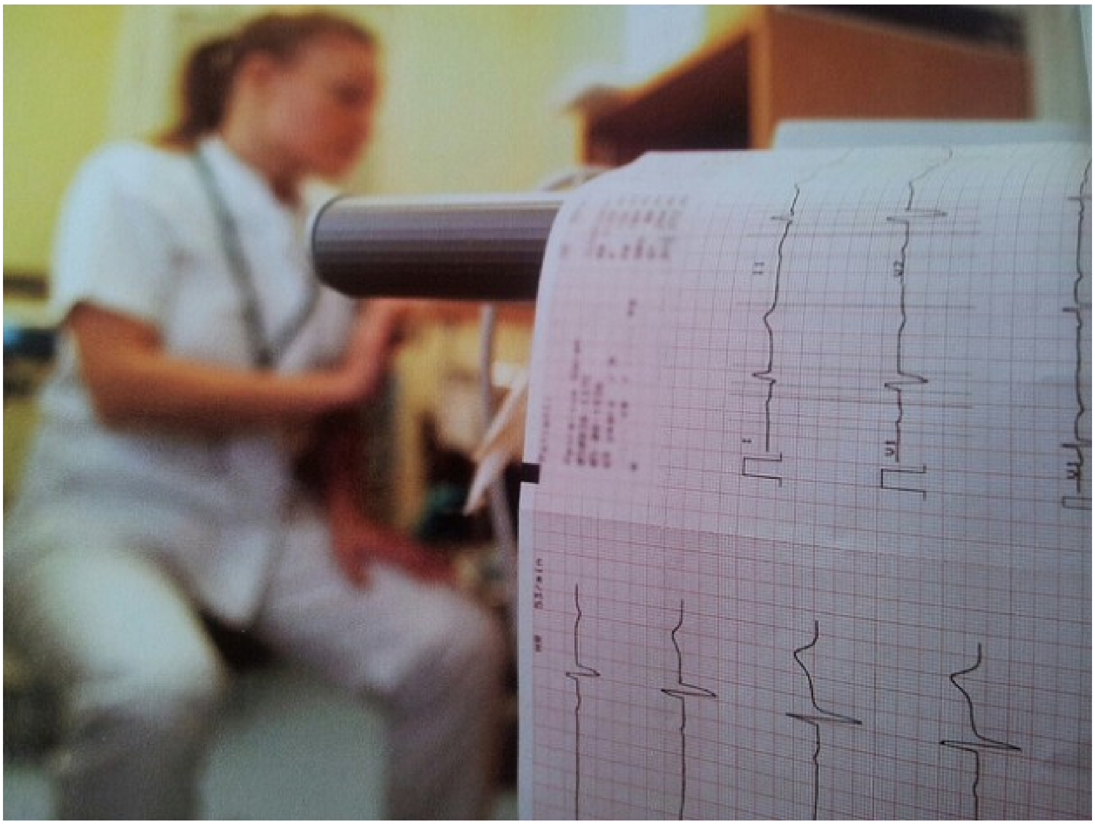
How to Interpret an ECG in Seven Steps

See online here

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

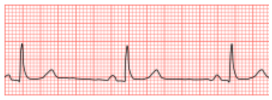
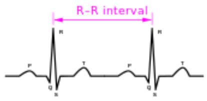
The heart rate can be determined via the paper speed and the distance between two R waves. There are two paper speeds: 25 or 50 mm/s.

For the paper speed of 50 mm/s, one minute equals a strip length of 3000 mm or 600 large squares (one large square equals 5 mm):

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

It is easier to determine the heart rate with the aid of an ECG ruler that simply lets you read the rate on its scale.

Heart rate	Term	Examples

< 50 beats/min	Bradycardia	 Image : “Sinus bradycardia as seen in lead 2. HR about 50.” by James Heilman, MD. License: CC BY-SA 3.0
50 – 100 beats/min	Normal heart rate	 Image : “ECG-RRinterval.” by Created by Agateller (Anthony Atkielski), converted to svg by atom. derivative work: Kychot (talk). License: Copyrighted free use
> 100 beats/min	Tachycardia	 Image : “Sinus tachycardia! DD atrial flutter.” by MoodyGroove. License: CC BY-SA 3.0

Step 2: Heart Rhythm

When interpreting the heart rhythm, **you should look for P waves, which a sign of atrial excitation.** When every P wave is followed by a QRS complex, then the ECG shows **sinus rhythm**.

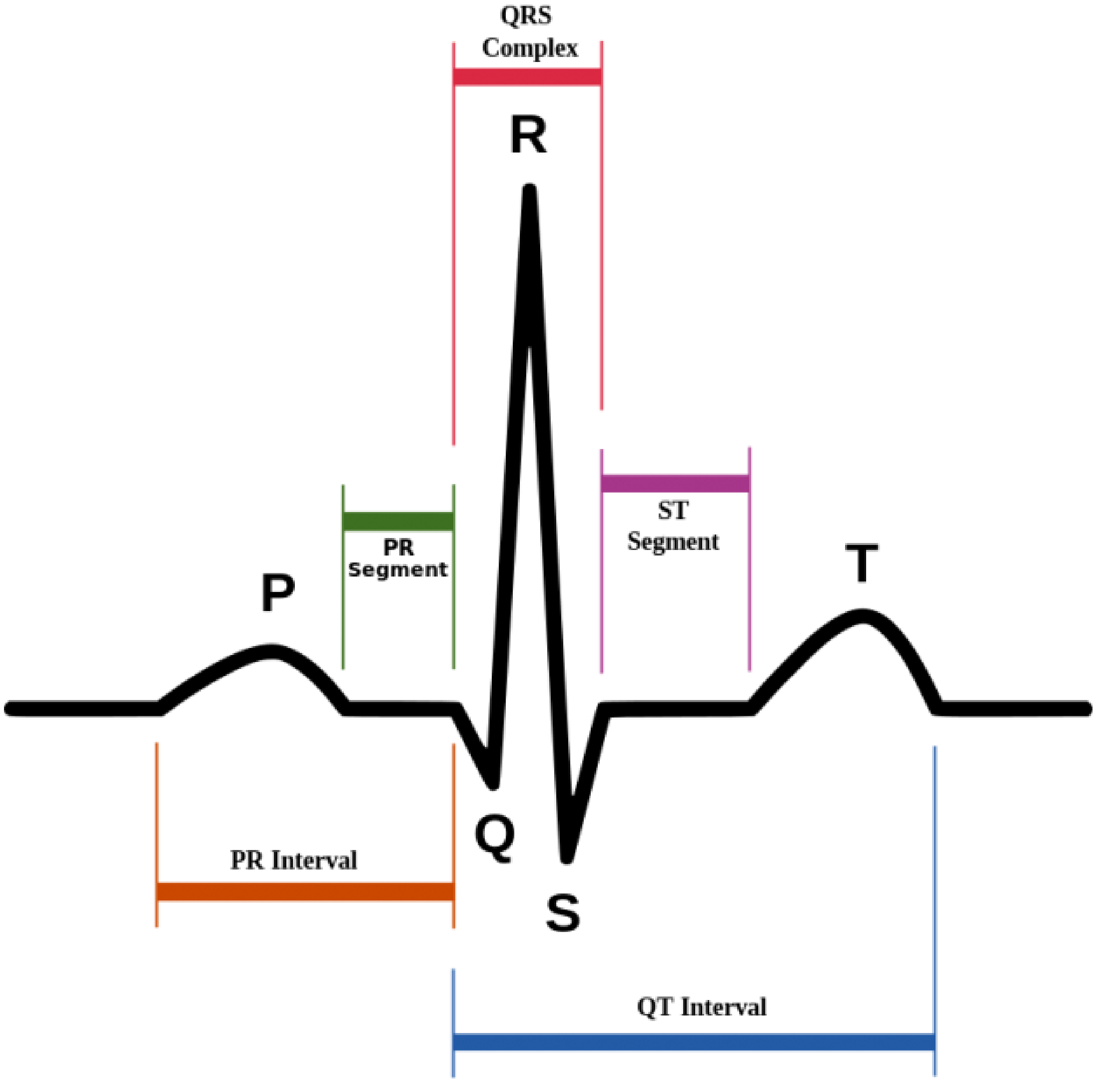


Image: “Schematic diagram of normal sinus rhythm for a human heart as seen on ECG” by Agateller (Anthony Atkielski)/atom. License: Public Domain

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.

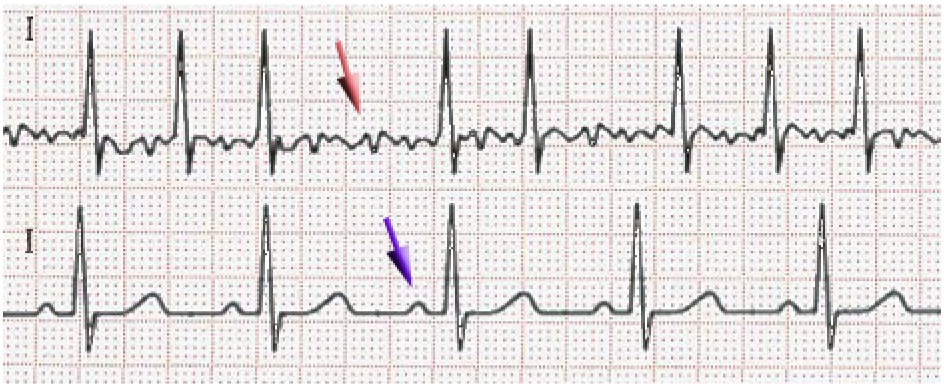
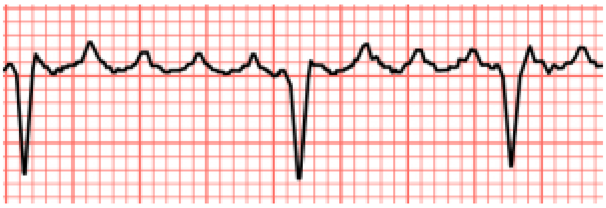


Bild: “Scheme of atrial fibrillation (top) and sinus rhythm (bottom). The purple arrow indicates a P wave, which is lost in atrial fibrillation.” by J. Heuser. License: CC BY-SA 3.0

- **Atrial flutter:** the flutter waves are configured in a saw-tooth pattern.



[Image](#): "Atrial flutter with variable block (between 3 and 4 to 1)" by James Heilman, MD. License: [CC BY-SA 3.0](#)

- **Sinus arrest with escape rhythm**: 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 (the QRS complexes and P waves are synchronized).

Step 3: Electrical Heart Axis

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

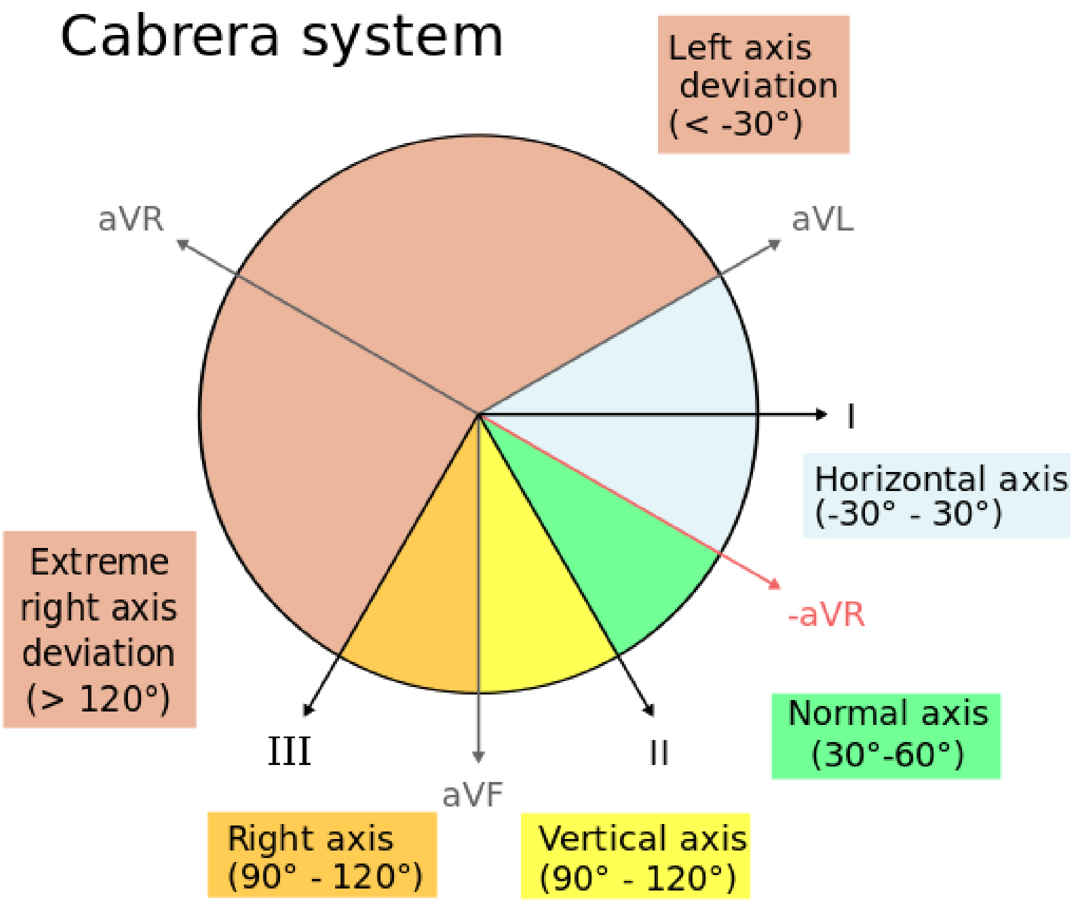


Image : "Cabrera circle." by Andthu. License: CC BY-SA 3.0

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

- **Right heart axis deviation**: leads I and II have negative deflection and lead III has positive deflection.

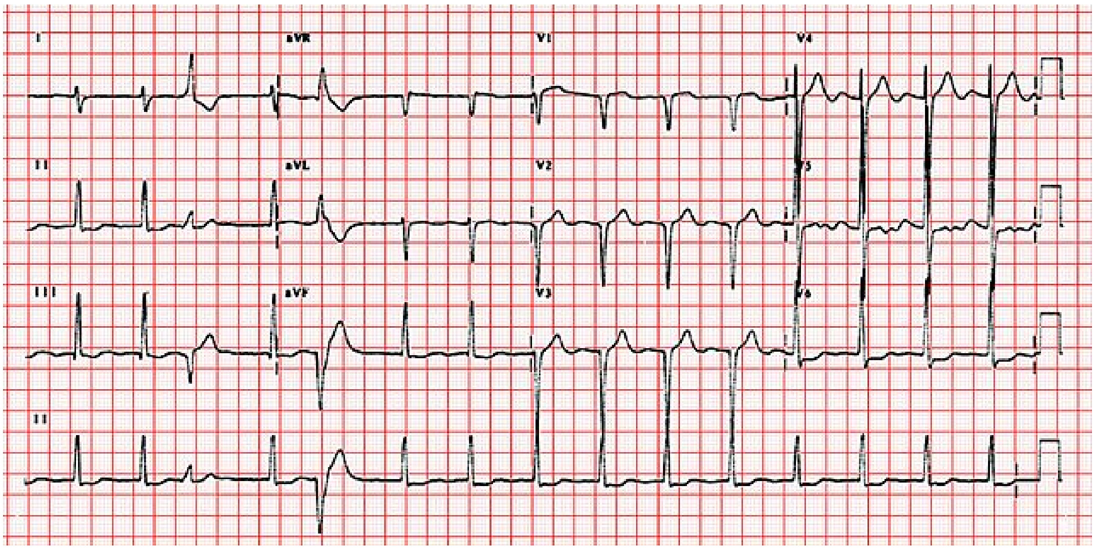


Image : "ECG showing right axis deviation." by Michael Rosengarten BEng, MD.McGill. License: CC BY-SA 3.0

- **Right heart axis**: lead I has negative deflection and leads II and III have positive deflection.
- **Vertical cardiac axis**: all leads have positive deflection, R in III > R in I.
- **Normal cardiac axis**: all leads have positive deflection, R in I > R in III.
- **Left heart axis**: lead III has negative deflection, leads I and II have positive deflection.
- **Left heart axis deviation**: leads II and III have negative deflection, lead I has positive deflection.

Step 4: The PR Interval

The normal PR interval is between **120 – 200 ms** (0.12 – 0.2s). If the **PR-interval** remains **> 200ms, a first degree AV block is present**.

- **First degree AV block:** 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 failure in impulse transmission occurs (dropped beat, missing QRS complex)
- **Second degree AV block (Mobitz II):** constant PR interval with sudden failure of conduction to the chambers (missing QRS complex), frequent 2:1 conduction (two P waves followed by one QRS complex) or 3:1 conduction (three P waves followed by a QRS complex)
- **Third degree AV block:** the atria and ventricles act independently of each other (AV dissociation)

	AV block

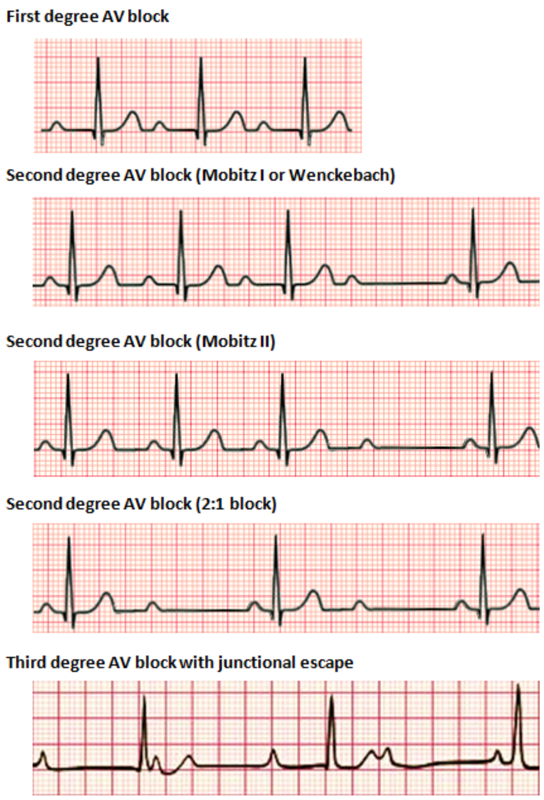
<table>
<tr><td>Type I</td><td></td><td rowspan="4">

Image : “Heart block.” by Npatchett. License: CC BY-SA 4.0</td></tr>
<tr><td>Type II</td><td>Wenckebach block</td></tr>
<tr><td>Type II</td><td>Mobitz block</td></tr>
<tr><td>Type III</td><td></td></tr>
</table>

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 a small R and S wave. The physiological QRS duration is **60 – 100 ms (0.06 – 0.1 s)**.

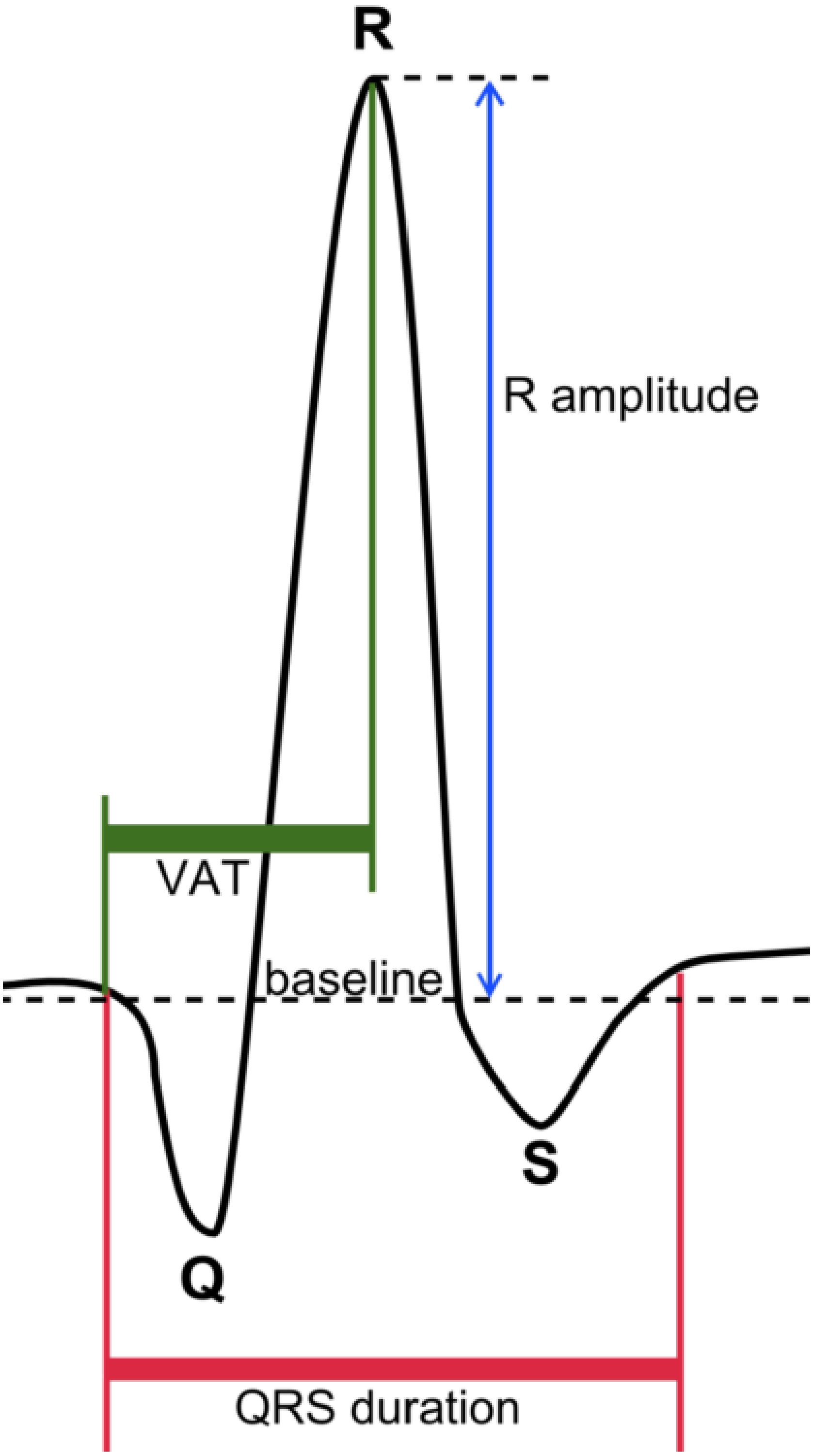
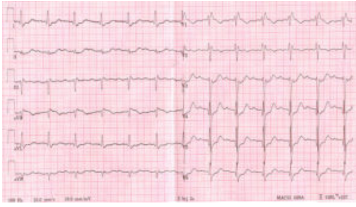
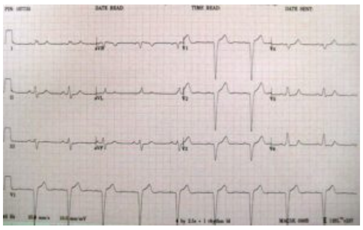


Image : “Schematic representation of the QRS complex.” by Häggström, Mikael (2014). “Medical gallery of Mikael Häggström 2014”. WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.008. License: Public Domain

Broad and deformed QRS complexes can occur in the case of:

- Ventricular extrasystoles (VES; no preceding P wave)
- Conduction system disorders

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	 Image : “Trifascicular block consisting of first degree AV block and right bundle branch block and left axis deviation.” by Steven Fruitsmaak. License: CC BY-SA 3.0
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	 Image : “A left bundle branch block.” by James Heilman, MD. License: CC BY-SA 3.0

Step 6: Repolarization

Repolarization includes the ST segment and the T wave (repolarization of chambers). The standard **ST segment** should be 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).

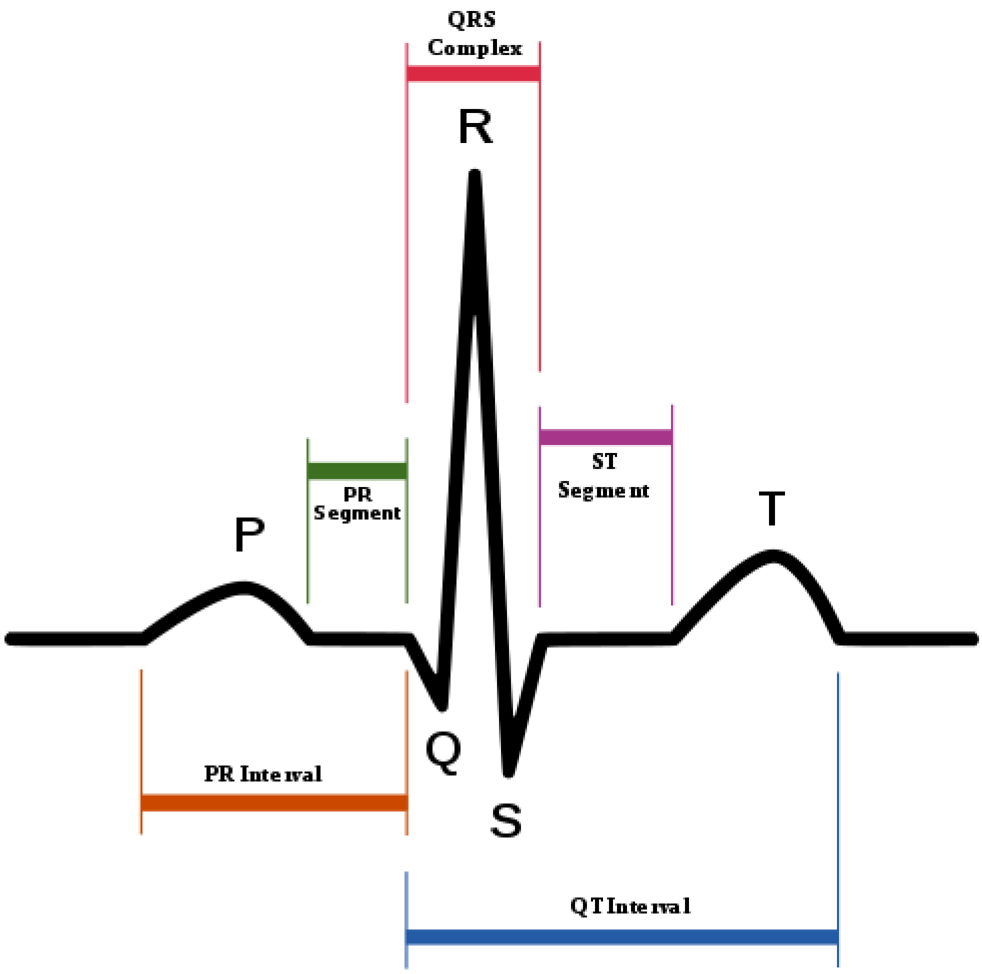


Image: “Schematic diagram of normal sinus rhythm for a human heart as seen on ECG.” by Agateller (Anthony Atkielski). License: Public Domain

The most important causes for such this 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.

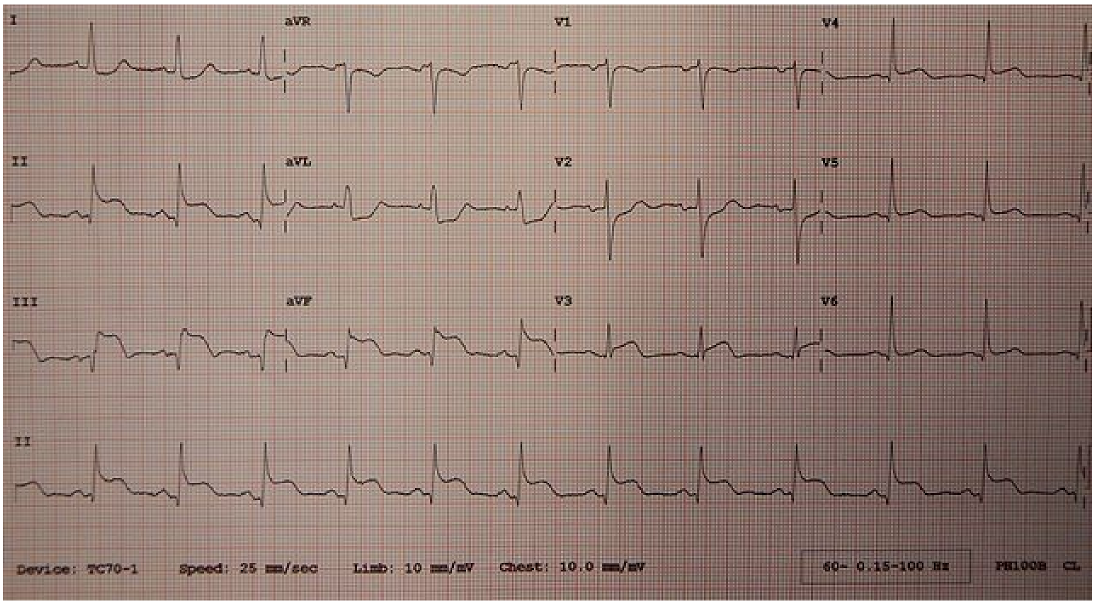


Image: "A 12-lead ECG showing a STEMI. Elevation of the ST segment can be seen in some leads." by James Heilman, MD. License: CC BY-SA 4.0

Note: An indication for STEMI is ST-segment elevation with poor R wave progression in at least two limb leads (amplitude > 0.1 mm) or two adjacent breast leads (amplitude > 0.2 mm). ST-segment depressions > 1 mm that is downsloping, horizontal or descending are considered pathological and point to acute myocardial ischemia. Downsloping depressions can also be found in digitalis therapy.

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

- **Tent-shaped T waves** as signs of **hypercalcemia**;
- **Inverted T waves**: the causes for Inverted T waves vary, including acute myocardial infarction, pulmonary embolism. Therefore, these findings should always be analyzed in conjunction with the rest of the ECG, as well as the patient's other clinical signs.

Keep in mind: inverted T waves are not considered pathological per se. They are obligatory in lead aVR and can also be found in leads III, V1 and V2, without being a sign of disease.

	Age (ethnicity)	n	V1	V2	V3	V4	V5	V6
Children								
	1 week—1 year	210	92 %	74 %	27 %	20 %	0.5 %	0 %
	1 year—2 years	154	96 %	85 %	39 %	10 %	0.7 %	0 %
	2 years—5 years	202	98 %	50 %	22 %	7 %	1 %	0 %
	5 years—8 years	94	91 %	25 %	14 %	5 %	1 %	1 %
	8 years—16 years	90	62 %	7 %	2 %	0 %	0 %	0 %
Males								
	12 years—13 years	209	47 %	7 %	0 %	0 %	0 %	0 %

	13 years—14 years	260	35 %	4.6 %	0.8 %	0 %	0 %	0 %
	16 years—19 years (whites)	50	32 %	0 %	0 %	0 %	0 %	0 %
	16 years—19 years (blacks)	310	46 %	7 %	2.9 %	1.3 %	0 %	0 %
	20 years—30 years (whites)	285	41 %	0 %	0 %	0 %	0 %	0 %
	20 years—30 years (blacks)	295	37 %	0 %	0 %	0 %	0 %	0 %
Females								
	12 years—13 years	174	69 %	11 %	1.2 %	0 %	0 %	0 %
	13 years—14 years	154	52 %	8.4 %	1.4 %	0 %	0 %	0 %
	16 years—19 years (whites)	50	66 %	0 %	0 %	0 %	0 %	0 %
	16 years—19 years (blacks)	310	73 %	9 %	1.3 %	0.6 %	0 %	0 %
	20 years—30 years (whites)	280	55 %	0 %	0 %	0 %	0 %	0 %
	20 years—30 years (blacks)	330	55 %	2.4 %	1 %	0 %	0 %	0 %

Table: "Numbers from Lepeschkin E in." by Antaloczy, Z (1979). Modern Electrocardiology. Amsterdam: Excerpta Medica. p. 401.

Step 7: The R/S Ratio

Usually, the R wave height 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 to be 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. This may be an indication of myocardial infarction or left ventricular hypertrophy.

How to Interpret an ECG: An Overview

In order to be able to get a good first impression of an ECG, these seven steps are sufficient.

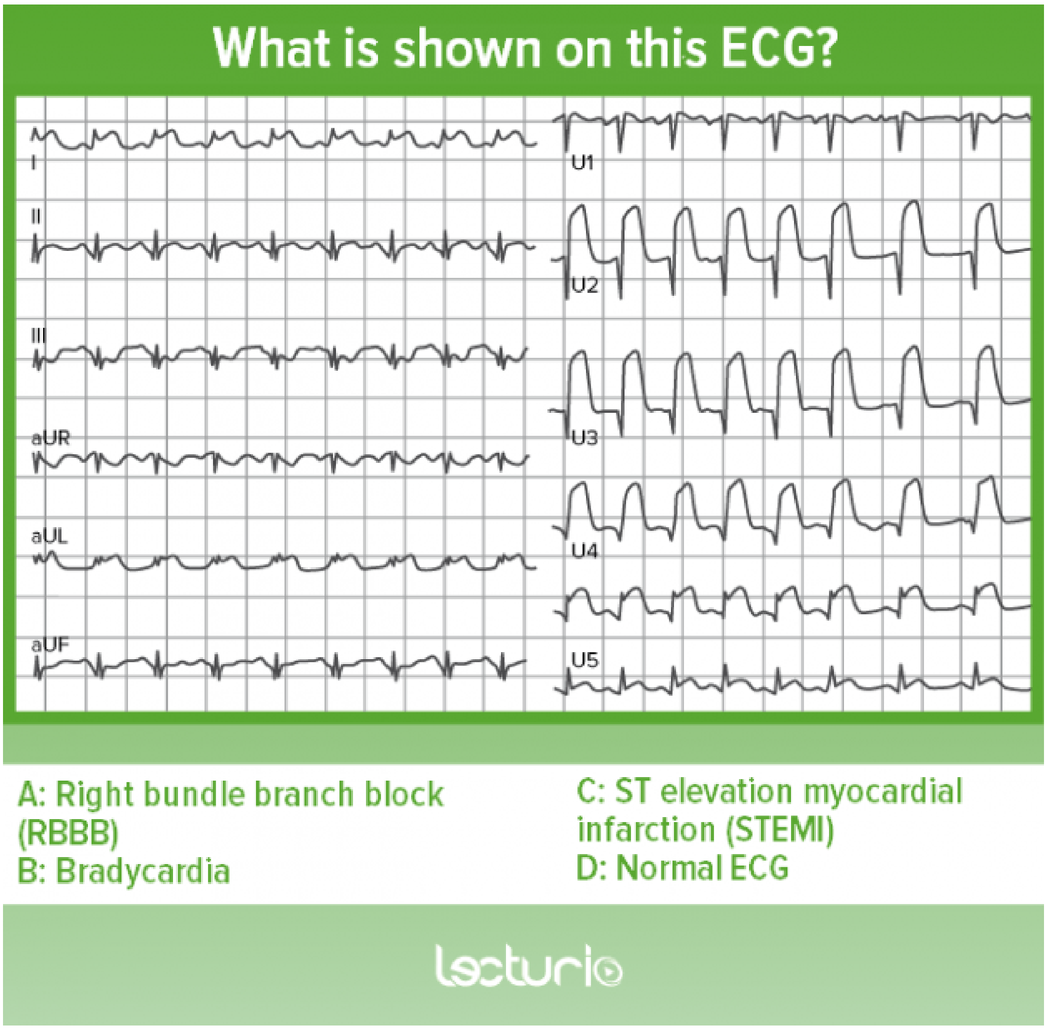
How to interpret an ECG in seven easy steps:

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 are a good start, these guidelines are not to be considered complete. Rather, these simple steps will simplify the approach to reading an ECG, which will help create a systematic interpretation of the ECG during clinical practice.

Review Question

The correct answer is below.



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Correct answer: C

Notes