

## Electrocardiography

Although the interpretation of electrocardiograms (ECGs) has traditionally been performed by physicians, exercise physiologists, and nurses, nuclear cardiology technologists are increasingly being called upon to interpret ECG results. Therefore, it is important for technologists to be generally familiar with reading ECGs as a part of their daily activities.

### FUNDAMENTALS OF ELECTROCARDIOGRAPHY

The ECG is a record of the voltage variations of the heart plotted against time. From the surface of the body, an ECG measures the electrical currents that the heart generates. The waveforms recorded by the ECG are labeled alphabetically from P to U. Each waveform represents a particular event in the depolarization-repolarization cycle of the heart (Figures 1 and 2):

- P wave: Atrial depolarization<sup>1</sup>
- PR interval: Atrial depolarization and atrioventricular delay (0.12-0.2 sec)<sup>1,2</sup>
- QRS complex: Ventricular depolarization (<0.1 sec)<sup>1</sup>
- J point: The junction between the end of the QRS complex and the beginning of the ST segment (a convex "hump" at the J point is associated with hypothermia)<sup>1</sup>
- ST segment: End of ventricular depolarization, start of ventricular repolarization<sup>2</sup>
- T wave: Ventricular repolarization and relaxation (if inverted, may represent ischemia)<sup>2</sup>
- U wave: Thought to represent the final phase of ventricular repolarization, sometimes seen following the T wave<sup>3</sup>
- RR interval: Period of time between the start of one heartbeat and the next<sup>3</sup>

The routine ECG records 12 leads using 10 electrodes. Only the standard limb leads are bipolar; the other leads are unipolar (Figures 3 and 4 and Table 1)<sup>1,2</sup>:

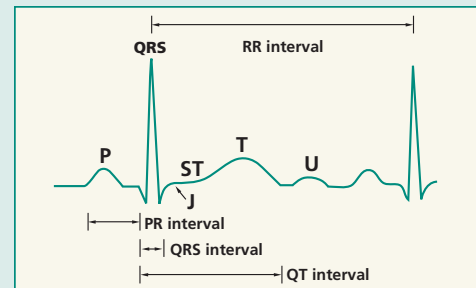
- Limb leads: I, II, III (bipolar)
- Augmented leads: aVR, aVL, aVF (unipolar)
- Precordial (chest) leads: V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, V<sub>5</sub>, V<sub>6</sub> (unipolar)

Each lead records the same electrical impulse on the ECG but from a different position in relation to the heart. Each lead can be read separately, or they can be read in combination. By examining the relationship between the leads and the anatomy of the heart, clinicians can localize the area of pathology shown on the ECG<sup>1,2</sup>:

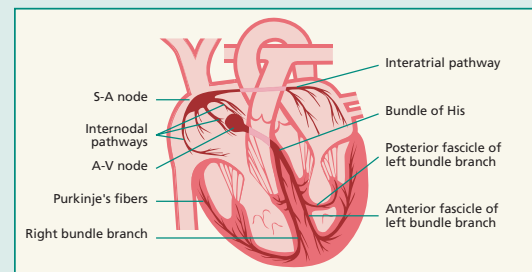
- V<sub>1</sub>, aVR: Right side of the heart
- V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>: Transition between right and left sides of the heart
- V<sub>5</sub>, V<sub>6</sub>, I, aVL: Left side of the heart
- II, III, aVF: Inferior heart

The heart rate can be calculated from ECG results (normal = 60 to 100 beats per minute [bpm])<sup>2</sup>:

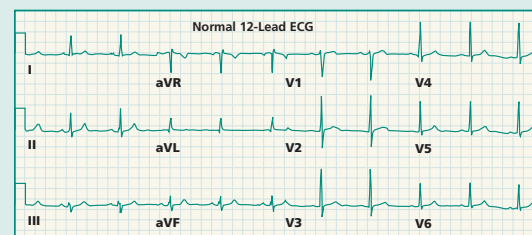
- Multiply the number of R waves in a 6-second strip by ten<sup>2</sup>
- Divide 1500 by the number of small boxes between 2 R waves<sup>1</sup>
- Divide 300 by the number of large boxes between 2 R waves<sup>1</sup>



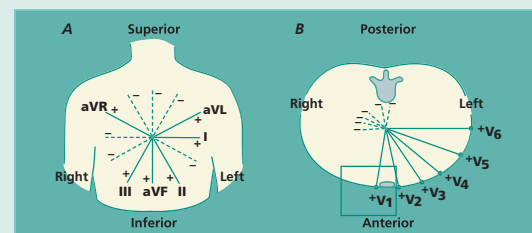
**Figure 1.** Basic ECG waveforms and intervals. Reproduced with permission from Kasper DL, et al, eds. *Harrison's Principles of Internal Medicine* (online version). McGraw-Hill Companies, Inc.



**Figure 2.** Conduction system of the heart.



**Figure 3.** Standard 12-lead ECG. Reprinted with permission of the Society of Nuclear Medicine from: Crawford ES and Husain SS. *Nuclear Cardiac Imaging – Terminology and Technical Aspects*. Reston, VA: Society of Nuclear Medicine, 2003.



**Figure 4.** A, Limb leads. B, Chest leads. Reproduced with permission from Kasper DL, et al, eds. *Harrison's Principles of Internal Medicine* (online version). New York, NY: McGraw-Hill Companies, Inc.

## ABNORMAL HEART RATES AND RHYTHMS

The term *arrhythmia* is used to describe any abnormality in the heart-beat, including a disturbance in the rate, rhythm, or conduction. Causes of cardiac arrhythmia can include the following<sup>4</sup>:

- Normal automaticity—for example, the firing of nonsinus “pacemaker” cells when the sinus rate slows below the intrinsic rate of these ectopic cells or an abnormal speeding up or slowing down of the sinus node (sinus tachycardia or sinus bradycardia)
- Abnormal automaticity—for example, atrial and ventricular myocardial cells develop an abnormal type of automatic firing
- Conduction disturbances, including abnormal prolongation of conduction time or block of conduction
- Simultaneous abnormalities of impulse generation and conduction

Here are some basic steps to help identify arrhythmias on ECG:

- Calculate the heart rate (normal = 60 to 100 bpm)
- Note the regularity of R waves
- Examine the P wave and its relationship to the QRS complex
- Measure the PR interval
- Measure the QRS complex duration

## HEART BLOCK

When electrical conduction throughout the heart is disrupted, a heart block can occur. The bundle branch block (BBB) is the most prevalent type of heart block, and it can occur in both the right and left bundle branches. BBBs are identified by a notched QRS complex on the ECG.<sup>2</sup>

## ISCHEMIA AND INFARCTION

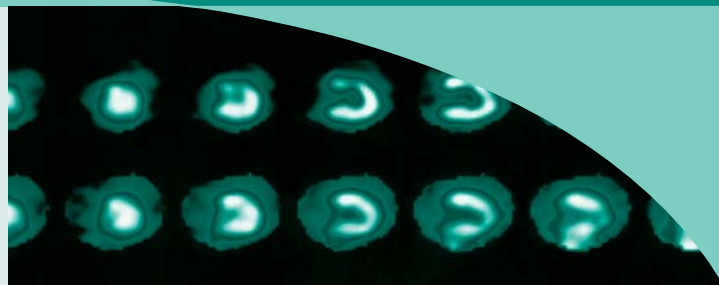
In some patients, ischemia and infarction may also be noted on the ECG. ST-segment depression is evidence of transient exercise-induced ischemia. It may also be seen in patients on digitalis and in patients who have had a subendocardial infarction. In some cases, ischemia may be depicted by T-wave inversion. Infarction is represented by the presence of a Q wave (Figure 5) because Q waves are normally not large enough to be significant. It is necessary to examine all 12 leads for the presence of a Q wave.<sup>2</sup>

## CONCLUSION

ECG results serve several clinical purposes. ECGs are used to screen for atrial and ventricular enlargement, although the diagnostic utility of the ECG is limited due to both false-positive and false-negative responses.<sup>1</sup> Therefore, stress myocardial perfusion imaging (MPI) may provide more clinically useful diagnostic information with regard to these conditions. ECG results are also used to determine whether additional cardiovascular testing (eg, MPI) is needed. Patients with abnormal ECG stress test results who are asymptomatic or who present with nonanginal chest pain are candidates for stress MPI.<sup>5</sup> Patients with nondiagnostic ECG who present with chest pain are also candidates for stress MPI.<sup>6</sup> ECG interpretation requires detailed knowledge that should be obtained through course instruction designed to provide meaningful conclusions.

For the American College of Cardiology/American Heart Association guidelines on ECG interpretation, please see the following article: Kadish AH, Buxton AE, Kennedy HL, et al. ACC/AHA clinical competence statement on electrocardiography and ambulatory electrocardiography. *Circulation*. 2001;104:3169-3178.

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LEAD	CORRESPONDING VOLTAGE
Bipolar:	
I	Right arm-left arm
II	Right arm-left leg
III	Left arm-left leg
Unipolar:	
aVR	Right arm
aVL	Left arm
aVF	Left leg (foot)

Table 1. Limb leads and corresponding body parts.

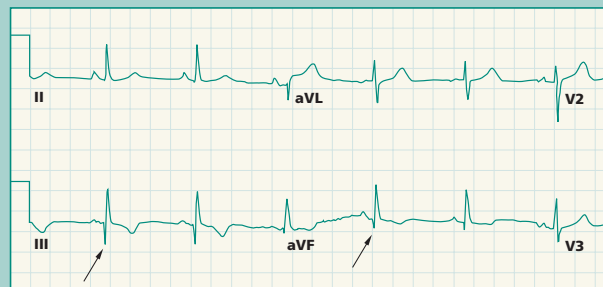


Figure 5. Example of an ECG with Q waves present (arrows) indicating infarction.

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### References

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