

ELECTROCARDIOGRAPH

As cardiac impulses pass through the heart, electrical currents spread into the tissues surrounding the heart, and a small portion of these currents spread throughout the surface of the body. If electrodes are placed on the skin on opposite sides of the heart, electrical potential generated by these currents can be recorded. Electrocardiograph is an instrument which records the electrical activity of the heart during a cardiac cycle. A record of the minute electrical pulses generated by the heart used to determine the condition of the patient's heart is the ElectroCardioGram. Electrodes are placed on the chest and limbs, and the impulses which they detect are amplified by the electrograph to which the electrodes are connected.

The ECG was developed by William Einthoven of Leiden University, England between 1903 and 1910

Electrical impulses in the heart originate in the sinoatrial node and travel through the heart muscle where they impart electrical initiation of systole or contraction of the heart. The electrical waves can be measured at selectively placed electrodes (electrical contacts) on the skin. Electrodes on different sides of the heart measure the activity of different parts of the heart muscle. An ECG displays the voltage between pairs of these electrodes, and the muscle activity that they measure, from different directions, also understood as vectors. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle. It is the best way to measure and diagnose abnormal rhythms of the heart, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or abnormal rhythms caused by levels of dissolved salts (electrolytes), such as potassium, that are too high or low. In myocardial infarction (MI), the ECG can identify damaged heart muscle. But it can only identify damage to muscle in certain areas, so it can't rule out damage in other areas. The ECG cannot reliably measure the pumping ability of the heart; for which ultrasound-based (echocardiography) or nuclear medicine tests are used.

ECG graph paper

Timed interpretation of an ECG was once incumbent to a stylus and paper speed. Computational analysis now allows considerable study of heart rate variability. **A typical electrocardiograph runs at a paper speed of 25 mm/s**, although faster paper speeds are occasionally used. **Each small block of ECG paper is 1 mm²**. At a paper speed of 25 mm/s, **one small block of ECG paper translates into 0.04 s (or 40 ms)**. **Five small blocks make up 1 large block, which translates into 0.20 s (or 200 ms)**. Hence, there are **5 large blocks per second**. A diagnostic quality 12 lead ECG is calibrated at 10 mm/mV, so 1 mm translates into 0.1 mV. A calibration signal should be included with every record. **A standard signal of 1 mV must move the stylus vertically 1 cm, that is two large squares on ECG paper.**

Leads used in ECG

Limb Leads

Leads I, II and III are the so-called limb leads

Lead I is a dipole with the negative (white) electrode on the right arm and the positive (black) electrode on the left arm.

Lead II is a dipole with the negative (white) electrode on the right arm and the positive (red) electrode on the left leg.

Lead III is a dipole with the negative (black) electrode on the left arm and the positive (red) electrode on the left leg.

Augmented limb

Leads aVR, aVL, and aVF are 'augmented limb leads'. They are derived from the same three electrodes as leads I, II, and III. However, they view the heart from different angles

Lead aVR or "augmented vector right" has the positive electrode (white) on the right arm. The negative electrode is a combination of the left arm (black) electrode and the left leg (red) electrode, which "augments" the signal strength of the positive electrode on the right arm.

Lead aVL or "augmented vector left" has the positive (black) electrode on the left arm. The negative electrode is a combination of the right arm (white) electrode and the left leg (red) electrode, which "augments" the signal strength of the positive electrode on the left arm.

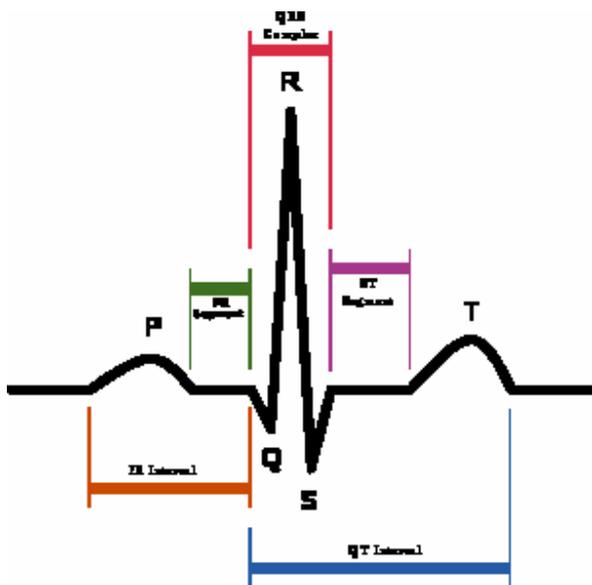
Lead aVF or "augmented vector foot" has the positive (red) electrode on the left leg. The negative electrode is a combination of the right arm (white) electrode and the left arm (black) electrode, which "augments" the signal of the positive electrode on the left leg.

Precordial

The precordial leads V1, V2, V3, V4, V5, and V6 are placed directly on the chest. Because of their close proximity to the heart, they do not require augmentation

Waves and intervals

A typical ECG tracing of a normal heartbeat (or cardiac cycle) consists of a P wave, a QRS complex and a T wave. A small U wave is normally visible in 50 to 75% of ECGs. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave.



Schematic representation of normal ECG P wave

During normal **atrial depolarization**, the main electrical vector is directed from the SA node towards the AV node, and spreads from the right atrium to the left atrium. This turns into the P wave on the ECG, which is upright in II, III, and aVF and inverted in aVR. A P wave must be upright in leads II and aVF and inverted in lead aVR to designate a cardiac rhythm as Sinus Rhythm.

The relationship between P waves and QRS complexes helps distinguish various cardiac arrhythmias.

The shape and duration of the P waves may indicate atrial enlargement.

QRS complex

The QRS complex is a structure on the ECG that **corresponds to the depolarization of the ventricles**. **Because the ventricles contain more muscle mass than the atria, the QRS complex is larger than the P wave**. In addition, because the His/Purkinje system coordinates the depolarization of the ventricles, the QRS complex tends to look "spiked" rather than rounded due to the increase in conduction velocity. A normal QRS complex is 0.08 to 0.12 sec (80 to 120 ms) in duration represented by three small squares or less, but any abnormality of conduction takes longer, and causes widened QRS complexes.

Not every QRS complex contains a Q wave, an R wave, and an S wave. By convention, any combination of these waves can be referred to as a QRS complex. However, correct interpretation of difficult ECGs requires exact labeling of the various waves. Some authors use lowercase and capital letters, depending on the relative size of each wave. For example, an Rs complex would be positively deflected, while a rS complex would be negatively deflected. If both complexes were labeled RS, it would be impossible to appreciate this distinction without viewing the actual ECG.

PR/PQ interval

The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex. It is usually 120 to 200 ms long. On an ECG tracing, this corresponds to 3 to 5 small boxes. In case a Q wave was measured with a ECG the PR interval is also commonly named PQ interval instead.

A PR interval of over 200 ms may indicate a first degree heart block.

A short PR interval may indicate a pre-excitation syndrome via an accessory pathway that leads to early activation of the ventricles, such as seen in Wolff-Parkinson-White syndrome.

A variable PR interval may indicate other types of heart block.

PR segment depression may indicate atrial injury or pericarditis.

Variable morphologies of P waves in a single ECG lead is suggestive of an ectopic pacemaker rhythm such as wandering pacemaker or multifocal atrial tachycardia

The duration, amplitude, and morphology of the QRS complex is useful in diagnosing cardiac arrhythmias, conduction abnormalities, ventricular hypertrophy, myocardial infarction, electrolyte derangements, and other disease states.

Q waves can be normal (physiological) or pathological. Pathological Q waves refer to Q waves that have a height of 25% or more than that of the partner R wave and/or have a width of greater than 0.04 seconds. Normal Q waves, when present, represent depolarization of the interventricular septum. For this reason, they are referred to as septal Q waves, and can be appreciated in the lateral leads I, aVL, V5 and V6.

Q waves greater than 1/3 the height of the R wave, greater than 0.04 sec (40 ms) in duration, or in the right precordial leads are considered to be abnormal, and may represent myocardial infarction.

"Buried" inside the QRS wave is the atrial repolarization wave, which resembles an inverse P wave. It is far smaller in magnitude than the QRS and is therefore obscured by it.

ST segment

The ST segment connects the QRS complex and the T wave and has a duration of 0.08 to 0.12 sec (80 to 120 ms). It starts at the J point (junction between the QRS complex and ST segment) and ends at the beginning of the T wave. However, since it is usually difficult to determine exactly where the ST segment ends and the T wave begins, the relationship between the ST segment and T wave should be examined together. The typical ST segment duration is usually around 0.08 sec (80 ms). It should be essentially level with the PR and TP segment.

The normal ST segment has a slight upward concavity.

Flat, downsloping, or depressed ST segments may indicate coronary ischemia.

ST segment elevation may indicate myocardial infarction. An elevation of >1mm and longer than 80 milliseconds following the J-point. This measure has a false positive rate of 15-20% (which is slightly higher in women than men) and a false negative rate of 20-30%.

T wave

The T wave represents the repolarization (or recovery) of the ventricles. The interval from the beginning of the QRS complex to the apex of the T wave is referred to as the absolute refractory period. The last half of the T wave is referred to as the relative refractory period (or vulnerable period).

In most leads, the T wave is positive. However, a negative T wave is normal in lead aVR. Lead V1 may have a positive, negative, or biphasic T wave. In addition, it is not uncommon to have an isolated negative T wave in lead III, aVL, or aVF.

Inverted (or negative) T waves can be a sign of coronary ischemia, Wellens' syndrome, left ventricular hypertrophy, or CNS disorder.

Tall or "tented" symmetrical T waves may indicate hyperkalemia. Flat T waves may indicate coronary ischemia or hypokalemia.

The earliest electrocardiographic finding of acute myocardial infarction is sometimes the hyperacute T wave, which can be distinguished from hyperkalemia by the broad base and slight asymmetry.

When a conduction abnormality (e.g., bundle branch block, paced rhythm) is present, the T wave should be deflected opposite the terminal deflection of the QRS complex. This is known as appropriate T wave discordance.

QT interval

The QT interval is measured from the beginning of the QRS complex to the end of the T wave. Normal values for the QT interval are between 0.30 and 0.44 seconds.[citation needed]

The QT interval as well as the corrected QT interval are important in the diagnosis of long QT syndrome and short QT syndrome. The QT interval varies based on the heart rate, and various correction factors have been developed to correct the QT interval for the heart rate.

The QT interval represents on an ECG the total time needed for the ventricles to depolarize and repolarize

U wave

The U wave is not always seen. It is typically small, and, by definition, follows the T wave. U waves are thought to represent repolarization of the papillary muscles or Purkinje fibers. Prominent U waves are most often seen in hypokalemia, but may be present in hypercalcemia, thyrotoxicosis, or exposure to digitalis, epinephrine, and Class 1A and 3 antiarrhythmics, as well as in congenital long QT syndrome and in the setting of intracranial hemorrhage. An inverted U wave may represent myocardial ischemia or left ventricular volume overload