Electrocardiogram(ECG)

An electrocardiogram (ECG or EKG) is one of the simplest and fastest tests used to evaluate the heart. Electrodes (small, plastic patches that stick to the skin) are placed at certain spots on the chest, arms, and legs. The electrodes are connected to an ECG machine by lead wires. The electrical activity of the heart is then measured, interpreted, and printed out. No electricity is sent into the body.

Natural electrical impulses coordinate contractions of the different parts of the heart to keep blood flowing the way it should. An ECG records these impulses to show how fast the heart is beating, the rhythm of the heart beats (steady or irregular), and the timing of the electrical impulses as they move through the different parts of the heart. Changes in an ECG can be a sign of many heart-related conditions.

Why might I need an electrocardiogram?

- To look for the cause of chest pain
- To evaluate problems that may be heart-related, such as severe tiredness (fatigue), shortness of breath, dizziness, or fainting
- To identify irregular heartbeats
- To help assess the overall health of the heart before procedures, such as surgery; after treatment for a heart attack (myocardial infarction), endocarditis (inflammation or infection of one or more of the heart valves), or other condition; or after heart surgery or cardiac catheterization
- To see how an implanted pacemaker is working
- To find out how well certain heart medicines are working
- To get a baseline tracing of the heart's function during a physical exam, which can be compared with future ECGs

What are the risks of an electrocardiogram?

An ECG is a quick, easy way to assess the heart's function. Risks associated with ECG are minimal and rare. You won't feel anything during the ECG. You may feel some discomfort when the sticky electrodes are taken off. If the electrode patches are left on too long, they may cause skin irritation. There may be other risks depending on your specific medical condition. Be sure to discuss any concerns with your provider before the test.

Certain factors or conditions may interfere with or affect the results of the ECG. These include:

- Obesity
- Anatomical considerations, such as the size of the chest and the location of the heart within the chest
- Movement during the test
- Exercise or smoking before the test
- Certain medicines
- Electrolyte imbalances, such as too much or too little potassium, magnesium, or calcium in the blood

How do I get ready for an electrocardiogram?

- Generally, fasting (not eating) isn't required before the test.
- Tell your provider about all the prescription and over-the-counter medicines, vitamins, herbs, and supplements that you take.
- Tell your provider if you have a pacemaker.
- Based on your medical condition, your provider may request other specific preparation.

What happens during an electrocardiogram?

Generally, an ECG follows this process:

- You'll be asked to remove any jewelry or other objects that may interfere with the test.
- You'll be asked to remove clothing from the waist up. You will be given a sheet or gown to wear so that only the necessary skin is exposed during the test.
- You'll lie flat on a table or bed for the test. It's important for you to lie still and not talk during the ECG, so that you don’t change the results.
- If your chest, arms, or legs are very hairy, the technician may shave or clip small patches of hair so that the electrodes will stick to your skin.
- Electrodes will be attached to your chest, arms, and legs.
- The lead wires will be attached to the electrodes.
- Once the leads are attached, the technician may enter identifying information about you into the machine's computer.
- The ECG will be started. It will take only a short time for the tracing to be completed.

Once the tracing is completed, the technician will disconnect the leads and remove the electrodes.

What happens after an electrocardiogram?

Generally, there is no special care needed after an ECG. Tell your provider if you have any chest pain, shortness of breath, dizziness, fainting, or other symptoms that you had before the ECG.Your provider may give you other instructions after the test, depending on your situation.

ECG Waveform

Parts of an ECG

The standard ECG has 12 leads. Six of the leads are considered “limb leads” because they are placed on the arms and/or legs of the individual. The other six leads are considered “precordial leads” because they are placed on the torso (precordium).

The six limb leads are called lead I, II, III, aVL, aVR and aVF. The letter “a” stands for “augmented,” as these leads are calculated as a combination of leads I, II and III.

The six precordial leads are called leads V1, V2, V3, V4, V5 and V6.

The Normal ECG

A normal ECG contains waves, intervals, segments and one complex, as defined below.

Wave: A positive or negative deflection from baseline that indicates a specific electrical event. The waves on an ECG include the P wave, Q wave, R wave, S wave, T wave and U wave.

Interval: The time between two specific ECG events. The intervals commonly measured on an ECG include the PR interval, QRS interval (also called QRS duration), QT interval and RR interval.

Segment: The length between two specific points on an ECG that are supposed to be at the baseline amplitude (not negative or positive). The segments on an ECG include the PR segment, ST segment and TP segment.

Complex: The combination of multiple waves grouped together. The only main complex on an ECG is the QRS complex.

Point: There is only one point on an ECG termed the J point, which is where the QRS complex ends and the ST segment begins.

The main part of an ECG contains a P wave, QRS complex and T wave. Each will be explained individually in this tutorial, as will each segment and interval.

The P wave indicates atrial depolarization. The QRS complex consists of a Q wave, R wave and S wave and represents ventricular depolarization. The T wave comes after the QRS complex and indicates ventricular repolarization.

P Wave

The P wave indicates atrial depolarization. The P wave occurs when the sinus node, also known as the sinoatrial node, creates an action potential that depolarizes the atria.

The P wave should be upright in lead II if the action potential is originating from the SA node. In this setting, the ECG is said to demonstrate a normal sinus rhythm, or NSR. As long as the atrial depolarization is able to spread through the atrioventricular, or AV, node to the ventricles, each P wave should be followed by a QRS complex.

Atrial enlargements can widen the P wave or increase the P wave amplitude. Ectopic atrial rhythms can alter the normal morphology of the P waves. There are many heart rhythms in which the P waves are not able to be identified, including atrial fibrillation and sometimes junctional rhythms. At times, the P waves can be buried at the end of the QRS complex, causing a “short RP” scenario.

TP Segment

The TP segment is the portion of the ECG from the end of the T wave to the beginning of the P wave.

This segment should always be at baseline and is used as a reference to determine whether the ST segment is elevated or depressed, as there are no specific disease conditions that elevate or depress the TP segment.

During states of tachycardia, the TP segment is shortened and may be difficult to visualize altogether. It is good to examine the TP segment closely for the presence of U waves or atrial activity that could indicate pathology.

T Wave

The T wave occurs after the QRS complex and is a result of ventricular repolarization.

T waves should be upright in most leads; the exceptions are aVR and V1. Further, T waves should be asymmetric in nature. The second portion of the T wave should have a steeper decline when compared with the incline of the first portion. If the T wave appears symmetric, cardiac pathology such as ischemia may be present.

Many abnormal T wave patterns exist; These include hyperkalemia, Wellens’ syndrome, left ventricular hypertrophy with repolarization abnormalities, pericarditis (stage III), arrhythmogenic right ventricular dysplasia or ARVD, and hyperacute T waves during myocardial infarction.

QT Interval

The QT interval is the time from the beginning of the QRS complex, representing ventricular depolarization, to the end of the T wave, resulting from ventricular repolarization.

The normal QT interval is controversial, and multiple normal durations have been reported. In general, the normal QT interval is below 400 to 440 milliseconds (ms), or 0.4 to 0.44 seconds. Women have a longer QT interval than men. Lower heart rates also result in a longer QT interval.

A quick way to distinguish a prolonged QT interval is to examine if the T wave ends beyond the halfway point between the RR interval. If the T wave ends past the halfway point of the RR interval, it is prolonged.

Due to the effects of heart rate, the corrected QT interval (QTc) is frequently used. The QTc is considered prolonged if greater than 450 ms in males and 470 ms in females. It is calculated using Bezett’s formula, described below:

<u>Bezett’s formula :</u> $QTc = (QT\ Interval)/(\sqrt{RR})$

Prolongation of the QT interval can result from multiple medications, electrolyte abnormalities — hypocalcemia, hypomagnesemia and hypokalemia — and certain disease states including intracranial hemorrhage.

S Wave

The S wave is the first downward deflection of the QRS complex that occurs after the R wave. However, a S wave may not be present in all ECG leads in a given patient.

In the normal ECG, there is a large S wave in V1 that progressively becomes smaller, to the point that almost no S wave is present in V6. A large slurred S wave is seen in leads I and V6 in the setting of a right bundle branch block.

The presence or absence of the S wave does not bear major clinical significance. Rarely is the morphology of the S wave discussed.

In the setting of a pulmonary embolism, a large S wave may be present in lead I — part of the S1Q3T3 pattern seen in this disease state. At times, the morphology of the S wave is examined to determine if ventricular tachycardia or supraventricular tachycardia with aberrancy is present.

R Wave

The R wave is the first upward deflection after the P wave and part of the QRS complex. The R wave morphology itself is not of great clinical importance but can vary at times.

The R wave should be small in lead V1. Throughout the precordial leads (V1-V6), the R wave becomes larger — to the point that the R wave is larger than the S wave in lead V4. The S wave then becomes quite small in lead V6; this is called “normal R wave progression.” When the R wave remains small in leads V3 to V4 — that is, smaller than the S wave — the term “poor R wave progression” is used.

R wave is usually quite small in lead V1; if the R wave is large in V1 — that is, greater in amplitude than the S wave — significant pathology may be present.

The causes for a R/S wave ratio greater than 1 in lead V1 include right bundle branch block, Wolff-Parkinson-White syndrome, an acute posterior myocardial infarction, right ventricular hypertrophy and isolated posterior wall hypertrophy, which can occur in Duchenne muscular dystrophy.

If a right bundle branch block is present, there may be two R waves, resulting in the classic “bunny ear” appearance of the QRS complex. In this setting, the second R wave is termed “R’” or “R prime.”

QRS Complex

A combination of the Q wave, R wave and S wave, the “QRS complex” represents ventricular depolarization.

This term can be confusing, as not all ECG leads contain all three of these waves; yet a “QRS complex” is said to be present regardless.

For example, the normal QRS complex in lead V1 does not contain a Q wave — only a R wave and S wave — but the combination of the R wave and S wave is still referred to as the QRS complex for this lead.

The normal duration (interval) of the QRS complex is between 0.08 and 0.10 seconds — that is, 80 and 100 milliseconds. When the duration is between 0.10 and 0.12 seconds, it is intermediate or slightly prolonged. A QRS duration of greater than 0.12 seconds is considered abnormal.

The QRS duration will lengthen when electrical activity takes a long time to travel throughout the ventricular myocardium. The normal conduction system in the ventricles is called the His-Purkinje system and consists of cells that can conduct electricity quite rapidly. Thus, normal conduction of an electrical impulse through the atrioventricular, or AV, node, then to the ventricles via the His-Purkinje system, is fast and results in a normal QRS duration. When electrical activity does not conduct through the His-Purkinje system, but instead travels from myocyte to myocyte, a longer time is necessary, and the QRS duration is widened.

A widened QRS duration occurs in the setting of a right bundle branch block, left bundle branch block, non-specific intraventricular conduction delay and during ventricular arrhythmias such as ventricular tachycardia

Q Wave

When the first deflection of the QRS complex is upright, then no Q wave is present. The normal individual will have a small Q wave in many, but not all, ECG leads.

Abnormalities of the Q waves are mostly indicative of myocardial infarction and discussed further inside the relevant sections of ECG Reviews and Criteria. The terms "Q wave myocardial infarction" and "non-Q wave myocardial infarction" are earlier designations of different types of MIs ultimately resulting in, respectively, Q wave development or the absence of Q wave development.

How Or Solution is different from the existing ECG Monitoring System?

- Our IoT-based Wireless ECG System consists of wireless sensors that capture heart signals and transmit this data via Bluetooth to a website. This **eliminates the need for traditional bulky wired ECG machines**, making cardiac monitoring more accessible and convenient.
- The system enables **continuous real-time monitoring** of cardiac signals, displaying live ECG readings on a website. This innovation is particularly beneficial for patients in rural areas, elderly individuals, and those requiring frequent ECG monitoring, enhancing accessibility, mobility, and convenience.
- To further improve diagnostic capabilities, we have integrated **AI-powered ECG signal classification** into the system. The AI model analyzes real-time ECG data, detecting and classifying abnormalities such as arrhythmias, atrial fibrillation, and other cardiac conditions. This helps in early detection of heart diseases, providing timely alerts and insights to healthcare professionals and users, ultimately improving patient outcomes.