Electrical signal from the heart- the electrocardiogram

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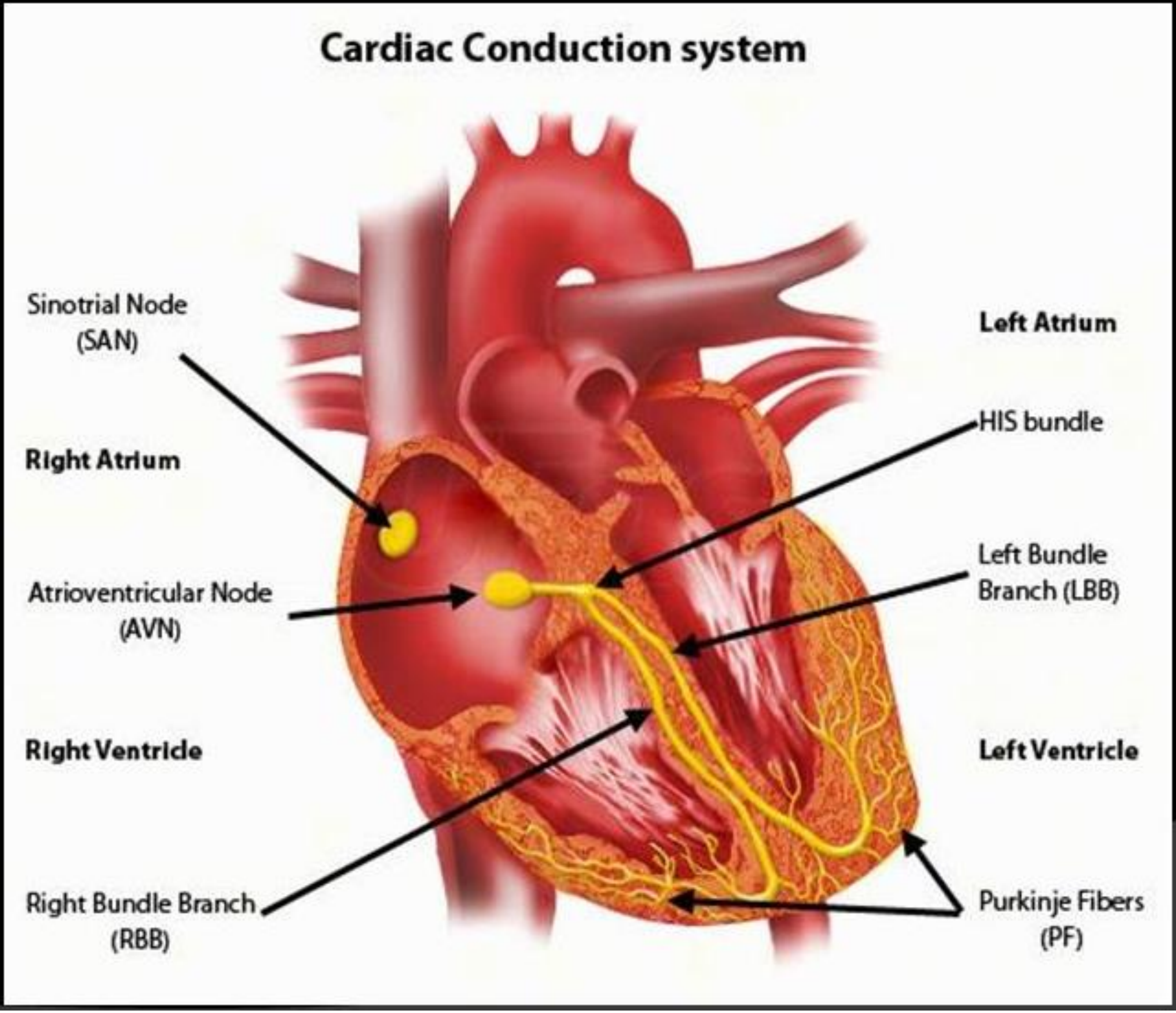
Introduction

The body relies on the heart to circulate blood throughout the body. The heart is responsible for pumping oxygenated blood from the lungs out to the body through the arteries and also circulating deoxygenated blood back to the lungs. from the body through the veins. The heart is divided into four chambers and each chamber is responsible for a different part of the circulatory process mentioned above. Deoxygenated blood first enters the right atrium via the vena cava, where it is then pumped into the right ventricle. The right ventricle pumps this deoxygenated blood through the pulmonary artery to the lungs, where it flows through the alveoli, receives oxygen, and then is returned to the heart through the pulmonary vein and into the left atrium. The left atrium then pumps this oxygenated blood into the left ventricle, where then it is pumped out to the rest of the body through the aorta. This process of contracting the different chambers is highly coordinated and the coordination is controlled by specialized regions of the heart responsible for electrical stimulation of cardiac muscle. Life several other bioelectrical signals, the electrical impulses generated by the heart can be measured on the surface of the skin with electrodes. Using surface electrodes, the cardiac potential of the heart can be measured and correlated with regions of cardiac excitation. This measurement is called an electrocardiogram (ECG). The ECG can be used to evaluate cardiac function, heart rate, and cardiac arrhythmias. The electrical activation that creates the normal heartbeat can in some instances cause abnormal cardiac function. Disorders such as bradycardia (slow heart rate), tachycardia (fast heart rate) and electrical conduction problems such as bundle branch blocks can be all diagnosed from the ECG

Special Conductive Tissues in the Heart

There are several specialized regions within the heart to initiate electrical signals that cause cardiac contraction . The primary area responsible for cardiac activation is the sinus node (also known as the sinoatrial or SA node). The SA node is located at the top of the right atrium and is the major structure responsible for pacing the heart. Connecting the SA nodes to the atrioventricular (AV) nodes are the internodal pathways. These internodal pathways are located along the walls of the right atrium. The electrical signal propagates down the internodal pathways and enters the AV node. At the AV node the signal is slightly delayed. The AV node is located in the heart septum, between the right and left atrium. After the AV node, the electrical signal flows through the Bundle of His, located in the septal wall between the left and right ventricles. The Bundle of His then divides into two branches, the right branch and left branch. These branches continue along the septal wall, and then go into the Purkinje fibers, which innervate' the right and left ventricular walls.

CONDUCTIVE TISSUE OF HEART

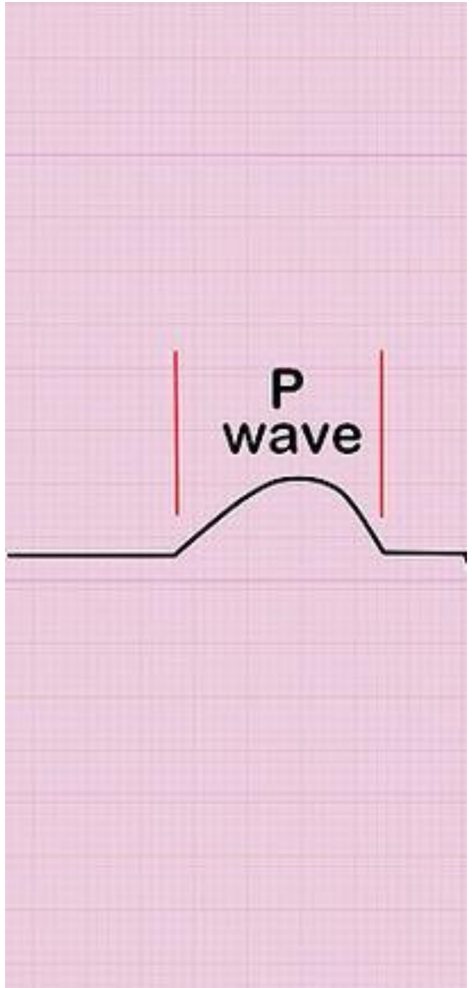


Origin of the ECG Signal

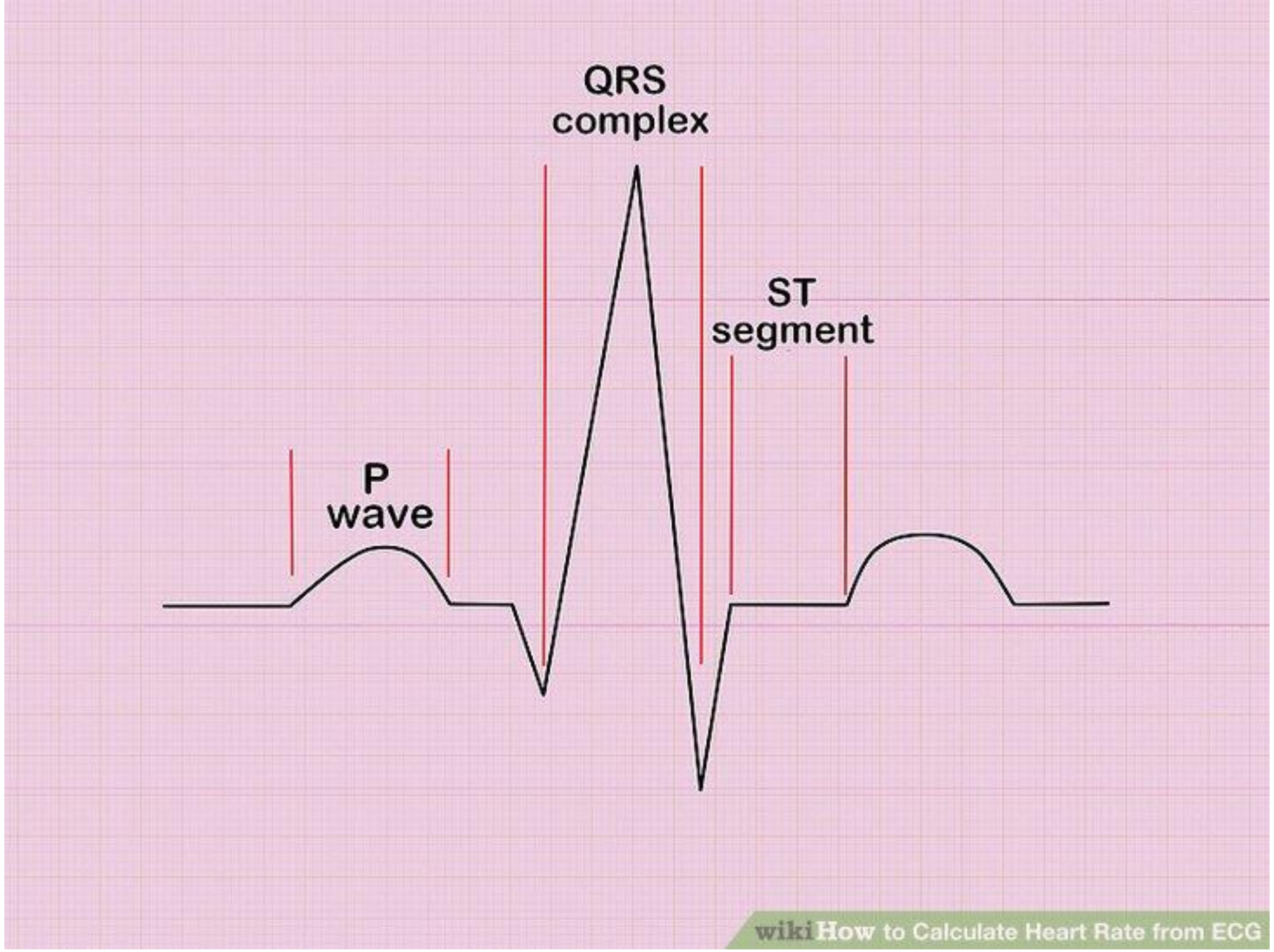
In normal cases, the SA node is the heart's natural pacemaker with the autonomic nervous system to regulate its excitation. Therefore, the electrical impulse responsible for the cardiac cycle originates at the SA node. Pulses from the SA node propagate via the internodal fibers of the right atrium, and then to the left atrium, causing immediate atrial contraction. This electrical potential then travels to the AV node. At the AV node, the depolarization potential is then delayed, allowing the atria to fully contract. This delay allows the atrium to completely empty its contents into the ventricles before ventricular contraction. After this delay in the AV node, the potential travels down the Bundle of His, which splits into the right and left branch bundles. These bundles then innervate the ventricular walls via the Purkinje fibers. When the signal reaches the Purkinje fibers, ventricular contraction occurs, sending blood from the right ventricle into the lungs and blood from the left ventricle out the aorta. This process then repeats for the next heartbeat. Other tissues in the heart also have natural pacing rates controlled by the autonomic nervous system. The AV node, without-outside stimulation, has a natural discharge rate of 40 to 60 times a minute, while the Purkinje fibers fire between 15 and 40 times a minute. This is in contrast to the SA node that fires between 70 and 80 times a minute. The reason that neither the AV node nor the Purkinje fibers are responsible for setting the heart rate is due to the discharge rate of the SA node. The SA node fires faster than the AV node or Purkinje fibers, so these other tissues are excited from the SA impulse rather than their own rhythmic rate. In normal conditions, the SA node is the natural pacemaker of the heart. However, sometimes the AV node or Purkinje fibers begin pacing faster than the SA node.

This condition is known as an ectopic pacemaker. An ectopic pacemaker occurs when electrical activation of the heart is initiated elsewhere than the SA node. Another condition that can lead to an ectopic pacemaker is when the signals from the SA node are prevented from conducting to the rest of the heart. This usually occurs when the signal is blocked at the AV node or the AV fibers that innervate the ventricles. In this instance, the SA node fires at its own normal rate, but these signals do not conduct down to the ventricles. Since the Purkinje fibers do not receive these impulses from the SA node, they begin to fire at their own intrinsic rate, between 15-40 times a minute. This leads to a very slow contraction rate of the ventricles, failing to pump blood. If this continues, the brain may become deprived of oxygen, and the person may faint.

The Electrocardiography(ECG) signal illustrates the electrical depolarization and repolarization of the heart during a contraction. the depolarization of the cardiac muscle cells in the atrium occurs first. Therefore, the first wave in the ECG signal corresponds to the depolarization Of the atrium. This is known as the P wave

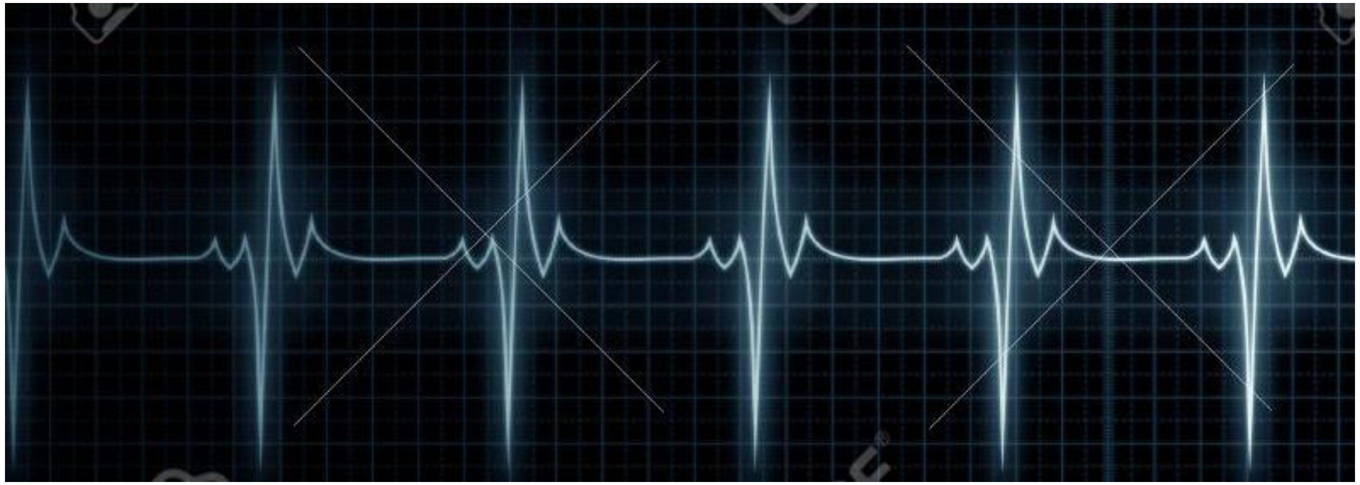


the start of ventricular contraction is the QRS wave. The ventricles stay contracted for a few milliseconds until ventricular repolarization occurs, which is seen as the T wave. Atrial repolarization typically occurs between 0.15 to 0.20 seconds after the P wave



this is the same time when the QRS complex occurs. The QRS complex is of much greater amplitude than atrial repolarization so it dominates the signal. Typical Duration and Amplitudes. The voltage of the ECG signal can vary depending on the location of the electrodes placed on the body. If the electrodes are located close to the heart, the recorded potentials can be as high as 5 m V. However, if the electrodes are placed further apart, such as at the wrists, a typical value is 1mV. Both of these measurements, however, are small compared to electrodes placed directly in contact with the heart muscle membrane. Here the potential can as high as 110 mV. Typical amplitudes are around 1mV for the top of the Q wave to the bottom of the S wave, 0.1 - 0.3 mV for the P wave, and between 0.2 - 0.3 mV for the T wave. The PQ interval (also known as the PR interval) is the amount of time from the beginning of the P complex to the QRS complex. This represents the amount of time between the beginning of atrial contraction and the beginning of ventricular contraction, The normal duration is approximately 0.16 seconds. Similarly, the QT interval is the time between ventricular contraction and ventricular repolarization

This is measured from the beginning of the Q wave to the end of the T wave and typically lasts 0.35 seconds. The heart rate can be determined directly from the ECG. The heart rate is the inverse of the time between similar segments in the ECG recording. For example, if the time measured between two QRS complexes is 0.8 seconds, then the number of beats per second is the inverse, 1.25 beats / second. In order to obtain the heart rate per minute, you would simply multiply by 60 seconds/minute. This would yield 75 beats per minute.



P wave

Remove the polarization resulting from the passage of an electric current in both the left and right atrium

إزالة الاستقطاب الناتج عن مرور التيار الكهربائي في الأذين الأيسر والأيمن

Q wave

Remove the polarization from the ventricle between the ventricles

إزالة الاستقطاب من البطين بين البطينين

R wave

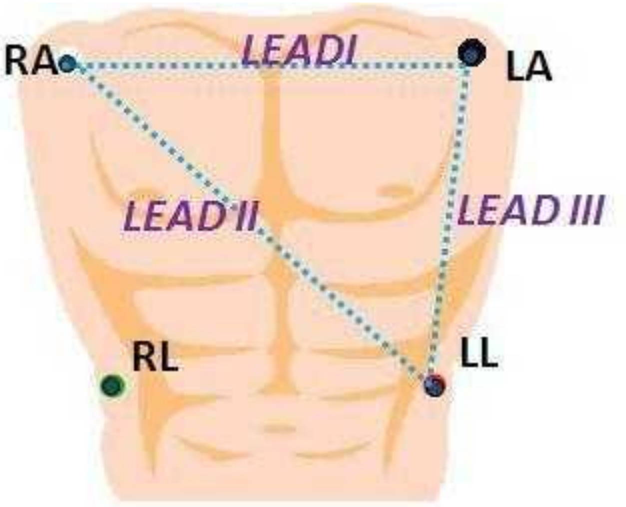
Passage of an electric current resulting in de-polarizationمرور تيار كهربائي يؤدي إلى إزالة الاستقطاب

S wave

The passage of an electric current in the walls of the ventricles towards the top, which removes the polarizationمرور تيار كهربائي في جدران البطينين نحو الأعلى ، مما يزيل الاستقطاب

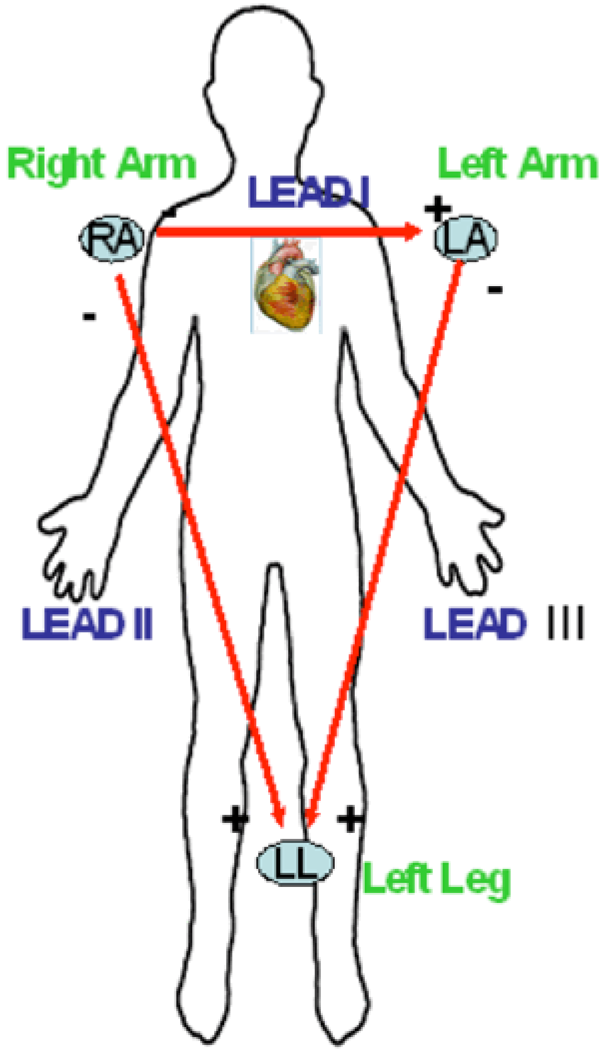
Electrode Configuration

There is a standard placement of electrodes when performing ECG recordings called a standard bipolar limb lead. A lead refers to the potential difference between two electrodes. For this lab, lead placement involves three leads, which are placed on the right arm (RA), left arm (LA), and left leg (LL). The electrodes can be attached to the wrists and inner ankle, but for clinical applications, are usually attached to the chest for a more accurate signal. Leads I, Il, and Ill constitute the standard limb lead ECG connected as follows:



Lead	Composition
I	LA – RA
II	LL – RA
II	LL – LA

Using these three leads, we can form what is called Einthoven's Triangle. This is a representation of vectors demonstrating the formation of the ECG signal. In interpreting these measurements, each lead is assumed to be equivalent to measurements taken across all sides of an - equilateral (Einthoven's) triangle



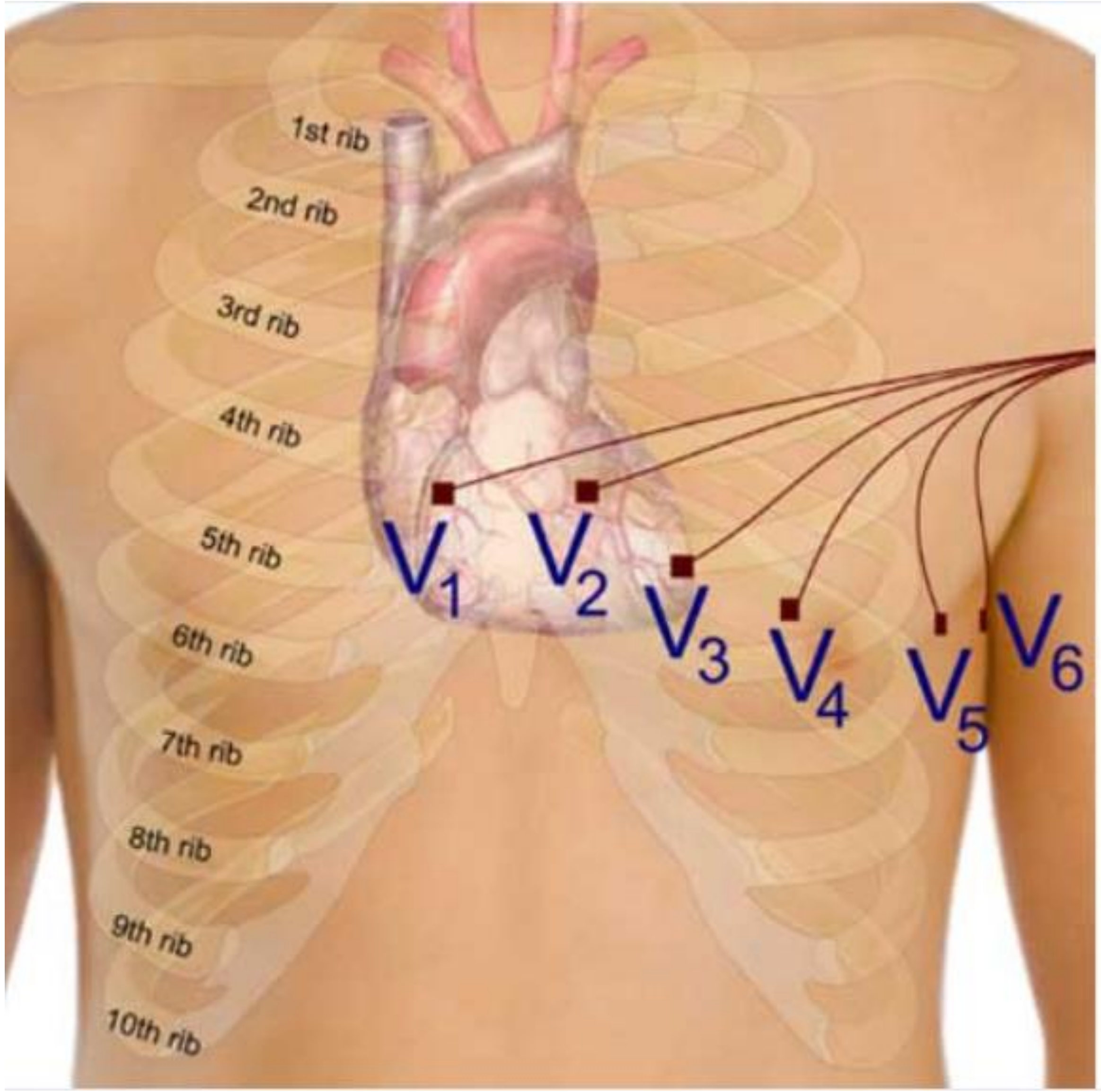
With Einthoven's Triangle, there is an equation that relates all three vectors. Graphically, Einthoven's Law says that if the potentials of the first two leads are known, than the third lead can be found by adding the two - vectors together. Mathematically, Einthoven's law states that for the potentials on each lead:

Lead I + Lead III = Lead II

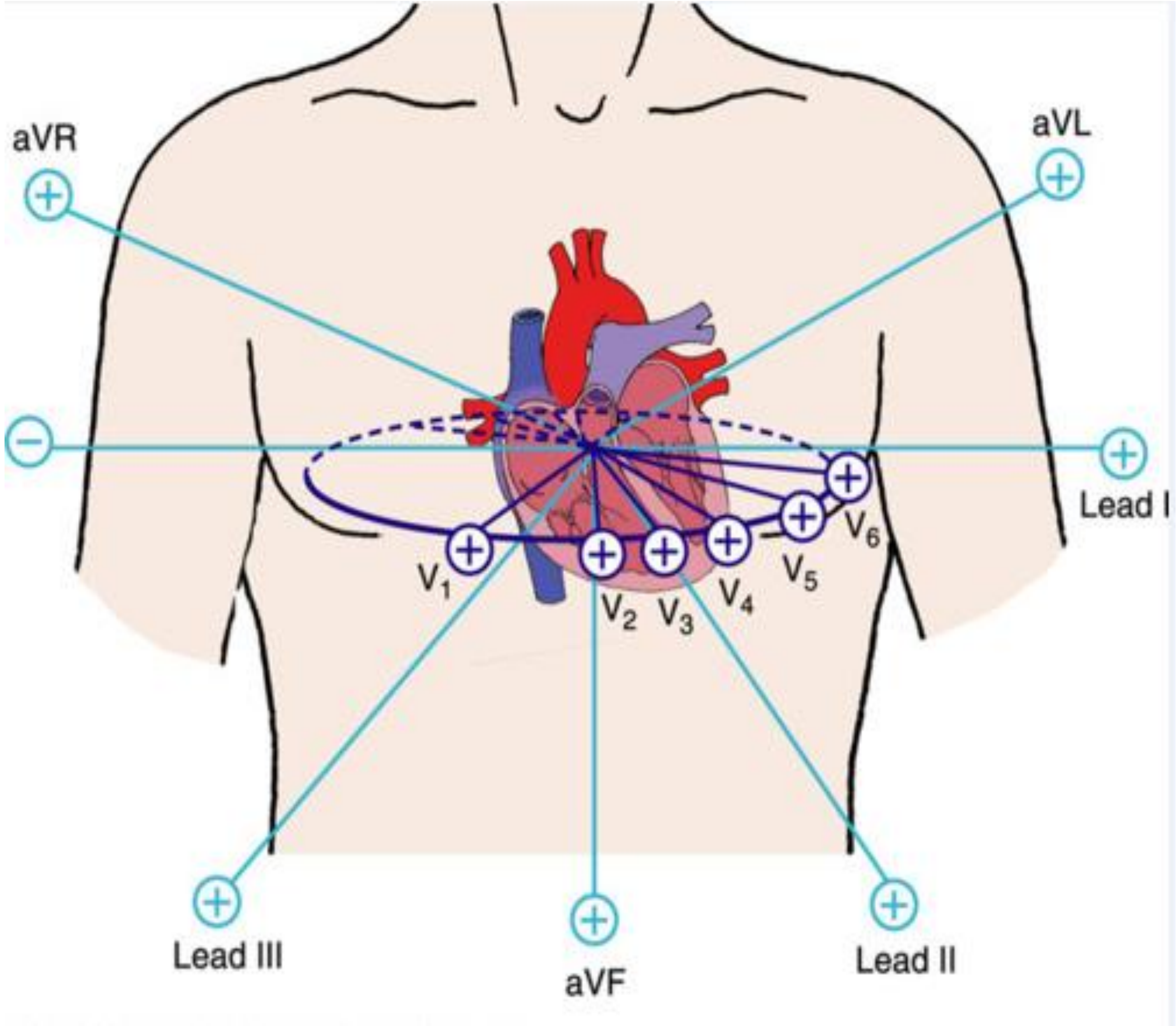
Some may notice that this equation is similar to Kirchoff's Voltage law, which states that all of the voltages in a loop must equal zero. Using this equation, we only need to record two of the leads. The third lead can be determined mathematically, provided that the two leads were measured simultaneously. Einthoven's Triangle also allows us to determine the mean electrical axis of the heart. This mean electrical axis is the vector representing the summation of all the vectors that occur in a cardiac cycle. This electrical axis can be thought of as a dipole. The dipole illustrates the strength and direction of the heart's polarization during a cardiac cycle. There are two ways of determining the mean electrical axis. Lead I measures lateral voltage and the other two measure from top to bottom. One method is to measure the magnitude of the R complex along Lead I and Lead III, and to extrapolate the vector of Lead II, which would give the magnitude and angle of the vector. A more accurate way of measuring the mean electrical axis would be to add the Q, R, and S potentials for the two leads, instead of only the R wave. The QRS potentials are measured along Lead I and III, added together, and then the mean electrical axis can be computed by finding the magnitude and the. vector representing Lead II. If a complete measurement of the mean electrical axis is desired, twelve leads are required, since the mean electrical axis is precisely defined in three dimensions, x, y, and z. In this lab, we will only focus on the frontal plane mean electrical axis. In normal conditions, the mean electrical axis of the heart is typically around 60 degrees.

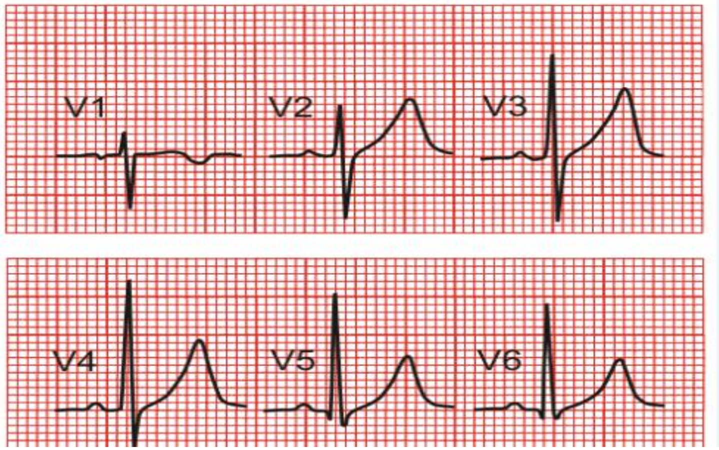
the ECG electrode positions should be found in the following locations:

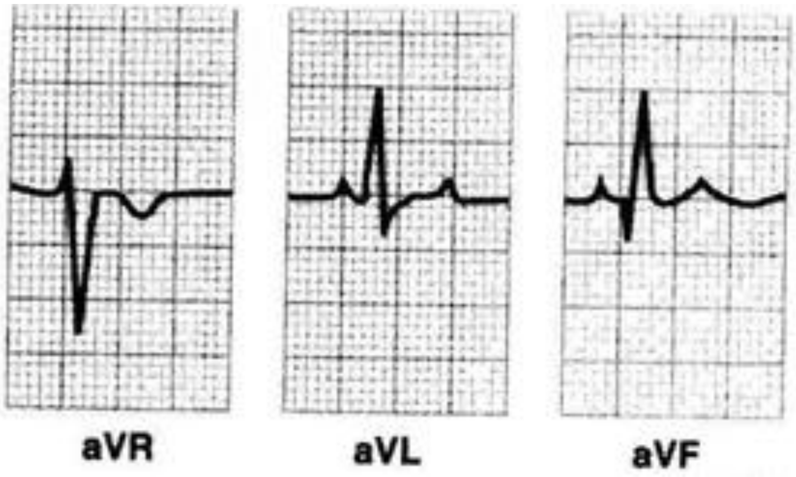
V1 (C1)	Fourth intercostal space at the right sternal border
V2 (C2)	Fourth intercostal space at the left sternal border
V3 (C3)	Halfway between leads V2 and V4
V4 (C4)	Fifth intercostal space in the midclavicular line
V5 (C5)	Left anterior axillary line on the same horizontal plane as V4
V6 (C6)	Left midaxillary line on the same horizontal plane as V4 and V5



placement of the precordial electrodes.


aVR
aVL
Lead I
V1
V2
V3
V4
V5
V6
Lead III
aVF
Lead II


V1
V2
V3
V4
V5
V6


aVR
aVL
aVF