

Biology 347 General Physiology Lab

Advanced Cardiac Functions

ECG Leads and Einthoven's Triangle

Objectives

- Students will record a six-lead ECG from a resting subject and determine the QRS axis of the subject.
- Students will understand the principles behind the derivation of ECG leads as they relate to Einthoven's triangle.

Introduction

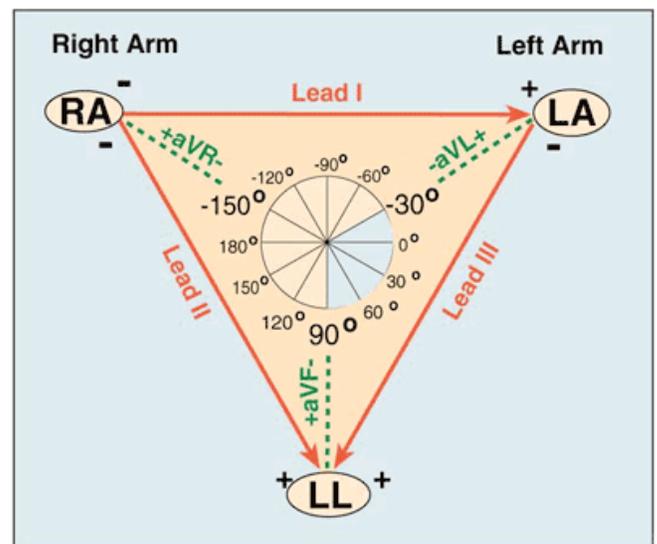
The cardiac cycle involves a sequential contraction of the atria and the ventricles. These contractions are triggered by the coordinated electrical activity of the myocardial cells. The electrical currents produced by the heart are large and can be recorded through electrodes placed on the skin. The recording is known as an electrocardiogram or ECG. When diagnosing the health of the heart, electrocardiograms are recorded from specific locations around the heart and then analyzed. These positions or combinations of positions are called leads or views. When the shapes of the electrocardiograms recorded from these different views are analyzed, the health of the subject's heart and the presence or absence of cardiac disease can be determined.

Cardiac action potentials are different from the action potentials of nerves and skeletal muscle. Cardiac action potentials contain three phases. In addition to the rapid depolarization and repolarization of the membrane potential in nerve and muscle action potentials, cardiac action potentials contain a plateau depolarization after the period of rapid depolarization. This plateau is pronounced in the potentials from ventricular fibers. A recording from a single lead is adequate for demonstrating the basic components of the ECG. There are specific waveforms associated with the electrical activity of the atrial and ventricular fibers.

These events and waveforms are:

- The atrial depolarization which produces the P wave.
- The atrial repolarization and the ventricular depolarization which produce the QRS complex.
- The ventricular repolarization which produces the T wave.

There are actually twelve cardiographic leads, six limb and six chest. The six limb leads are in the frontal plane of the body, the plane parallel to the floor when the subject is reclining. These leads are also known as the coronal set. The six chest leads are in a plane parallel to the floor when the subject is standing; they are called the precordial leads. Examining the electrical activity of the heart from twelve different angles can be a valuable clinical tool. The way that currents pass through different parts of the heart can indicate abnormalities or problems such as: hypertrophies, bundle branch or fascicular blocks, cushion defects, pulmonary hypertension, and more. By measuring the magnitudes of the electrical activity from different directions, the areas of the heart that are abnormal can be identified. A clinician can gain a better understanding of the health of the heart by having more views of that organ.



The placement of the recording and reference electrodes determines the view or lead used for the ECG recording. For example, the recording electrode in Lead I is placed on the left shoulder or arm. From its position on the left shoulder, the recording electrode has a view of the electrical activity of the heart while it is "looking" toward the right shoulder. The diagram that describes the axes of the leads, or the vectors of the ECG directed toward the leads, is known as Einthoven's Triangle. As shown on this diagram, the axis of Lead I is parallel to a line that connects the shoulders. Since the electrical activity recorded by each lead is a vector quantity with magnitude and direction, the vector for Lead I points toward the recording electrode on the left arm. By definition, the axis of Lead I is defined as zero degrees.

In a subject with a normal heart in a normal position, the ECG recording from Lead II will yield an R wave with the highest amplitude of all the limb leads. In Lead II, the recording electrode on the left leg has a “head-on” view of the electrical activity of the heart because this electrode is facing the right shoulder. The axis of Lead II is right through the septum that divides the ventricles; this is the site of the tissue bundles responsible for carrying the depolarization of the heart to the muscle fibers in the apex of the heart. By definition, the axis of Lead II is a +60 degrees.

The axes and angles for the limb leads (I, II, III, aVL, aVF, aVR) are shown on the diagram. If the electrical activity from two of the six leads is recorded, the activity on the other four leads can be derived using trigonometric functions.

In this lab, you will attach one ground and four recording electrodes to the subject and record electrocardiograms from the positions known as Lead I and Lead II. The other four limb leads will be synthesized from the ECG recordings from Leads I and II and a series of equations. These equations are incorporated into the LabScribe software as computed functions in the **right-click** menu. They only need to be activated to work. If Leads I and II are recorded on Channels 1 and 2, respectively, the limb lead computed functions take the raw data recorded on these channels and derive the electrocardiograms for the other four limb leads. These leads can be displayed on any of the six available channels.

Introduction adapted from iWorx lab manual, copyright from CB Sciences Inc.

Procedure: Equipment Set-up

1. Verify that your iWorx unit is connected to your computer via a USB cable from the back of the iWorx unit to the computer.
2. On the desktop there should be an icon that says **LabScribe**. Click on this icon to start the program.
3. When the program loads, go to the **Settings** menu at the top of the window. Select **Human Heart** from this menu.
4. Please select **SixLeadECG-LS2** lab.
5. Once selected, the configurations for this lab will load onto the screen. You will also notice that an adobe file for the lab will pop-up. You are welcome to use this file to help you through the exercises.
6. Have the test subject remove all jewelry from their wrists and ankles.
7. Gently wipe the areas on both wrists and both ankles with an alcohol swab. Allow the areas to air dry.
8. Place the sticky electrodes on these four areas. On the right wrist place another electrode adjacent to the other.
9. Attach the large end of the patient cable to the isolated Channel 1 and 2 input on the iWorx unit.
10. Now attach the leads as follows:
 - The red +1 lead attached to the right wrist
 - The black -1 lead attached to the left wrist
 - The white +2 lead attached to the right wrist
 - The brown -2 lead attached to the left ankle
 - The green “C” lead (the ground) attached to the right ankle
11. The test subject should sit quietly with their hands on their lap.

Procedure: Six-Lead ECG from Resting Subject

1. Click **Start**, then click **AutoScale** on all the channels. If the R wave on Channel 1 or 2 is inverted, click **Stop** and check to which electrodes the lead wires are attached. Check the Equipment Setup section of this experiment. If a larger signal is required, the electrodes should be moved from the wrists to the skin immediately below each clavicle.
2. When you have a suitable trace, type “<Subject’s Name> resting ECG” on the comment line to the right of the **Mark** button. Press the **Enter** key on the keyboard to attach the comment to the data.
3. Click **Stop** to halt recording.
4. Save your recording.

Procedure: Data Analysis

1. Click the **2-Cursor** icon so that two blue vertical lines appear over the recording window.

2. Drag the lines left and right so that four complete heart beat cycles are located between the two blue lines.
3. Click the **Analysis** to open the **Analysis** window.
4. Use the mouse to click and drag the cursors around the **Analysis** window to measure:
 - The amplitude (V2-V1 from onset of Q to peak of R) of three adjacent R waves on each of the six ECG leads.
 - The amplitude (V2-V1 from onset to peak of P) of three adjacent P waves on each of the six ECG leads.
 - The amplitude (V2-V1 from onset to peak T) of three adjacent T waves on each of the six ECG leads.
5. Record the data in Table 1. Then record your averages in Table 2.
6. Calculate the QRS axis of the subject:
 - Examine the recordings from the six limb leads and find the isoelectric lead. This is the lead where the R wave is equal in magnitude to the S wave but in the opposite direction. Often this is the lead with the smallest QRS.
 - Find the two leads that are perpendicular to the isoelectric lead. The QRS axis is the perpendicular that best fits the direction of the other ECG leads.
 - If none of the leads are isoelectric, two of the six leads should be nearly isoelectric. These two leads are always 30° apart. Find the perpendiculars for each lead and choose an approximate QRS axis within the 30° range.
 - Occasionally each of the 6 frontal plane leads is small and/or isoelectric. The axis cannot be determined and is called *indeterminate*. This is a normal variant.

Table 1: Amplitudes (millivolts) of Waves Recorded from Each Lead

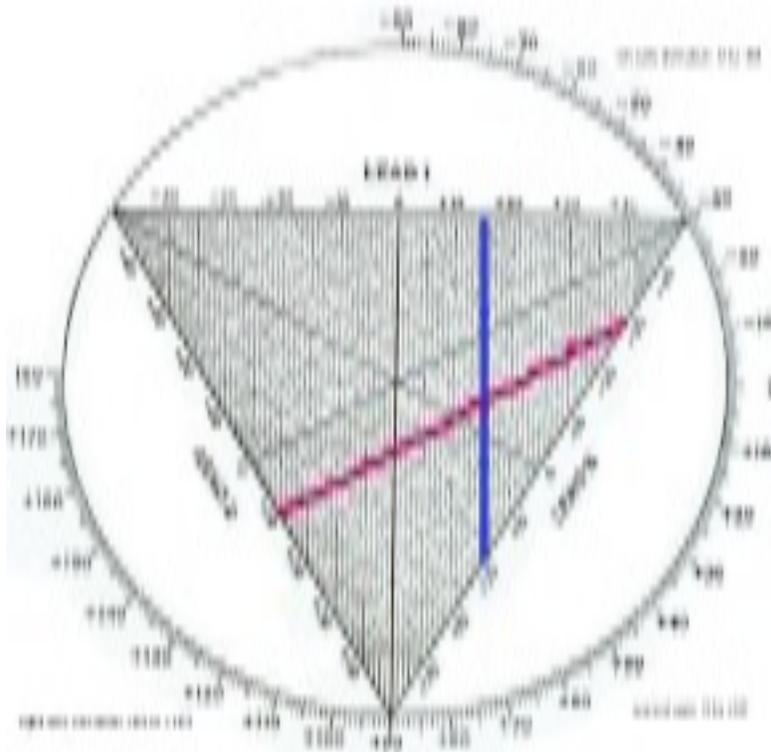
Amplitudes	P - Wave			R - Wave			T - Wave			S - Wave		
Lead I												
Lead II												
Lead III												
aVL												
aVR												
aVF												

Table 2: Average Amplitude (millivolts) of Waves Recorded from Each Lead

Average Amplitude	P - Wave	R - Wave	T - Wave	S -Wave
Lead I				
Lead II				
Lead III				
aVL				
aVR				
aVF				

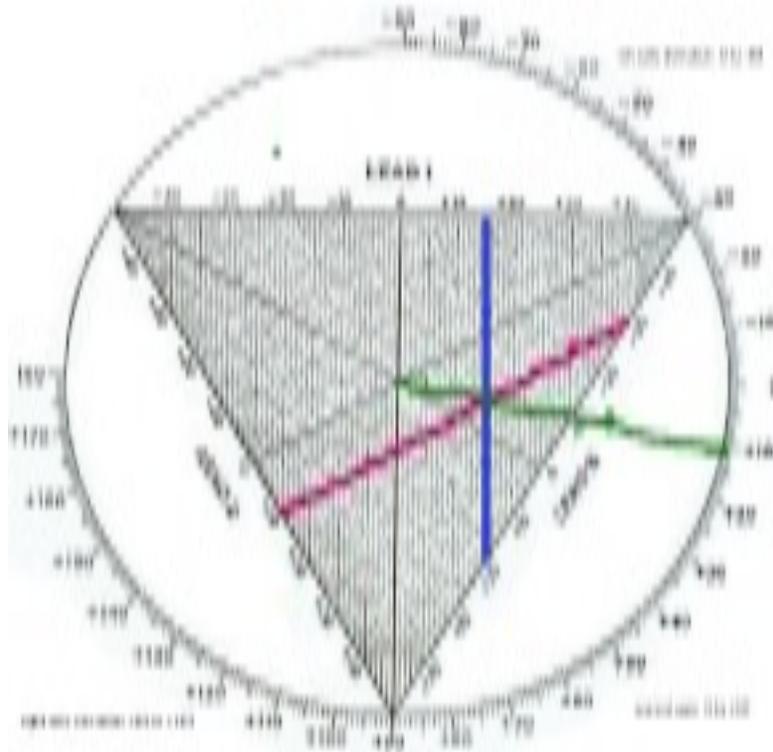
Procedure: Finding the Electrical Axis of the Heart

1. Calculate the height of the QRS complex, in millimeters (1 cm vertical deflection in the ECG = 1 mV), from any 2 limb leads. Remember, to get the height of the QRS complex, we measure the height of R above the iso-electric line and subtract the depth of S below the iso-electric line. It is possible to get a negative value if the depth of S below the iso-electric line is greater than the height of R above the iso-electric line. It is also possible that S will not drop below the iso-electric line in some recordings.
2. After you calculate the height of the QRS complex from, say, Lead I and Lead II, plot the heights on the appropriate side of the triangle.
3. Let's say that we found the height of the QRS complex in a Lead I ECG to be 15 mm; we would draw a perpendicular line passing through +15 on the Lead I side (perpendicular to Lead I) of the triangle. Now, let's say that we calculated the height of the QRS complex as 10 mm; we draw a second line passing through +10 on the Lead II side (perpendicular to the QRS Lead I line) of the triangle.



4. Notice that the lines we have drawn through each of our leads intersect with one another. Notice also that all of the zero points from all of the leads intersect at the hypothetical null point over the center of the heart (a point at

which we would theoretically measure no net electrical activity). Now, we just draw a line (a vector) from the zero point at the center of Einthoven's triangle that passes through our lead intersection point and passes out from the triangle and bisects the circle surrounding the triangle.



5. The vector that we have just drawn summarizes the net direction of electrical activity in the heart we are examining. Simply read the value at the point where the vector bisects the circle. Here, we read a value of approximately +56 (note that our vector heads down and to the left). Human references listing the normal human electrical axis as from 0 to +90 and also from -30 to +120 (evidently, everyone does not agree on the normal electrical axis for a human).
6. Following the above example, find the electrical axis of your subject's heart.

