Experiment HH-4: The Six-Lead Electrocardiogram

Background

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 in the heart. 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 (Figure HH-4-B1). When diagnosing the health of the heart, electrocardiograms are recorded from specific positions around the heart and analyzed to determine existence of cardiac disease. These positions or combinations of positions are referred to as leads or views. However, the data collected from this experiment should not be used to determine the health of fitness of any subject's heart.

ECG Components

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, like Lead I in Figure HH-4-B1, 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.

Multiple Leads

There are twelve common cardiographic leads, six limb and six chest. The six limb, or coronal, leads are in the frontal plane of the body which is the plane parallel to the floor when the subject is reclining. The six chest, or precordial, leads are in the transverse plane of the body which is the plane perpendicular to the floor when the subject is reclining.

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.

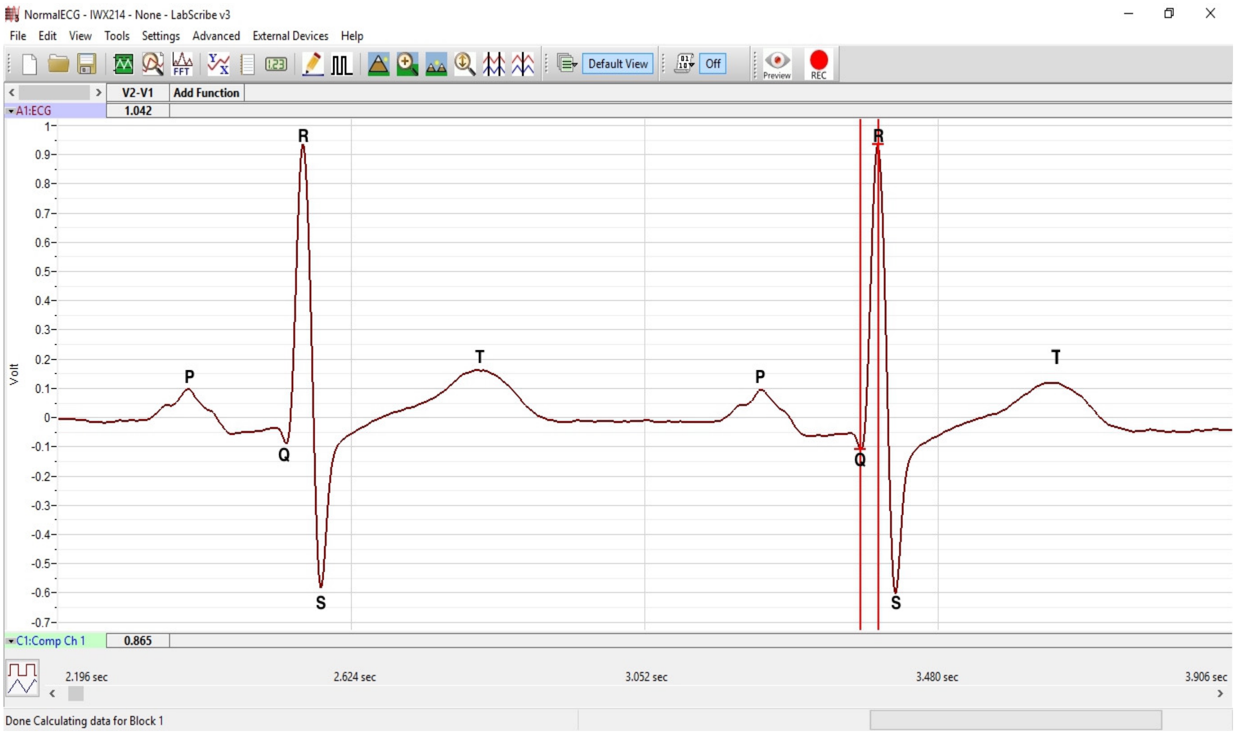

Figure HH-4-B1: ECG trace in the Main window with labels showing the P, QRS and T waves.

In this experiment, students will place five electrodes on a subject and be able to record six different views of the subject's heart. Each view is often referred to as a lead. This is possible because the electrodes are used in different combinations, as either recording or reference electrodes, to create six different views of the heart.

The standard limb leads, or bipolar leads, measure the potential difference between a positive recording electrode and a negative recording electrode. The standard limb leads are:

- Lead I (I): the positive electrode is on the left arm and the negative electrode is on the right arm.
- Lead II (II): the positive electrode is on the left leg and the negative electrode is on the right arm.
- Lead III (III): The positive electrode is on the left leg and the negative electrode is on the left arm.

The augmented limb leads, or unipolar leads, measure the potential difference between a signal recording electrode and a combination of other electrodes that form a composite negative electrode. Each augmented limb lead has a view of the heart that at a right angle to one of the standard limb leads. The augmented limb lead are:

- aVR: The positive electrode is on the right arm and the electrodes on the left arm and the left leg form a composite negative electrode.
- aVL: the positive electrode is on the left arm and the electrodes on the right arm and the left leg form a composite negative electrode.

- aVF: The positive electrode is on the left leg and the electrodes on the right arm and the left arm form a composite negative electrode.

The diagram that describes the axes of the leads and the vectors of the ECG signals directed toward the leads is known as Eithoven's Triangle (Figure HH-4-B2). For example, the positive electrode in Lead I, which is on the left arm, has a view of the electrical activity of the heart while it is looking toward the right shoulder. As shown in the same figure, the axis of Lead I is parallel to a line that connects the shoulders. By definition, the axis of Lead I is defined as zero degrees.

In a subject with a normal heart in a normal orientation, the ECG recording from Lead II will yield an R wave with the highest amplitude of all the limb leads. In Lead II, the positive 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. the septum 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 +60 degrees.

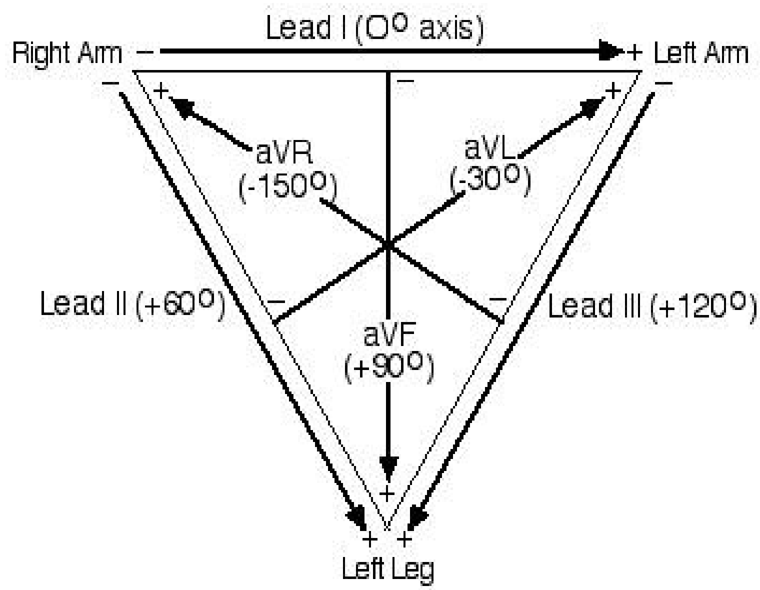

Figure HH-4-B2: Einthoven's Triangle identifying the axes of the six limb leads.

In this lab, students 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 recordings from Leads I and II and a series of equations. These equations are incorporated into the LabScribe software as computed functions in the add function pull-down 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.

The derivations used to synthesize ECG's for different leads are appended to the end of this experiment. The equations do not need to be used by students since the LabScribe recording software is programmed to perform those measurements.