

Experiment HH-4: The Six-Lead Electrocardiogram

Exercise 1: Six Lead ECG from Resting Subject

Aim: To record a Six Lead ECG from a resting subject and determine the QRS axis of the subject's heart.

Procedure

1. Click on the Record button, located on the upper right side of the LabScribe Main window ([Figure HH-4-L1](#)). The signal should begin scrolling across the screen.

Note: If the user clicks the Record button and there is no communication between the iWorx unit and computer, an error window will appear in the center of the Main window. Make sure the iWorx unit is turned on and connected to the USB port of the computer. Click OK and select the Find Hardware function from the LabScribe Tools menu.

2. Click on the AutoScale buttons at the upper margin of all the channels. Your recording should look like [Figure HH-4-L1](#).
 - If the signal on either the Lead I or the Lead II channel is upside down when compared to trace in [Figure HH-4-L1](#), click on the downward arrow to the left of the channel title and select the Invert function. The trace should now look similar to the one in the figure
 - If a larger ECG signal is required, the electrodes should be moved from the wrists to the skin immediately below each clavicle.

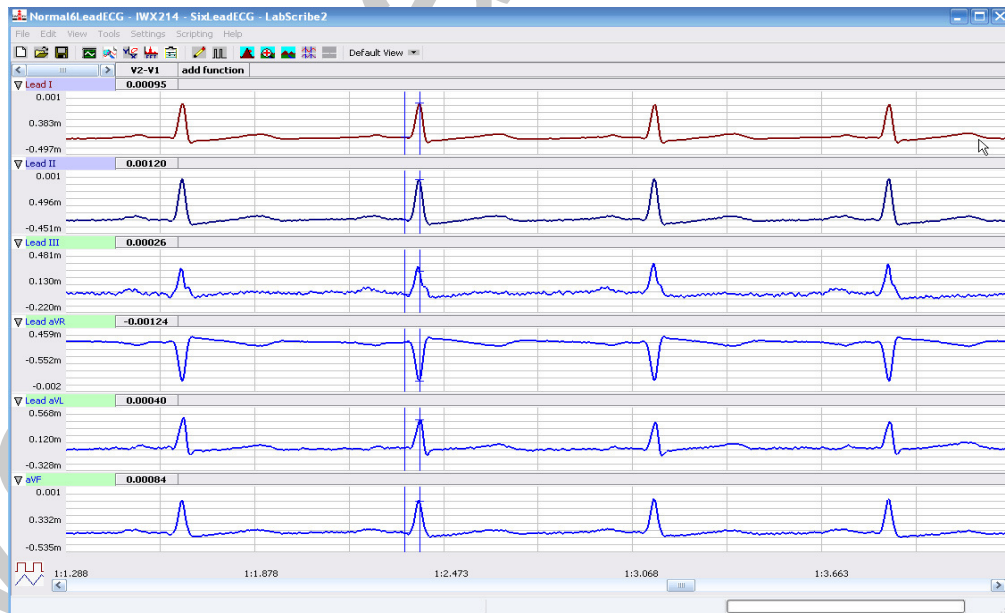


Figure HH-4-L1: Six lead ECG generated by recording Leads I and II on Channels 1 and 2, respectively. The remaining limb leads are derived by computed functions.

3. When you have a suitable trace, type <Subject's Name> Resting ECG/Pulse in the Mark box to the right of the Mark button. Press the Enter key on the keyboard to attach the comment to the data. Record for a minute or two.
4. Click Stop to halt recording.
5. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file, like your lab group folder). Designate the file type as *.iwxdata. Click on the Save button to save the data file.

Data Analysis

1. Scroll through the recording and find a section of data with four to six exemplary ECG cycles in succession.
2. Use the Display Time icons to adjust the Display Time of the Main window to show at least four complete ECG cycles on the Main window. Four adjacent ECG cycles can also be selected by:
 - Placing the cursors on either side of a group of four complete ECG cycles.
 - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the segment with the four selected ECG cycles to the width of the Main window.

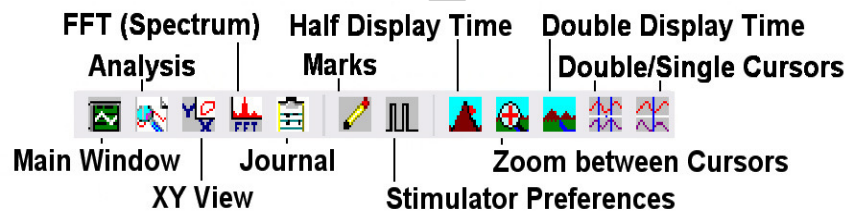


Figure HH-4-L2: The LabScribe toolbar.

3. Click on the Analysis window icon in the toolbar ([Figure HH-4-L2](#)) or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window ([Figure HH-4-L3](#)).
4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The name of the mathematical function used in the analysis, V2-V1, appears in this table. The values for V2-V1 from each channel are seen in the table across the top margin of each channel.
5. Once the cursors are placed in the correct positions for determining the amplitudes of each wave in an ECG cycle, the values of the amplitudes can be recorded in the on-line notebook of LabScribe by typing their names and values directly into the Journal, or on a separate data table.

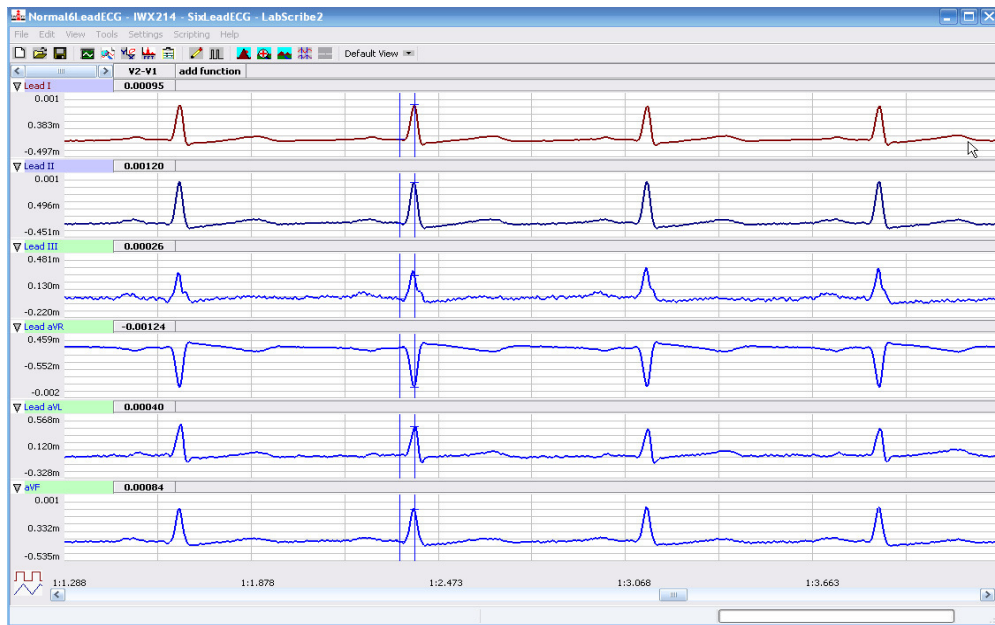


Figure HH-4-L3: Six lead ECG displayed on the Analysis window with cursors in position to measure the amplitude of the R wave.

6. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the parameters from the recording to the Journal. To use these functions:
 - Place the cursors at the locations used to measure the amplitudes of the waves in the ECG cycle.
 - Transfer the name of the mathematical functions used to determine the amplitudes to the Journal using the Add Title to Journal function in the ECG Channel pull-down menu.
 - Transfer the values for the amplitudes to the Journal using the Add Ch. Data to Journal function in the ECG Channel pull-down menu.
7. Use the mouse to click on and drag the cursors to specific points on the ECG recording ([Figure HH-4-L4](#)) to measure the following:
 - The R-wave amplitude. To measure the R wave amplitude, place one cursor on the Q wave that precedes the R wave and the second cursor on the peak of the R wave. The value for V2-V1 on the ECG channel is this amplitude. Measure the amplitudes of two additional R waves.
 - The P-wave amplitude. To measure the P wave amplitude, place one cursor on the baseline that precedes the P wave and the second cursor on the peak of the P wave. The value for V2-V1 on the ECG channel is this amplitude. Measure the amplitudes of two additional P waves.
 - The T-wave amplitude. To measure the T wave amplitude, place one cursor on the baseline that precedes a P wave and the second cursor on the peak of the T wave that is in the same cycle as the P wave. The value for V2-V1 on the ECG channel is this amplitude. Measure the amplitudes of two additional T waves.

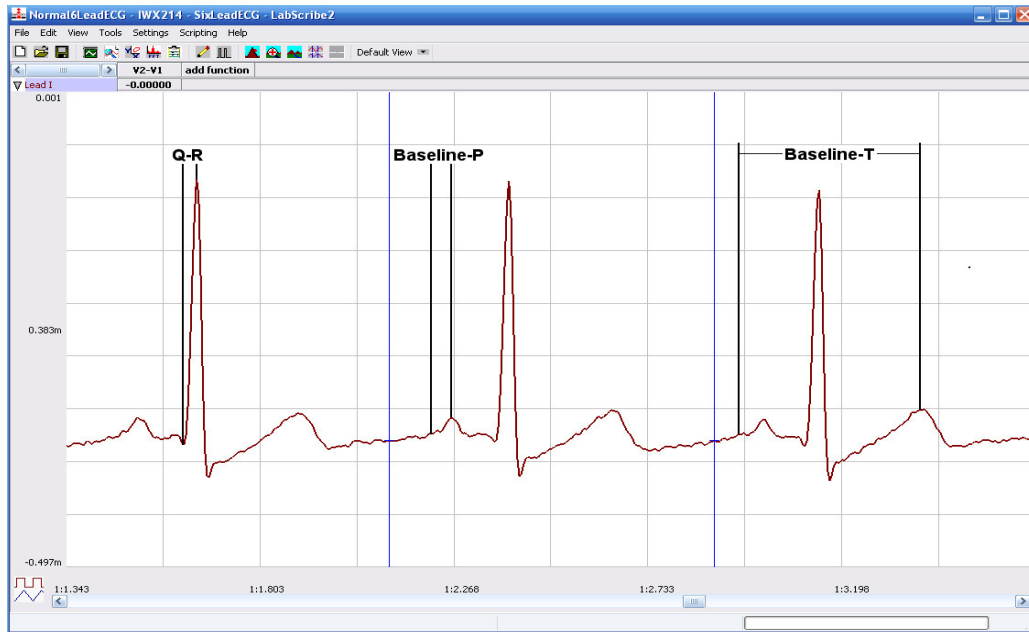


Figure HH-4-L4: ECG recording displayed in the Analysis window. Lines and labels were added to indicate the locations where cursors should be placed to measure the amplitudes of R (Q-R), P (Baseline-P), and T (Baseline-T) waves.

- Calculate the mean amplitudes of the P wave, the R wave, and the T wave for each ECG lead. Enter your results into the Journal and [Table HH-4-L1](#).

Table HH-4-2: The Mean Amplitudes (in millivolts) for Each ECG Wave Recorded from Each Lead.

	Mean Amplitudes (mV)		
	P Wave	R Wave	T Wave
Lead I			
Lead II			
Lead III			
aVR			
aVL			
aVF			

9. Determine the QRS axis of the subject:

- Examine the ECG recordings from the six limb leads. Find the lead that creates an ECG where the magnitude of the R wave is equal to magnitude of the S wave, but the two waves go in opposite directions. This lead is known as the isoelectric lead. The isoelectric lead often has the smallest QRS.
- Examine a diagram of Einthoven's Triangle in the Background section. Determine which two leads are close to being perpendicular to the isoelectric lead. The QRS axis is the perpendicular lead that best fits the direction of the other ECG leads.
- If none of the leads are isoelectric, look for two of the leads that are close to being 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 six coronal leads is small and/or isoelectric. The axis cannot be determined and is called indeterminate. This is a normal variant.

Questions

1. From which leads were upright R waves recorded? From which electrode (left arm, right arm, left leg, or right leg) and along which axis ($-150, -30, 0, 60, 90, 120$ degrees) were these leads "looking" at the depolarization of the ventricle? You may need to refer to the Background information to answer these questions.
2. From which leads were inverted R waves recorded? From which electrode (left arm, right arm, left leg, or right leg) and along which axis ($-150, -30, 0, 60, 90, 120$ degrees) were these leads looking at the depolarization of the ventricle?
3. Which lead is the isoelectric lead?
4. What is the QRS axis of the subject's heart? Is the QRS axis of your subject within the normal range of the QRS axis? Refer to your textbook to find the normal range.
5. Which ECG lead provided the largest R wave for the subject?
6. Which lead is closest to the QRS axis of the heart?

Exercise 2: Six Lead ECG from Other Subjects

Aim: Record or obtain Six Lead ECGs from other subjects and determine the QRS axes of their hearts.

Procedure

Repeat Exercise 1 on another subject. Record a six lead ECG from as many subjects as possible.

Data Analysis

Use the same techniques used in Exercise 1 to analyze the data from other subjects.

Questions

1. Do the R waves from the same lead go in the same direction for all subjects? The P waves? The T waves?
2. What would cause an ECG wave from the same lead to go in the opposite directions in different subjects?
3. Do all subjects have the same QRS axis? What is the range of QRS axes from all the subjects in the class? Does the any subject have a QRS axis that is outside the normal range?
4. Does any subject have an inverted P or T wave on any lead when compared to the same lead from a normal ECG?

Appendix: Equations Used by LabScribe to Graph the Augmented Limb Leads

The ECG is a representation of the electrical activity of the heart. It is a vector quantity with magnitude and direction. The various leads (I, II, III, aVL, aVR, aVF) measure the magnitude of the ECG along a particular direction ([Figure HH-4-L5](#)).

The derivations of the equations used to calculate the cardiograms for the four other limb leads (III, aVL, aVR, aVF) from the cardiograms recorded from Leads I and II are provided for your information. These equations do not need to be used to perform this experiment. The computed functions that calculate the four remaining limb leads are already programmed in the settings file for this experiment.

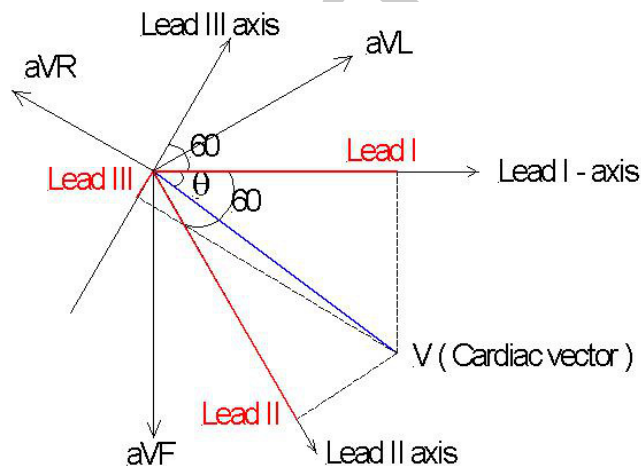


Figure HH-4-L5: Lead I is the projection of the cardiac vector (V) along the Lead I axis. Similarly Lead II is the projection of cardiac vector along the Lead II axis, and so on.

Treat ECG as a Vector with magnitude V and an angle θ :

$$\text{Lead I} = V \cos(\theta)$$

$$\text{Lead II} = V \cos(60 - \theta)$$

$$\text{Lead III} = -V \cos(60 + \theta)$$

$$aVF = V\sin(\theta)$$

$$aVL = V\cos(30 + \theta)$$

$$aVR = -V\cos(30 - \theta)$$

1. Calculate Lead III from Leads I and II:

$$\text{Lead I} = I = V\cos(\theta) \quad (1)$$

$$\text{Lead II} = II = V\cos(60 - \theta) \quad (2)$$

$$\text{Lead III} = III = -V\cos(60 + \theta) \quad (3)$$

Using the following trigonometric identities:

$$\cos(A + B) = \cos A \cos B - \sin A \sin B \quad (4)$$

$$\cos(A - B) = \cos A \cos B + \sin A \sin B \quad (5)$$

2. From equations 3 and 4:

$$III = -V\{\cos(60)\cos(\theta) - \sin(60)\sin(\theta)\} \quad (6)$$

3. Using equations 2 and 5:

$$II = V\{\cos(60)\cos(\theta) + \sin(60)\sin(\theta)\} \quad (7)$$

4. Adding equations 6 and 7:

$$II - III = 2*V*\cos(60)*\cos(\theta) = 2*V*0.5*\cos(\theta) = V\cos(\theta)$$

5. Therefore:

$$II - III = I; III = II - I; \text{ and, Lead III} = \text{Lead II} - \text{Lead I}$$

Calculate aVF from Leads I and II:

$$aVF = V\sin(\theta) \quad (8)$$

1. From equation 7:

$$II = V\{\cos(60)\cos(\theta) + \sin(60)\sin(\theta)\}$$

$$II = (1/2)*V\cos(\theta) + (\sqrt{3}/2)*V*\sin(\theta)$$

$$2(II) = I + (\sqrt{3})*V*\sin(\theta)$$

2. Therefore:

$$V*\sin(\theta) = (2(II) - I) / \sqrt{3} \quad (9)$$

and:

$$aVF = (2(II) - I) / \sqrt{3} \quad (10)$$

Calculating aVL from Leads I and II:

$$aVL = V\cos(30+\theta)$$

1. Therefore:

$$aVL = V\{\cos(30)\cos(\theta) - \sin(30)\sin(\theta)\}$$

$$aVL = \cos(30)V\cos(\theta) - \sin(30)V\sin(\theta)$$

$$aVL = \cos(30)I - \sin(30)aVF$$

2. Therefore:

$$aVL = ((\sqrt{3})/2)*I - (1/2)*(2*II - I)/\sqrt{3}$$

$$aVL = ((\sqrt{3})/2)*I - II/\sqrt{3} + (1/2)*I/\sqrt{3}$$

$$aVL = (2*I - II)/\sqrt{3} \quad (11)$$

Calculate aVR from Leads I and II:

$$aVR = -V\cos(30-\theta)$$

1. Therefore:

$$aVR = -V\{\cos(30)\cos(\theta) + \sin(30)\sin(\theta)\}$$

$$aVR = -\cos(30)I - \sin(30)aVF$$

2. Therefore:

$$aVR = -((\sqrt{3})/2)*I - (1/2)*(2*II - I)/\sqrt{3}$$

$$aVR = -((\sqrt{3})/2)*I - II/\sqrt{3} + (1/2)*I/\sqrt{3}$$

$$aVR = -(I+ II)/\sqrt{3} \quad (12)$$

Calculate Cardiac Angle from Leads I and II:

1. From equation 9:

$$V*\sin(\theta) = (2*II - I)/\sqrt{3}$$

2. From equation 1:

$$V\cos(\theta) = I$$

3. Dividing equation 9 by equation 1:

$$\tan(\theta) = \{(2*II - I)/\sqrt{3}\}/I$$

$$\theta = + \text{Arctan}((2*II - I)/\sqrt{3} * I) \quad (13)$$