Experiment 30: Pulse Contour Analysis

Background

In the numerous studies conducted on cardiovascular disease, one of the many parameters studied is the shape of the pulse wave. At first, the analysis of the pulse wave involved its comparison to waveforms that were correlated with cardiovascular disease and its risk factors. As time passed, mathematical relationships were developed that quantified the correlation between pressure pulse and volume pulse waves and cardiovascular risk factors.

An example of a parameter that can be derived from the pulse wave is an index of arterial stiffness. As a human ages, his or her arteries stiffen because structural changes occur in the arterial wall: elastins fragment and degenerate, collagen increases, and walls thicken. Stiffening leads to changes in the hemodynamics of the subject. Generally, young, healthy subjects have aortas that are more distensible and contain a greater volume of blood for a given systolic pressure than the aortas of older subjects. As humans age, their aortas stiffen. As arterial stiffness increases, systolic pressure in large arteries increases, which means the cardiac workload and myocardial demand increase. Increases in arterial stiffness also contribute to the progression of hypertension and left ventricular hypertrophy and a decrease in myocardial perfusion.

Information about arterial stiffness and vascular tone can be obtained through invasive and non-invasive techniques. Many of the techniques have been compared and it has been concluded that some of the non-invasive methods can provide information that is consistent with the data recorded invasively. Three of the non-invasive techniques commonly employed are:

- Ultrasound, which determines the increase in the diameter of the lumen of the carotid artery during systole.
- Pulse Wave Velocity, which determines the velocity of the pulse wave between the carotid and femoral arteries.
- Pattern recognition, which analyzes the pulse pressure signal and identifies changes in aortic compliance through changes in the signal.

Research has shown that some of the devices and methods used in pattern recognition techniques, like a photoplethysmograph used to record digital volume pulse, are just as reliable as the definitive standard for measuring arterial stiffness, pulse wave velocity (PWV).

The photoplethysmograph is used to record the pulse wave from the finger of the subject. The recorded wave is the digital volume pulse and is similar to the pressure pulse wave. Since time measurements are absolute and the amplitude measurements are made dimensionless when a ratio is used. indices which indicate arterial stiffness and vascular tone were easily devised and used.

Stiffness Index (SI)

Indices allow risk factors to be quantified and compared to standards established by research studies. The Stiffness Index (SI) is one of these parameters.

If a plethysmograph is used on a subject's finger, the pulse wave generated at the site of the plethysmograph has two components. The first component in the pulse wave is caused by systolic pressure wave (Figure 6-1 on page 1) that is directly transmitted down the artery to the finger from the root of the aorta. The second component in the pulse wave is the diastolic component, which is the pressure wave reflected back up the aorta from the lower body (Figure 6-1 on page 1). The reflected wave then travels down the arm and to the finger with the plethysmograph. The time difference between the peaks of the two components, known as the reflection time, is inversely proportional to the arterial stiffness (Figure 6-2 on page 2).

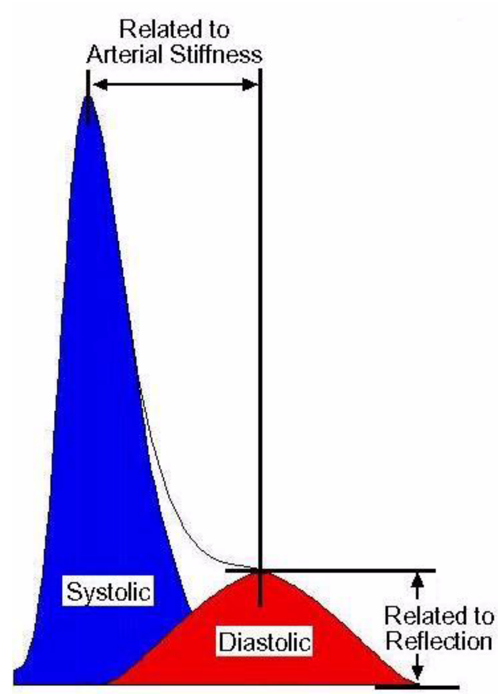

Figure 6-1: A typical pressure pulse with the systolic and diastolic components identified. The ratio of the heights of the systolic and diastolic components are related to vascular tone; the time between the systolic and diastolic components is related to arterial stiffness.

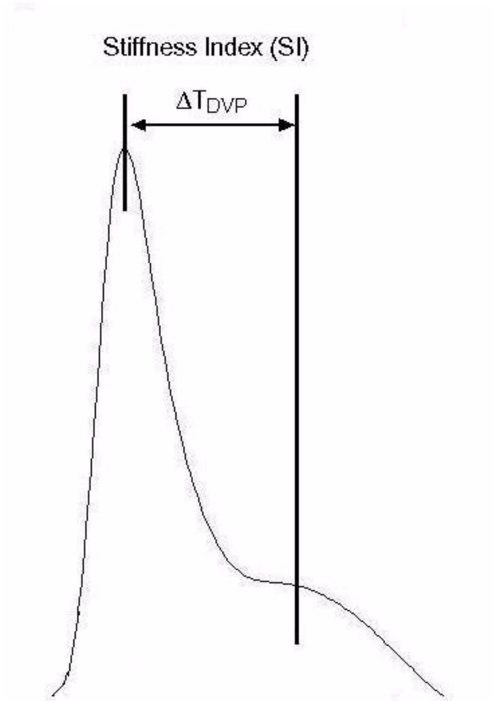

Figure 6-2: The time between the peak of the systolic and the inclination point of the diastolic components used to calculate the Stiffness Index (SI).

To correct for the size of the subject, the reflection time is divided into the height of the subject. The resultant value is the Stiffness Index (SI), which is expressed in meters/second. The SI is comparable to the definitive measure of arterial stiffness, the pulse wave velocity (PWV).

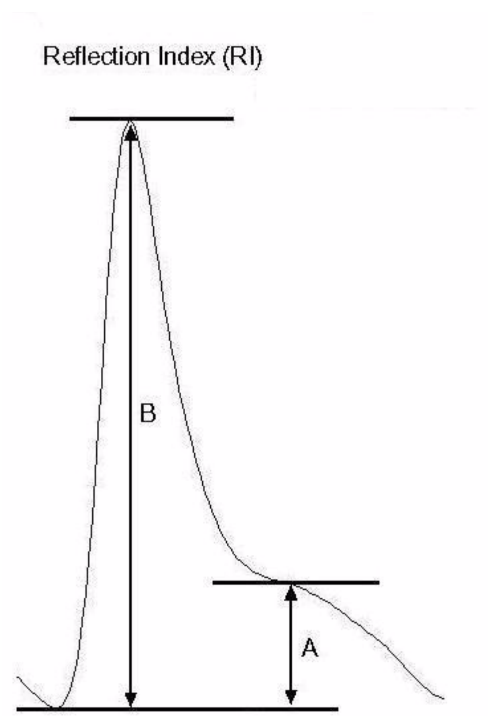

Figure 6-3: Heights of the systolic (B) and the diastolic (A) components in a pressure pulse used to measure the Reflection Index (RI).

Reflection Index

Another index that can be extracted from the pressure pulse wave is the Reflection Index (RI), which is a measure of vascular tone. It is calculated by dividing the height of the systolic component into the height of the diastolic component (Figure 6-3 on page 2). This ratio is expressed as a percentage. RI is also directly proportional to the diastolic pressure.

In this experiment, students will use a piezo-type pulse plethysmograph to record the pulse wave from their fingers. During the recording, the pulse waves are transformed to a waveform (pulse integral) that is consistent with the pressure pulse. Measurements taken from the pulse integral are expressed as indices that will help students understand the implications of pulse contour analysis. Students will also measure their systolic and diastolic blood pressures and compare these to the indices.

Equipment Required

PC Computer

iWorx unit, and USB or serial cable

PT-104 Pulse plethysmograph

BP-600 Non-Invasive blood pressure sensor

Meter stick

Equipment Setup

1 Connect the iWorx unit to the computer (described in Chapter 1).

2 Plug the DIN connector on the end of the plethysmograph cable into Channel 3 (Figure 6-4 on page 2).

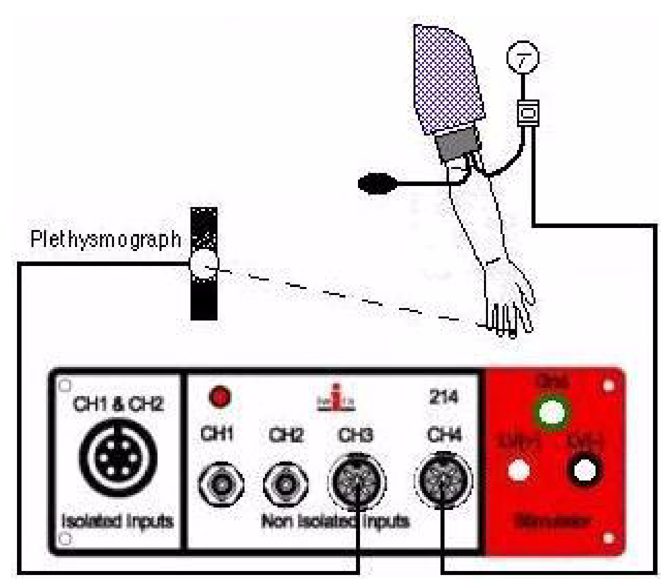

Figure 6-4: The equipment used for measuring blood pressure with a non-invasive blood pressure sensor.

3 Plug the DIN connector of the non-invasive blood pressure transducer into the female end of the DIN-DIN extension cable. Plug the male end of the DIN-DIN extension cable into Channel 4 (Figure 6-4 on page 2). Put the cuff aside until it is needed in Exercise 3.

Start the Software

1 Click the Windows **Start** menu, move the cursor to **Programs** and then to the **iWorx** folder and select **LabScribe**; or click on the LabScribe icon on the Desktop.

2 When the program opens, select **Load Group** from the **Settings** menu.

3 When the dialog box appears, select **AddedLabs.iws**. Click **Load**.

4 Click on the **Settings** menu again and select the **PulseContour** settings file.

5 After a short time, LabScribe will appear on the computer screen as configured by the **PulseContour** settings.

Exercise 1: Arterial Stiffness

Aim: To determine the Student Stiffness Index (SSI) of the subject's major arteries.

Procedure

1 Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of the middle finger, and wrap the Velcro strap around the end of the finger to attach the unit firmly in place.

2 Make sure the subject's hands and arms are warm to promote good peripheral circulation. The subject should resting in the supine position for at least one minute before a recording is made.

3 Click **Start** to begin recording the subject's pulse wave. The subject should remain motionless. Record for thirty seconds. Click **Stop**.

4 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(e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an ***.iwd** file).

Analysis

1 Scroll through the data recorded on the **Pulse Integral** channel (CH 2) to find a section that has a relatively flat baseline with five adjacent pulse integrals (Figure 6-6 on page 3). If necessary, use the **Display Time** icons on the LabScribe toolbar (Figure 6-5 on page 3) to adjust the display of the Main window.

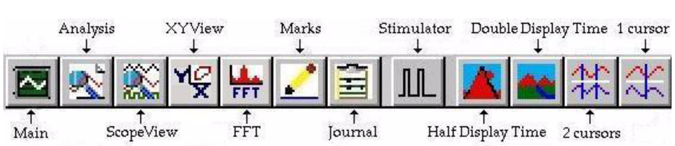

Figure 6-5: The LabScribe toolbar.

2 Click the **2-Cursor** icon (Figure 6-5 on page 3) so that two blue vertical lines appear over the recording window.

3 Drag the lines left and right so that five complete pulse integrals are located between the two blue lines.

4 Click the **Analysis** icon (Figure 6-5 on page 3) to open the **Analysis** window and display the selected data on the window.

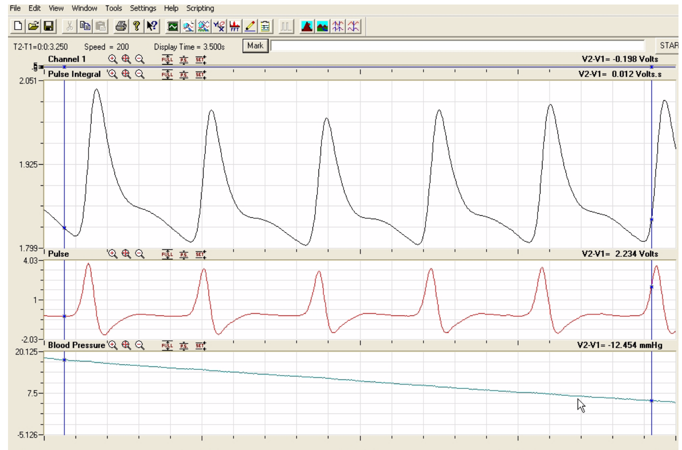

Figure 6-6: Recording of the pulse integral (top), pulse wave (middle), and blood pressure (bottom) from a normotensive subject.

5 Display the **Pulse Integral** channel (CH 2) by selecting it on the **Display Channel** list, on the left side of the **Analysis** window. Select **Title** and **T2-T1** from the **Table Functions** list to identify the channel and the parameter measured.

6 Use the mouse to place one cursor on the systolic peak of the first pulse integral and the second cursor on the inclination point of the diastolic component of the pulse integral (Figure 6-7 on page 4). The value for **T2-T1**, seen in the table at the top of the **Analysis** window, is the reflection time of the pulse integral.

7 Enter the title of the channel and the value of the reflection time (**T2-T1**) into the **Journal** by either typing the title and the value directly or by using the **right-click** menu. When using the functions in the **right-click** menu, first, place the cursors to obtain the needed values, and then select **Add Title to Journal** or **Add Data to Journal** from the menu to make entries to the **Journal.**

8 Repeat Steps 6 and 7 for the four adjacent pulse integrals displayed on the **Analysis** window.

9 Select **Save** in the **File** menu.

10 Open the **Journal** and find the average reflection time for the five measured pulse integrals.

11 Use a meter stick to measure the height of the subject in meters. Enter that value in the **Journal**.

12 Calculate the Student Stiffness Index (SSI) by dividing the average reflection time into the height of the subject:

SSI (meters/sec)=Height (meters)/Reflection Time (sec)

13 Enter the Student Stiffness Index for each subject in Table 6-1 on page 6.

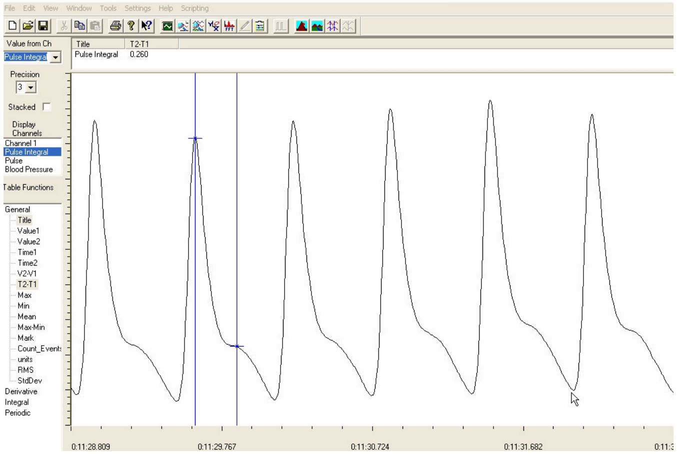

Figure 6-7: Pulse integrals recorded from a normotensive subject, displayed in Analysis window for the purpose of measuring the reflection time. The cursors are placed on the systolic peak and the diastolic inclination point.

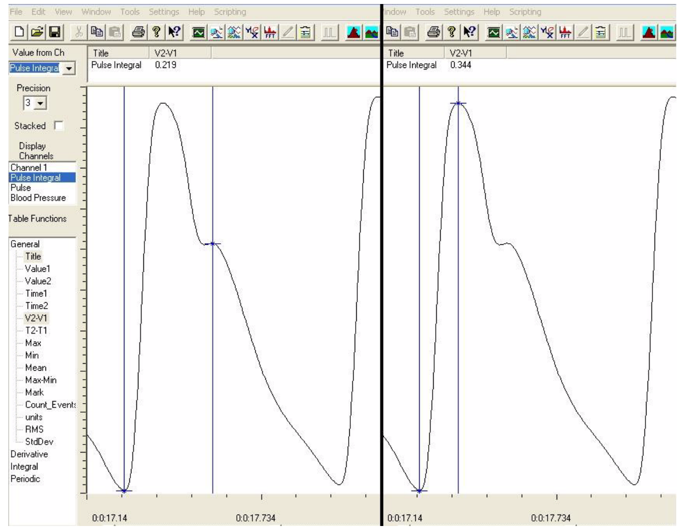

Figure 6-8: The Pulse integral recorded from a hypertensive subject. The panel on the left shows the position of the cursors for measurement of the relative height of the diastolic component, and the panel on the right shows the measurement of the relative height of the systolic peak.

Exercise 2: Vascular Tone

Aim: To determine the Student Reflection Index (SRI) of the subject's large vessels.

Procedure

Use the data recorded in Exercise 1 to provide the information about the systolic and diastolic components needed to calculate the Student Reflection Index.

Analysis

1 Use the same section of data used in the determination of the Student Stiffness Index (SSI) in Exercise 1.

2 Display the selected data from the **Pulse Integral** channel in the **Analysis** window as it was done in Exercise 1.

3 Use the mouse to place one cursor at the minimum value before the first pulse integral and the second cursor on the peak or inclination point of the diastolic component of the first pulse integral (Figure 6-8 on page 4). The value for **V2-V1**, seen in the table at the top of the **Analysis** window, is the relative height of the diastolic component.

4 Enter the title of the channel and the value of the relative height of the diastolic peak (**V2-V1**) into the **Journal** by either typing the title and the value directly or by using the **right-click** menu. When using the functions in the **right-click** menu, first, place the cursors to obtain the needed values, and then select **Add Title to Journal** or **Add Data to Journal** from the menu to make entries to the **Journal.**

5 Move the second cursor from the peak of the diastolic component to the peak of the systolic component in the same pulse integral.

6 Enter the value for the relative height of the systolic component into the **Journal**.

7 Repeat Steps 3 through 6 for the four adjacent pulse integrals displayed on the **Analysis** window.

8 Select **Save** in the **File** menu.

9 Open the **Journal** and find the average relative heights of the diastolic and systolic components for the five measured pulse integrals.

10 Calculate the Student Reflection Index (SRI) by dividing the average relative height of the systolic peak (B in Figure 6-3 on page 2) into the average relative height of the diastolic peak (A in Figure 6-3 on page 2):

SRI(%) = (Diastolic Height/Systolic Height) x 100.

11 Enter the Student Reflection Index (SRI) for each subject in Table 6-1 on page 6

Calibration of the Non-Invasive Blood Pressure Sensor

Procedure

1 Put the blood pressure cuff on the upper arm of the subject. align the arrow on the cuff over the subject's brachial artery. Have the subject rest in the supine position while the blood pressure sensor is calibrated.

2 With the blood pressure cuff on the subject, inflate the pressure in the cuff to 20 mmHg as read on the aneuroid gauge of the cuff.

3 Click **Start** and record the output of the non-invasive blood pressure sensor for five seconds (Figure 6-9 on page 5). Type "70 mmHg" on the comment line to the right of the **Mark** button. Continue recording.

4 Increase the pressure in the cuff to 70 mmHg and press the **Enter** key on the keyboard. Hold the pressure in the cuff at this level for another five seconds. Type "140 mmHg" on the comment line. Continue recording

5 Increase the pressure in the cuff to 140 mmHg and press the **Enter** key on the keyboard. Hold the pressure in the cuff at this level for another five seconds.

6 Click the **Stop** button. Release all the pressure from the blood pressure cuff. Other than flexing and extending his or her fingers to encourage blood circulation, the subject should continue to relax in the supine position.

7 Select **Save** in the **File** menu.

Units Conversion

1 Use the **Display Time** icons on the LabScribe toolbar (Figure 6-5 on page 3) to adjust the time displayed on the **Main** window so that the complete block of calibration data can be viewed on the screen (Figure 6-9 on page 5).

2 Click the **2-Cursor** icon (Figure 6-5 on page 3) so that two blue vertical lines appear on the **Main** window. Place one cursor on the section of the recording marked as “70 mmHg” and the second cursor on the section of the recording marked as “140 mmHg”.

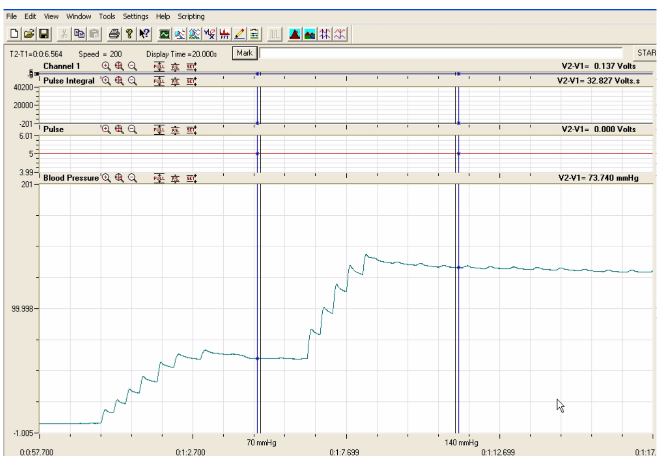

Figure 6-9: Recording of the output of the non-invasive blood pressure used to calibrate the sensor at known pressures.

3 **Right-click** on the data area of the **Blood Pressure** channel (CH 4) to open its **right-click** menu. Select **Units** from this menu, and **Simple** from the submenu, to open the **Units Conversion** dialogue window.

4 Perform a two-point calibration by selecting **2 point cal** from the pull-down menu at the top of the window. The voltages at the positions of the two cursors are already entered on the window.

5 Change the values in the boxes to the right of these voltages to the corresponding calibration pressures, **70** and **140**. Change the units to **mmHg**. Click **OK** and the units on the y-axis of the **Blood Pressure** channel (CH 4) change.

6 Select **Save** in the **File** menu

Exercise 3: Blood Pressures

Aim: To determine if the subject is normotensive or hypertensive.

Procedure

1 Place the blood pressure cuff around the upper portion of the left arm, between the elbow and the shoulder. Place the plethysmograph on the volar surface (where the finger-prints are located) of the distal segment of the middle finger, and wrap the Velcro strap around the end of the finger to attach the unit firmly in place.

2 The subject should be resting in the supine position for at least five minutes before taking his or her blood pressure.

3 Click **Start** to begin recording the subject’s pulse wave and the pressure in the cuff of the blood pressure sensor. Inflate the blood pressure cuff until the finger pulse wave on the **Pulse** channel (CH 3) disappears (Figure 6-10 on page 5).

4 Once the pulse wave disappears, release the cuff pressure at the rate of 10 mmHg per second. Continue to release the cuff pressure until the aneuroid gauge reads 0 mmHg.

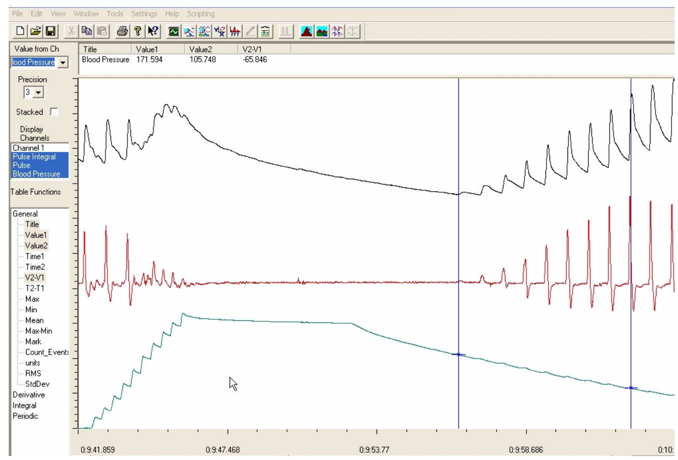

Figure 6-10: A recording of the pulse wave before, during, and after the occlusion of the brachial artery. Pulses disappeared as the pressure in the cuff exceeded that in the artery. As the pressure in the cuff is released, the pulse waves reappears with increasing amplitude.

5 Click the **Stop** button. Remove the blood pressure cuff and the pulse plethymograph from the subject. The subject should flex and extend their fingers to encourage blood circulation. Make sure the subject keeps his or her hands and arms warm, to promote good peripheral circulation, while waiting for the next exercise to begin.

6 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(e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an ***.iwd** file).

Analysis

1 Scroll to the section of data recorded while the pressure in the cuff was being released (Figure 6-10 on page 5). Use the **Display Time** icons on the LabScribe toolbar (Figure 6-5 on page 3) to display the data that includes the reappearance of the pulse wave and its return to maximum amplitude on one screen.

2 Click the **1 Cursor** icon on the LabScribe toolbar (Figure 6-5 on page 3) to place a single blue cursor on the window.

3 On the **Pulse** channel (CH 3), find the first detectable pulse wave that occurs as pressure is released from the cuff. Place the cursor over this pulse wave.

4 The pressure in the cuff during this particular pulse wave is equal to the systolic blood pressure of the subject. Look in the upper right corner of the data window for the **Blood Pressure** channel (CH 4) to find the systolic blood pressure. It is listed next to the label **Value** (**V**). Record the subject's systolic blood pressure in Table 6-1 on page 6.

5 To the right of the cursor, the amplitude of the pulse wave increases as the pressure in the cuff decreases. In this sequence of progressively larger pulse waves, find the first pulse wave that has the greatest amplitude. Place the single cursor on the peak of this pulse wave.

6 The pressure in the cuff during this particular pulse wave is equal to the diastolic blood pressure of the subject. Look in the upper right corner of the data window for the **Blood Pressure** channel (CH 4) to find the diastolic blood pressure. It is listed next to the label **Value** (**V**). Record the subject's diastolic blood pressure in Table 6-1 on page 6.

7 Subtract the subject's diastolic blood pressure from his or her systolic blood pressure to determine the subject's pulse pressure. Enter the subject's pulse pressure and age in Table 6-1 on page 6.

8 Divide the subject's diastolic blood pressure by his or her systolic blood pressure. Enter this ratio into Table 6-1 on page 6.

9 If the subject's blood pressures are less than 140/90, list the subject as normotensive. If the subject's blood pressures are greater than 140/90, list the subject as hypertensive.

Table 6-1: Resting Blood Pressures

Subject	Age	Student Stiffness Index (SSI)	Student Reflection Index (SRI)	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)	Pulse Pressure (mmHg)	Diastolic/ Systolic	Normotensive or Hypertensive

Questions

1 Does the Student Reflection Index of a subject correlate to his or her blood pressure?

2 Does the Student Stiffness Index of a subject correlate to his or her age?

3 Is there a correlation between the Student Reflection Index and the Student Stiffness Index?

4 Divide the subjects into groups based on age (11-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79). Compare the average Student Stiffness Index of each age group to the other groups. What is the trend?

5 Compare the average Student Reflection Index of each age group to the other groups. What is the trend?

6 To which parameter in the table does the Pulse Pressure correlate?

7 To which parameter in the table does the Diastolic/Systolic ratio correlate?