Experiment HS-9: USB-PulseOx Challenge

Background

One of the best methods of monitoring the cardio-pulmonary status of a patient in a hospital is the measurement of the pH and the concentrations of oxygen (pO_2), carbon dioxide (pCO_2), and bicarbonate in the patient's blood. The device used to measure these parameters is known as a blood gas analyzer, which can normally provide the values for these parameters in less than five minutes. Some blood gas analyzers are also designed to provide information on glucose, lactate, hemoglobin, potassium, and sodium concentrations. However, the sample used in a blood gas analyzer must be drawn from the patient's artery with appropriate safe handling of the patient, the sample, and the equipment used to draw the sample.

In operating and recovery rooms, on wards, in laboratories, in training facilities, and on airplanes without pressurized cabins, an easy, non-invasive method can be used to determine the amount of oxygen in a person's blood indirectly. This method is known as pulse oximetry and the most common type of pulse oximeter measures the oxygen saturation (SpO_2) of hemoglobin in the subject's blood.

Pulse oximeters that measure oxygen saturation do so by measuring the absorbance of light by hemoglobin with a sensor clipped over a fingertip or on an earlobe. The sensor emits two different wavelengths of light, one in the red and the other in the infrared portion of the spectrum, and detects the absorbance of those wavelengths by the oxygenated and deoxygenated forms of hemoglobin in the blood. The absorbance at each wavelength depends on the level of oxygen saturation or desaturation of hemoglobin. Since one form of hemoglobin absorbs more light at a specific wavelength than the other form, the pulse oximeter can determine the ratio between the concentrations of the oxygenated and deoxygenated hemoglobin and express the level of oxygen in the blood as the percentage of oxygen saturation.

In this experiment, students will perform exercises that demonstrate how air exchange in the lungs, also known as ventilation, affects the oxygen saturation of the subject's blood. Students will record oxygen saturation levels in the blood of the subject during normal breathing, and a hypothesis testing of something they think will change their SpO2. At the same time the oxygen saturation level is recorded, the subject's heart rate and breathing will be monitored as a demonstration of the integration of the cardiovascular and pulmonary systems.

Experiment HS-9: USB-PulseOx Challenge

Equipment Required

PC or Mac Computer

IXTA, USB cable, IXTA power supply

SP-304 Spirometer

A-FH-300L Spirometer flow head and plastic tubes

PO2-CMS50D (USB) Pulse Oximeter

PT-104 Pulse Sensor

Start the Software

1. Click on LabScribe
2. Click Settings → Human Spirometry → USB-PulseOxChallenge
3. Once the settings file has been loaded, click the **Experiment** button on the toolbar to open any of the following documents:
    - Appendix
    - Background
    - Labs
    - Setup (opens automatically)

Pulse Oximeter and Spirometer Setup

1. Locate the A-FH-300 flow head and the airflow tubing (Figure HS-9-S1) in the iWorx kit. Also, locate the USB pulse oximeter (Figure HS-9-S2).

Figure HS-9-S1: The FH-300 flow head and the airflow tubing.

2. Firmly push the two air flow tubes onto the two outlets on the A-FH-300L flow head.

3. Carefully connect the other ends of the two air flow tubes into the Channel A1 input of the IXTA. Connect the red port to the red connector on the tubing.
4. Connect the USB Pulse Oximeter directly to the computer via the USB cable provided.

Figure HS-9-S2: The PO2-100D pulse oximeter.

Figure HS-9-S3: The flow head connected to the internal spirometer of the IXTA unit. The USB Pulse oximeter will be connected directly to the computer.

5. Plug the USB connector of the pulse oximeter to a USB port on the computer.
6. Clip the sensor over the end of the subject's left middle finger. Press the power button and wait for the oximeter to power on. Once on, the display will read both the O2 saturation and the heart rate. Both of these parameters will also be recorded in LabScribe.

Warning: The photoplethymograph sensor passes two wavelengths of light through the subject's fingernail. For proper recording, the subject's fingernail should not be covered with nail polish, artificial nails, or any coating, clear or otherwise.

7. Connect the PT-104 Pulse sensor to channel A5. Strap the sensor to the volar surface of the subject's left thumb. Make sure it is not too loose or too tight.

Preparations Before Recording

1. Please read the procedures for each exercise completely before beginning the experiment. You should have a good understanding of how to perform these exercises before making recordings.
2. The spirometer will monitor breathing from a subject. It is important that the subject is healthy and has no history of respiratory or cardiovascular problems.
3. The outlets on the flow head should always be in the upright position to avoid problems with condensation developing in the airflow tubes.
4. To reduce turbulence, the subject should place his or her lips around the outside of the opening of the flow head, or around the cardboard mouthpiece attached to the flow head.
5. Use a nose-clip to prevent air from entering or leaving the nose as the subject is breathing. Air that passes through the nose causes errors in the lung volume values.
6. Check the calibration of your spirometer on the Lung Volumes channel:
    - Click on the words Vol.Human (Air Flow), that are next to the title of the Lung Volumes channel, to open the computed function pull-down menu.
    - Select Setup Function from this pull-down menu to open the Spirometer Calibration Dialog window.
    - Check that the internal spirometer is being used by making sure the Type of Spirometer is the IXTA.
    - Make sure the reset time is set to “No Reset”, and the first 10 seconds of the recording are used to zero the baseline of the Lung Volumes channel.
    - Enter room temperature, barometric pressure and expired air temperature as needed.
    - Click OK.
7. Allow the IXTA to warm up for 10 minutes before recording for the first time.
8. When spirometry data is recorded in the conventional manner, inhalation is always displayed as an upward deflection. To determine if the subject is breathing through the correct end of the flow head:
    - Click on the Preview button. Have the subject inhale through the spirometer flow head. Click on the AutoScale button at the upper margin of the Air Flow and Volume channels. If the flow head is oriented properly, the traces on the Air Flow and Volume channels will go up during inhalation. If the traces on these channels go down during inhalation, have the subject breathe through the other end of the flow head, or reverse the positions of the airflow tubes at the outlets of the flow head.
9. Click on the Stop button.

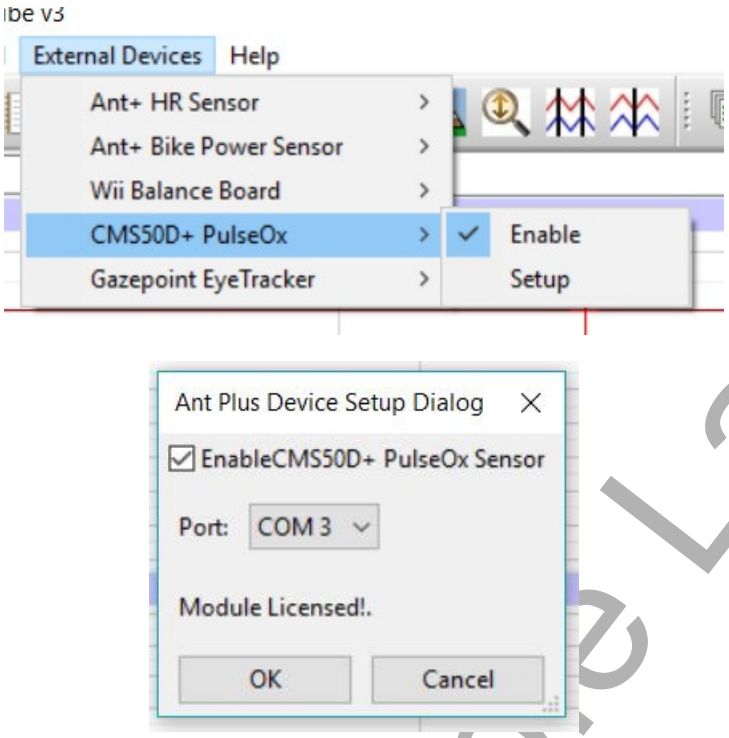

Figure HS-9-S4: Enable External Devices dialog box.

Set-up and Enable the USB Pulse Oximeter

1. Once the setting file has been opened
    - Click External Devices on the main menu bar.
    - Select CMS50D+ Pulse Ox.
    - Click Setup.
    - Put a check mark in the box to Enable CMS50D - PulseOx Sensor.
    - Check to make sure a Port is being recognized – choose that port.
    - Click on the OK button.

Experiment HS-9: USB-PulseOx Challenge

Exercise 1: Oxygen Saturation Level While Breathing at Rest

Aim: To determine the effect of breathing on the oxygen saturation level in the blood of a subject at rest.

Approximate Time: 20 minutes

Procedure

1. Instruct the subject to:
    - Sit quietly and become accustomed to breathing through the flow head.
    - Breathe normally before any recordings are made.
    - Hold the flow head so that its outlets are pointed up.
    - Remove the flow head from his or her mouth and hold it at mouth level in a position that prevents a breath from moving through the flow head.

Note: *The LabScribe software will zero the Volume channel during the first ten seconds of recording. No air should be moving through the flow head during this time.*

2. Type “Breathing at Rest” in the Mark box to the right of the Mark button. Press the mark button to attach the comment to the data.
3. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volume channel. Record at least five to six breaths, which normally takes about forty-five seconds to record.
4. Click Stop to halt recording. Your data may look like Figure HS-9-L1.
5. Select Save in the File menu.

Data Analysis

1. Scroll through the recording and find the section of data recorded when the subject was breathing while resting.
2. Use the Display Time icons to adjust the Display Time of the Main window to show 30 seconds of breathing that are free of artifacts on the Main window.
3. Click AutoScale All.

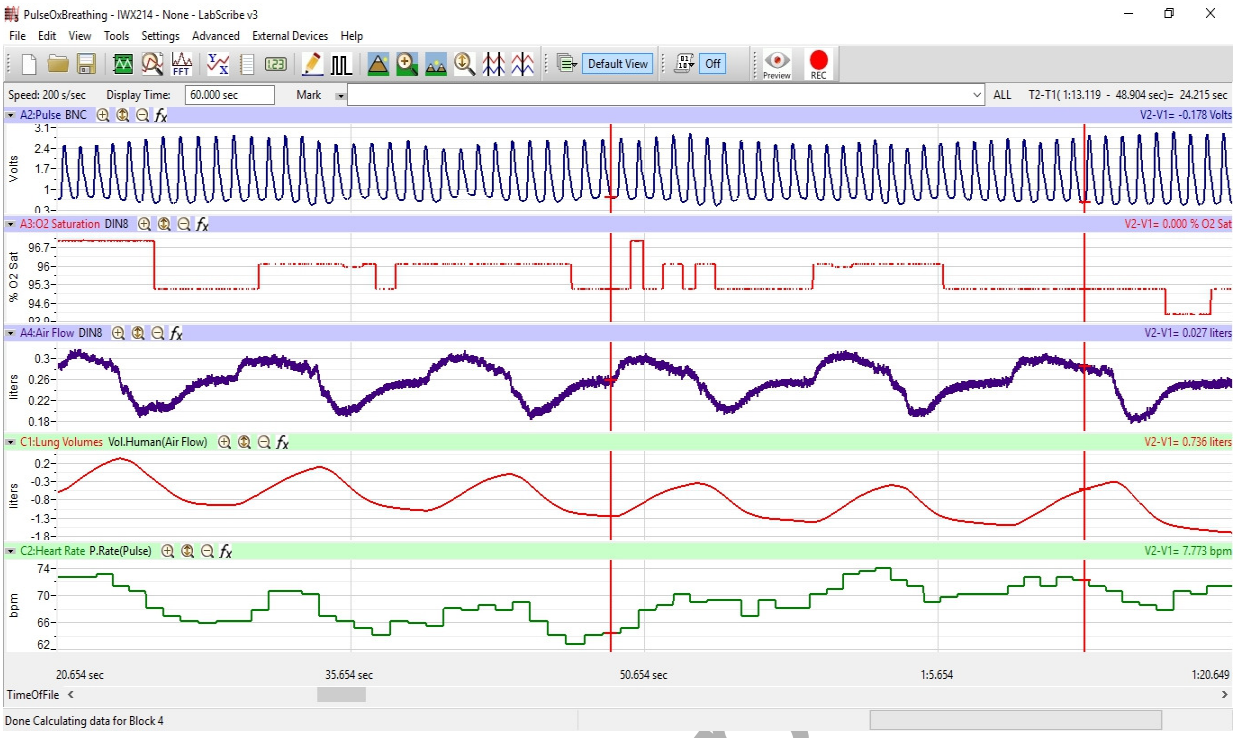

Figure HS-9-L1: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate during breathing at rest, displayed on the Main window.

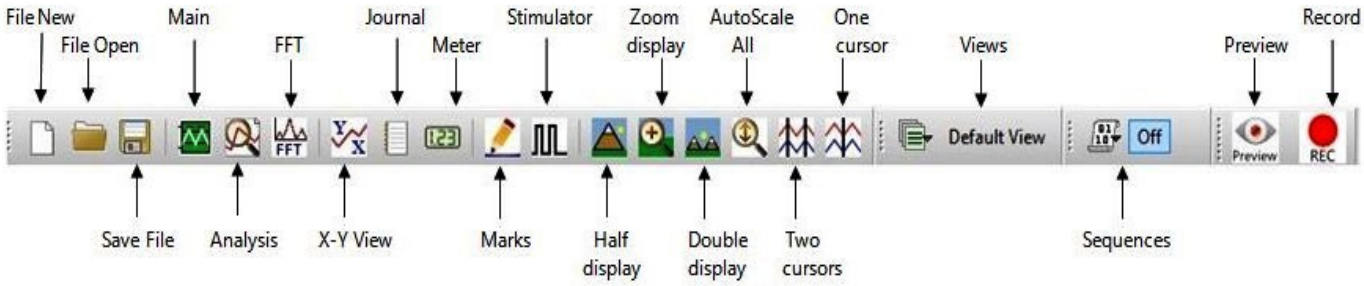

Figure HS-9-L2: The LabScribe toolbar.

4. Sections of the data displayed on the Heart Rate channel may be calculated incorrectly if pulses on the raw data (Pulse) channel have low amplitudes. Pulses with low amplitudes might not be identified by the rate function on the Heart Rate channel and used in the calculation of the subject's heart rate. Pulses used in the rate calculation can be properly identified by either adjusting the position of the trace on the Pulse channel or adjusting the position of the threshold, a parameter in the rate function dialogue window which identifies the pulses to be counted in the rate calculation.

    - To raise the level of the trace on the Pulse channel, use the mouse to click on and drag the trace higher on the screen. If the pulse trace is moved up by the proper amount, the peaks of the missed pulse will intersect the invisible threshold level set by the rate function dialogue window.

- The pulses or waves that used to be missed in the rate calculation will now be included in the calculation. On the Heart Rate channel, the revised plot of the rate calculation will be displayed automatically. If the rate is still not displayed properly, the pulse trace can be moved up again.
- To adjust the level of the threshold parameter for the Heart Rate channel, click on the Channel Function/Mode area to the right of the Channel Title on the Heart Rate channel. Select Setup from the menu to open the rate function dialogue window. Change the level of the threshold: by typing a new value in the box; or, by clicking on the up or down arrows on the right side of the box; or, by clicking on and sliding the threshold line, that is displayed on the graph of the pulse data at the bottom of the dialogue window, up or down.

Note: *Setting the proper threshold level also prevents small artifacts in the data from being counted as pulse waves.*

5. Click on the Analysis window icon in the toolbar (Figure HS-9-L2) or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure HS-9-L3).
6. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Max, Min, Max-Min, Mean, and T2-T1 should appear on the Functions Table at the top of the Analysis window. Values for Max, Min, Max-Min, Mean, and T2-T1 on each channel are seen in the table across the top margin of each channel.
7. Once the cursors are placed in the correct positions for determining the saturation levels and heart rate, the values of the parameters in the Function Table can be recorded in the on-line notebook of LabScribe by typing their names and values directly into the Journal.
8. 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:
9. Place the cursors at the locations used to measure the oxygen saturation levels and the heart rate in each breath.
10. Transfer the names of the mathematical functions used to determine the values to the Journal using the Add Title to Journal function on the pull-down menu of any channel.

11. On the Lung Volume channel, use the mouse to place a cursor at the beginning of the inhalation of the first breath being measured. Place the second cursor at the end of the exhalation of the same breath. Measure the following levels and rates.
    - Maximum Oxygen Saturation Level, the value for Max on the O2 Saturation channel.
    - Minimum Oxygen Saturation Level, the value for Min on the O2 Saturation channel.
    - Mean Oxygen Saturation Level, the value for Mean on the O2 Saturation channel.
    - Maximum Heart Rate, the value for Max on the Heart Rate channel.
    - Minimum Heart Rate, the value for Min on the Heart Rate channel.
    - Mean Heart Rate, the value for Mean on the Heart Rate channel.

Figure HS-9-L3: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate of a resting subject displayed in the Analysis window.

12. Record the values in the Journal using the one of the techniques described in Steps 7 or 8, and on Table HS-9-L1.
13. Repeat Steps 8 through 10 for two additional breath cycles.
14. Average the values obtained for each parameter and enter the means in the Journal and on Table HS-9-L1.

Questions

1. Does the subject's oxygen saturation level change in response to inhalation or exhalation?
2. Does the oxygen saturation level change during a normal breath? By how much?
3. Is there any significant difference in the mean oxygen saturation levels among the three breaths?

Table HS-9-L1: Oxygen Saturation Levels during Breathing at Rest.

Subject	%O2 Saturation			Heart Rate (BPM)		
_____	Min	Max	Mean	Min	Max	Mean
Breath 1						
Breath 2						
Breath 3						
Mean						

Exercise 2: Pulse Ox Challenge

Aim: To measure the effect of your hypothesis on the subject's oxygen saturation level.

Approximate Time: 20 minutes

SAMPLE TESTING IDEAS: Apnea, Hyperventilation, Bellows Breathing, Valsalva Maneuver

Procedure

1. The subject should sit quietly and breath normally before this exercise begins. The subject should already be accustomed to breathing through a flow head.
2. Before the recording begins, instruct the subject about the breathing pattern you have chosen for this exercise:
    - After the 10 second calibration period, the subject should take 5 normal breaths through the flow head.
    - Then, the subject will perform whatever breathing parameter you have chosen.
    - When the subject resumes breathing, he or she should continue to breath through the flow head until the breathing pattern is back to normal.
3. Click on the Record button. After waiting ten seconds for the Lung Volume channel to zero, have the subject place the flow head in his or her mouth and begin breathing.
4. Type "Rest" in the Mark box to the right of the Mark button. Press the mark button to attach the comment to the data.

5. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volume channel. Record three to breaths, which normally takes about twenty seconds to record. Type "Hypothesis Started" in the Mark box.
6. Press the mark button as the subject performs the breathing parameter chosen.
7. While the subject is doing the experiment, type "Breathing Normally" in the Mark box. Press the mark button to mark the recording when the subject resumes breathing normally.
8. The subject should continue to breathe through the flow head until his or her breathing returns to normal.
9. Click Stop to halt recording. Your data should look like Figure HS-9-L4.
10. Select Save in the File menu.

Figure HS-9-L4: Example recording of pulse, oxygen saturation level, air flow, lung volumes, and heart rate before, during and after apnea, displayed in the Main window.

Data Analysis

1. Scroll to the recording of the subject's breathing before, during and after the experiment that is displayed in the Main window.
2. Use the Display Time icons to adjust the Display Time of the Main window to show the normal breath before testing, the period of testing, and a couple of normal breaths after testing in the Main window.
3. Click AutoScale All.

4. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure HS-9-L5).

Figure HS-9-L5: Sample data of pulse, oxygen saturation level, air flow, lung volumes, and heart rate before, during and after apnea, displayed in the Analysis window.

5. On the Lung Volume channel, use the mouse to place a cursor at the beginning of the maximum inhalation that precedes the start of the test. Place the second cursor at the beginning of the first normal breath that follows the test. Measure the following levels and rates.
    - Maximum Oxygen Saturation Level, the value for Max on the O2 Saturation channel.
    - Minimum Oxygen Saturation Level, the value for Min on the O2 Saturation channel.
    - Change(Δ) in Oxygen Saturation Level, the value for Max-Min on the O2 Saturation channel.
    - Maximum Heart Rate, the value for Max on the Heart Rate channel.
    - Minimum Heart Rate, the value for Min on the Heart Rate channel.
    - Change(Δ) in Heart Rate, the value for Max-Min on the Heart Rate channel.

6. Record the values in the Journal using the one of the techniques described in Exercise 1, and on your own data table.

7. Measure the following parameters and record their values in the Journal:
    - Response Time to Experimental Testing. Place one cursor at the beginning of the maximal inhalation that precedes testing, and the second cursor at the first change in the oxygen saturation level during testing. The value for the T2-T1 function is the response time to apnea. Record the values in the Journal.
    - Recovery Time from Testing Place one cursor at the end of testing, when the subject starts to exhale, and the second cursor at the return of the oxygen saturation level to normal. The value for the T2-T1 function is the recovery time from your testing parameter. Record the values in the Journal.
8. Click the Save button to save the file.

Questions

1. Does the subject's oxygen saturation level change in response to the breathing parameter chosen?
2. If so, by how much?
3. Is there any significant difference in the mean oxygen saturation levels before, during and after testing?
4. What are the physiological parameters involved in maintaining pulse oxygen saturation levels?
5. If the SpO2 did change, how long did it take to recover?