

Blood Pressure Laboratory



Introduction

The blood that circulates throughout the body maintains a flow and pressure. The nervous system can change the flow and pressure based on the particular needs at a given time. For example, during exercise the blood pressure and flow may increase. Blood pressure is an important physiological signal to measure and monitor over time. There are dangers associated with blood pressures that are too high or too low. Obesity is a leading cause of high blood pressure. High blood pressure puts a greater workload on the heart. High blood pressure has been correlated with an increased risk for many diseases including stroke, heart attack, cardiovascular disease, and kidney failure. Typically, there are no symptoms of high blood pressure. This is why it is such an important parameter to periodically have checked. High blood pressure has been treated with medication, exercise, and even meditation practices.



Figure 1. An analog blood pressure cuff.

Your blood pressure consists of two numbers, the systolic and diastolic pressures. These will be explained in more detail below. The optimal value for the systolic pressure should be below 120mmHg and the optimal value for the diastolic pressure should be below 80mmHg. The normals range from 120 to 130mmHg and from 80 to 85mmHg. High blood pressure or hypertension occurs when the systolic blood pressure is above 140mmHg or the diastolic pressure is above 90mmHg.

As a part of this laboratory session, you will learn how to use a blood pressure cuff to monitor blood pressure. Additionally, you will learn how a system can be designed to automatically measure and calculate blood pressure based on a pressure transducer with an electrical signal input to a computer.

Equipment required:

- CleveLabs Kit
- CleveLabs Course Software
- Three (3) Snap Electrodes and Snap Leads
- Blood Pressure Cuff and Transducer Interface Cable
- Microsoft® Excel, MATLAB®, or LabVIEW™

Background

The Circulatory System

The circulation of blood through the body is a cooperation of many parts of the circulatory system. Each individual part plays its role in maintaining the blood flow that the body requires. The circulatory system is made up of complex pumping and feedback mechanisms. There are two distinct circuits of blood flow in the body. In the systemic circuit, blood starts in the heart and is pumped from the left ventricle through the aorta to the tissue beds of the body. The blood then returns to the heart from the body through the systematic veins. It returns to the right atrium, and is pumped to the right ventricle. From the right ventricle the blood is pumped through the pulmonary arteries to the lungs, where gas exchange occurs. The blood is returned to the heart through the pulmonary veins to the left atrium. Then it is pumped to the left ventricle to complete the circuit.

The pulmonary arteries are somewhat of an exception from the rest of the circulatory system. Blood vessels carrying blood away from the heart are labeled arteries, and blood vessels returning blood to the heart are labeled veins. For most of the circulatory system this means that arteries carry oxygenated blood, while veins carry de-oxygenated blood. The pulmonary circuit of blood flow is an exception. The pulmonary arteries carry de-oxygenated blood from the heart to the lungs, and the pulmonary veins return oxygenated blood from the lungs to the heart.

The pressure at which the heart pumps blood throughout the body must be able to overcome the resistance in the circulatory system. Blood vessels are more important than simply being paths of blood flow. They contribute to regulating blood flow to the tissue beds. Blood vessels have a few characteristics which allow them to play a more involved role than simply being conduits of blood flow. The blood vessel walls are composed of smooth muscle, and as such help the heart to maintain a constant flow to individual tissue beds. The heart beats in a distinct rhythm, which causes the pressure gradient, allowing blood flow. However, tissue of the body can use the metabolites, which the blood carries, more efficiently from a constant blood flow rather than the distinct and successive spurts of flow the heart supplies to the aorta. In order to accommodate this, the blood vessels work to even out the pressure gradient inherent with each beat of the heart, and consequently this makes the blood flow steady. As the heart beats and forces blood into the systematic vessels, they expand to accommodate the pulse of blood during systolic pressure and contract during diastolic pressure to supply the body with a constant blood flow. They expand and contract in a rhythm out of phase with the heart beats to regulate the pressure to create a constant blood flow to the body.

The arteries of the systematic system carry blood to all of the tissue beds of the body. As the blood reaches the tissue beds, the arteries branch off to smaller vessels known as arterioles. The diameter of the arterioles is much smaller than that of the arteries. Consequently, the resistance of blood flow through the arterioles is much greater.

The walls of the arterioles are made up of smooth muscle, but these vessels use the muscle to play a different role in the vascular system. The arterioles regulate the amount of blood flow that each local tissue bed in the body gets. As demand to a particular tissue bed increases, the smooth muscles of the arterioles relax and the diameter increases, allowing greater blood flow. As demand to a particular tissue bed decreases, the smooth muscle contracts and the diameter of the arteriole decreases. Most all of the resistance to blood flow which occurs in the body is in the arterioles; therefore by adjusting their diameter arterioles can perfectly regulate the local blood flow paths throughout the body. This system works efficiently to direct blood flow where the body needs it most.

Capillaries follow the arterioles in the blood flow path back to the heart. The capillaries are in the tissue beds, and are the sites where cellular exchange occurs. Having very thin walls and being only approximately 1 mm long, capillaries form a vast network ideally suited for cellular exchange throughout the body. Capillary walls are only one cell thick, which makes diffusion through them very easy. After the cellular exchange takes place in the capillaries, the de-oxygenated blood begins its return through the veins back to the heart. The blood pressure in the veins is less than that of the arteries.

During normal conditions when the body is at rest, the arterial pressure required to provide adequate tissue flow is 100 mm Hg. However, blood flow and blood pressures are not a constant value. Since the heart acts as a pump approximately once a second, the pressure in the blood is pulsatile. Arteriole blood pressure is lowest at the end of ventricular diastole and reaches a peak during ventricular systole. However, the elastic properties of the arteries help to maintain a somewhat constant flow of blood through the more peripheral circulatory system. Diastolic pressure is known as the minimum that the blood pressure reaches when blood flows out of the arteries. The peak pressure that occurs during ventricular contraction is known as the systolic pressure. In a normal blood pressure measurement, the numbers are recorded as systolic/diastolic pressure. The difference between them is the pulse pressure.

Measuring Blood Pressure

Blood pressure is typically measured with a blood pressure cuff around the arm. A clinician can use the blood pressure cuff and a stethoscope to record blood pressure. The cuff is inflated around the upper arm to a pressure which cuts off all blood flow down the brachial artery. The stethoscope is then also placed over the artery downstream from the cuff occlusion. When the cuff is inflated to a level that collapses the artery and prevents blood flow, no blood sounds are heard in the stethoscope. As the pressure is slowly released in the blood pressure cuff and it decreases just below the systolic pressure, blood will forcefully flow past the cuff and can be heard through the stethoscope with a distinct noise. The pressure at which this is noticed is recorded as the systolic pressure. The cuff pressure then continues to be slowly decreased. As the pressure is decreased, the sound of the blood flowing past the stethoscope gets longer and longer. Finally, when the diastolic pressure has been reached, no sound is heard any longer. That point is recorded as the diastolic pressure.

The mean arterial pressure (MAP) can be calculated from the systolic and diastolic pressures using the formula:

$$\text{MAP} = 1/3 \text{ pulse pressure} + \text{diastolic pressure}$$

Instead of using a stethoscope, blood pressure can also be recorded using electrical pressure transducers and computer software. A blood pressure cuff is placed around the upper arm over the brachial artery. The pressure is recorded and sampled by software. The pressure in the arm cuff is increased to a level that stops blood from flowing through the brachial artery. The pressure is then very slowly decreased from the cuff as the data is recorded to the computer or viewed in real-time. When the pressure in the cuff is decreased to just below the systolic pressure, blood will be pulsed through the cuff and you will begin to see tiny pulses in the recorded pressure signal. The point in the signal when these begin to occur is the systolic pressure. When the pressure in the cuff is decreased to just below the diastolic pressure, these pulses in the pressure signal will disappear again since the cuff is not tight enough to detect the blood pressure. The point at which they disappear is known as the diastolic pressure. Therefore, an automated program which can find these features in the pressure signal and record them can automatically record blood pressure from a subject in the absence of a clinician.

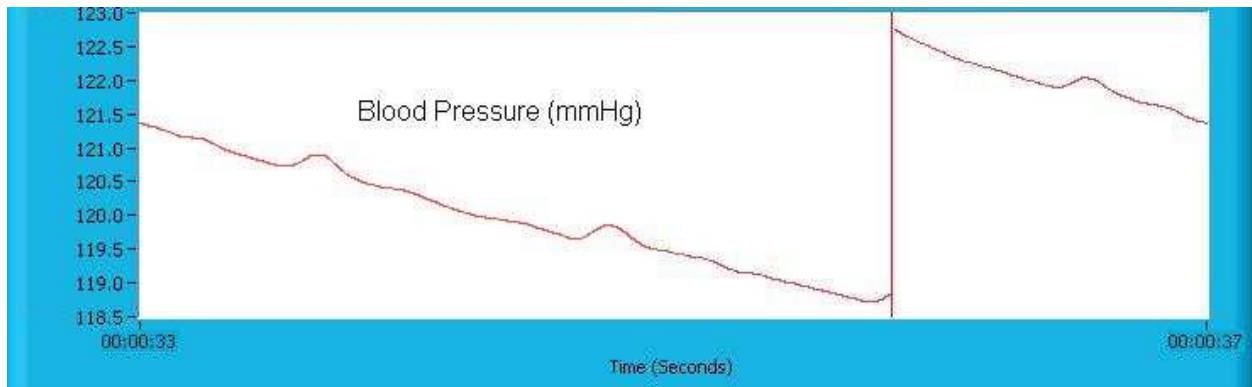


Figure 2. When the pressure in the cuff is between the systolic and diastolic pressures of the blood, the pumping action of the heart can be seen in the recorded signal.

Experimental Methods

Experimental Setup

During this laboratory session you will record blood pressure using the blood pressure cuff and one channel of electrocardiography (ECG) with surface electrodes. These experiments will allow you to learn how to record blood pressure and how the blood pressure signal is correlated to the ECG. You should be sure to watch the experimental setup movie included with the CleveLabs software before beginning the initial setup in the experiment.

1. For this laboratory you will need to use three snap electrodes from the CleveLabs Kit. Remember that the electrode needs to have good contact with the skin in order to get a high quality recording. The surface of the skin should be cleaned with alcohol prior to electrode attachment. For the best recordings, it is best to mildly abrade the surface with pumice or equivalent to minimize contact resistance by removing the outer dry skin layer. Attach one electrode to the inside of the left wrist, one electrode to the inside of the right wrist, and one electrode on the right ankle.
2. After the electrodes have been placed on the subject, connect one snap lead to each electrode. Then, connect those snap leads to inputs channel 1 and the ground using Fig 3 as a reference.

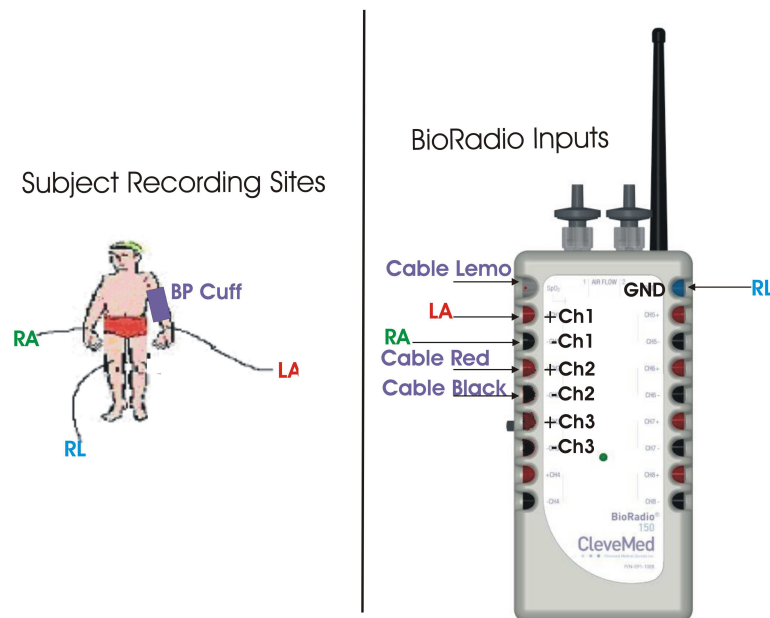


Figure 3: Blood Pressure Setup

3. Connect the transducer interface cable to input channels 2 and the pulse oximeter input on the BioRadio 150. The pulse oximeter input provides power to the transducer.
4. Connect the blood pressure sensor to the transducer interface cable.

Procedure and Data Collection

1. Run the CleveLabs Course software. Log in and select the "Blood Pressure" laboratory session under the Advanced Physiology subheading and click on the "Begin Lab" button.
2. Turn the BioRadio ON.

3. Click on the BioRadio Data Tab and then on the green “Start” button. One channel of ECG and one channel of blood pressure should begin scrolling across the screen. Your BioRadio should be programmed to the “BloodPressure” configuration.
4. Make sure the all the pressure from the cuff has been released using the release valve. Then click on the “Zero BP Sensor” button to calibrate or zero the transducer.
5. First you will record your ECG signal and blood pressure at rest. The subject should be sitting in a chair relaxed. Begin recording data to a file named “relaxed1”.
6. Slowly increase the pressure in the cuff by repeatedly squeezing the ball on the blood pressure cuff. The pressure in the cuff will be displayed on the screen. Continue to increase the pressure to a level just above where the heart pumping can no longer been seen in the blood pressure signal on the screen. This it the level at which you restrict blood from flowing through the brachial artery. This level should be around 150 or 160 mmHg. *Be sure not to squeeze the cuff so tight that the subject is uncomfortable.*
7. Now, slowly begin to release the pressure from the cuff by pressing on the release valve of the blood pressure cuff. Continue to slowly release the pressure until the pressure in the cuff is down to 0.
8. Repeat steps 5 – 7 two more times. You should collect three trials of relaxed blood pressure named relaxed1, relaxed2, and relaxed3.
9. Instruct the subject to run in place or complete some other type of exercise to increase their heart rate for two minutes.
10. Now repeat steps 5 – 8 naming the data files exercise1, exercise2, and exercise3.

Data Analysis

1. Using MATLAB, LabVIEW, or Excel, open each of your saved data files. Calculate the systolic and diastolic pressure for each data file by determining when the heart beats appear and disappear in the blood pressure waveform.
2. Calculate the average MAP, systolic, and diastolic blood pressures for the resting trials.
3. Calculate the average MAP, systolic, and diastolic blood pressure for the exercise trials.
4. Calculate the delay between the blood pressure increases from the heart beat in the blood pressure waveform and the QRS complex in the ECG waveform.

Discussion Questions

Blood Pressure Laboratory

1. What are common symptoms of high blood pressure?
2. What can occur if hypertension is not treated?
3. What was the average value of your blood pressures for the resting trials? What was the average value for the exercise trials? Which was higher? Is this what you would expect?.
4. What was the delay between the heart beat in the blood pressure recording compared to the heart beat in the electrical ECG recording? Why would a delay exist?
5. How would you design an automated system to monitor blood pressure in the absence of a clinician?

References

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3. Rhoades and Phlanzer. Human Physiology, Third Edition. Saunders College Publishing, Forth Worth, 1996.