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Biopac Student Lab® Lesson 16

BLOOD PRESSURE

Introduction

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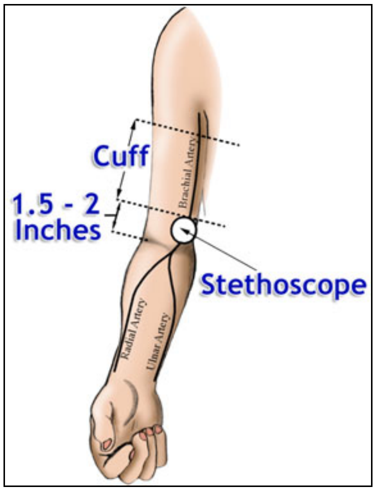
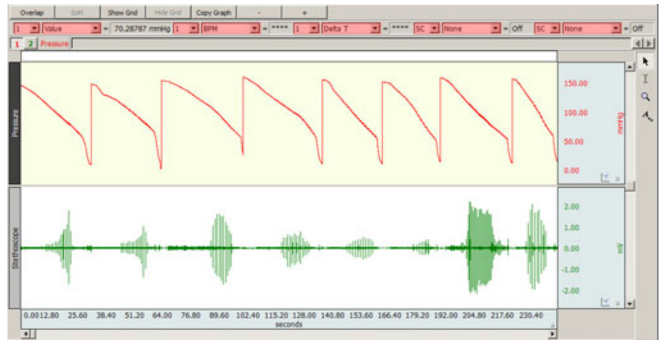




I. INTRODUCTION

In this lesson, you will record your blood pressure, which is comprised of two numbers: systolic pressure (the force of blood in your arteries as the heart contracts and pushes it out) and diastolic pressure (the force of your blood between heartbeats). Understanding circulation will help you understand and accurately measure your blood pressure.

Circulating blood provides a transportation and communication system between the body's cells and serves to maintain a relatively stable internal environment for optimum cellular activity. Blood circulates because the heart pumps it through a closed circuit of blood vessels (Fig. 16.1 and 16.2).

Blood flow through the heart and the blood vessels is unidirectional, flowing into the heart from the pulmonary and systemic veins, and out of the heart into pulmonary and systemic arteries.

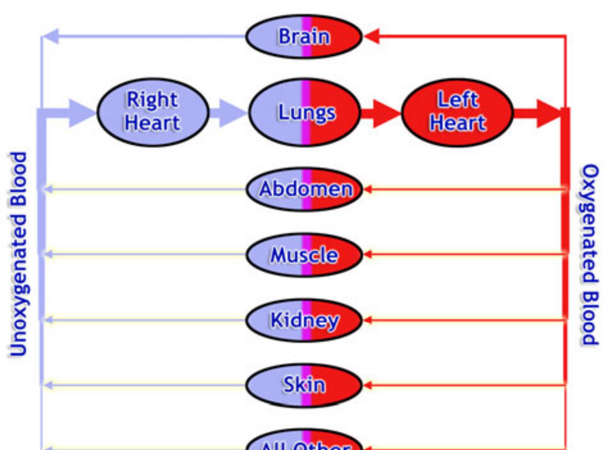


Fig. 16.1

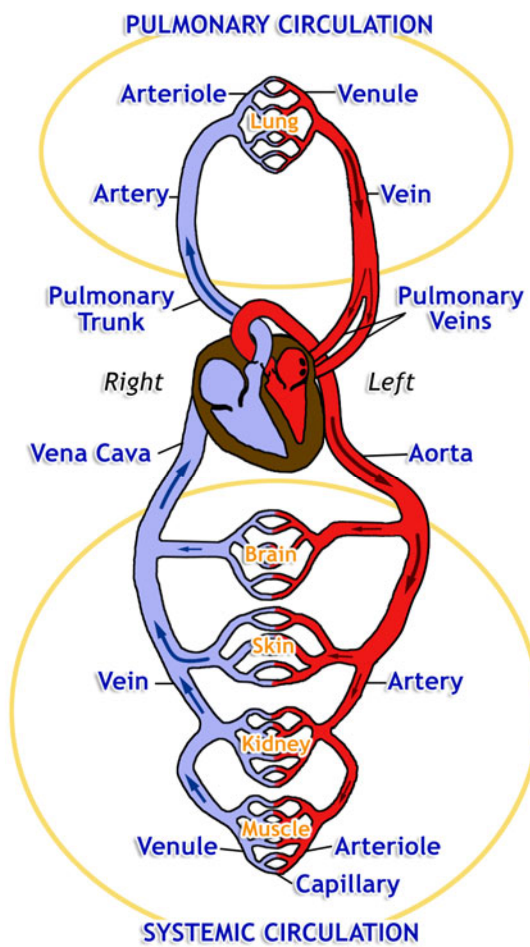


Fig. 16.2

Blood flow through the chambers of the heart is unidirectional because of the action of four valves inside the heart (see Fig. 16.3) that normally prevent retrograde or backward flow during the cardiac cycle (one heartbeat).

- ❖ The **right atrioventricular valve** (tricuspid) and the **left atrioventricular valve** (bicuspid or mitral) prevent the backward flow of blood from the ventricles into the atria.
- ❖ The **pulmonary semilunar valve** and the **aortic semilunar valve** prevent the backward flow of blood from arteries into the ventricles.

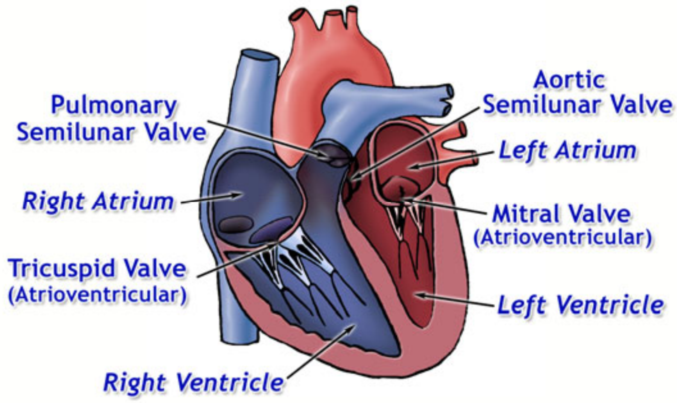
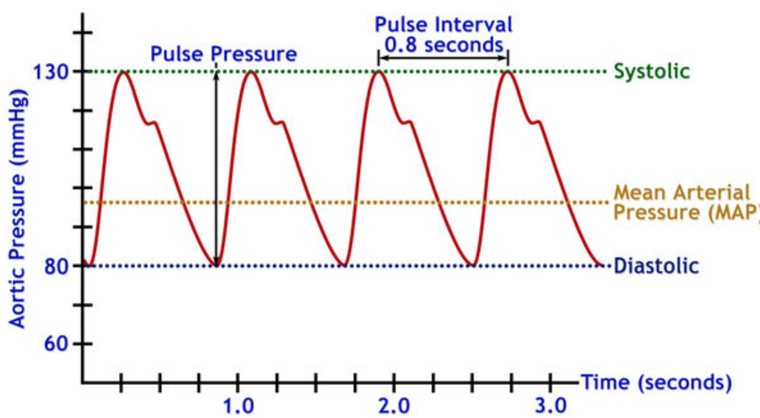


Fig. 16.3 Heart valves

The left and right ventricles are the primary pumping chambers of the heart. During relaxation of the ventricles (**ventricular diastole**) the atrioventricular valves open and the semilunar valves close, allowing the ventricles to fill with blood. During contraction of the ventricles (**ventricular systole**) the atrioventricular valves close and the semilunar valves open, allowing the ventricles to eject blood into the arteries.

As the heart works at pumping blood, the ventricles relax and fill with blood, then contract and eject blood, then repeat the cycle of filling and ejecting. Due to the nature of the cardiac cycle the ejection of blood by the ventricles into the arteries is not continuous. Therefore, both blood pressure and blood flow in the arteries is **pulsatile**, increasing during ventricular systole and decreasing during ventricular diastole.

Fig. 16.4 represents a graphic recording of changes in systemic arterial blood pressure measured directly by inserting a small catheter into an artery and attaching the catheter to a pressure measuring and recording device.



Pulse Pressure (mmHg) = Systolic Pressure - Diastolic Pressure
Mean Arterial Pressure (mmHg) = 1/3(Pulse Pressure) + Diastolic Pressure
Heart Rate (BPM) = 60 seconds/minute ÷ Pulse Interval (seconds/beat)

Fig. 16.4 Example of systemic arterial blood pressure changes

Systolic pressure is the highest arterial pressure reached during ventricular systole. The normal range of systolic pressures for a resting adult is 100 - 139 mm Hg.

Diastolic pressure is the lowest arterial pressure reached during ventricular diastole. The normal range of diastolic pressures for a resting adult is 60 - 89 mm Hg.

The mathematical difference between systolic pressure and diastolic pressure is called **pulse pressure**. Pulse pressure is directly related to stroke volume of the heart and inversely related to heart rate and peripheral resistance.

- ❖ For example, when the volume of blood ejected per beat (called **stroke volume**) increases at the beginning of exercise, systolic pressure increases more than diastolic pressure, resulting in an increase in pulse pressure.

In the systemic circuit (refer back to Fig. 16.2,) blood flows out of the left ventricle into systemic arteries and then serially through arterioles, capillaries, venules, and veins before returning to the heart to be pumped through the pulmonary circuit. Flow through a closed circuit such as the systemic circuit is determined by the pressure energy causing the flow, and the resistance to flow offered by the blood vessel walls (friction) and the internal viscosity of the blood.

The relationship between flow (F,) pressure (P) causing the flow and resistance (R) to the flow is expressed as: **F = P/R**

Flow is expressed as liters/min., pressure is expressed as **mm Hg** (**torr**,) and resistance is expressed as peripheral resistance units.

The pressure (P) is neither systolic nor diastolic but rather a pressure in between the two, called **mean arterial pressure** (**MAP**). Mean arterial pressure converts a pulsatile pressure (systolic/diastolic) into a continuous pressure that determines the average rate of blood flow from the beginning of the circuit (left ventricle) to the end of the circuit (right atrium).

During the cardiac cycle, or one heartbeat, the ventricle spends more time in diastole than it spends in systole. As a result, mean arterial pressure is not the mathematical average of systolic and diastolic pressure but rather an approximation of the geometric mean. Mean Arterial Pressure (MAP) can be calculated using either of the following equations:

$$\text{MAP} = \frac{\text{pulse pressure}}{3} + \text{diastolic pressure} \qquad \textit{OR} \qquad \text{MAP} = \frac{(\text{systolic pressure} + 2\ \text{diastolic pressure})}{3}$$

If systolic pressure were 130 mm Hg and diastolic pressure were 80 mm Hg, then the mean arterial pressure would be 96.67 mm Hg, as calculated below:

$$\text{MAP} = \frac{50}{3} + 80 = 16.67 + 80 = 96.67 \text{ mm Hg} \qquad \textit{OR} \qquad \text{MAP} = \frac{(130 + 2(80))}{3} = \frac{(130 + 160)}{3} = \frac{290}{3} = 96.67 \text{ mm Hg}$$

IMPORTANT CONCEPT!

Systemic arterial blood pressure is commonly measured with indirect methods because direct methods of measurement are invasive and neither practical nor convenient for routine use. It is important to recognize the limitations of indirect measurement:

- Indirect methods can only give an approximation of the actual blood pressure.
- Indirect methods may be influenced by the person taking the measurement—for example, the person may not be able to hear the sound changes accurately.
- Indirect methods can be influenced by the quality and calibration of the equipment being used.

The most common indirect method of measuring systemic arterial blood pressure is referred to as an **auscultatory** method, which simply means external diagnostic monitoring of the sounds made by internal organs. This involves the use of a stethoscope and a sphygmomanometer. The **sphygmomanometer** is comprised of an inflatable cuff to restrict blood flow, an inflation bulb with release valve, a pressure gauge (which can be a mercury or mechanical manometer,) or an on-screen gauge. The BIOPAC stethoscope contains a microphone that picks up sounds traveling through the tubing. The microphone is very sensitive and can pick up sounds that may not be heard. It is useful to compare the sounds heard to those recorded by the microphone.

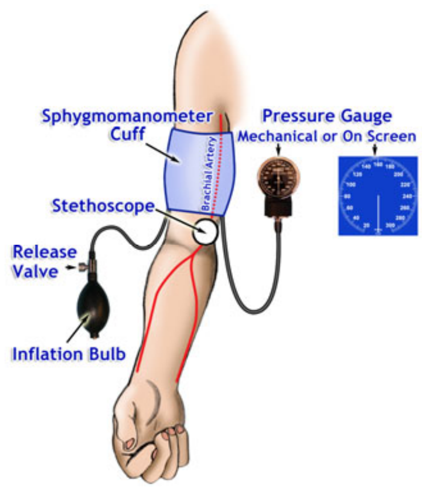


Fig. 16.5 Blood pressure cuff placement

> The sounds detected during blood pressure measurement are referred to as **Korotkoff Sounds** and were first identified by Russian surgeon Nicolai Sergeivich Korotkov in 1905.

Arterial pressure is determined by placing an inflatable rubber cuff, attached to a pressure gauge, around the arm, inflating it to collapse the underlying artery, and listening over the vessel below the cuff with a stethoscope or microphone (Fig. 16.5).

Sound is created by the turbulent flow of blood through the compressed vessel. When cuff pressure exceeds systolic arterial pressure, the artery is collapsed, blood flow through it ceases, and no sound is produced. As cuff pressure is slowly reduced, blood flow through the artery begins when cuff pressure falls just below systolic arterial pressure.

At this point, a sharp tapping sound (the first sound of **Korotkoff**) may be heard with the stethoscope or microphone over the artery. The cuff pressure when this sound is first heard is taken as an approximation of systolic pressure.

As cuff pressure is further reduced, the sounds increase in intensity (and may resemble swishing,) then suddenly become muffled (the second sound of Korotkoff) at the level of diastolic pressure, then disappear. Sounds disappear when the vessel is no longer compressed by the pressure cuff and normal non-turbulent blood flow resumes.

Since it is easier to determine when the sound disappears than when it becomes muffled, and since only a few millimeters of mercury pressure differential exist between the two, the disappearance of sound is commonly used as an indicator of diastolic pressure.

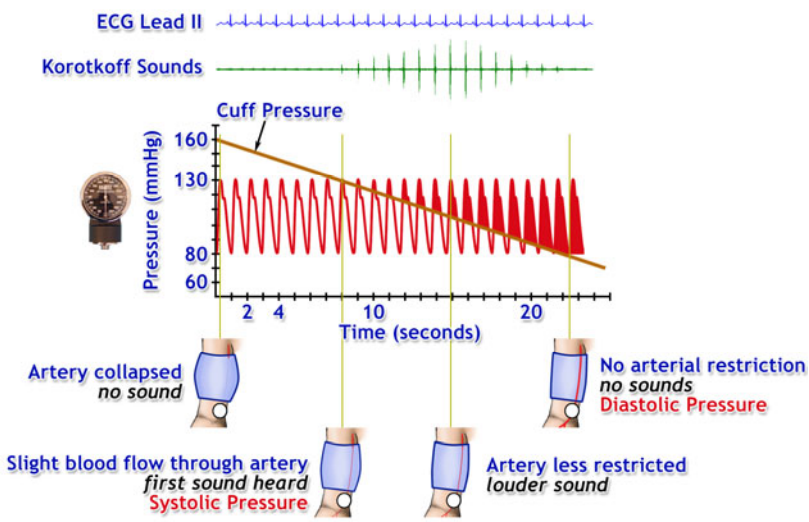


Fig. 16.6

Fig. 16.6 (above) is a graphic display that summarizes this concept. The diagram shows the relationship in time between the ECG waveform, the Korotkoff sounds (as heard through the stethoscope,) the cuff pressure, the blood pressure pulse waveform (at the arm,) and the condition of the brachial artery under the cuff. The pulse waveform represents the brachial pressure in the artery above the cuff. The shaded area of the Aortic pressure wave represents the blood flow that can pass below the cuff as soon as the aortic pressure exceeds the cuff pressure.

One concept that can be examined in this lesson is the timing of the Korotkoff sounds with respect to the ECG waveform. The sounds appear at about the time of the T-wave. This sound occurs approximately near the time of peak pressure (systole,) which, if measured at the heart, would occur immediately after the R-wave. However, there is a delay due to the time it takes the pressure wave to reach the arm, so the sounds are shifted in time with respect to the R-wave. Although the ECG wave will vary based on the experimental condition (i.e., pre-exercise, post-exercise,) the relationship of the P-wave to the sound should be a consistent interval within each condition. Using this fact, you will be able to distinguish actual Korotkoff sounds from extraneous noise.

In some cases (such as when a Subject has hypertension) you may notice what is called an "auscultatory gap." This occurs when you hear sound at a higher cuff pressure, but it fades out as the pressure is decreased, and then reappears at a still lower pressure. This may require an alternate method of blood pressure measurement, using a strictly palpatory technique.

By convention, blood pressures determined by indirect methods are expressed in the form of a ratio: systolic pressure/diastolic pressure. For example, if systolic pressure was measured as 135 mm Hg and diastolic pressure was measured as 80 mm Hg, systemic arterial blood pressure would be expressed as 135/80, and pulse pressure would be 55 mm Hg. If the sound became muffled at 85 mm Hg and disappeared at 80 mm Hg, the systemic arterial blood pressure would be expressed as 135/85-80.

A note about your BP reading from this lab

There are many factors that influence blood pressure measurement, such as: genetics, age, body weight, state of physical activity, level of salt, caffeine or other drugs in the system, monitor's hearing, etc.

The Journal of the American Medical Association published the following blood pressure classification data (Table 16.1) from the Seventh Report of the National High Blood Pressure Education Program's Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7):

CLASSIFICATION OF BLOOD PRESSURE for Adults Aged 18 Years or Older				
BP CLASSIFICATION	**Systolic** mmHg		**Diastolic** mmHg	*LIFESTYLE MODIFICATION*
Normal	< 120	and	< 80	Encourage
Prehypertension	120-139	or	80-89	Yes
Stage 1 hypertension	140-159	or	90-99	Yes
Stage 2 hypertension	≥ 160	or	≥ 100	Yes
Note:Diagnosis of high blood pressure is based on the average of two or more readings taken at each of two or more visits after initial screening. Unusually low readings should be evaluated for clinical significance. © 2003 AMA				

Table 16.1 JNC 7 Blood Pressure Classifications

If your blood pressure as determined from this lesson is "high," you should not be too concerned. A mistake may have been made in the measurement, or there may be other factors affecting your system that resulted in a temporarily high reading.

If you are concerned about it, please consult your doctor. Do not try to diagnose or treat yourself based on the laboratory blood pressure readings.

Please review the following procedure before you come into the lab so recording can proceed quickly.

Blood Pressure Measurement

The following is a review of the basic clinical blood pressure measurement procedure using the sphygmomanometer and stethoscope, with an explanation of the logic behind each step.

As discussed earlier, this is an indirect blood pressure measurement. It can be fairly accurate if performed exactly as described, but will nonetheless provide only an approximation of the absolute blood pressure.

It is important that you try to minimize errors by following the measurement procedure as detailed, and it is also important that you realize it is impossible to eliminate all errors.

Note: The actual procedure used in this lesson will have a few additional steps since you will be simultaneously recording the parameters.

Basic measurement step	***Reason***
1. Select the proper size cuff for your Subject. ❖ The BIOPAC sphygmomanometer cuff is designed for arms with a circumference from 25.4 cm (10 inches) to 40.6 cm (16 inches). This is the standard adult range, and is marked on the cuff to make sure you fall within it. If this cuff does not fit your Subject, you should use another Subject for this lesson so the readings are accurate.	Cuffs come in several sizes and it is important that you select the right size cuff for Subject's arm because if the cuff is too large you may get incorrect low readings, and if it is too small you may get incorrect high readings.
2. Make sure all the air in the sphygmomanometer cuff is expelled before use. ❖ Turn the release valve fully counter-clockwise and roll the cuff up while squeezing it.	If air is left in the cuff you may get a false high reading because an excessive amount of pressure will be required to occlude the brachial artery.
3. Close the valve. ❖ Turn the release valve fully clockwise.	
4. Position Subject's arm at heart level. ❖ Hold up Subject's arm, or ❖ Have Subject rest his/her arm on the lab table.	You need to minimize the effects of gravity. Arm above heart level can give false low readings, and arm below heart level can give false high readings.
5. Place the cuff so that the "Artery" label is over Subject's brachial artery (with the arrow on the label facing down). ❖ There is an "Artery" label (with arrow) that is sewn into the cuff.	The cuff pressure must be applied directly to the artery, which requires the bladder inside the cuff to be in the proper position.
6. Position the cuff such that the lower edge of the cuff is 1.5 to 2 inches above the antecubital fossa (inner aspect of elbow).	The cuff edge should be high enough to avoid covering any part of the stethoscope diaphragm. This is to minimize any extraneous noise cause by the cuff rubbing against the diaphragm.
7. Wrap the cuff evenly and snugly around Subject's arm and allow the Velcro® to hold it in place. ❖ After it is snugly in place, you may wish to inflate the cuff slightly (10-20 mmHg) so that it will stay in place.	A loose cuff can give a false high reading because of the increased pressure required to occlude the brachial artery.
8. Make sure all the rubber tubing and cables of both the sphygmomanometer cuff and stethoscope are not tangled or pinched.	Any tubing on the sphygmomanometer that is pinched can cause false pressure reading and if the stethoscope tubing is pinched, it can greatly reduce the loudness of the Korotkoff sounds.

Basic measurement step	*Reason*
9. Position the sphygmomanometer pressure dial indicator such that you can read the face of the dial straight on. ❖ The dial indicator can be clipped to the strap sewn into the cuff above the “Artery” label.	Reading the dial at an angle can cause inaccurate readings due to parallax error.
Notes for the following steps: a) It is important to not inflate the cuff higher than is needed.	Besides causing pain for Subject, an overinflated cuff may produce a vasospasm, which can cause incorrect pressure readings.
b) It is important to not leave the cuff at a high pressure for an extended period of time.	Besides discomfort for Subject (which can elevate blood pressure,) occlusion of blood caused by the cuff creates venous congestion in the forearm. The blood must be allowed to drain or it can lead to incorrect pressure readings. For the same reason, it important to wait at least one (1) minute between successive blood pressure measurements.
Step we will use: 10. Palpate the brachial artery between the antecubital fossa and the lower edge of the cuff to find where the pulse is best felt. ❖ Use your first and second fingers to feel the pulsation of the brachial artery on the inside of your elbow. ❖ During the actual lesson, you can note this position by marking the spot with a washable felt pen.	The stethoscope diaphragm needs to be placed over the brachial artery where the Korotkoff sounds are best heard. This procedure can be a bit tricky so take note: The pulse is felt when the artery is compressed over bone or firm tissue. To feel the pulse, compress the artery firmly then ease up on the pressure slightly. After a few tries you should get the hang of it.
<u>*Alternate technique*</u>: 10. Inflate the cuff to 110 mmHg and place the stethoscope diaphragm over the brachial artery between the antecubital fossa and the lower edge of the cuff and move it around to find the place where the sounds are best heard.	This alternate procedure can result in optimal placement of the stethoscope diaphragm, but it can take longer to find. As noted above, it is not safe to inflate the cuff for a long period of time, so this technique is not used in the lesson because when you add the steps required to perform the recording, it simply takes too long.
Step we will use: 11. Inflate the cuff to 160 mmHg. ❖ Pump the cuff rapidly then release to reduce distal vasculatory engorgement. ❖ It is assumed that the majority of Subjects in the physiology lab will have systolic pressures below this pressure.	If cuff is not inflated high enough, true systolic pressure may be missed. This technique has the advantage of being quick and easy, and for reasons discussed above, it is preferable to minimize the amount of time the cuff is at high pressure. The disadvantage of this technique is that it uses more pressure than most Subjects probably need, and (in rare cases) it may miss the point of diastolic pressure. However, because a simultaneous recording will be per-formed, and time will be time spent reviewing the recording procedure, this is the best technique because it is fast.
<u>*Alternate technique*</u>: 11. Either by listening through the stethoscope, or by palpating the radial artery (on flexor surface of wrist,) inflate the cuff 20 to 30 mmHg above the point at which the sounds or pulse disappear.	This technique makes sure the cuff pressure does not go excessively high.
12. Place the stethoscope in the correct position. ➢ Do not push down excessively on it and try to maintain a constant pressure against the skin.	Excessive pressure could distort the artery and give incorrect pressure indications (usually gives a diastolic pressure reading that is too low). Also, excessive pressure can cause the stethoscope to rub on Subject’s skin, which may generate extraneous noise.

Basic measurement step	***Reason***
13. Release the pressure at a rate of 2 to 3 mmHg/second.	Deflating too slowly produces venous congestion, which can give false high diastolic pressure readings. Deflating too rapidly leads to inaccuracies because the actual point of systolic or diastolic pressure could lie between heartbeats. The slower the heart rate, the more inaccurate the reading.
14. Note the pressure at which the Korotkoff sounds first appear (systolic).	This sound indicates the pressure closest to the **systolic pressure**.
15. Continue to listen and note the pressure when the sounds completely disappear (diastolic).	This pressure is close to the point of **diastolic pressure.** Note: The point at which the sounds become muffled is closer to the diastolic pressure but since it's easier to detect the disappearance of sound—and the difference between the two is small—we will use the point of disappearance of sound.
16. Deflate the cuff as rapidly as possible after all the sounds disappear.	This will minimize patient discomfort and reduce venous congestion.

When evaluating a patient or Subject, you will normally take blood pressure readings at different points in time and/or under different circumstances (at rest vs. after exercise, etc). to see how the blood pressure changes. With this in mind, it becomes important that your technique is consistent every time you do it. If two people use different techniques, they may get slightly different readings, but the difference (or delta)—which can be the more important factor—will be very consistent for each person.