Factors Affecting Blood Pressure

The professor passes out the exam. You turn to page one and read the questions. At that moment your heart is in your mouth and your blood is pounding in your ears because you realize that you have studied the wrong material! In lab, the teaching assistant euthanizes a frog for a muscle contraction experiment and the student next to you faints. Both of these situations reflect a dramatic change in blood pressure.

Fainting is the result of a sudden, huge drop in blood pressure. The blood pounding in your ears is caused by a dramatic rise in blood pressure. But what is blood pressure? And why does it go up and down? In this tough topics section, we will discuss the components of blood pressure and the factors that regulate it.

We'll start by discussing how blood flow and resistance correlate to blood pressure in the vessels. To do that, we'll have to define some terms and talk about how they're related. After we cover those basics, we'll talk about how your body maintains blood pressure. Let's begin with a look at the overall system.

Your body is like a factory with steam pipes running outward from one big furnace. But instead of steam pipes, you have blood vessels and instead of a furnace you have a heart. Just like the steam pipes, if the pressure is too high, they burst and if it isn't high enough, the steam doesn't move and the furnace gets backed up. Part of the body's homeostatic control involves making fine or dramatic adjustments as needed to keep blood pressure within safe limits.

Before we go on to talk about how blood pressure is regulated, let's look more closely at the factors that are involved in establishing the blood pressure in the first place.

We define blood pressure, or BP, as the force per unit area exerted on a blood vessel wall by the blood contained within the wall. The more force the blood puts on the blood vessel, the higher the blood pressure. This pressure is expressed as millimeters of mercury. So a BP of one hundred twenty millimeters of mercury is the amount of pressure exerted to raise a column of mercury one hundred twenty millimeters high and keep it there.

Blood pressure refers to the arterial pressure in the largest arteries closest to the heart. The pressure initially established in the aorta after ventricle contraction begins a pressure gradient. This pressure gradient is highest near the heart and lowest in the tissues. The blood flows down the gradient because there is less resistance. By the time the blood reaches the veins, the pressure is very low.

What do we mean when we say that resistance decreases as the blood flows down the pressure gradient? Well, resistance is a measure of the amount of friction blood encounters as it travels through the vessels. Resistance is also used to describe any opposition to blood flow. Since most of the resistance is located in the peripheral circulation, we often call this peripheral resistance. There are three important sources of resistance: vessel length, blood viscosity, and vessel diameter. Let's discuss blood vessel length first.

Resistance, as it pertains to total blood vessel length is easy: The longer the blood vessel, the greater the resistance. As people gain weight, they need to build miles of small blood vessels to vascularize all of the extra tissue. This means that peripheral resistance increases dramatically, which can increase blood pressure. That's one of the reasons why obesity is correlated with high blood pressure.

Blood is thicker than water, according to the saying. And it is a correct observation. Blood viscosity in defined as the internal resistance to flow related to the thickness or stickiness of the fluid. The thicker the fluid, the more difficult it is for the molecules to keep flowing along. Maple syrup flows more slowly than water, because the syrup is more viscous. Generally speaking, blood thickness is pretty constant. However, if there is an abnormal increase in red blood cells as in the case of polycythemia, or significantly fewer blood cells like in the case of some anemias, the blood viscosity will vary and directly affect the peripheral resistance.

The last factor affecting resistance is blood vessel diameter. This factor is the most variable of the three and has the greatest impact on resistance. It changes often to adjust to internal cues. For example, if you get hot, the hypothalamus sends a message that you need to radiate away heat. So the peripheral blood vessels dilate to increase blood flow to the limbs. The increase in blood flow to the limbs, coupled with the cooling effect of sweating, will help cool the blood and consequently reduce your core body temperature.

In contrast to this, if it is cold outside, your hypothalamus sends a signal for blood vessels to constrict. This reduces blood flow to the periphery, which has the consequence of limiting the amount of cold blood entering the body core from the limbs. As your blood vessel diameter changes, so does the resistance, and so does the blood pressure.

The other reason that diameter impacts resistance so strongly is that the radius of the blood vessel varies inversely to the fourth power with resistance. That may sound like complicated mathematics, but really it just means that if the radius of the vessel doubles, the resistance will decrease to one-sixteenth of its original value—a dramatic drop. So while larger vessels reduce resistance, small vessels increase the resistance. And there are many more smaller vessels than there are larger ones.

Okay. Let's summarize what we have discussed about factors that are involved in establishing your blood pressure. The three factors that contribute to blood pressure are resistance, blood viscosity, and blood vessel diameter. Resistance in peripheral circulation is used as a measure of this factor. The longer the vessel, the greater the resistance. Blood viscosity tells you how thick your blood is. Thicker blood is harder to push and pressure goes up. Blood vessel diameter is the most important factor in determining your blood pressure. Peripheral blood vessels are used to measure this since they are more numerous than centralized blood vessels. The smaller the vessel, the more pressure is needed to push the same volume of blood through. As a result, blood pressure increases.

Now that you have a better understanding about the relationships between diameter, length, and viscosity, let's discuss the relationships between these factors in different flow systems. Let's start with arterial blood pressure.

Arterial blood pressure is a consequence of two factors: the amount of blood forced into a vessel and how wide the arteries near the heart can expand. In the arteries, this translates to systolic pressure, the pressure exerted when the left ventricle forces blood into the aorta. One hundred twenty millimeters of mercury or one twenty over X is considered a normal measurement of arterial pressure.

When the contraction phase is complete and the ventricles relax, the elastic recoil of the aorta and other major arteries near the heart keeps the blood flowing, although at much lower pressures. Typically diastolic pressure—the pressure as measured when the ventricles are relaxed--is measured at eighty millimeters of mercury. The difference between systolic and diastolic pressures is called the pulse pressure. So when a nurse takes your pulse, she is actually measuring your heart rate using pulse pressure to determine ventricular contractions.

When your heart beats faster, it also beats more forcefully. This results in more blood being pushed out into the aorta and pulmonary trunk. Therefore, your arterial blood pressure changes in relation to your heartbeat, as a function of your activity. Mean arterial pressure or M.A.P. is an important pressure determinant. M.A.P. is the pressure that pushes your blood to the tissues. The farther away from the heart you get, the lower the M.A.P. This is due to increasing resistance and the loss of elastic recoil in the smaller arterial blood vessels. Take an athlete for example. Their M.A.P. will be greater than in someone who doesn't work out because the heart, muscles, and arterial blood vessels will be able to carry the blood farther. If there is a problem with arterial circulation, the M.A.P. will drop significantly. In addition, the limbs may appear pale and feel cold to the touch. By monitoring M.A.P., a clinician can tell the physical condition of a person as well as whether there may be a problem with peripheral circulation.

By the time the blood reaches the peripheral tissues, the blood pressure has decreased to thirty-five millimeters of mercury, and once it exits the capillary beds the blood pressure is down to fifteen millimeters of mercury. This low pressure is a good thing, because if the pressure was too high and blood flow too fast, the nutrients carried in circulation could not diffuse out into the tissues and cells would die. In addition, the capillaries are only one cell layer thick. So pressures that are higher could easily rupture these vessels.

The last type of pressure we will discuss is venous blood pressure. Arterial blood pressure pulsates with each ventricular contraction. Venous blood pressure is steady. That is why you cannot take your pulse on a vein. The pressure gradient in the veins is only about fifteen millimeters of mercury (the same as in the capillaries).

By the time the blood reaches the venous system, there is not enough pressure to return the blood to the heart. Veins have several modifications that help them get the blood to flow back to the heart. First, veins have valves, which prevent blood from flowing backwards. Secondly, more skeletal muscle activity increases the efficiency of venous return. As the skeletal muscles surrounding the deep veins contract and relax, they move blood toward the heart. This is called the *muscular pump*. In addition to this, the pressure changes in the thoracic cavity during breathing help facilitate venous return. This is called the *respiratory pump*. Of the two, the skeletal muscle pump is the more important.

In this final part of this tough topics section, we'll discuss the mechanisms for maintaining the blood pressure. The most important mechanisms to regulate are peripheral resistance and blood volume. This occurs through the cooperation of the heart, blood vessels, and kidneys. In this section we will discuss examples of short term mechanisms as well as long term mechanisms for blood pressure maintenance. Let's begin with short term mechanisms.

Short term mechanisms for regulating blood pressure involve hormonal control and neural mechanisms. Many hormones are involved in BP regulation, including norepineprhine and epinephrine, antidiuretic hormone, angiotensin two, erythropoietin, and natriuretic peptides. Norephinephrine and epinephrine predominate during periods of stress. These hormones enhance the sympathetic fight-or-flight response in stressful situations like finding out that you didn't prepare properly for your biology test. Antiduretic hormone, or ADH, stimulates water conservation at the kidneys. In cases where blood pressure falls dangerously low, like when you cut yourself very badly, ADH is released to increase pressure by causing dramatic vasoconstriction in your peripheral arterioles.

Erythropoietin is a hormone secreted by the kidneys that causes an increase in red blood cell production. This increases blood viscosity, which causes BP to increase.

Atrial natriuretic peptide causes blood volume and blood pressure to decrease by blocking renin and aldosterone, causing the kidneys to excrete more sodium and water. This lowers the blood volume and consequently causes the blood pressure to drop.

Short-term neural control mechanisms all function by altering peripheral blood resistance and consequently, cardiac output. They insure that MAP is adequate by altering blood vessel diameter. In addition, they can redirect flow based on organ demand. So while you work out, blood flow to the digestive system decreases and increases to the skeletal muscles. These changes are regulated by the vasomotor center located in the medulla of the brain.

These few examples of hormone-related mechanisms for short term regulation of BP all target peripheral resistance, primarily through vasoconstriction and vasodilation. Now let's discuss some mechanisms of long term regulation of blood pressure.

Long term control of blood pressure is mediated by the kidneys and targets blood volume as the regulatory mechanism. To maintain a constant blood volume, the kidneys keep the average blood volume at about five liters, although this volume can vary slightly, depending upon age, size, and gender.

Kidneys can act directly and indirectly to stabilize the mean arterial pressure. First let's look at direct mechanisms. Direct action by the kidneys involves increasing the filtration rate through the kidneys. If the blood volume and consequently the blood pressure rise, the filtrate is rushed through the kidney tubules quickly. The result is an increase in the volume of filtrate lost in the urine. This decrease in blood volume causes a parallel decrease in the blood pressure and the kidneys resume their normal filtration rate.

The indirect mechanism for renal control of blood pressure is through the interactions of the hormones renin and angiotensin. If arterial blood pressure decreases, the kidneys release renin. Renin causes the formation of angiotensin. Angiotensin is a strong vasoconstrictor. *Angio* means blood vessels and *tensin* means tension. So this hormone regulation targets necessary increases in blood pressure by increasing the peripheral resistance.

Angiotensin also causes the secretion of the hormones aldosterone to retain sodium and ADH to retain water at the kidneys, which in turn causes more water to be reclaimed. This effectively increases the blood volume and pressure.

Let's summarize what we have discussed. You should now know that blood pressure is measured in the arterial blood vessels closet to the heart and is a direct function of ventricular contractions. BP can be measured as a function of the resistance through the blood vessels and blood flow. The most important factor affecting BP is the diameter of the blood vessel, but vessel length and the viscosity of the blood are also factors. In addition, the greater the blood volume in the vessels, the greater the blood pressure. Blood pressure can be controlled in the short term through hormones and in the long term through kidney function.