Phys Lab Protocols

Blood Pressure and Heart

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Labs aim: Explore biology in context through brain and hands

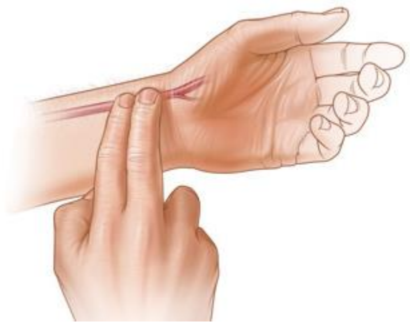
From the physical point of view, the blood pressure is the force exerted by blood acting on a given area of vessel wall. Most of that pressure is generated by the heart pumping the blood along the circulatory system, with its arterial portion being mostly affected by the work of the heart. There are surely also other important factors contributing to or affecting the blood pressures at different parts of the body, on different time scales, quantitatively or rather qualitatively. Among them belong breathing (breathing movements changing the pressure inside the chest), volemia (the volume of blood in the circulation), contraction of striated muscles (augmenting the venous return during physical exercising), the activity of smooth muscles (ensuring vasoconstriction or relaxation), the effect of gravity which is dependent on the actual position of the body, the activity of the autonomic nervous system (sympathetic vs. parasympathetic), and many other factors with more or less pronounced physiological or pathophysiological significance.

Blood pressure, along with the respiratory rate, heart rate, oxygen saturation, and body temperature, belongs to the so-called **vital signs** that are evaluated by healthcare professionals. The blood pressure practicals focus on how the relevant information related to the function of the circulatory system can be obtained by using our senses, the tonometer, and the stethoscope, alongside the appropriate knowledge of how that information could be meaningfully interpreted. It emphasizes the understanding of principles of non-invasive examination of the cardiovascular system, which have not been pushed into the background even by modern diagnostic techniques. They are still used in the daily routine work of a doctor. The emphasis of the practical exercises is on mastering the measurement of heart rate and blood pressure.

Heart rate measurement:

Heart rate is most often determined by palpation of the pulse on the radial artery. We palpate the radial part of the lower third of the volar side of the forearm. First, we notice respiratory arrhythmia during deep and slow breathing. Next, we evaluate the effect of body position on heart rate.

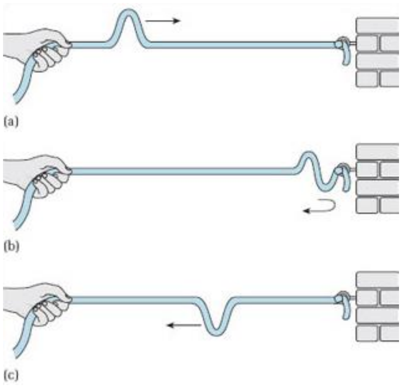
We measure the heart rate in a completely relaxed lying person, and we perform the same measurement immediately after the examined person stands up.



A person's heart rate is usually about 70 to 80 beats per minute when resting. Normally when you sit up or stand suddenly, gravity pulls some of your blood down to your belly area, hands, and feet. In response, some of your blood vessels quickly constrict and your heart rate increases slightly (increasing herewith the cardiac output that belongs to the main blood pressure determinants), preventing blood pressure drops in the upper regions of our body, and thus maintaining the blood flow into the brain. The heart rate increases by 10 to 15 beats per minute when standing up, and then it settles down again.

Proof of pulse wave propagation

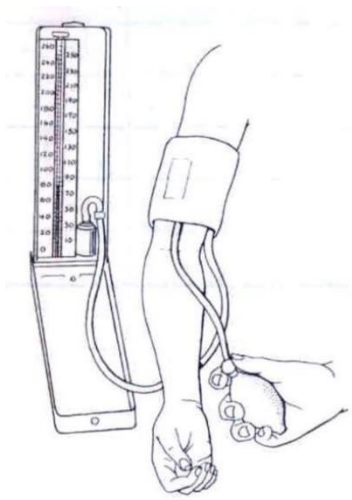
Every time the blood is ejected from the left ventricle into the aorta, the aortic wall is distended and this pressure wave, distending distal segments of the vessel propagates distally into all arterial branches where it can be felt as an arterial pulse. The pulse wave propagates independently of the speed of blood flow through the arteries, at speeds 5 to 8 m/s. That speed depends on the elasticity and stiffness of the vessel walls. To test this phenomenon, we palpate the pulses on the carotid artery and on the posterior tibial artery simultaneously. The pulse wave arrives at the tibial artery a bit later than it does at the carotid artery due to the fact it is more proximal to the heart. The difference in arrival times of these pulses can thus be practically measured, and the speed of pulse propagation calculated based on the expected distance of palpated sides from the heart. When palpating the carotid artery with the tips of the fingers, we must be very careful, say gentle, because exhibiting a higher pressure on the carotid sinus could cause severe bradycardia, and, in sensitive individuals, can result into cardiac arrest.



Blood pressure measurement:

When we speak about blood pressure, we usually refer to the pressure of the blood in the arteries. The highest value reached during the cardiac cycle is called the **systolic pressure** and the lowest value is called the **diastolic pressure**. The difference between these two pressures is the ***pulse pressure*** or ***pressure amplitude***. The **mean arterial pressure (MAP)** is an average pressure over the cardiac cycle, and in principle, it can be obtained by the time integration of the course of blood pressure during the cardiac cycle (practically, over more cardiac cycles). Approximately, it is possible to assess the MAP based to the following formula: **MAP** = diastolic pressure + 1/3 pulse pressure, or **MAP** = 1/3 systolic pressure + 2/3 diastolic pressure (you can easily prove both forms are mathematically equivalent, note that from the second formula it is apparent that the diastolic pressure makes 60 - 70% of the MAP, which is valid in particular under physiological conditions).

<u>Blood pressure can be measured:</u>
• **Directly,** using a catheter inserted into an artery and connected to the manometer (gauge reading, showing the actual pressure).
• **Indirectly**, primarily obtained by **auscultatory methods** or by **palpation methods**, in which we measure (better said, indirectly estimate) the pressure in the brachial artery using a tonometer or sphygmomanometer that is a device connecting the cuff, the rubber balloon used to inflate the cuff, and the pressure gauge - mercury manometer, altogether with the rubber tubes).



The balloon is equipped with a screw valve, by means of which we regulate the speed of air deflation of the cuff. The cuff consists of a flat inflatable rectangular rubber bag, 12.5 cm wide, inserted into strong fabric strap placed on the arm.

<u>Steps of indirect blood pressure measurement</u>:
1. The initial procedure is the same for all indirect methods. The examined person is lying or sitting, with his arm resting freely along the body, or leaning on some suitable support (armrest or desk). The arm must not be compressed by any clothing, and its muscles must be relaxed (active movement of the arm being measured could cause interference with the blood pressure measurement)
2. Then a fully deflated cuff is tightly placed around the middle part of the arm, the valve of the balloon is closed, and the balloon repeatedly pressed to inflate the cuff, while the pulse on the radial artery of the same arm is felt. Once the pressure in the cuff exceeds the systolic pressure in the brachial artery (then, the artery is completely compressed and thus the blood flow through it stops completely - the pulse on the radial artery disappears – is not felt anymore), the cuff should be inflated by another 15 – 20 mmHg (2 kPa). The next step is then different:

in the **palpation method**, we keep our fingers on the radial artery, and with the other hand, the valve on the balloon is loosened so that the air slowly escapes from the cuff (the speed of cuff pressure release should respect the heart rate of the examined person – the lower the heart rate the slower is the speed of cuff deflation). As soon as the pressure in the cuff drops below the systolic pressure value, we start feeling the pulse on the radial artery - at this point we read the pressure on the gauge (manometer scale), which should be close to **systolic pressure** in the brachial artery (observed value is about 5 mmHg lower than the actual systolic pressure). Mind, that the diastolic pressure cannot be determined by this method.

For the **auscultation method**, we place the earpiece of the stethoscope on the brachial artery below the lower edge of the cuff so that it does not compress the artery and does not touch the cuff of the tonometer, and slowly deflate the cuff. As soon as we hear the first murmur, we read the ***systolic pressure*** on the gauge. With a further decrease in pressure in the cuff, the murmurs become longer, intensify, the sound is clearer, then weakens, first slowly and then quickly disappears. At the moment of the sudden disappearance of the murmur, we read the ***diastolic pressure***.

These murmurs, the so-called Korotkoff sounds, arise during turbulent flow in a partially compressed brachial artery, when the blood flow velocity is higher than in the uncompressed artery, exceeding the critical value at which the laminar flow turns turbulent. If the cuff pressure is higher than the diastolic pressure, blood flow stops at least during part of the diastole and the murmur is intermittent. When the pressure in the cuff drops below the diastolic pressure, the artery is still compressed, but the flow is already smooth (if it is still turbulent, a faint smooth murmur could be heard).

To obtain reliable values of blood pressure using the auscultatory method, it is necessary to:

- make sure the cuff is at the level of the heart when measuring the pressure (otherwise measured values would be affected by gravity)
- inflation of the cuff should be controlled by simultaneous palpation of the pulse on the radial artery (to not bother the patient by inflating the cuff to exceedingly high pressure values – we inflate the cuff to values at which we can no longer feel the pulse on the radial artery, thus the pressure in the cuff is indeed higher than the systolic pressure)
- repeat the pressure measurement after a while - if the first measured value is higher than the normal value for a given age (increased pressure is often caused by the examinee's stress or agitation)
- do not leave the cuff inflated too long (prolonged compression of the arm is unpleasant and can reflexively lead to an increase in blood pressure)

The **oscillometric method** is implemented in most automatic measuring digital devices. There is no need to place the cuff on the arm so precisely (with the auscultation method, the stethoscope must be very close to the brachial artery, otherwise the measurement could be very inaccurate or even impossible). The oscillometric method analyses pressure changes in the cuff caused by arterial pulsation. The device stops inflating the cuff soon after those pulsations disappear, then automatically deflates the cuff slowly while analysing the change in amplitude of pulsations, which could be conceived as an analogy to Korotkoff v sounds. The disadvantage of this method is that it measures the mean arterial pressure (MAP) quite accurately, nevertheless, the systolic and diastolic pressures are just algorithmically derived from estimated MAP values, therefore not as accurate as auscultatory ones, especially when meeting nonstandard patient circulatory conditions. Oscillometric methods are mostly used by so-called ambulatory blood pressure monitors, which can measure the course of blood pressure over 24 hours (so-called Holter monitoring). Nowadays, oscillometric methods implemented in automatic patient monitors significantly improved their precision over the last two decades and gained a good reputation that is comparable with manual measurements using the cuff, stethoscope, and skilled examiner.

In adults, normal resting values of systolic pressure of mentally relaxed individuals are **110-140 mmHg**, and for diastolic pressure **60-90 mmHg**. A resting systolic pressure of 150 mmHg could be normal in elder people, but pressures above 160 mmHg are already considered abnormal, and such a condition is called hypertension, with resting diastolic pressures also higher than 95 mmHg. At higher age, an increase in systolic pressure without an increase in diastolic pressure above the normal values is commonly caused by a decrease in elasticity of arteries.

Tasks:

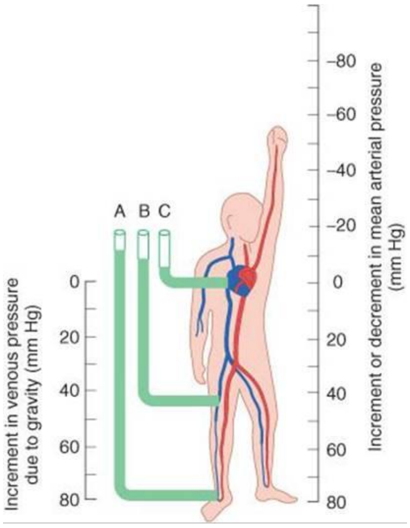
a. compare results of auscultation, palpation and oscilometry measurement

b. compare the reading from left and right artery

c. demonstrate the effect of gravity on BP

d. check pressure during and after exercise

Monitoring the effect of gravity on blood pressure



Due to the effect of gravity the blood in a vessel that is not horizontal has a nonzero gradient of hydrostatic pressure. This effect also causes the pressures measured above the level of the heart to be reduced and pressures measured below the level of the heart to be increased, compared to the blood pressure measured at the level of the heart. This effect of gravity is related to the hydrostatic pressure of the blood column whose height is equal to the vertical distance between the point at which we measure the pressure and the level of the heart. With a specific gravity of blood of 1,055 kg/dm^3 and a specific gravity of mercury of 13.6 kg/dm^3, each cm of a column of blood exerts a pressure equal to the pressure of a 0.77 mm tall column of mercury. Therefore, for every cm of vertical distance above the level of the heart, the blood pressure decreases, and below the level of the heart increases by 0.77 mmHg. It has to be stressed that apart from gravity, the vessel's own resistance continuously decreases the blood pressure as the blood flows to the periphery, decreasing the pressure separately from the effect of gravity.

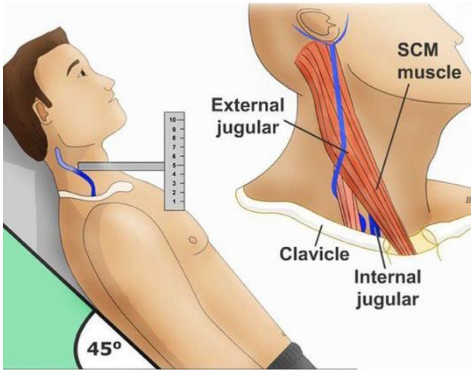
Central venous pressure (CVP)

CVP is the pressure of blood in the big veins (venae cavae) near the right atrium and correlates with the filling pressure of the right heart. CVP can be roughly determined based on observing a venous filling of the jugular veins. When the examined person lies on his back with his head slightly supported, we could find a place on the neck where the partially filled jugular veins are visible (the veins above that point are collapsed). At this point, the venous pressure is zero due to effect gravity and blood pressure below that point in the jugular vein is higher than zero. CVP is as large as the hydrostatic pressure of the blood column of the height equal to the vertical distance between the point where the jugular veins collapse and the position of right atrium, which corresponds roughly to the level of mitral valve. The mitral valve is located roughly in the middle between the side walls of the chest, at 61% anteroposterior chest diameter measured from the chest back. At this location, the central venous pressure is nearly unaffected by changes in the body position, and this place is conceived as the reference for measuring the central venous pressure. In a healthy person, the central venous pressure is up to 8 mm Hg, so the values from 0 mm Hg to 8 mm (0 cm to 10 H_20) are considered physiological at rest (the instantaneous values fluctuate with the phase of the breathing cycle, and even more during the exercise)

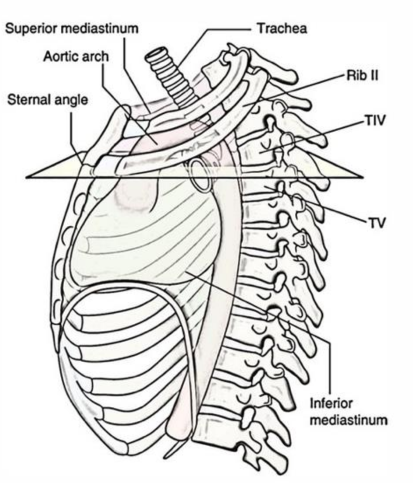
Estimation of the central venous pressure:

1. examined person is lying on his back with his head slightly elevated by a pillow or any suitable support. The vertical distance D_1 between the *point where the jugular veins collapse* and the *back of the chest* is measured.

2. then, the anteroposterior chest diameter D_2 is measured (distance between the back of the chest and sternum), 61% of which is subtracted from the previous parameter D_1. The result is the central venous pressure, $D_1 - 0.61 \cdot D_2$, measured in cm of H_2O (corresponds to the height of the blood column whose hydrostatic pressure equals the central venous pressure). As already shown, pressures measured in cm of H_2O could easily be converted into mm of Hg, knowing the densities of H_2O (1000 kg/m^3) and Hg (13500kg/m^3):



pressures in cm of H_2O = 13.5 x pressures in mm of Hg.



Tasks:

a. perform aspection of jugular veins (sitting and lying object)

b. increase CVP voluntarily and observe jugular veins

c. estimate CVP by observing emptying of peripheral veins during elevating hand

Questions:

What are the determinants of arterial blood pressure?
What is the role of the heart in blood pressure generation?
What might be the most relevant reason(s) that the arterial blood pressure at rest is close to 120/80 mm Hg?
Why the pressure gauge does not need to be at the level of the heart whereas the cuff does?
Why the speed of cuff deflation adjusted by actual heart rate improves the accuracy of blood pressure measurement? Consider patients with severe bradycardia.
What is the advantage of using mercury in a tonometer instead of H_2O?
What is the reason arterial pressures are higher than venous ones?
In which vessels and under which conditions the negative blood pressure can be found?
What are the phases of the cardiac cycle?
Why the systolic pressure increases with aging more than the diastolic one?
In which portion of the circulatory system is found most of our blood?
What is the role of breathing on blood pressure in various parts of our body?
What is the role of gravity on blood pressure and on blood flow in various parts of our body?
Why the central venous pressure correlates with volemia more than arterial pressure?