ARterial Pressure Measurement

Definition
With each beat of the heart a new surge of blood fills the arteries. Arterial pressure (AP) is the force exerted by the blood against any unit area of the vessel wall. The tension represents the level of twisting of the arterial wall under the action of blood pressure.

Observation as between blood pressure in the vessel and the degree of vascular wall tension there is a directly proportional relationship, to express blood pressure we use the term blood pressure (or tension).

Determinants of blood pressure are: the cardiac output and peripheral/systemic vascular resistance (resistance to blood flow)

- the cardiac output is the amount of blood pumped into the aorta by the heart each minute. It can be calculated:
  \[ Q = HR \times SV = 5-6 \text{ l/min} \]
  Factors on which cardiac output (direct proportional) depends:
  - systolic volume (SV) - the amount of blood (70-80 ml) expelled from the heart at each systole depends on the strength of a heart contraction;
  - venous return (preload) and aortic pressure (after load);
  - heart rate - number of systole within 1 minute (normal 60-80 / min);
  - total blood volume (equal to 3 l/m\(^2\)).

- peripheral vascular resistance (PVR) - friction force opposing blood flow through vessels.
  Factors of which peripheral vascular resistance depends on:
  - viscosity of the blood - directly proportional
  - diameter and arterial wall elasticity – inverse proportional

<table>
<thead>
<tr>
<th>Determinants</th>
<th>Increase AP</th>
<th>Decrease AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic volume</td>
<td>positive heart contraction agents</td>
<td>negative heart contraction agents</td>
</tr>
<tr>
<td>Heart rate</td>
<td>tachycardia</td>
<td>bradycardia</td>
</tr>
<tr>
<td>Plasma volume</td>
<td>hyper hydration</td>
<td>dehydration</td>
</tr>
<tr>
<td>Globular volume, viscosity</td>
<td>poliglobulia</td>
<td>anemia</td>
</tr>
<tr>
<td>Diameter vascular</td>
<td>vasoconstriction</td>
<td>vasodilatation</td>
</tr>
<tr>
<td>Vascular elasticity</td>
<td>decreased vascular elasticity (the elderly)</td>
<td>increased vascular elasticity (the young)</td>
</tr>
</tbody>
</table>

Table 1 Factors on which blood pressure depends on

Parameters of blood pressure

For each heartbeat, BP varies between systolic and diastolic pressures. Systolic pressure is peak pressure in the arteries, which occurs near the end of the cardiac cycle when the ventricles are
contracting. Diastolic pressure is minimum pressure in the arteries, which occurs near the beginning
of the cardiac cycle when the ventricles are filled with blood.

- **Systolic blood pressure (maximum)** – SBP - is determined by the propel blood in the vascular
arterial system during ventricular systole; depends primarily on the cardiac output and blood volume;
normal value in healthy adults 100-130 mm Hg
- **Diastolic blood pressure (minimum)** – DBP- is determined by the arterial blood flow during
ventricular diastole, depends primarily on the elastic properties and quality of ships, and peripheral
resistance; normal value in healthy adults 60 to 85 mm Hg.
- **Differential arterial pressure or pressure pulse** is the difference between systolic and diastolic
blood pressure normal: 40-50 mm Hg.
- **Mean arterial pressure** –MAP -is the propulsion of blood pressure in the arterial system in
continuous flow mode (without oscillations systolic-diastolic); MAP is considered to be the
perfusion pressure seen by organs in the body. It is believed that a MAP that is greater than 60
mmHg is enough to sustain the organs of the average person. MAP is normally between 70 to 110
mmHg If the MAP falls significantly below this number for an appreciable time, the end organ will
not get enough blood flow, and will become ischemic. It can be calculated as following:

\[
\text{MAP} = \text{DBP} + \frac{1}{3} (\text{SBP-DBP})
\]

**Methods for measuring the blood pressure**

There are direct and indirect methods.

- **Direct** methods require the introduction of a cannula or catheter into the artery, vein or heart, and
can connect to a system of measuring and recording the systolic-diastolic pressure; are used in
research or cardiovascular surgery.
- **Indirect** methods are commonly used in medical practice, involving measuring the arterial wall
tension using pressure gauges/manometers. These methods consist in the determination by mean of a
manometer the necessary contra pressure to equal the pressure of the blood exerted on the arterial
walls.

  Classification methods for determining blood pressure:
  - **Palpatory** (probe) method (Riva-Rocci) -> determines TAS
  - **Auscultatory** method (Korotkoff)->determine SBP and DBP
  - **Oscillometric** method (Pachon)->MAP, SBP and DBP

1. **Auscultatory (hearing) method** - is in current use, very simple and allows the determination of
both systolic and diastolic pressure.
   **Principle:** SBP and DBP are determined according to the perception of the stethoscope of Korotkoff
sounds (vibration of the arterial wall in turbulent flow of arterial blood vessel partially compressed)
by applying external pressure.
   **Material required**
   - Stethoscope
   - Sphygmomanometer: mercury or aneroid capsule or electronic, adjustable valve rubber pear
   - Communicates with pressure gauge by rubber tubes and a pneumatic cuff- sufficiently long (15 cm
     wide).
Work technique

- the pneumatic cuff is wrapped up around the third media arm, arm outstretched, relaxed, high in the heart; the first run of the cuff should cover the whole front of the arm;
- the stethoscope capsule is fixed on the elbow in the right of antecubital artery; do not perceive noise as uncompressed artery because blood flow is laminar, so quiet;
- introducing air in the cuff until the radial artery pulse disappearance - do not perceive noises because the movement in the artery is interrupted; the time long the pressure in the cuff is higher than AP, the artery being completely collapsed, there is no sound listened in the stethoscope;
- the slow decompression of the cuff is performed (2-3 mm Hg / sec) until the perception of the stethoscope of the first Korotkoff sound (sound I) corresponding on the gauge to the value of SBP
- continue unpacking, the noises that increase in intensity are of blowing character and become stronger; the stethoscope perception of the last Korotkoff sound corresponds on the gauge to the value of DBP.

Korotkoff are the sounds that medical personnel listen for when they are taking blood pressure using a non-invasive procedure. They are named after Dr. Nikolai Korotkoff, a Russian physician who described them in 1905, when he was working at the Imperial Medical Academy in
St. Petersburg. The sounds heard during measurement of blood pressure are not the same as the heart sounds 'lub' and 'dub' that are due to vibrations inside the ventricles that are associated with the snapping shut of the valves. If a stethoscope is placed over the brachial artery in the antecubital fossa in a normal person (without arterial disease), no sound should be audible. As the heart beats, these pulses are transmitted smoothly via laminar (non-turbulent) blood flow throughout the arteries, and no sound is produced. Similarly, if the cuff of a sphygmomanometer is placed around a patient's upper arm and inflated to a pressure above the patient's systolic blood pressure, there will be no sound audible. This is because the pressure in the cuff is high enough such that it completely occludes the blood flow. This is similar to a flexible tube or pipe with fluid in it that is being pinched shut.

If the pressure is dropped to a level equal to that of the patient's systolic blood pressure, the first Korotkoff sound will be heard. As the pressure in the cuff is the same as the pressure produced by the heart, some blood will be able to pass through the upper arm when the pressure in the artery rises during systole. This blood flows in spurts as the pressure in the artery rises above the pressure in the cuff and then drops back down beyond the cuffed region, resulting in turbulence that produces an audible sound. As the pressure in the cuff is allowed to fall further, thumping sounds continue to be heard as long as the pressure in the cuff is between the systolic and diastolic pressures, as the arterial pressure keeps on rising above and dropping back below the pressure in the cuff. Eventually, as the pressure in the cuff drops further, the sounds change in quality, then become muted, and finally disappear altogether. This occurs because, as the pressure in the cuff drops below the diastolic blood pressure, the cuff no longer provides any restriction to blood flow allowing the blood flow to become smooth again with no turbulence and thus produce no further audible sound.

Korotkoff actually described five types of sounds:

1. The first Korotkoff sound is the snapping sound first heard at the systolic pressure. Clear tapping, repetitive sounds for at least two consecutive beats is considered the systolic pressure.
2. The second sounds are the murmurs heard for most of the area between the systolic and diastolic pressures.
3. The third sound was described as a loud, crisp tapping sound.
4. The fourth sound, at pressures within 10 mmHg above the diastolic blood pressure, was described as "thumping" and "muting".
5. The fifth Korotkoff sound is silence as the cuff pressure drops below the diastolic blood pressure. The disappearance of sound is considered diastolic blood pressure -- 2 mmHg below the last sound heard.

The second and third Korotkoff sounds have no known clinical significance.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal value (mm Hg)</th>
<th>Optimal value (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>100-130</td>
<td>100-120</td>
</tr>
<tr>
<td>DBP</td>
<td>60-85</td>
<td>60-80</td>
</tr>
</tbody>
</table>

Table The normal values of blood pressure

Traditionally, the systolic blood pressure is taken to be the pressure at which the first Korotkoff sound is first heard and the diastolic blood pressure is the pressure at which the fourth Korotkoff sound is just barely audible. However, there has recently been a move towards the use of the fifth Korotkoff sound (i.e. silence) as the diastolic blood pressure, as this has been felt to be more reproducible. For pediatrics auscultation of the fifth Korotkoff sound is the guiding indicator of diastolic pressure. The time average of the first Korotkoff sound represents a reliable pressure marker of systole of the heart. The time average of the fourth Korotkoff sound represents a reliable pressure marker of diastole of the heart.

<table>
<thead>
<tr>
<th>Change in blood pressure</th>
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<tbody>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>-is low in children between 1 and 15 years</td>
<td></td>
</tr>
<tr>
<td>-SBP increases by 5 mm Hg / 5 years - 90-115 mm Hg</td>
<td></td>
</tr>
<tr>
<td>DBP 60 mm Hg;</td>
<td></td>
</tr>
<tr>
<td>-since puberty the same values like adults</td>
<td></td>
</tr>
<tr>
<td>-60 years old: 160/100 mmHg</td>
<td></td>
</tr>
<tr>
<td>Sex of the person</td>
<td>females have lower values than males (decreased red blood cell), but the difference disappears in 45-50 years</td>
</tr>
<tr>
<td>Posture</td>
<td>decreases at the rise to stand (the action of gravity); normally SBP decreases by 10-15 mm Hg and DBP by 5-10 mm Hg</td>
</tr>
<tr>
<td>Rhythm sleep / wake</td>
<td>decreases in sleep (decrease sympathetic tone, resting muscle)</td>
</tr>
<tr>
<td>Physiological condition</td>
<td>-increase in pregnancy by increasing the volume expansion</td>
</tr>
<tr>
<td></td>
<td>-decreases in pregnancy by decreasing vascular resistance in the uterus</td>
</tr>
<tr>
<td>Exercise</td>
<td>-dynamic effort increases SBP and decreases DBP (decrease in vascular resistance within the muscle)</td>
</tr>
<tr>
<td></td>
<td>-isometric effort increased SBP and DBP (increased vascular resistance within the muscle)</td>
</tr>
<tr>
<td>Strong emotions</td>
<td>increases or decreases depending on the sympathetic and parasympathetic autonomic reactivity</td>
</tr>
<tr>
<td>Thermoregulatory effort</td>
<td>exposure to cold increases BP, heat exposure decreases it</td>
</tr>
<tr>
<td>Digestion time</td>
<td>BP decreases in the first phase by the decrease of the RPV in the digestive territory; BP increases in the second phase by increasing the blood volume expansion.</td>
</tr>
</tbody>
</table>

Table no. Physiological variations of the blood pressure
**Table Pathological variations of BP**

<table>
<thead>
<tr>
<th>Category</th>
<th>SBP (mm Hg)</th>
<th>DBP (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP &quot;high normal&quot; or prehypertension</td>
<td>130-139</td>
<td>85-89</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage I - Easy</td>
<td>140-159</td>
<td>90-99</td>
</tr>
<tr>
<td>stage II – Moderate</td>
<td>160-179</td>
<td>100-119</td>
</tr>
<tr>
<td>stage III - Severe</td>
<td>&gt; 180</td>
<td>&gt; 120</td>
</tr>
<tr>
<td>Arterial hypotension</td>
<td>&lt;90</td>
<td>&lt;60</td>
</tr>
</tbody>
</table>

**Recommendations for the correct assessment of the BP**

A small amount of normal fluctuation in blood pressure occurs during different times of the day. While obtaining multiple measurements corrects for these daytime fluctuations, there are some special timing issues that should be addressed when measuring blood pressure.

In general, blood pressure should be measured:

- Before taking any morning doses of high blood pressure medicine
- No less than 1 hour after exercising, smoking, or consuming caffeine
- After allowing for about 10 minutes to adjust to the temperature in the examining room
- Thermal comfort conditions

One of the most important factors that can influence the accuracy of blood pressure readings is the size of the blood pressure cuff that is used. While a very specific set of guidelines regarding precise cuff sizing is in place, it can be difficult for patients to tell, just by looking, if their healthcare provider is using a correctly sized cuff. The official guidelines specify the following cuff sizes:

- Arm circumference 22 to 26 cm, 'small adult' cuff: 12 x 22 cm
- Arm circumference 27 to 34 cm, 'adult' cuff: 16 x 30 cm
- Arm circumference 35 to 44 cm, 'large adult' cuff: 16 x 36 cm
- Arm circumference 45 to 52 cm, 'adult thigh' cuff: 16 x 42 cm

Proper positioning is vital in obtaining accurate blood pressure readings. In general, blood pressure should be measured while the subject is seated comfortably. The arm being used should be relaxed, uncovered, and supported at the level of the heart. Only the part of the arm where the blood pressure cuff is fastened needs to be at heart level, not the entire arm.

One blood pressure reading is not enough to get an accurate measurement. While the specifics of how many readings are necessary can change based on many factors, the essential need for multiple measurements does not. The blood pressure should be checking:

- In both arms, not just one; on repeated determinations unilaterally on the higher value arm; if the differences are greater than 10 mm Hg on repeated measurements, shall be further reading;
- At both the beginning and the end of the appointment;

Accuracy determination: introducing air in the cuff to about 30 mm Hg above the SBP (radial artery pulse loss); cuff decompression is slow (2-3 mm Hg / sec) for DBP value in adults, it is noted when Korotkoff sound disappearance, and in children time decrease their intensity; if Korotkoff sounds are
weak in intensity it is recommended to lift the arm, opening and closing the fist 5-10 times before determination.

2. Palpatory (probe) method

Pneumatic cuff is wrapped around the arm above the elbow; with the help of the rubber pear the air is introduced in the system until the radial pulse dissappears. Slowly decompress maneuvering the screw with valve and carefully following the radial pulse. The maximum blood pressure value is read on the manometer when the pulse reappears. This method allows the measurement only of the SBP.

3. Oscillometryc method is based on Marey principle; when the external pressure exerted on the arterial walls is equally with MAP, arterial walls present the maximum oscillations. It uses an oscillometer Pachon and is useful to determine the grade of permeability of the arteries.