ELECTROCARDIOGRAPHY, ECG

Introduction:

**Electrocardiography** is a method to register the heart electric activity, e.g. electric potentials from outside of body. It is possible to record the changes of these potentials from the surface of our body and to register them after we amplify them.

**Electrodes for recording the heart potentials** are placed on the skin. We usually place ion-rich (ECG) gel between the electrode and skin to decrease transitional resistance. Electrodes fixed to the skin by rubber bands, clips, suction cups or single use sticker-electrodes.

If we imagine a man with stretched arms sideways and with electrodes placed on both wrists and ankle of the left leg – we create equilateral triangle called **Einthoven triangle**. Heart is almost in the middle of it. You can see the Heart on picture visualized by the arrow, so called **heart axis**. The difference of potentials always between the two electrodes, called **leads** are marked here by roman digits: I, II, III.

*Obr.1 Einthoven triangle*

L – electrode on left wrist;
R – electrode on right wrist;
F – electrode on left ankle;
E – electric axis of the heart, vector defined as spatial position and the size of potential (physiol. range of -30° to + 90°)
I, II, III – bipolar leads
Bipolar limb leads are registering difference of potentials between two places of electrodes. Unipolar limb leads are registering difference of potentials between one place where the real electrode is placed and referential potential. This referential (average) potential is produced after connection of all three electrodes with huge resistance of 5 kΩ on each electrode (Wilson clip, picture 3). These unipolar leads are marked by “V” and specification of relevant electrode (L,R,F). Commonly, unipolar leads are used on limbs and chest where we record potentials from 6 well defined places. Some special assessments or examinations use electrodes placed on the back up to total number of 12 electrodes, other places are also used (oesophageal, intra-heart electrodes).

AS the unipolar limb leads have just the small divergence, Goldberger modified the connection and strengthened the outcome. He reached the increased amplitude by 50 percent. These leads are called „augmented unipolar limb leads“, or „Goldberger leads“ and we mark them as aVR, aVL, aVF (a = augmented). Potential from one limb electrode is recorded and measured/registered against modified referential potential made by connection of remaining two electrodes, again with big
resistances of 5kΩ. For example, \( aV_R \) is the lead registering potential from right upper arm/wrist and potential from connected electrodes from left upper limb/wrist and left lower limb/ankle. In reality, the difference of potentials of action electric currents in heart muscle is very small (0.1 - 1 mV). From this reason it is needed to provide further **amplification of these heart potentials.** Nowadays we still can use electron tube amplifiers but more often we use semiconductor/transistor amplifiers and amplifiers with integrated circuit systems.

**Placement of electrodes to register ECG record**

<table>
<thead>
<tr>
<th>Lead marking/name</th>
<th>Placement – color of the electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_R )</td>
<td>Right arm – red</td>
</tr>
<tr>
<td>( V_L )</td>
<td>Left arm – yellow</td>
</tr>
<tr>
<td>( V_F )</td>
<td>Left leg - green</td>
</tr>
<tr>
<td>( V_1 )</td>
<td>2. intercostal place by the right edge of sternum</td>
</tr>
<tr>
<td>( V_2 )</td>
<td>2. intercostal place by the left edge of sternum</td>
</tr>
<tr>
<td>( V_3 )</td>
<td>Between ( V_2 ) and ( V_4 )</td>
</tr>
<tr>
<td>( V_4 )</td>
<td>5(^{th}) or 6(^{th}) intercostal place - medioclavicular line</td>
</tr>
<tr>
<td>( V_5 )</td>
<td>Level of ( V_4 ) in left anterior axillary line</td>
</tr>
<tr>
<td>( V_6 )</td>
<td>Level of ( V_4 ) in left middle axillary line</td>
</tr>
<tr>
<td>Grounding</td>
<td>Right leg - black</td>
</tr>
</tbody>
</table>

Evaluation of graphic record of electric activity of the heart muscle we provide based on the knowledge of physiologic course of electrocardiographic curve including its voltage and duration of its partial sections.

On the course of the curve we describe following items: wave P, complex QRS and wave T. Pathological curve is found to have either changed voltage, changed course of the waves or their durations.

**The wave P** shows depolarisation of heart atria, **complex QRS** (ventricle complex) means depolarisation phase of heart ventricles. **ST segment** is repolarisation phase of ventricles, **wave T** means the completion of repolarisation phase of ventricles. Origin of the **wave U** is not clear. Repolarisation of atria is not visible on the ECG record because it is overlapped by the depolarisation of ventricles, e.g. By QRS complex.
Duration of the particular section of ECG record is possible to measure by the grid printed on paper. The speed of the paper movement is very important. The distance of two thick vertical lines of the grid last 0,2 seconds when the speed 25 mm per second is used. This distance is devided by 4 thinner vertical lines to make 5 small 1 mm long sections, each of 0,04 seconds. Besides that, horizontal lines are also visible on the paper grid to measure amplitudes of particular sections of ECG curve.

Wave P lasts 0,06 - 0,11 second and means depolarisation of atria. PQ segment lasts 0,12 - 0,20 seconds and shows the transition of signal (excitement) from sino-atrial node by the conductive system to ventricle muscles. Complex QRS lasts 0,06 - 0,10 s and means depolarisation of ventricles. Interval QT lasts 0,32 - 0,42 s and means the full time of ventricle electric activity.

Iso-electric line is a horizontal line produced by cardiograph running without any electric input, for ex. between the heart revolutions (cycles).

Curve description:

Waves P and T may be positive as well as negative (e.g. they go above or under isoelectric line), negative wave P, T are physiologic for example in the lead aVR.

“Q” is the first negative part (can be only negative).

“R” is a positive wave and we can see more waves “R” then we mark them as R¹,R² ,r, R.

“S” is the first negative wave after R (may be only negative).
Conductive system of the heart:

The speed and regularity of the heart activity is governed by the sino-atrial node - node Keith-Flack (S-A) which is located in the right heart atrium, ventrally and on the right side of vena cava anterior entry. This node acts roughly 70 times per minute by producing the signal and provides excitement wave running all directions to both atria. There is another node: atrio-ventricle - Tawar node (A-V) close to the ventricle entry. This node provides electric impulses of slower rate and it is discharged prematurely by the excitement wave coming from sino-atrial node. Electric impulsl is then running down by His bundle that is going through membranose part of interventricle wall and splits in right and left bundle branch of Tawar. Branches are pointing down and splitting further into Purkinje fibres bringing excitement into ventricle myocardium.
Physiology of stimulus conduction:

Cell (fiber) is going through the phases:

- *polarisation* – surface of the fiber is charged positively;
- *depolarisation* – polarity is changed;
- *transpolarisation* - surface of the fiber is charged negatively;
- *repolarisation* – return to original polarity

Cells of the heart muscle have membrane rest potential (during diastola) of -80 to -90 mV (picture 7). Its value is given mainly by not even distribution of K⁺ ions outside and inside of the cell. Action potential starts the course of systola. The depolarisation phase is quite fast, repolarisation very slow (plateau phase). The full course of action potential and refractory phase is much longer than in the nerve fiber. During depolarisation, like in the nerve cell, we see fast influx of Na⁺ through ion channels. During plateau it is different; we can see opening of voltage gated Ca²⁺ channels (and subsequent slow current of incoming Ca²⁺ ions into cells) and it is holding the depolarisation status. Further, the leakage of potassium ions out of cell is decreased which prevents repolarisation. Only after the decrease of permeability of membrane for Ca++ ions which causes the permeability of membrane for K+ ions to increase, plateau phase can switch into repolarisation of membrane and restoration of rest potential.

![Action potential course on membrane of heart muscle cell](image)

*Picture 7: Action potential course on membrane of heart muscle cell*

**Device and material:**

1) ECG device and accessories
2) ECG gel
3) Wadding, alcohol
Task:
Provide an ECG record of the lead I, II, III, aVR, aVL, aVF and analyse them.

Execution
1) Student who is subject to ECG recording is calm, in lying position, arms along the body. Other colleagues of the group will place the electrodes on correct places
2) Electrodes should be cleaned before its use by alcohol. Please, release the cables connecting machine to electrodes carefully to prevent mixing and damaging them. Make sure the skin is clean on spots where electrodes will be places
3) Apply small amount of ECG gell (water can be used instead) on the metal part of each electrode and place them according to this plan:
   - red color – right wrist ;
   - yellow color – left wrist ;
   - green color – left ankle;
   - black color – right ankle;

Note: heavy hair of the legs can prevent the signal transition and it is needed to cut it.

4) Click on icon ECG on screen - Seiva Database
5) Choose “Ins” and make a new patient chart, resp. yourself. Put your surname, name, date of birth, gender and save clicking OK. If you wish to change the data click on icon Alt+C. After saving the data you will see the comment that birth number is not complying the rules - please click “BERU NA VĚDOMÍ” (I am aware of that).
6) Choose F4 or icon
7) Please check the parameters of ECG (paper speed should be 25mm/s, voltage 10mm/1mv. (if not, use F7 to set it this way)
8) Follow the record of ECG and heart rate for a minute, and then choose -using F3 icon for automatic settings for 10s.
9) Save, choose Print but then the result (record) forward to yourself (by email)
10) Provide for all members of your group the same assessment
11) Fill in required data in the protocol. Compare results between each other and measure the duration of:
   - P wave
   - PQ segment
   - QRS complex
12) describe your ECG record in all leads.
13) Make the electric axis of your heart.

Control questions:
1. What is it - electric axis of the heart?
2. Explain the difference between the bipolar and unipolar leads
3. Explain the term rest membrane potential and the development of action potential in the heart cell