Cardiovascular System

Sheet 6

Subject | Physiology

Done by | Dr.2016

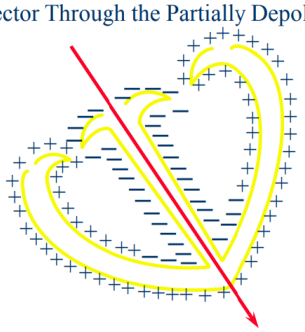
Corrected by | Rand Abu Anzeh

Doctor | Faisal

Flow of Electrical Currents in the Chest around the Heart

- The electrical current flows from a negatively charged area to a positively charged one.
- As we said before, the depolarization of ventricles starts in the interventricular septum.
- The electrical current spreads this depolarization from the depolarized area to the still polarized area.
- The last part of the heart that gets depolarized is the posterior aspect of the left ventricle. So, we have many currents that are spreading in different directions from the depolarized areas to the still polarized areas. Each current is a *vector* (has a magnitude and a direction), so having different vectors means that we must calculate a *resultant vector.*

Mean Vector Through the Partially Depolarized Heart



How is the ECG recorded?

To record ECG, we place different leads in different positions to "look at it from different perspectives" to better understand the status of the heart.

Nowadays, we use a 12-lead ECG (12 galvanometers present in the ECG machine). It has 10 electrodes, they allow the electrical activity of the heart to be looked at from 12 different positions. There are ***4 limb*** electrodes and ***6 chest*** electrodes.

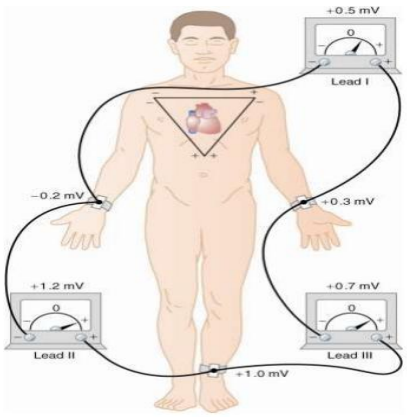
- Leads can be:

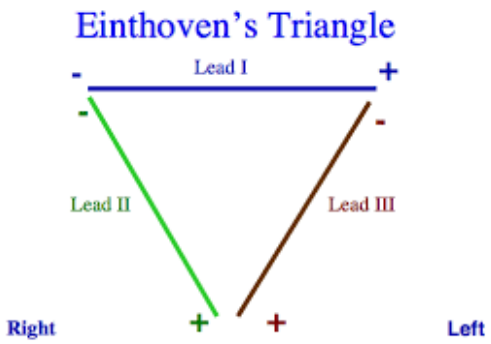
- Bipolar: composed of two electrodes of opposite polarity (one positive and one negative).
- Unipolar: composed of a single positive electrode and a reference point.

❖ **Bipolar Limb Leads**: Also known as ***Einthoven's Connections***.

- There are **3** bipolar limb leads (Leads I, II and III).
- In each lead, we have a galvanometer with <u>two electrodes</u>, (*positive* and *negative*).
- In all leads, we use the right arm, left arm and the left foot. *The right foot is considered an earth (ground lead).*

- Lead I: RA (-) to LA (+).
- Lead II: RA (-) to LL (+).
- Lead III: LA (-) to LL (+).





Remember that: - Right Arm is Always (Negative).
- Left Leg is Always (Positive).

Einthoven made the connections in this manner to make the recordings Positive, forming the *Einthoven's triangle* found above. If we switch the electrodes, we will get reverse recording.

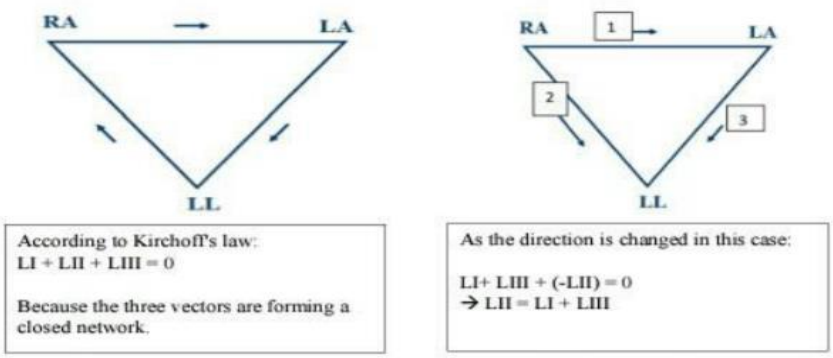
- ***Einthoven's triangle****: an equilateral triangle*
  - The sides of this triangle are between the right arm, left arm and left foot (The heads of this triangle represent the RA, LA and LL), with the heart at the center.
  - An equilateral triangle is also equiangular; and here you must know that all three internal angles are 60°.
  - The center of this triangle is a center for a circle that you can draw around this triangle.
  - When you draw a perpendicular line from the midpoint to the sides you are going to have two equal sides.
- **Einthoven's law: Lead II = Lead I + Lead III**

  (QRS in lead I + QRS in lead III = QRS in lead II) from ECG. (Will be discussed later)

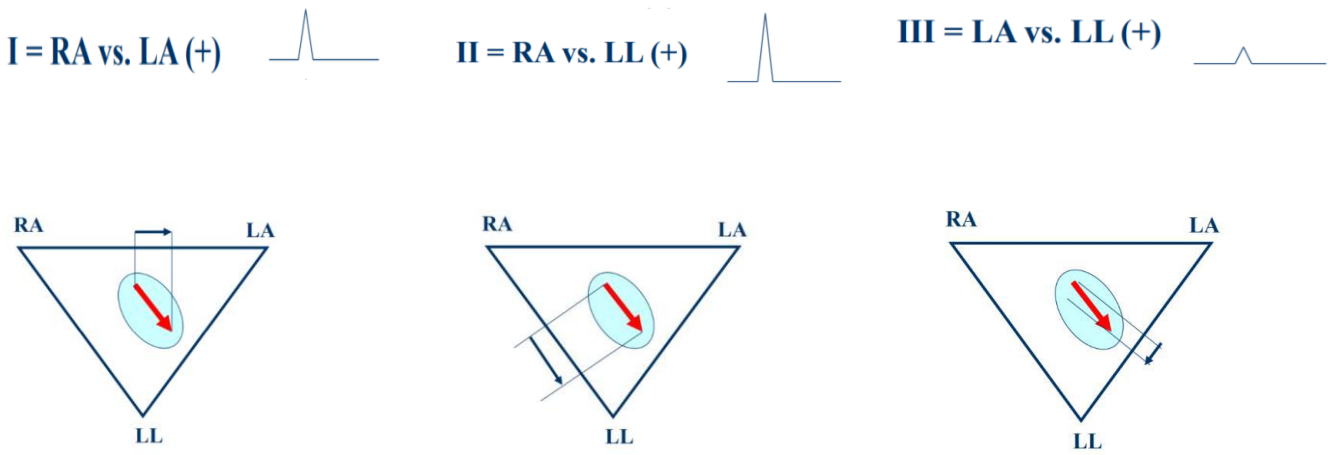
Remember That: The current goes from the negative to the positive direction, as we know it is a vector (has a direction & magnitude).

If we change the direction of *Lead II* to go from *Left Foot* to *Right Arm* the resultant *summation* of all three leads would equal to ZERO. This is because the three vectors form a closed circuit.

- According to Second Law of Electricity (Kirchhoff's law): if a current goes in a closed circuit, the summation of the currents of lead I, lead II and lead III equals zero. Einthoven reverses the direction of lead II; so that there is no closed circuit. Einthoven used Vector Transformation to achieve this. (The figure below may help!)



We have the resultant vector; however, we want to know the value each lead contributes to this vector. What we do is we project lines perpendicular to the lead to connect the lead with the resultant vector. (Look at the diagram to understand it)

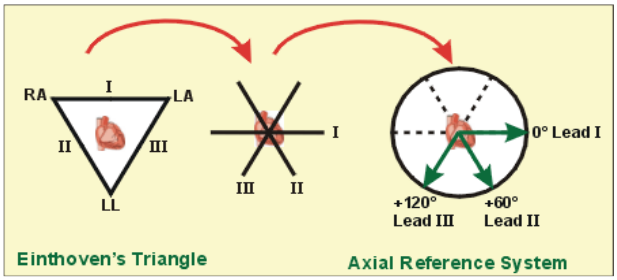


From the three leads it is clear that Lead II contributes the most to the resultant vector (as it is parallel to it) so will have the highest magnitude. In ECG we translate these vectors to peaks.

- **Triaxial Reference System:**

  We can also convert the information from equilateral triangle to a triaxial reference system shown below:

- We want to draw all of these axes in order to meet at one point without changing the magnitude or direction.
- This is done by moving them in a parallel manner. After moving lead l, ll and lll they meet at the center, we call it trigonal axis.
- They remain to have the properties of an equilateral triangle, mainly that the angles between them= 60°



Each Lead is 60 degrees clockwise of the next. We take Lead I as the reference = 0. Moving Clockwise, lead II is at 60 degrees, Lead III is at 120. Moving anticlockwise we move -60.

The normal physiological range is between **-30** to **+110**. Clinically, easier reference ranges are used, from **0** to **+90**.

NOTE:

Depolarization is followed by contraction, and repolarization is followed by relaxation.

(QRS in lead I + QRS in lead III = QRS in lead II)

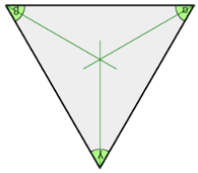
When the positive vector is directed towards the:

- Positive electrode, it will be recorded as a positive deflection.
- Negative electrode, negative deflection.
- When there's no current flowing, there would be an isoelectric line.

Watch the lecture at 20:00. It's a little bit hard to be written!

❖ Augmented Unipolar Limb Leads:

One of the properties of circuits is that if we place 3 electrodes of high resistance in an equilateral triangle, the net potential will be **Zero** and **in the center of the triangle.**



We connect on the negative electrode three connections on the same exact positions where we put the Bipolar Limb Leads (Right Arm, Left Arm and Left Foot). (All three connections are considered one negative electrode) These connections have Very High Resistance (=5000 Ohms) so that the net current in these three connections will be **ZERO (**called **indifferent electrode)**

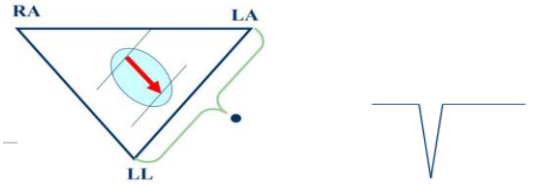
Then we place the positive electrode on a different position (Right Arm, Left Arm and Left Foot) <u>each at a time</u> calculating (VR, VL, and VF, respectively).

The electrode is called **exploring electrode**.

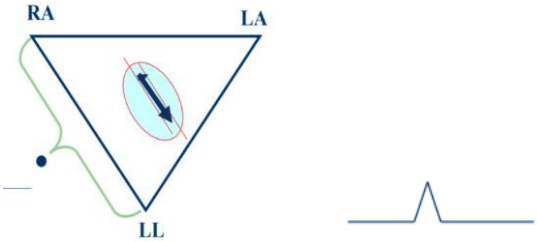
The problem with this is that the recording is too small, so we need to amplify it. What Wilson did is that he disabled the negative electrode on the same position he put the positive electrode (he removed the high resistance electrode from where he was calculating).

After amplification we have aVL, aVR and aVF (a for augmented).

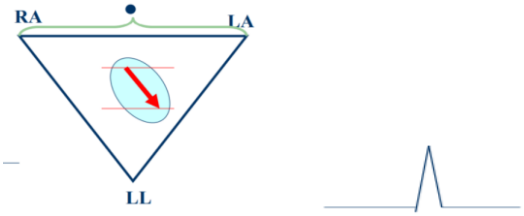
- aVR = (LA-LL) vs. RA(+)
- aVL = (RA-LL) vs. LA(+)
- aVF = (RA-LA) vs. LL(+)



aVR: the measured potential difference is between RA (+) and Center point between LA and LL (-). aVR is moving in opposite direction to the resultant so recording will be NEGATIVE



aVL: the measured potential difference is between LA (+) and Center point between RA and LL (-). aVL is moving in same direction to the resultant so recording will be barely Positive



aVF: the measured potential difference is between LL (+) and Center point between RA and RA (-). aVF is moving in same direction to the resultant so recording will be Positive(It will be most positive)

❖ Chest Leads (Precordial):

In the limb leads we looked at the activity of the heart from the frontal plane, however using the Chest leads we will look at it from the horizontal plane.

There are 6 **unipolar** chest leads (V1, V2, … V6) or (C1, C2, … C6). C for chest.

Unlike limb leads, they are very close to each other, so we must learn how to position each electrode using the bony landmarks of the chest.

V1/C1: On the right side parasternal at the level of 4th intercostal space.

V2/C2: Opposite to V1 in the left side parasternal 4th intercostal space.

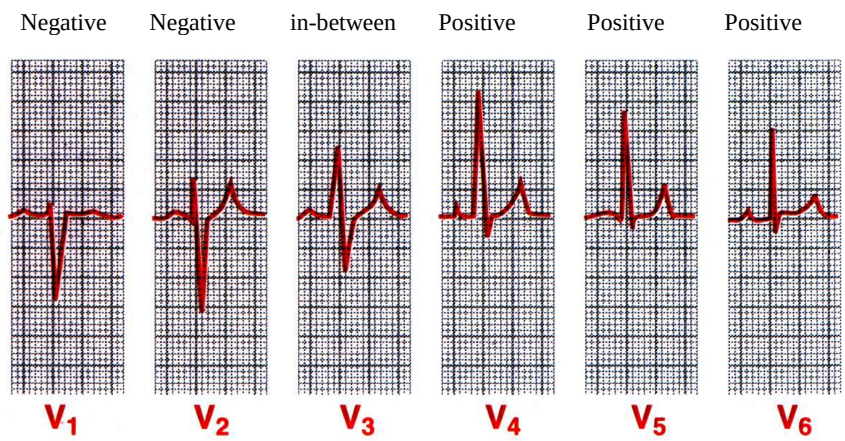
Now skip V3

V4/C4: Midclavicular 5th intercostal space.

V3/C3: Midpoint between V2 & V4.

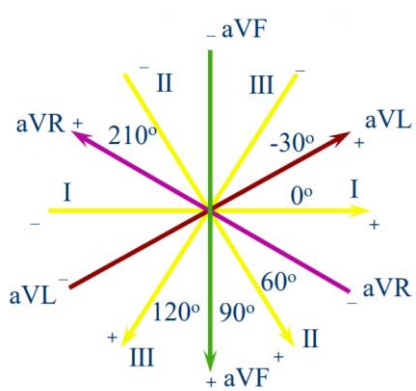
V5/C5: Anterior axillary, 5th intercostal space.

V6/C6: Mid axillary, 5th intercostal space.



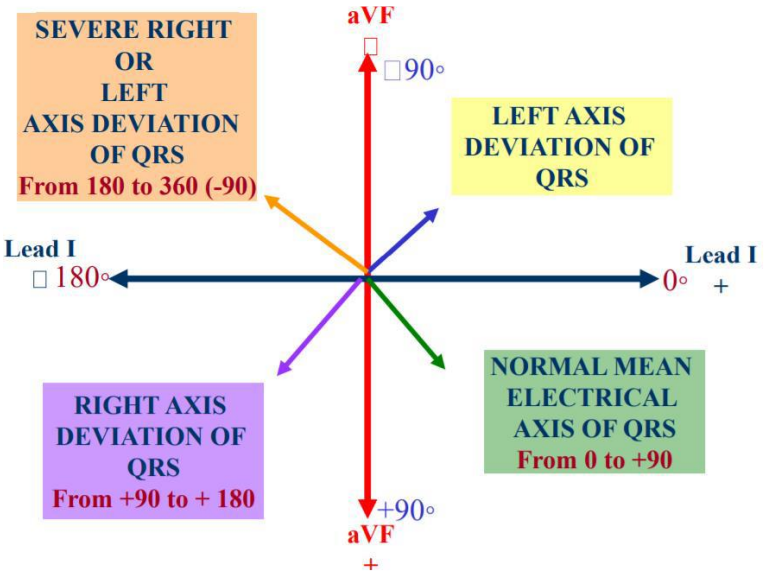
Sometimes we want to look that the conductance of electricity from the ***posterior aspect*** of the heart. We do so by adding an **esophageal electrode/ esophageal lead** (in the esophagus) so it will be just behind the heart. We will know if there is a problem in the posterior aspects, or sometimes we use it if conditions in the chest do not allow us to place electrodes on it.

❖ Principles of Vectorial Analysis of ECG's:



Direction:

- We can determine the direction or what quadrant the Mean Electrical Axis lies in by the signs of Lead I and Lead aVF:
  - If lead I (+ve) and aVF is (+VE) it will be in the Quadrant between 0 and 90
    NORMAL MEAN ELECTRICAL AXIS OF QRS
  - If lead I (-ve) and aVF is (+VE) it will be in the Quadrant between 90 and -180
    RIGHT AXIS DEVIATION OF QRS
  - If lead I (+ve) and aVF is (-VE) it will be in the Quadrant between 0 and -90
    LEFT AXIS DEVIATION OF QRS
  - If lead I (-ve) and aVF is (-VE) it will be in the Quadrant between -90 and -180
    SEVERE RIGHT OR LEFT AXIS DEVIATION OF QRS



Good Luck