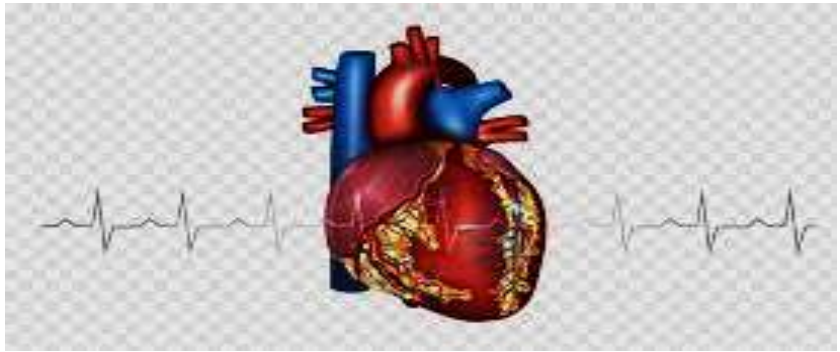
5. ECG



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ELECTROCARDIOGRAM (ECG)

The potential changes (fluctuations) that represent the algebraic sum of the action potential of myocardial fibers which occurs regularly with each cardiac cycle are conducted along the body fluids to the body surface and can be recorded extra-cellularly because the body fluid is a good conductor to potential fluctuations.

Recording of ECG :

ECG is recorded by electrocardiography machine (sensitive galvanometer), which record these potential changes (during the cardiac cycle) on a moving strip of paper (electrocardiogram film).

Lead :

-**It is** the position (site) of the two electrodes.

Types of electrodes :

1. Exploring electrode :It is the electrode which is put at a point having electric activity.
2. Indifferent electrode : It is the electrode which is put at a point having a **zero**-potential.

- **Classification of leads** :

A. Bipolar leads (standard limb lead) :

-Each records the potential differences between **two** exploring electrodes (limbs).

1. Lead I : between the **left arm** and the **right arm**.
2. Lead II : between the **right arm** and the **left leg**.
3. Lead III : between the **left arm** and the **left leg**.

Einthoven's triangle

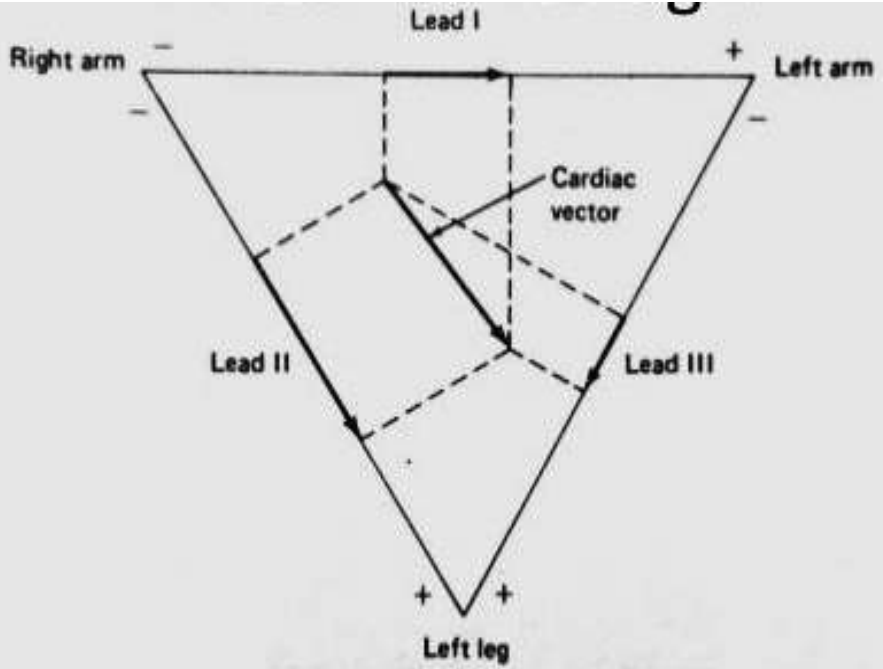
Is an equi-lateral triangle, its angles are right arm, left arm, and left leg formed of the three standard limb leads with the heart in its center.

Einthoven's law :

Lead II = lead I + Lead III

(in amplitude)

(lead I + lead II + lead III = zero)



The vector sum of the frontal plane Cardiac Vector at any instant onto the three axes of the Einthoven Triangle will be zero.

B. Unipolar leads :

Record the potential difference between an exploring electrode and an indifferent electrode (at zero potential).

A. The indifferent electrode is constructed by connecting the three limb electrodes to a central common terminal through a resistance of 5000 ohm.

B. The exploring electrode may be put on:

1. Limbs (unipolar limb lead).

2. The chest (unipolar chest lead)

{1} Unipolar limb leads

- VL records electric potential at the left arm.

- VR records electric potential at me right arm.

- VF records electric potential at the left leg.

The augmented unipolar limb leads :

The amplitude of the deflection of VL, VR, VF can be augmented (increased) and are called aVL, aVR, and aVF if the exploring electrode is placed on the corresponding limb, while the indifferent electrode is obtained by connecting the other two limb electrodes through a resistance of 5000 ohms.

N.B: This construction gives bigger amplitude (about 1.5 limes) with no difference in shape.

{2} Unipolar chest leads :

The exploring electrode is put on 6 points on the chest

They are called VI to V6 where V represents a unipolar lead:

VI : in the 4th intercostal space at right para-stenal border.

V2 : in the 4th intercostal space at left para-stenal border.

V3 : midway between V2 and V4

V4 : in the 5th intercostal space at the left **mid**clavicular line (heart apex).

V5 : in the 5th intercostal space at the **anterior** axillary line

V6 : in the 5th intercostal space at the **mid-axillary** line

N.B. - *V1& V2 : looked at the* ***right ventricle***

- *V3& V4: looked at the* ***septum and anterior wall of left ventricle****.*

- *V5 & V6: looked at the* ***left ventricle*** *(anterior and lateral wall).*

***Normal Atrial Activation** :

- Atrial depolarization starts by the activity of SA Node.

- The depolarization wave spreads downwards and to the left to activate the right atrium then the left atrium (Thus the first part of the P wave is formed by right atrial activation, while the terminal part is formed by left atrial activation).

***Normal Ventricular Activation :**

-The activation wave spreads down the bundle of his and its branches (right and left) to the ventricles.

-The septum is the first part to be activated from the left bundle (activation starts from the left side to the right).

-The septal activation wave spreads toward the recording electrode in the chest lead placed in V1 position and away from that placed in V6 position (This results in a small initial + ve 'r' wave in V1 and small - ve Q wave in V6).

- The excitation will then spread to the two ventricles in the purkinje fibers from the endocaridum to the epicardium.

- The depolarization of both right and left ventricles occurs at the same time (simultaneously).The net electric effect is the balance between them (i.e. as the left ventricle is thicken than the right its forces predominate and the equilibrium is toward the left producing : Negative (S) wave in V1 & Positive (R) wave in V6.

*Ventricular Repolarization :

-The spread of excitation wave will stop once the ventricles become totally activated, (the QRS complex deflections will come to baseline).

-is followed by a steady resting state (no electric activity occurs).

-The ECG will show no deflection, (isoelectric line = base line) tills is called S-T segment. Then the ventricles start to repolarize.

- The repolarization is also a slower process than depolarization. It produces the T-wave, which has the same direction as the QRS complex.

Normal ECG waves

1) P-wave :

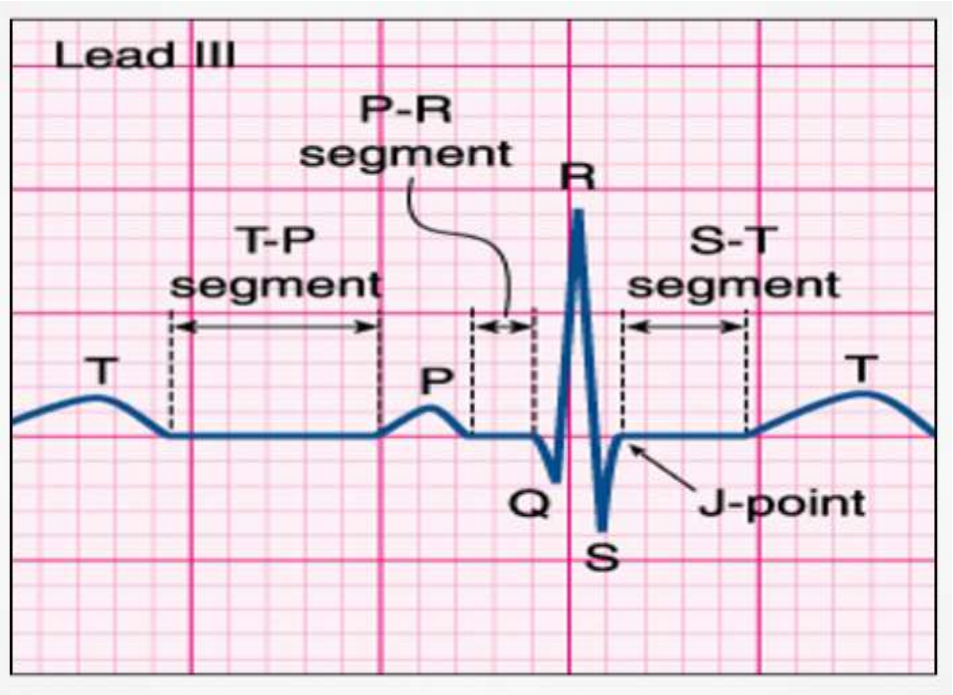
- It is the primary wave of ECG (hence it is called "P").

- Cause : due to depolarization of the atria.

- Duration : 0.08 - 0.1 second (sec).

- Amplitude : 0.2 mv (positive wave)

(starts 0.02 second before atrial contraction).



2) QRS complex :

- Cause: it is due to depolarization of the whole ventricles.
- Duration : 0.04 - 0.08 sec.
- Amplitude : 1 mv , (starts 0.02 second before ventricular contraction).

- Q-wave : - Cause : depolarization of inter-ventricular septum (from left to right).

- Duration : 0.02 sec
- Amplitude : small (negative wave)

- R -wave

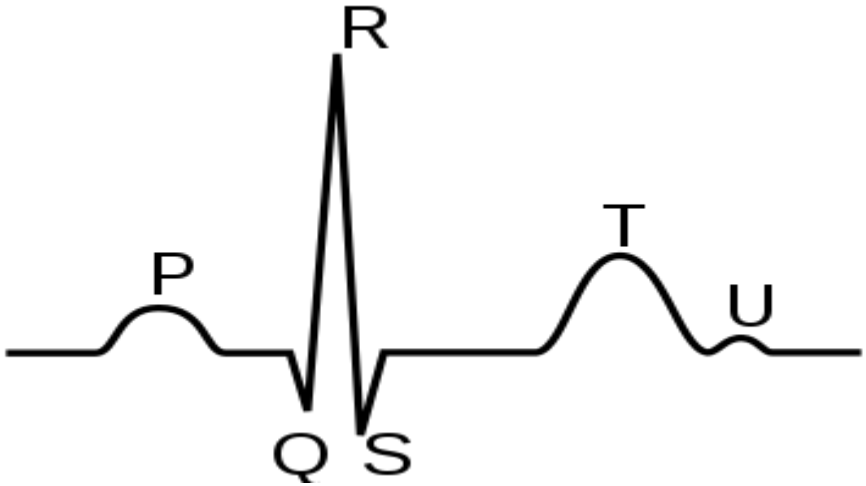
- Cause : depolarization of both ventricles.
- Duration" : 0.04 second
- Amplitude : 1 mv (positive wave)

- S-wave :

- Cause : depolarization of the remaining parts (postero-basal of the ventricle and pulmonary conus).
- Duration : 0.02 sec.
- Amplitude : small (negative wave)

3) T-wave :

- Cause : due to repolarization of the ventricles.
- Duration : 0.25 sec.
- Amplitude : 0.4 mv (positive wave)



4) U-wave :

- This wave is usually absent.
- Cause : it may be due to slow repolarization of papillary muscles (that is attached to A.V. valve) or it may be due to supernormal phase of excitability (i.e. if excitability of cardiac muscle is more than normal).

5) P-R interval:

- **It is** measured from the beginning of P to the beginning of R., - **Its duration** : 0.12 - 0.2 sec.
- **It represents** :

-atrial depolarization. , -conduction from atrium to ventricle (AVN & AVB).

- **Prolonged in:** -Increased parasympathetic (vagal) tone with bradycardia.

-AVN block (delayed conduction) - Atrial enlargement

- **Shorten in:**

- Increased sympathetic tone with tachycardia. - AV nodal rhythm

-Wolff-parkinson-white syndrome (accessory bundle conduct impulses from left atrium directly to the left ventricle), so, no AV nodal delay.

6) Q.T. interval:

- From the beginning of Q to the end of T wave., - Normal duration = 0.44-0.48
- It represents the electrical activity of the ventricle (depolarization and repolarization)
- It is called electrical ventricular systole.

N.B.: Increase Ca^{++} → decrease electrical ventricular systole → decrease Q-T interval

7) S-T segment:

- It is measured from the end of S to the beginning of T.
- Duration : 0.1 sec .
- It should be isoelectric (i.e. at the end of S all the ventricles are depolarized and repolarization starts with T wave, so during S-T segment the ventricles are completely depolarized without potential differences between any points on surface of the heart) So, S-T segment should be in isoelectric line).
- If it is displaced upward or downward (i.e. elevated or depressed) from isoelectric line this means myocardial ischaemia.

N.B. :

- Atrial repolarization is not recorded because:
  a. It is of very low voltage.
  b. Masked by QRS complex (because it occurs at the same time with ventricular depolarization).
- Electrical activity of pace-maker cells and specialized conducting cells (SAN, AVN, AVB) are not recorded because of their relatively small size.

-Relationship of (ECG) and action potential of a single ventricular fibre:

1.**QRS** complex coincides with ventricular depolarization (occurs at the beginning of the action potential).

2. **ST segment** coincides with the Plateau.

3. **T wave** coincides with rapid repolarization (occurs at the end of the action potential).

-The direction of the wave forms depend on :

1. The site of the recording electrodes on the body surface.

2. The direction of electrical activity (whether it is directed toward or away from the exploring electrode).

a) If a wave of depolarization is moving **toward** the exploring electrode a **+ ve** wave is recorded (upward deflection).

b) If a wave of depolarization is moving **away** from the exploring electrode a **-ve** wave is recorded (downward deflection).

-The direction of depolarization in the septum is from **left to right** and in ventricular wall from **endocardium to epicardium**. The direction of depolarization in both ventricles is algebric summation of both opposite directions (with direction of left ventricle which is the most thicker).

-Why the repolarization wave (T) is in the same direction (+ve) as the depolarization wave (R)?

-During depolarization the direction of dipole is from endocardium to epicardium → +ve wave (R).

-The last point of depolarization is the first point of repolarization (as epicardium has more blood supply with rapid repolarization but endocardium suffers from ischemia).

- So the direction of dipole during repolarization is the same as in depolarization → +ve wave (T).

N.B.: *in skeletal muscle the first part depolarized is the first repolarized → opposite direction of waves. Also in atria, SAN is the 1st depolarized & repolarized. So repolarization wave in atria is –ve and called Ta wave).*

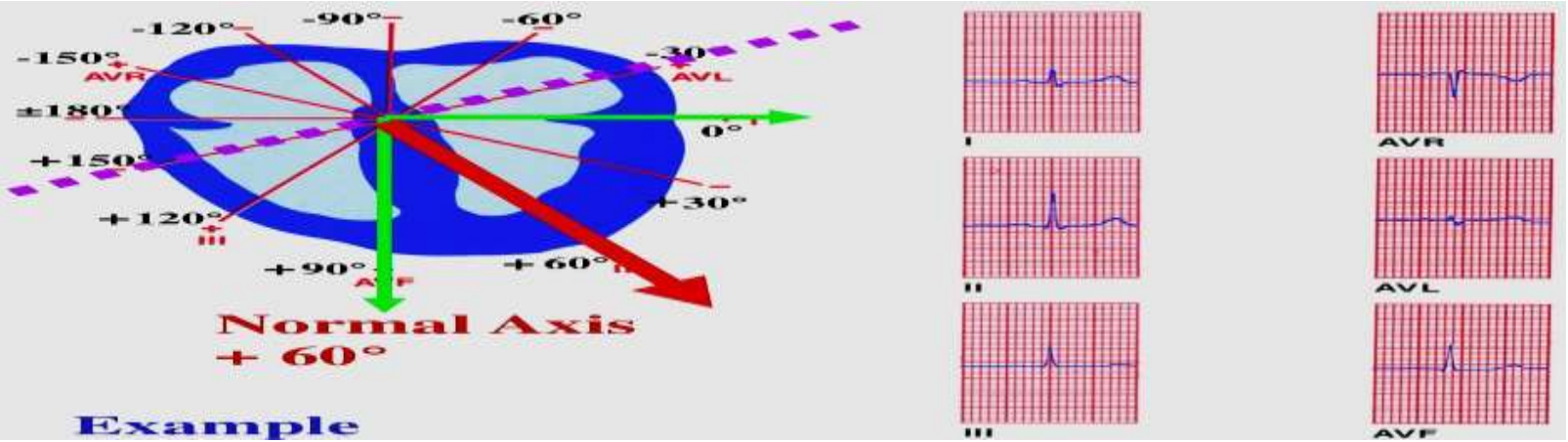
There is no potential (at all) recorded in the ECG when the ventricles are either polarized (during T-P segment) or completely depolarized (during S-T segment).

- **Applications on the standard limb leads :**

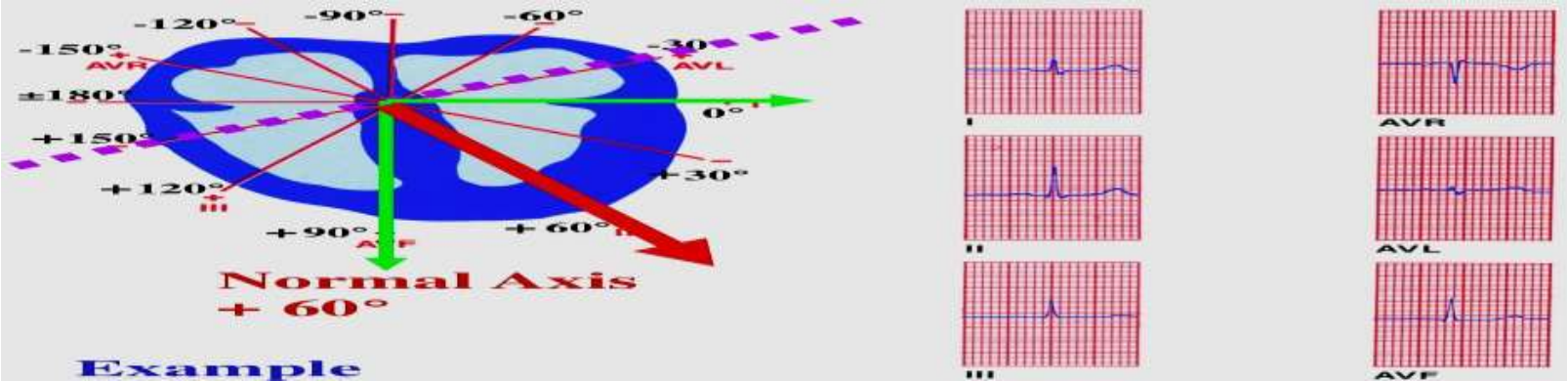
1. Vector cardiography :

- **Vector** is an arrow which represents the sum of the electrical activity of the heart at any moment (it has magnitude and direction).
- **Vector cardiogram** is a line connecting the tops of all cardiac vectors during the cardiac cycle. The line forms a series of 3 loops for P, QRS complex and T waves.

2. Electric axis of the heart (mean QRS vector) :



- It is the resultant vector of the heart.
- An equilateral triangle (einthoven's triangle) is represented.
- Perpendiculars are dropped from the mid point of the sides of the triangle to meet in the centre (point A).
- The average QRS complex deflections are measured in the standard limb leads and represented on the Einthoven's triangle
- Perpendiculars are dropped from the distances measured on each limb (representing the mean QRS complex) to meet at point B.
- An arrow drown between A & B represents the vector (normal direction is **– 30° to + 110°** with an average **60°** downward and to the left slightly anterior



Thank You