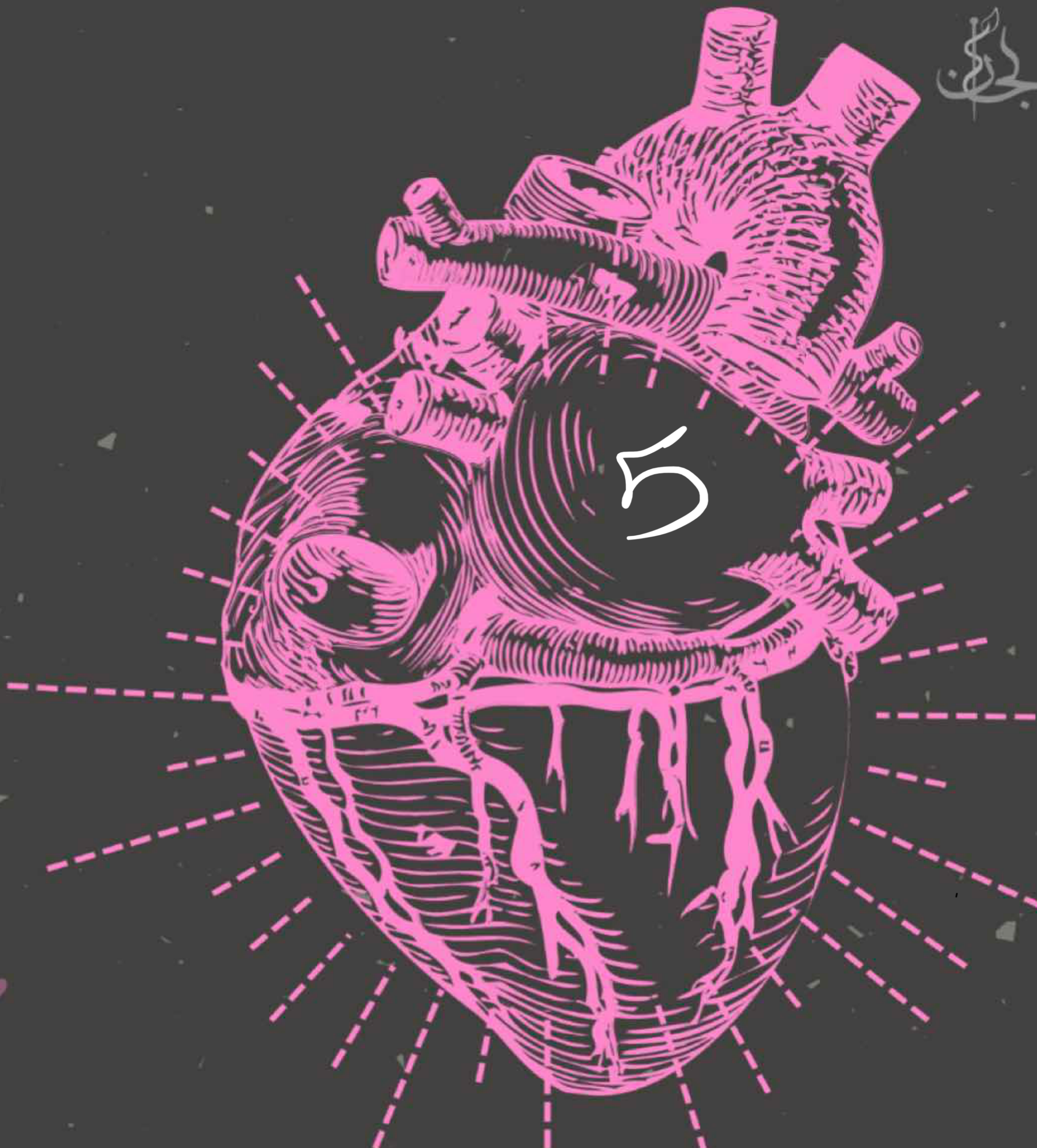
CVS



PHYSIOLOGY

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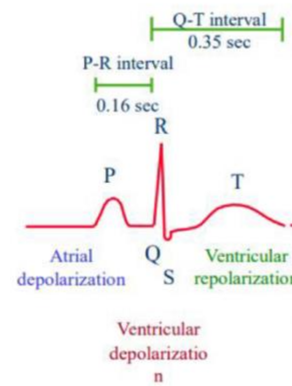
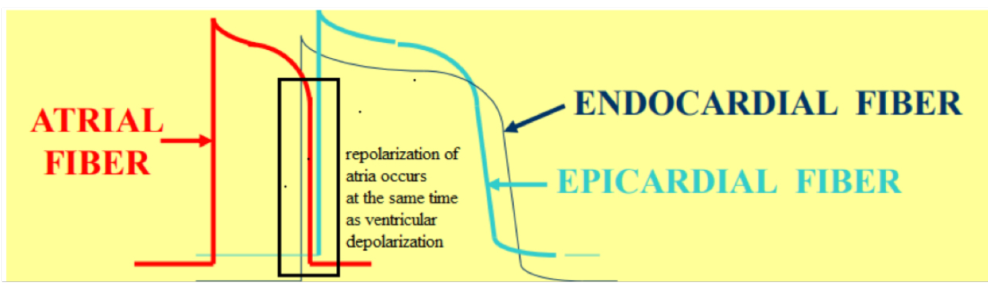
As a revision:

- The normal ECG is composed of **a P wave, a QRS complex, and a T wave**. The QRS complex is often, but not always, three separate waves: the Q wave, the R wave, and the S wave.
- The **P wave** is caused by electrical potentials generated when the **atria depolarize** before atrial contraction begins. The **QRS complex** is caused by potentials generated when the **ventricles depolarize** before contraction, that is, as the depolarization wave spreads through the ventricles.
  → Therefore, both the P wave and the components of the QRS complex are **depolarization waves.**
- The T wave is caused by potentials generated as the ventricles recover from the state of depolarization. The **T wave** is known as **a repolarization wave.**



In conclusion, the ECG is composed of both depolarisation and repolarization waves.

During each cardiac cycle, we record atrial depolarisation, ventricular depolarisation and ventricular repolarization. But what about atrial repolarization? Atrial repolarization occurs at the same time as ventricular depolarisation, and since the depolarisation of the ventricles is strong, it masks the repolarization of atria and that's why it doesn't show in the record.



The recording of ECG shows repeated cycles of P, QRS and T waves. The interval between 1 R and the following one represents a cardiac cycle. The same applies to each of the intervals between (P-P, T-T, S-S and Q-Q) but the R-R interval is the most definite one with significant sharp peaks.

The number of electrical cardiac cycles per minute is equal to the number of heart beats per minute (normally ranges from 60 to 100 BPM). Which means that we can calculate the heart rate using ECG.

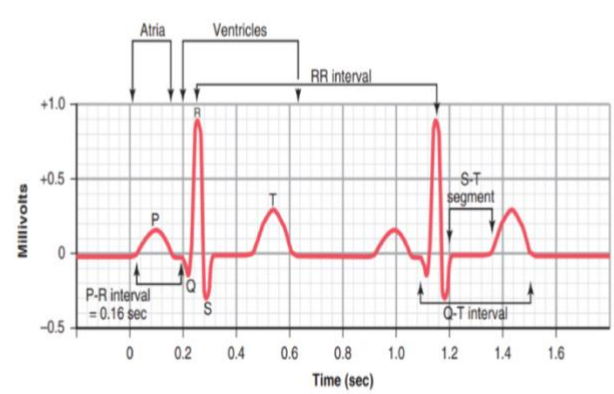


Figure 11-1. Normal electrocardiogram.

❖ **Standardised (ECG):**

- Time and voltage calibrations are standardised by putting a heat-sensitive vapor under the pointer of the electrocardiograph. Underneath this pointer, is a paper that is squared.

- The horizontal calibration lines (Y-axis) are arranged so that each 10 small squares upward or downward in the standard ECG represent 1 millivolt, with positivity in the upward direction and negativity in the downward direction.

- The vertical lines (X-axis) are time calibration lines. A typical ECG is run at a paper speed of 25 millimetres per second. Therefore, each 25 millimetres in the horizontal direction is 1 second, and each 5-millimetre segment (big square), indicated by the dark vertical lines, represents 0.20 second. The 0.20-second intervals are then broken into five smaller intervals by thin lines (5 small squares), and each small square represents 0.04 second.

- Now let's discuss the intervals and segments that are recorded in normal ECG:

1. Intervals:

- The term interval refers to a period that contains a wave

a) The P-Q or P-R Interval:

▪ The first interval that shows in normal ECG is the P-Q interval (often this interval is called the P-R interval because the Q wave is likely to be absent).

▪ The normal P-R interval is about 0.16 second and it represents the time between the beginning of electrical excitation of the atria and the beginning of excitation of the ventricles.

b) The QRS Interval:

▪ Represents the period of ventricular depolarisation

c) The Q-T interval:

▪ Extends from the beginning of ventricular depolarisation to part of ventricular repolarization.

▪ Contraction of the ventricles lasts almost from the beginning of the Q wave (or R wave, if the

Q wave is absent) to the end of the T wave. This interval ordinarily is about 0.35 second.

d) The R-R Interval:

▪ Represents the duration of the cardiac cycle

▪ If the time between 2 successive R is 20 small squares, and each small square as mentioned above is 0.04 sec, then the cardiac cycle is 0.8 sec.

▪ Now the question is, if each cardiac cycle takes 0.8 sec, how many cardiac cycles are in 1minute (60 seconds)? (60sec/0.8sec=75beats/minute).

▪ If the R-R interval is 15 small squares→cardiac cycle is 0.6 sec→heart rate = 100BPM.

▪ If the R-R interval is 25 small squares→cardiac cycle is 1 sec→heart rate = 60BPM.

➔ **In conclusion**, the heart rate is inversely proportional to the duration of the cardiac cycle.

2. Segments:

- Segments are the isoelectric (flat) lines between the end of a wave and the start of another. Thus, a segment doesn't contain waves.

- Here we study the deflection of these segments (depression or elevation) not time

a) P-R segment: the isoelectric line between the end of P to the beginning of R.

b) S-T segment: the isoelectric line between the end of S to the beginning of T.

-A deflected S-T segment (whether depressed or elevated) denotes ischemia to the muscle (decreased blood flow to the muscle) → might end with infarction (no blood flow).

c) T-P segment:the isoelectric line between the end of T to the beginning of P.

Relationship of Atrial and Ventricular Contraction to the Waves of ECG

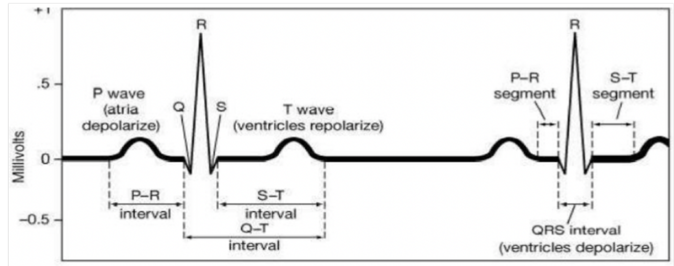
Record of electrical events in the myocardium can be correlated with mechanical events

P wave:

- Depolarisation of atrial myocardium
- Signals onset of atrial contraction (Atrial systole)

QRS complex:

- Ventricular depolarisation
- Signals onset of ventricular contraction (Ventricular systole)
- Should be equal to 0.12 sec



T wave:

- Repolarization of ventricles
- Signals onset of ventricular relaxation (Ventricular diastole)

PR interval or PQ interval:

- Extends from beginning of atrial depolarisation to beginning of ventricular depolarisation (QRS complex)

- It is prolonged by the delay caused by the AV node (in order for ventricular systole to occur after atrial diastole)

- The maximum accepted PR interval is 0.2 sec; can indicate damage to the conducting pathway or AV node if greater than 0.20sec

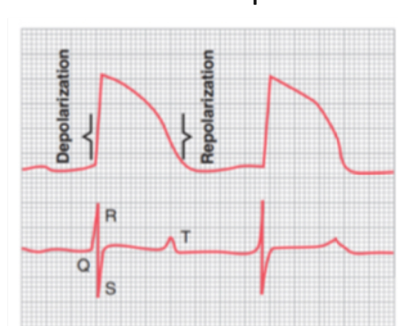
Q-T interval:

- Time required for ventricles to undergo a single cycle of depolarisation and repolarization

- It usually equals half the duration of the cardiac cycle (0.35-0.45sec)

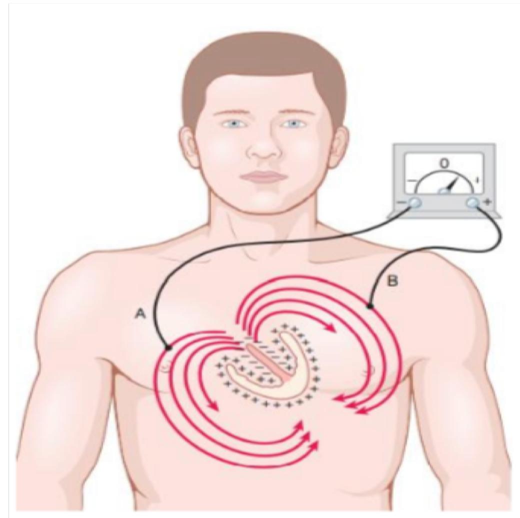
- Can be lengthened by electrolyte disturbances, conduction problems, coronary ischemia, myocardial damage

****Remember** that in order to record the potential difference (ECG), we place the electrodes on the surface of the muscle fibre (Biphasic action potential). However, in order to record the mono-phasic action potential, the electrodes are placed one inside the cell and the other outside.



Flow of Electrical Currents in the Chest Around the Heart

Ventricular depolarization starts at the ventricular septum and the endocardial surfaces of the heart and spreads to both ventricles at the same time.

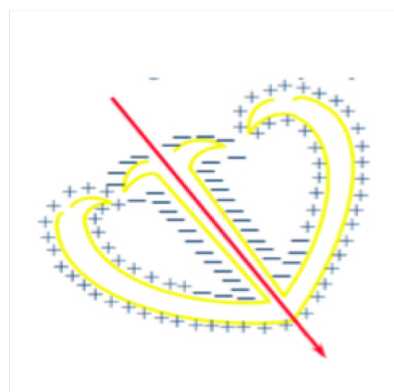


▪ When one portion of the ventricles depolarizes and therefore becomes electronegative with respect to the remainder, electrical current flows from the depolarised area to the still- polarised area in large circuitous routes, as noted in the figure.

In other words, the electrical current flows from a negatively charged area to a positively charged one.

▪ Each current is a vector (has a magnitude and a direction). We can calculate an instantaneous mean of the current flow when the heart is partially polarised.

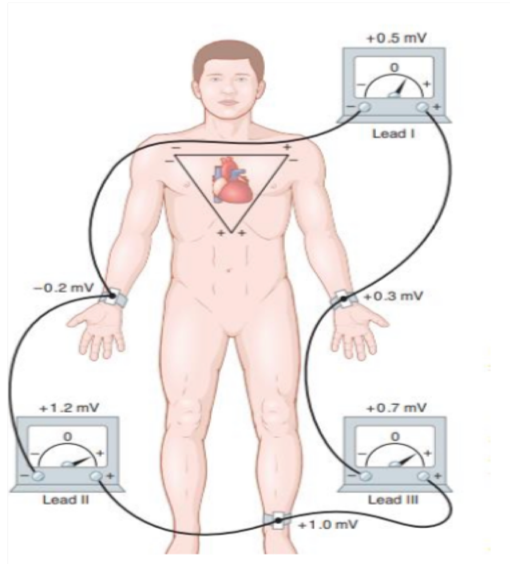
Since it's instantaneous, we get different means every time so we must calculate a resultant vector.



▪ Since we are talking about ventricular depolarisation, then the vector is QRS. We know that right and left ventricles contract simultaneously , therefore there are currents going towards the left and towards the right at the same time, but since the force of contraction in the left ventricle is way stronger than that of the right, we dan conclude that the mean QRS vector is directed anteriorly, inferiorly and to the left. As in, the average current flows positively from the base of the heart to the apex.

Bipolar Limb Leads

- Bipolar means that the ECG is recorded from two electrodes on the body.
- There are 3 bipolar limb leads (Leads I, II and III).
- In each lead, we have a galvanometer with two electrodes, positive and negative.
- In bipolar limb leads, we use the right arm, left arm and the left foot. The right foot is considered an earth (ground lead).



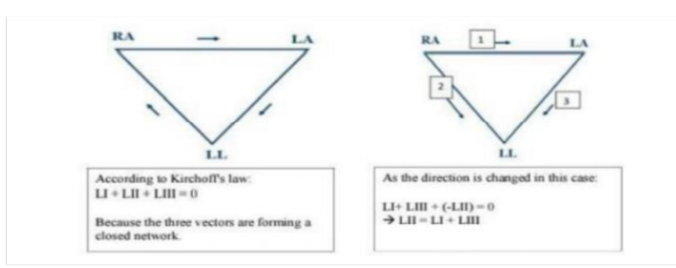
- Lead I: RA (-) to LA (+): the negative terminal of the electrocardiogram is connected to the right arm, and the positive terminal is connected to the left arm
- Lead II: RA (-) to LL (+): the negative terminal of the electrocardiogram is connected to the right arm, and the positive terminal is connected to the left leg
- Lead III: LA (-) to LL (+): the negative terminal of the electrocardiogram is connected to the left arm, and the positive terminal is connected to the left leg

Einthoven's law states that if the ECGs are recorded simultaneously with the three limb leads, the sum of the potentials recorded in leads I and III will equal the potential in lead II.

Lead I potential + Lead III potential = Lead II potential 0.5 + 0.7 = 1.2 mv

- In other words, if the electrical potentials of any two of the three bipolar limb electrocardiographic leads are known at any given instant, the third one can be determined by simply summing the first two. Note, however, that the positive and negative signs of the different leads must be observed when making this summation.
- 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.

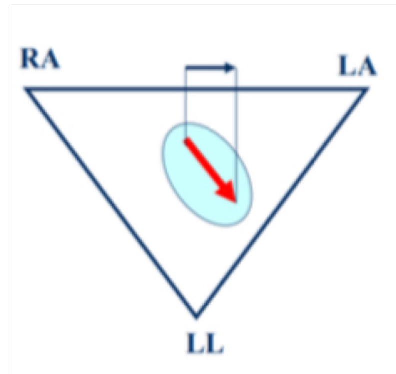
Lead I potential + Lead III potential + Lead II potential = 0



Now, we'll learn how to record the positive recording in those leads

- **Lead I**

▪ We said that the mean electrical axis of QRS is pointing to the left, inferiorly and anteriorly.



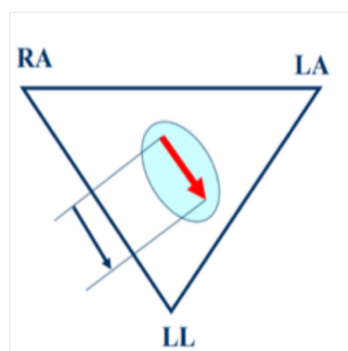
▪ In recording limb lead I, the negative terminal of the electrocardiograph is connected to the right arm and the positive terminal is connected to the left arm, so the axis of lead 1 will be directed from the right arm to the left arm

▪ In order to record the value of lead I we draw a perpendicular angle from the mean electrical axis to the axis of lead I and this will be the recording of the QRS in lead I

▪ When the point where the right arm connects to the chest is electronegative with respect to the point where the left arm connects, the electrograph records positively, when the opposite is true it records negatively.

▪ For better understanding, let's take a numerical example. Let us assume that momentarily, the right arm is −0.2 millivolts (negative) and the left arm is +0.3 millivolts (positive), and the left leg is +1.0 millivolts (positive). Lead I records a positive potential of +0.5 millivolts because this is the difference between the −0.2 millivolts on the right arm and the +0.3 millivolts on the left arm.

- **Lead II**



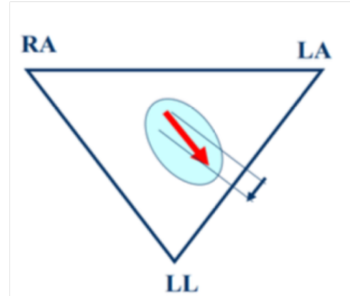
▪ In recording limb lead II, the negative terminal of the electrodiograph is connected to the right arm and the positive terminal is connected to the left leg

▪ We record the value of Lead II in the same way we calculated the value of Lead I by drawing a perpendicular angle

▪ When the right arm is negative with respect to the left leg, the electrodiograph records positively, when the opposite is true it records negatively

▪ Going back to our numerical example, lead II records a positive potential of +1.2 millivolts because these are the instantaneous potential differences between the respective pairs of limbs.

- **Lead III**



▪ To record Lead III, the negative terminal of the electrodiograph is connected to the left arm and the positive terminal is connected to the left leg

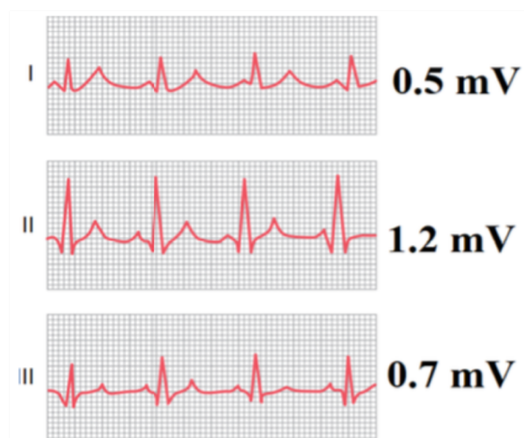
▪ Just like we did before, we record its value by drawing a perpendicular angle

▪ When the left arm is negative with respect to the left leg it records positively, when the opposite is true it records negatively

▪ As for the above-mentioned example, lead III records a positive potential of +0.7 millivolts as these are the instantaneous potential differences between the respective pairs of limbs.

-From the three leads, it is clear that lead II contributes the most to the resultant vector (as it is parallel to it) so it will have the highest magnitude.

-You can get the mean electrical axis by drawing a perpendicular line from every lead's axis and these three lines should meet in the middle in one point and this is the mean electrical value.



The following figure represents the recording of the mean QRS in every lead, we calculate the mean QRS by algebraic summation (it is done by the summation of the small squares)

▪ You can notice that **lead II** is equal to **lead I + lead III** and this is called **Einthoven's law**

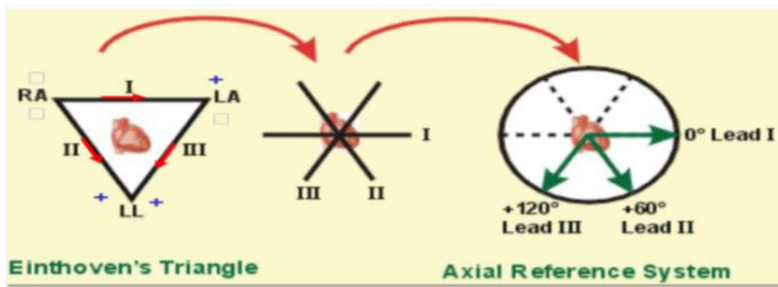
- By drawing the axis of each lead you'll end up with an equilateral, equiangular triangle (each angle is 60 degrees)

- The heads of this triangle are between the right arm, left arm and left foot, with the heart being at the center

- When you draw a perpendicular line from the midpoint to the sides you are going to have two equal sides

- We can also convert the information from equilateral triangle to a triaxial reference system, this is done by moving the axis of lead I, II, III in a parallel manner so that they meet at the center

- In the triaxial reference system, each lead is 60 degrees clockwise of the next and we take lead 1 as a reference.



The End