Note: watch the video, then use these note to keep the info in mind

"ECG from Dr.Najeeb videos"

By: Shad Mahdi

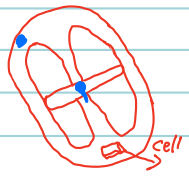
ECG Interpretation | Master Fundamentals of ECG | Electrocardiography

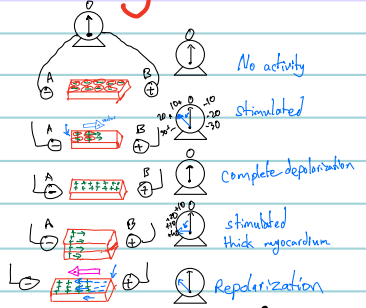
Note: Some notes are skipped, because I have written them in Part.1 Electrophysiology of heart

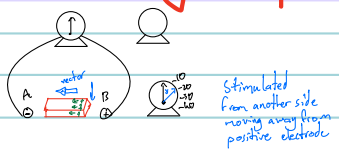
- ELECTROCARDIOGRAPHY - ECG

* Electrocardiography is the graphical representation of the electrical activity of the heart

How Electrical activity of the heart can eventually be presented as ECG pattern



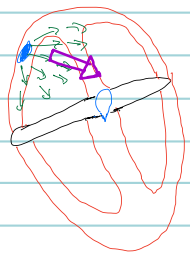
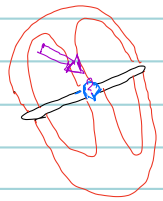


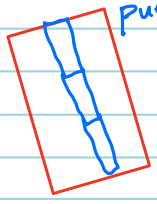


* ECG machine work on the principles of galvanometer
* If we take a piece of myocardium and apply galvanometer on it, we will see how the electrical activity will lead to fluctuations in the galvanometer
* The galvanometer has a negative and positive electrode. The function of the galvanometer is to detect electrical activity
* When the myocardium is at RMP (No activity) the needle will remain at zero.
* If the myocardium is stimulated from point A spreading towards point B. The cells go from Resting to depolarization and they become electrically positive. (wave of depolarization is still spreading)
* When all those positive charges are moving through the membrane, Electromagnetic forces are produced.
* Every force can be represented as a vector and is pointed towards the side where the charges are moving
* So the vector represents the electrical force generated in the myocardium
* Whenever Positive charges (depolarization) are moving towards the positive electrode, the needle will deflect positively.
* When wave of depolarization is spread from A to B completely (means all of it become completely depolarized) at that moment no charges are moving, so no electrical force is generated. Also the vector disappears and the needle goes back to its position, Zero.
* If we examine ventricular myocardium which is thicker. Total number of cells are increased and its depolarization is sodium dependent, this creates a greater electrical force represented by a longer vector. The deflection of the needle will also be greater
* If we stimulate it from point B, wave of depolarization will be moving towards point A (negative electrode)
* Whenever wave of depolarization is moving away from the positive electrode, the needle will deflect negatively.
* When it is completely depolarized, the process of repolarization starts which is negative (cell loses positive charges becoming electronegative again)
* The last point to depolarize will be the first point to repolarize. So in the case of depolarization from A to B, the repolarization will start at point B.
* By repolarization we mean K^+ ions are moving out, once it starts, it spreads toward point A (negative electrode)
* Whenever negative charges are moving toward the negative electrode, the deflection of the needle will be positive
* Some myocardial tissues are moderate conductors, others are fast conductors. So some myocardial tissue current passes slowly with moderate velocity, but other myocardial tissue current passes very rapidly
* Those myocardial tissues that conduct current with moderate speed will also deflect the needle with moderate speed
* Those tissues in the myocardium specialized in fast conduction will also deflect the needle fastly.

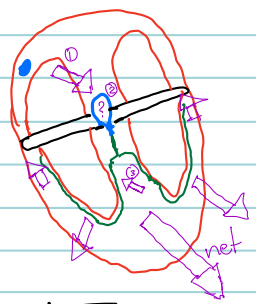
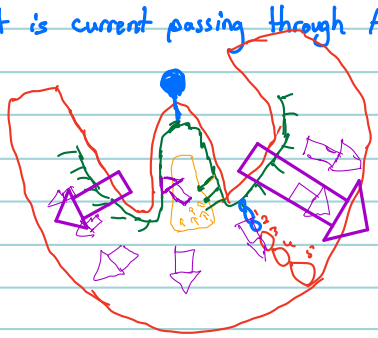
What are the electrical events in the heart during one cardiac cycle and how they lead to formation of cardiac vector and how cardiac vectors are translated to ECG pattern

* Electrical events in the heart during one cycle → Cardiac vectors → ECG pattern

* At the begining of the cardiac cycle, the SA node fires.
* The SA node will stimulate the cells adjacent to it firstly. And these cells are connected to next group of cells and stimulate them
* The wave of depolarization is spread through the atrium leftward and downward (direction of depolarization)
* The right and left atrium are syncitium, so electric current sweeps simultaneously on the right atrium and left atrium
* This wave of depolarization can be represented by a vector, and in this case it is a small vector moving downward and to left and with moderate velocity. The vector is small because atria is thin.
* So the first electrical event in the cardiac cycle is the depolarization of the atria.
* when both the atria are completely depolarized, wave of depolarization will hit the fibrous septum which is not a good conductor, so the wave of depolarization dies out.
* The only point through which electrical depolarization can pass from atria to ventricle is AV node.
* AV node is specialized in slow conduction. Depolarization takes 0.1 second to reach ventricles
* This delay ensures all the atria completely contract before ventricles are stimulated.
* The reasons that AV node is specialized in slow conduction are:
  - AV node has many small cells that are positioned in right angle to the direction of current flow, but in purkinje system they are large cells and less number of cells.
  - The gap junctions between AV nodal cells are few, but there are many in purkinje system.
  - The depolarization of AV node is calcium dependent, but those of purkinje are sodium dependent (sodium is fast)
  - AV node has small diameter which is resistant to current flow
  - The most important reason is that electronegativity of AV nodal cells are -60 mV, but those of purkinje system are -90 mV.
* So the second electrical event is current passing through AV node, but during this time heart is electrically silent.

Sorry for the awful drawing XD

* The next electricial event, the current has come to right and left bundle branches and to purkinje system, which both of them are specialized in fast conduction

As depolarizing current enters the ventricles through bundle of His and right and left bundle branches, the first portion to be depolarized is interventricular septum, the next portion is the major part of the ventricle, and then the last portion of the ventricle (basal depolarization). This means depolarization of ventricles is in 3 stages

First the interventricular septum depolarizes. The upper part of the septum is fibrous, the lower is muscular

The fibrous tissue forms a sleeve around the bundle branches. It acts as an insulating layer.

Septal myocardium is stimulated by the left bundle branch. It produces a wave of depolarization in its lower left portion.

This wave moves from lower left portion in right and upward direction (direction of vector)

During interventricular septum depolarization a small vector is generated but is fast

After that through bundle branches and purkinje fibers wave of depolarization to the major ventricular myocardium

Purkinje fibers are in the deeper myocardium. We have inner, middle and outer myocardium

So the first layer of the myocardium to depolarize is inner myocardium and then moves outward to middle and outer layer

The depolarization vector of left ventricle is greater than right ventricle because it is thicker.

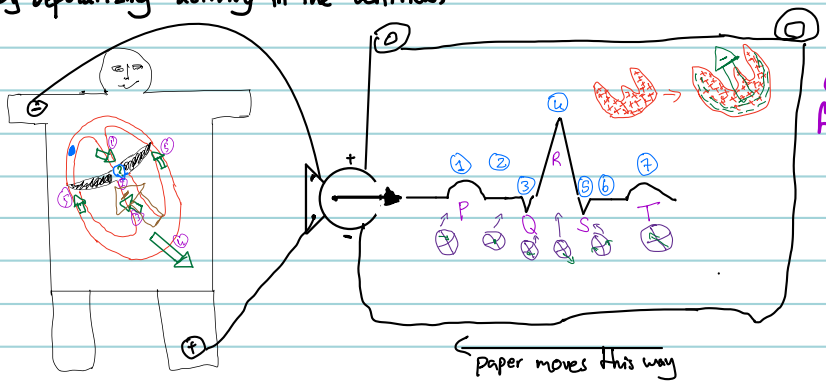
Many vectors are produced simultaneously, they can be added to generate a vector representing right and left ventricle. But the vector of the left ventricle will be greater.

Again these two vectors can be added, because they occur simultaneously, the net vector of the major ventricles will be in down and leftward direction.

Once the septum and major ventricles depolarize eventually depolarization reaches basal part of ventricles.

Here in base of ventricles, wave of depolarization moves right and upward and so the vectors of it.

When ventricular depolarization process start, At that time atria is undergoing repolarization. So repolarizing current in the atria is masked by depolarizing activity in the ventricles



Because our skin is a good conductor electrical activity of the heart can be detected by a galvanometer

If we put the positive electrode on the left leg and the negative electrode on the right arm of a patient and record electrical activity we will see:

When there is no electrical activity there will be no deflection only a straight line.

(1) Then suddenly SA node fires, first electrical event starts and atrial vector is produced. Since the vector is directed downward and leftward and we put the positive electrode on the left, this means the depolarization is moving towards the positive electrode. The atria is thin and has a moderate velocity. As a result deflection will be positive and small in magnitude. When atria fully depolarize, needle comes back to zero

(2) The next electrical event is AV nodal depolarization, but there is no significant electrical activity to move the needle. During this time heart is electrically silent.

(3) Suddenly current is released to purkinje system and ventricular depolarization starts. It is in 3 stages, the first one is depolarization of the ventricular septum. Its vector is upward to the right, small in magnitude, specialized in fast conduction. since it moves away from positive electrode it produces a negative deflection.

(4) The next electrical event is that current is moving into major ventricular myocardium. The vector produced is strong and fast. it is directed towards left and downward. this leads to a positive deflection

(5) The last event in ventricular depolarization is in basal part of the ventricles. when depolarization reaches there, it produces small vectors pointed up and right. They move away so produces negative deflection

⑥ At the end of QRS, both ventricles are completely depolarized. During this time there is no needle deflection

⑦ After this, ventricular repolarization starts. The part depolarized last will repolarize first. So the first area to repolarize is outer area and it moves inward. This means the direction of repolarization is exactly opposite to depolarization.

* The repolarization is moving rightward and upward.
* The repolarization moves from outer myocardium to inner myocardium, because outer myocardium has better blood supply during the systole as compared to the inner. Because during contraction outer layer compresses inner and middle layer, so blood supply will be stopped.
* We have only one vector in repolarization, because it is a slow process. K^+ channels are dead fast
* Since repolarization is negative and moves toward negative electrode, it produces a positive deflection. Also it has a moderate velocity, so needle moves gradually

* Isoelectric line is a line where need is not deflected at any direction.
* We have PR segment which represents AV nodal activity
* We also have ST segment representing both ventricles are completely depolarized and yet repolarization hasn't started
* Atrial repolarization is not recorded in the ECG pattern, because it is masked by QRS

ECG pattern and Depolarization graph timing!

* Onset of myocardial depolarization on the ECG is represented by QRS (voltage gated Na channels open)
* After depolarization, there is a plateau phase (calcium and potassium ions are open). this is shown in the ECG as ST segment

Different types of waves, segments and intervals of ECG pattern

① Waves

* They are produced due deflections of the needle during the ECG recording
* We have P, Q, R, S, T waves

② Segments

* They are lines where there is no deflection of the needle
* We have PR segment and ST segment

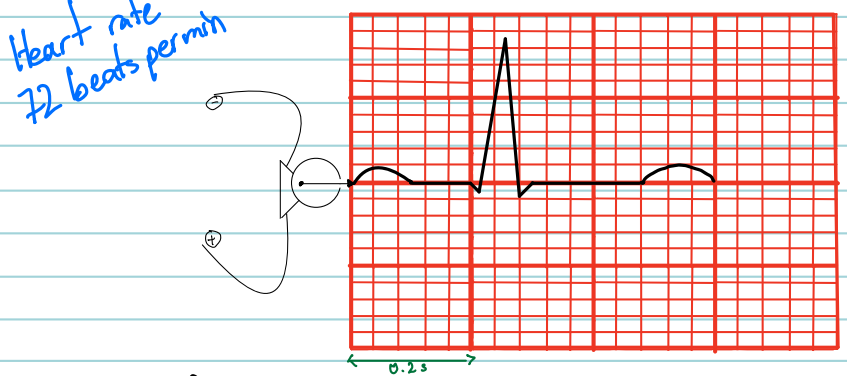
③ Intervals

* They are sum of some waves and segments. More than one wave together or Some wave plus segment
* At the beginning of the P wave to the beginning of QRS complex is called PR interval. It is a duration which current starts from SA node and depolarizes atria and then current passing into AV node.
* QRS interval is current spreading over ventricles
* At the beginning of QRS to the End of T wave is called QT interval. which shows ventricular systole and the first heart sound is heard at Q. At the End of T wave which is the onset of Diastole the second heart sound will be heard (closing of SL valve)

* Sometimes there is a small wave called "U" wave after T wave
* U wave is electrical activity in the papillary muscle. This occurs when the electrical activity in the papillary muscle is out of phase with the rest of the ventricle.
* So ventricular Depolarization and repolarization terminate, and after that electrical activity is still present due to ventricular papillary muscles

Timings and Durations of different ECG Waves, Segments and intervals

* ECG pattern is a drawing on a special caliberated paper



300 big sq = 60 seconds = 1 min
1 big sq = 0.2 second
1 big sq = 5 small sq = 0.2 second
1 small sq = 0.04 second

2.5 small sq. = 0.1 second

* The speed of the paper is 300 big squares in one minute.
* P waves take two and half sma squares.
* After that is PR segment which also takes two and half small squares.
* After that is QRS complex which is also two and half small squares.
* Until now each one of them took 0.1 second.
* from beginning ventricular depolarization to end of ventricular repolarization is 10-11 small squares. (QT interval)
* These numbers might slightly differ