Al-Mustaqbal University

College of Engineering and Technologies

Biomedical Engineering Department

Systemic Physiology I

Lecture: 4

The Electrocardiogram (ECG or EKG)

Prepared by:

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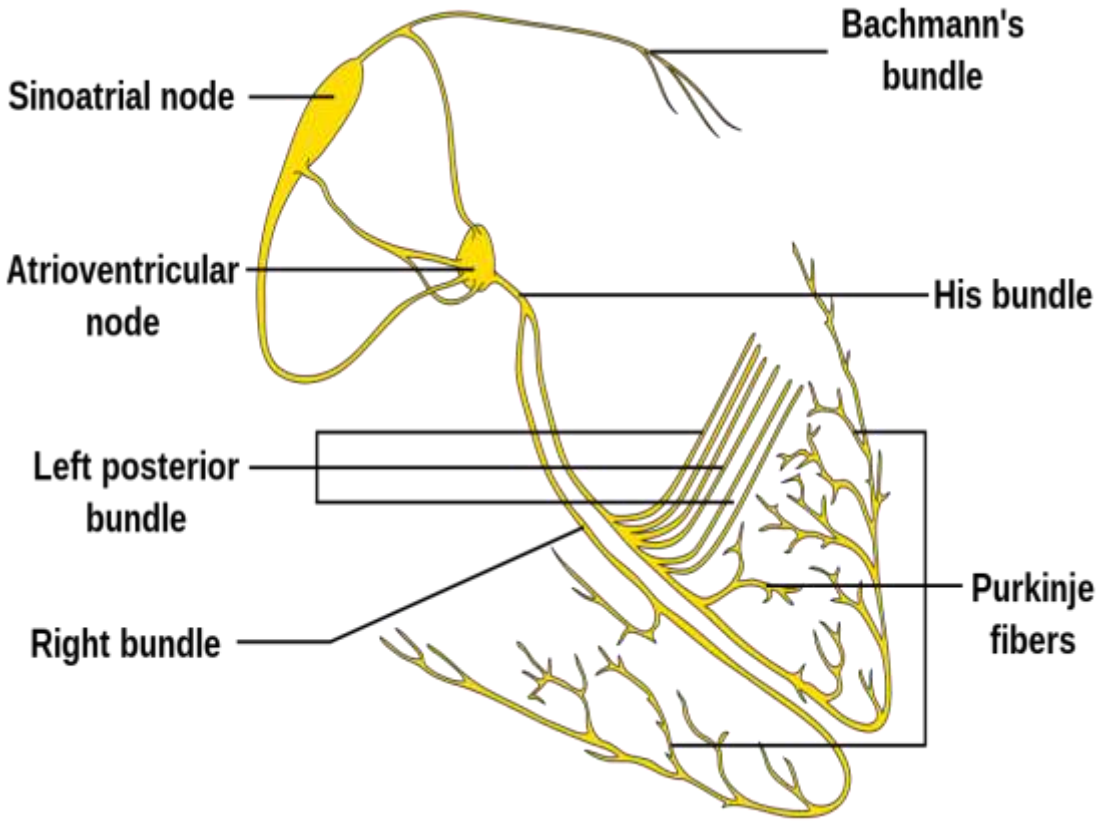

Figure (1). Cardiac electro-conduction system.

The Electrocardiogram (ECG or EKG)

The electrical activity of the heart produces potentials at body surfaces that can be recorded by placing surface electrodes, as the EKG. The electric currents from the heart pass into the surrounding tissues and spread to the surface of the body. The cardiac activity is obtained in the standard ECG by using 12 leads, six of which are limb leads and six are chest leads.

Clinical application of ECG

ECG is a non-invasive, inexpensive, and highly versatile test. By analyzing the details of these potential fluctuations, the physicians gain valuable insight concerning:

▪ The anatomical orientation of the heart.

▪ Relative sizes of its chambers.

▪ A variety of disturbances of rhythm of conduction.

▪ The extent, location, and progress of ischemic damage to the myocardium.

▪ The effects of altered electrolyte concentrations (e.g., hyperkalemia).

▪ The influence of certain drugs (notably digitalis and its derivatives).

Analysis of the EKG:

1. The 'P' wave

• Represents atrial depolarization & precedes contraction of the atria.

• Its duration indicates the time taken for the depolarization to spread through the atria from the SA node (0.08-0.10 sec).

2. The QRS Complex: consists of 'Q', 'R' &the 'S' waves.

- The complex represents ventricular depolarization preceding ventricular contraction.
  - Duration: 0.06 to 0.09 second.
  - It has higher amplitude than that of 'P' wave.
  - It has a shorter duration than the 'P' wave, because depolarization spreads very quickly through the purkinje network.
  - The large QRS complex completely masks obliterates any record of atrial repolarization, which occurs at this time.
  - Prolongation of QRS complex: indicates delayed conduction through the ventricles, is often caused by ventricular hypertrophy, with its increased muscle mass, and also increases the voltage of

the QRS complex. Another cause is conduction block of one of the bundle branches.

PR interval: it is an important parameter of the ECG; it is the time taken from the start of depolarization of the atria to the beginning of ventricular depolarization. Normal interval 0.12- 0.20 sec.

The S-T segment

• The S-T Segment is the flat base line/isoelectric line between the QRS complex and the T-wave.

• This segment represents the time during which all regions of the ventricles are still depolarized and presents the long plateau phase of the cardiac action potential.

• Has a duration of about 0.09 second.

• Is distorted in myocardial infarction.

The 'T' wave

• Represents ventricular repolarization.

• Its duration is longer than that of the QRS complex because repolarization is not synchronous throughout the ventricles like depolarization which is more synchronous.

The QT Interval coincides with the beginning and the end of ventricular systole. It lasts about 0.30 second, a time that varies with the heart rate.

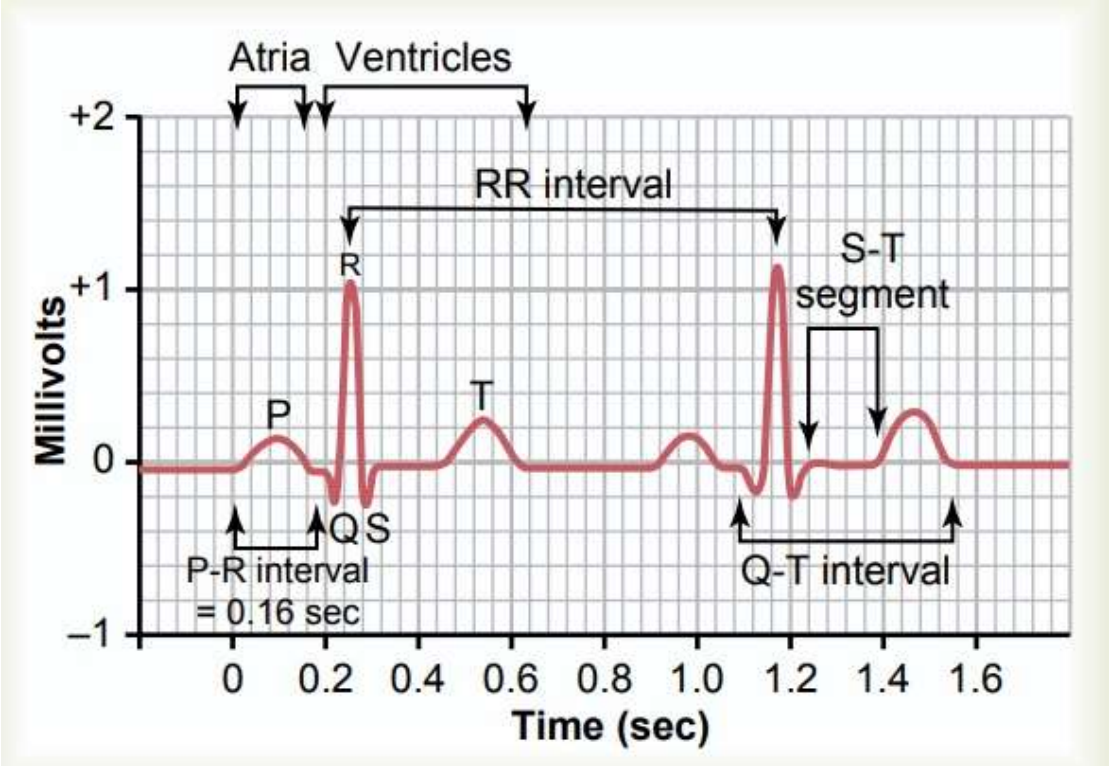

Figure (2). Normal Electrocardiogram.

Interpretation of ECG

An ECG provides information on heart rate and rhythm, conduction velocity, and even the condition of tissues Within the heart. The interpretation of an ECG begins with the following questions:

(1) What is heart rate?

Heart rate is normally timed from the beginning of one P wave to the beginning of the next P wave, or from Peak to peak of the QRS complexes. A faster rate is called tachycardia, and a slower rate is called bradycardia.

(2) Does the heartbeat occur at regular interval?

An irregular rhythm, or arrhythmia, can result from a benign extra beat or from more serious conditions such as atrial fibrillation, in which the SA node has lost control of pace making.

(3) Is the voltage normal?

Normally, the voltages in the three standard bipolar limb leads, as measured from the peak of the R wave to the bottom of the S wave, vary between 0.5mV and 2.0mV, with lead III usually recording the lowest and Lead II, the highest. However, these relations are not invariably true even in the normal heart. In general, When the sum of the voltages of all the QRS complexes of the three standard leads is greater than 4mV, one considers that the patient has a high-voltage ECG.

High-voltage ECG is common in ventricular hypertrophy. Low-voltage ECG is found in cardiac myopathies, fluid in the pericardium, pulmonary emphysema etc.

(4) Relationship of various waves

After determining the heart rate and rhythm, and voltage of ECG, the next stage in analyzing an ECG is to look at the relationship of the various waves. Does a QRS complex follow each P wave and is the PR segment constant in length? If not, a problem with conduction of signals through the AV node may exist. In heart block, action potentials from the SA node sometimes fail to be transmitted through the AV node to the ventricles. In these conditions, one or more P waves may occur without initiating a QRS complex.

(5) Alterations in the shape or duration of various waves or segments

The more difficult aspects of interpreting an ECG include looking for subtle changes such as alterations in the shape or duration of various waves or segments.

The cardiac cycle

The cardiac cycle is the period from the end of one heart contraction (Systole) and relaxation (diastole) to the end of next systole and diastole.

Cardiac contraction is preceded by electrical changes initiated by the pacemaker of the heart, the sino-atrial node. The contraction of the heart generates pressures within the heart that regulates the opening and closing of the valves and consequently directs the blood flow through the heart and the arteries. Electrical changes are recorded on the electrocardiogram, and the heart sounds are recorded on a phonocardiogram. Similar events occur in the right and left side of the heart, but ventricular and atrial pressures are lower in the right heart. At a heart rate of 75 beats/min, the total cycle time is about 800 milliseconds, a systolic time of 250 - 300 msec, a diastolic time of 500 - 550 msec.

Systole and diastole

Systole is contraction of the heart, relaxation is diastole. Each of the four chambers of the heart contract and relax rhythmically, filling with blood during diastole, ejecting the blood during systole. The right and left heart contract and relax simultaneously, ejecting equal blood volume at the same time, but with different pressures.

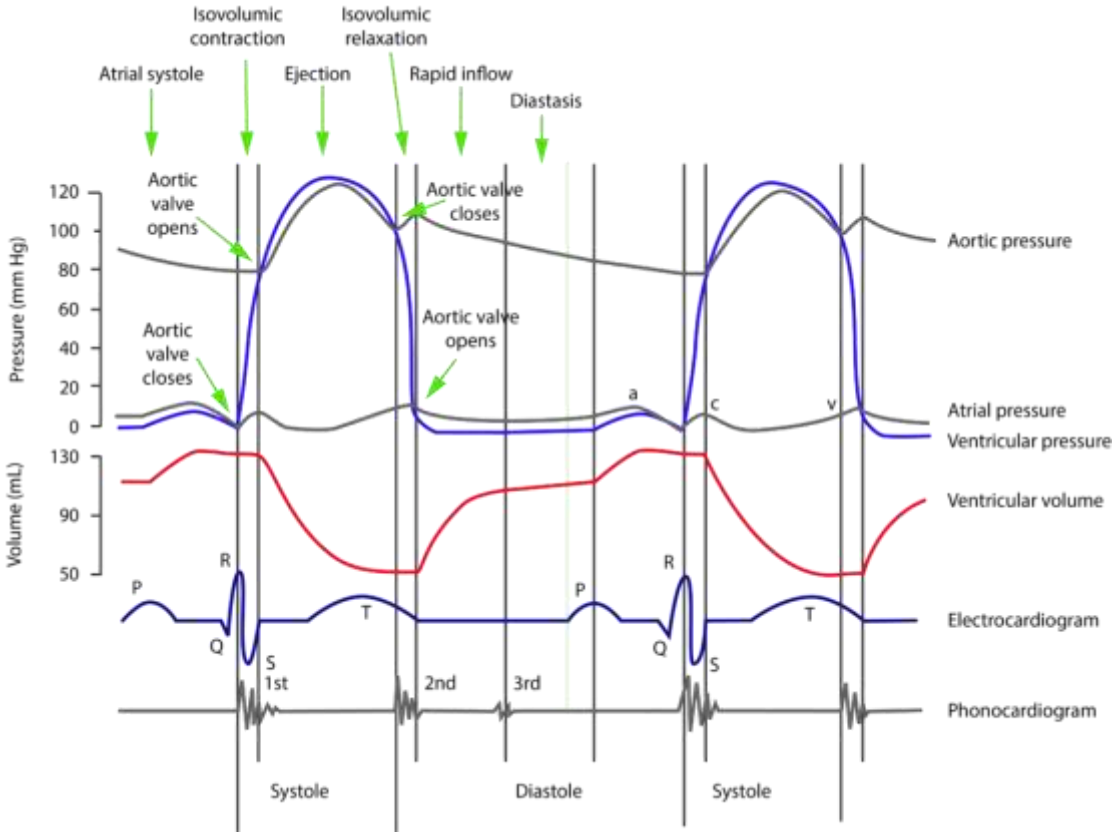

Figure (3). Cardiac cycle.

Cardiac output

Cardiac output is the amount of blood ejected by either ventricle per minute. The volume of blood returning to the left atrium from the lungs is the same volume, which was released by the right ventricle to the lungs; the output of the right and left ventricles is normally the same.

Cardiac output of a young adult female 67 kg, reclining = about 5L/min. "male of same age & wt = 10% more = 5.5 L/min.

Cardiac Reserve: Cardiac reserve is the difference between the Cardiac Output at rest and the maximum amount the heart is capable of pumping per minute. Cardiac output is affected by age, changes in posture, and exercise. It may be 20 –25 L/min in exercise and in very severe strenuous exercise in a trained athlete 35 – 40 L/min.

During anytime, the volume of blood flowing through the pulmonary circulation is the same as flowing through the systemic circulation. The two determinants of cardiac output are heart rate (beats/min) and stroke volume (SV) i.e. volume of blood pumped/beat or stroke.

***stroke volume (SV):** the volume of blood pumped out of the left ventricle of the heart during each systolic cardiac contraction.

The average HR= 70 beats/min (established by SA Node rhythmicity)

"SV =70 ml/beat

"CO = 70 x 70 = 4900 ml/min or close to 5 liter/min

The body's total blood volume averages 5 to 5.5 liters, each ventricle pumps the equivalent amount of blood/minute; right ventricle to the lungs and the left through the systemic circulation.

Factors Influencing Cardiac Output

The most important factors influencing Cardiac Output are of two categories:

1. Cardiac factors: heart rate & stroke volume, sympathetic stimulation and myocardial contractility؛

2. Systemic factors: Venous return is an important controlling factor. The heart is a "demand pump" adjusting its output to the demand of the body organisms.

Heart rate is determined primarily by influence on the SA node. The sino-atrial node (SA Node) is the pacemaker of the heart as it has highest rate of spontaneous depolarization due to a complex interplay of ions: low potassium constantly increasing sodium and increasing calcium Permeability. This action potential spreads through the heart, inducing the

heart to contract or have a “heart beat”. This happens at about 70 beats/min.

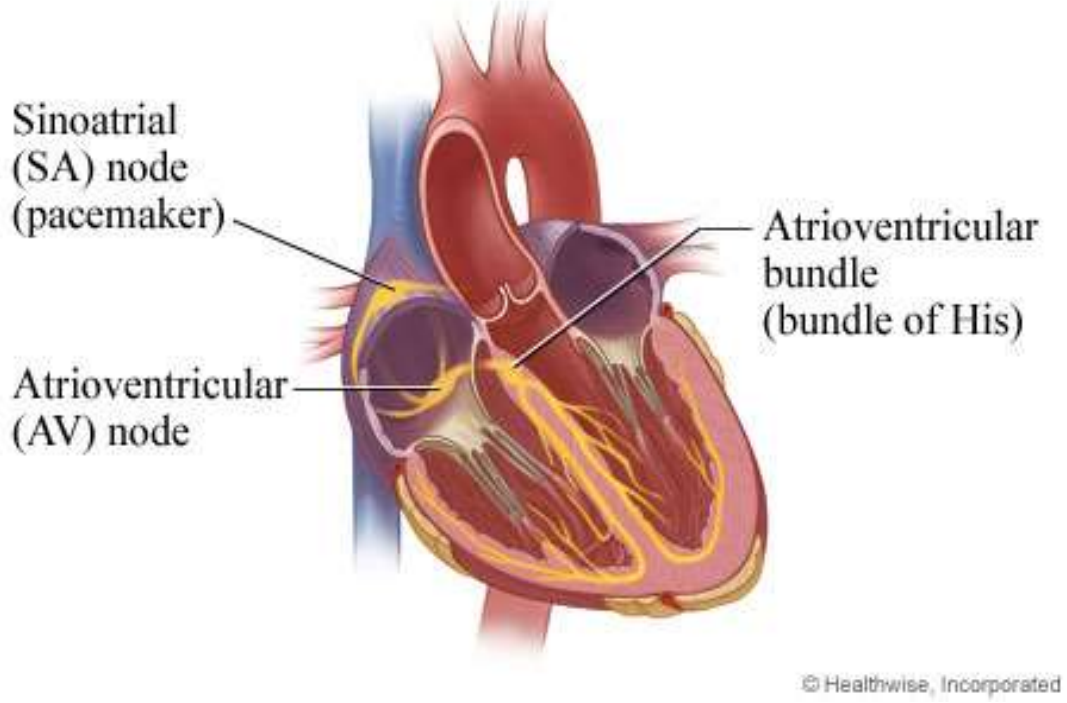

Figure (4). Sino-atrial Node (SA)….. (Pacemaker)