

## LECTURE 4

### *TOPIC: BIOPHYSICAL BASICS OF ELECTROCARDIOGRAPHY AND BLOOD PRESSURE MEASUREMENT TECHNIQUES*

*TIME: 2 HOURS*

The ECG - is a graphic representation of the electrical forces produced by the heart. It is a simple, useful and practical diagnostic test that has limitation and pitfalls. Knowledge of the clinical data is extremely helpful and important in arriving at an accurate ECG interpretation. There is definitely a distinct advantage of interpreting the ECG immediately "at the bedside". The ECG interpreter should know that there is a wide range of "normals" and that there may be an overlap between normal and pathologic findings. Coexisting factors such as drugs, electrolytes, body habitus, etc. can influence the ECG tracing. Additionally technical and real pitfalls (myocardial infarction in left bundle branch block, tachycardia, aberration etc.) must be recognized to avoid errors in interpretation and treatment. Often clear - cut diagnoses are not possible. Some tracings may not be unraveled by the most experienced interpreter. The correct ECG diagnosis required a knowledgeable ECG interpreter with intelligence, judiciousness, proper perspective and as such clinical data as possible at the time of interpretation. The aim of the lecture is explanation of biophysical principles of electrocardiography. An interpretation and clinical usefulness is rather reserved for cardiology.

### ANATOMY OF THE HEART AND CONDUCTING SYSTEM

A brief review of the heart's anatomy and conducting system is in order. The heart is divided into four chambers: right atrium, right ventricle, left atrium, left ventricle. The upper chambers, right and left atria, receive the blood from the systemic (body) and pulmonary (lung) circulations, respectively. The lower right and left ventricles propel blood to the circulations. The right ventricle pumps blood into the lungs (pulmonary circulation). The left ventricle pumps blood into the body (systemic circulation). Both ventricles contract together to pump blood into the pulmonary and systemic circulations. The process of contraction is initiated and maintained by the heart's electrical forces, which are recorded by the ECG.

Impulse formation and conduction (conducting system): the ECG is simply a display of the electrical currents that are generated by the heart and are spread through the surrounding tissue to the surface of the body. The electrical impulses are picked up by the surface electrodes and are then recorded in the ECG.

Involved in the process of electrical impulse formation, conduction and mechanical contraction are three types of heart cells:

1. *Pacemaker cells* initiate the electrical impulses. Normally pacemaker cells in the sinoatrial (SA) node start the electrical sequence, however other pacemaker cells are located throughout the heart.
2. *Specialized conducting cells* conduct the electrical impulses. The specialized conducting system consists of the SA node, atrial internodal pathways, arterioventricular (AV) node, bundle of His, right and left bundle branches, left anterior and posterior fascicles and Purkinje fibers.
3. *Muscle cells* have the functions of electrical conduction and mechanical contraction. These cells make up the majority of the mass of the atria and ventricles.

The pacemaker cells and specialized conducting cells transmit impulses too rapidly to be recorded in the ECG. Importantly, the surface ECG records electrical activity from only the

muscle cells. Stimulation of muscle cells causes mechanical contraction, which produces the normal heartbeat.

### ECG LEADS

The conventional records 12 leads. These twelve leads consist of the following:

- six **limb or extremity leads** designated standard limb leads I, II, III and unipolar limb leads aVR, aVL, aVF. These leads are derived from electrodes placed on the right arm, left arm and left leg. The right leg electrode acts as a grounding electrode.
- six **chest or precordial leads** designated V1, V2, V3, V4, V5, V6. These leads are derived from six electrodes placed on the chest in designated areas.

The conventional ECG machine records one lead at a time. Other machines may record 3 leads, 6 leads or even 12 leads simultaneously.

Placement of the limb electrodes is shown on the following figure. Electrodes are placed on the right arm (RA), left arm (LA) and left leg (LL). The right leg electrode (RL) is a ground electrode. The electrode on each extremity records electrical forces from the heart as viewed from the junction of that extremity with the body. In other words, the right and left arm electrodes record forces presented to the right and left shoulders, respectively the left leg electrode records forces presented to the left thigh. As an example, a patient with a left thigh amputation may have the electrode placed above the amputation site without alternating the ECG. The illustration on the right shows positions of the chest electrodes. The conventional six chest electrode sites are as follows:

V1: fourth intercostal space, right sternal border

V2: fourth intercostal space, left sternal border

V3: midway between V2 and V4

V4: fifth or sixth intercostal space (where apex of the heart is felt), midclavicular line

V5: anterior axillary line, same level with V4

V6: midaxillary line, same level with V4 and V5

### STANDARD LIMB LEADS

The six limb leads are divided into three bipolar and three unipolar leads. The bipolar leads are designated standard leads I, II, III. Each bipolar lead is actually a tracing of the electrical forces recorded between two extremities at one time. The unipolar leads record electrical forces from one extremity at a time in relation to a central terminal. The illustration shows three bipolar standard limb leads (I, II, III) and the two limb electrodes that are used to record each bipolar lead:

LEAD I: right arm to left arm

LEAD II: right arm to left leg

LEAD III: left arm to left leg

Each bipolar lead (I, II, III) has a designated positive (+) and negative (-) end.

### EINTHOVEN TRIANGLE

The three standard leads (I, II, III) may be transported into an equilateral triangle called the Einthoven triangle. The Einthoven triangle concept postulates that the three limb leads form an equilateral triangle with the heart in the center of the triangle. When the three sides of the triangle are transported to a common central point, a triaxial (3 axis) reference system is produced. This reference system is useful in determining axis (about vector and axis later).

## BASIC ECG PRINCIPLES

Each heartbeat is comprised of two electrical processes: *depolarisation and repolarization*. During depolarization, the positive electrical charges on the surface of the myocardial cells change to negative charges. The muscle cells are activated to contract during depolarization. Depolarization is followed by repolarization, return to the resting electrical state. During repolarization is necessary before depolarization can recur. If the myocardial cells are not allowed to repolarize fully (return to their resting electrical state), the cells will be refractory to the next electrical impulse. Thus, every depolarization (electrical activation) is followed by repolarization (return to the resting electrical state).

## RECORDING DEPOLARIZATION AND REPOLARIZATION

The ECG records the electrical processes of depolarization and repolarization for each heartbeat.

## ECG MEASUREMENT

The depolarization and repolarization processes are recorded as deflections in the ECG. Nomenclature of the deflections and waves in the normal electrography include the following:

P wave - depolarization of right and left atria

QRS complex - depolarization of right and left ventricles

ST segment - beginning of ventricular repolarization measured from the end of the QRS complex to the beginning of the T wave. The beginning of the ST segment is termed J point

T wave - repolarization of right and left ventricles

U wave - not always seen, but when present it immediately follows the T wave and probably represents late repolarization.

Basic ECG measurements include the following:

- P - R interval: interval measured from the beginning of P wave to the beginning of the QRS complex. This interval represents the time for the impulse to travel from SA node through the specialized atrial conduction pathways, entire musculature of both atria, AV node, Bundle of His, the ventricular bundle branches to the Purkinje cells in the ventricles. The P - R interval includes depolarization of atrial muscle cells and passage of the impulse to the point of ventricular muscle stimulation (0.12 - 0.2 second).

- QRS duration: interval from the beginning to the end of the QRS complex (0.06 - 0.1 second).

- Q - T interval: interval measured from the beginning of QRS complex to the end of the T wave (about 0.43 second).

## AXIS

Axis is simply the major direction that the heart's electrical forces travel in relation to the frontal plane of the body. The major directions of the depolarization forces in the atria (mean P axis) or ventricles (mean QRS axis), as well as the major directions of the repolarization forces in the ventricles (mean ST and T axis), can be determined by examining the ECG. Axis is an important ECG concept to understand, because many ECG diagnoses involve abnormalities in the axis. Determination of the mean QRS axis is most important and should be calculated in every electrocardiography. The range of normal mean QRS axis lies between +90 degree and -30 degree in the hexaxial reference system. The rest means deviations.

## BLOOD PRESSURE

Most of the blood volume is distributed in the veins of the systemic circulation. About 84% of the total blood volume is in the systemic circulation, 9% is in the pulmonary circulation and 7% is in the heart.

1. Blood flow is determined by the pressure gradient and the resistance to blood flow. When a blood vessel has a high pressure at one end and lower pressure at the other, the rate of blood flow through the vessel is directly proportional to the difference in pressure between the two ends of the vessel and inversely proportional to the resistance to blood flow along the vessel. The relationship can be expressed as:

$$\text{Blood flow (Q)} = \text{pressure difference (P)} / \text{resistance (R)}$$

Blood pressure is usually expressed in millimeters of mercury (mmHg).

2. According to the theory of Poiseuille, vascular resistance is directly proportional to the viscosity of the blood and the length of the blood vessel and inversely proportional to the radius of the vessel raised to the fourth power;

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$$\text{Resistance (R)} = (\text{constant} \times \text{viscosity} \times \text{length}) / \text{radius}^4$$

3. Total resistance can be expressed as follows:

$$1 / R_{\text{total}} = 1 / R_1 + 1 / R_2 + \dots + 1 / R_n$$

where R<sub>1</sub>, R<sub>2</sub>, R<sub>n</sub> are the resistances of the various vascular beds in the circulation

4. Vascular compliance (capacitance) - the total quantity of blood that can be stored in a given part of the circulation for each millimeter of mercury of pressure is called the compliance (capacitance) of the vascular bed:

$$\text{Vascular compliance} = \text{volume} / \text{pressure}$$

### TYPES OF PRESSURE

systolic pressure - highest point during the aortic pressure rising

diastolic pressure - lowest point during the aortic pressure falling

In the normal adult, the systolic pressure is approximately 120 mmHg and diastolic pressure is 80 mmHg. This is usually 120/80.

pulse pressure - difference between systolic and diastolic pressure (120 - 80 mmHg = 40 mmHg)

mean arterial pressure - is not simply the value halfway between systolic and diastolic.

$$\text{mean pressure} = 2/3 \text{ diastolic pressure} + 1/3 \text{ systolic pressure}$$

$$\text{example: } (2/3 \times 80) + (1/3 \times 120) = 93 \text{ mmHg}$$

### AUSCULTATORY METHOD

An auscultatory method is for determining systolic and diastolic arterial pressures. A stethoscope is placed over the antecubital artery and a blood pressure cuff is inflated around the upper arm. As long as the cuff compresses the arm with so little pressure that the artery remains distended with blood, no sounds are heard by the stethoscope. When the cuff pressure is great enough to close the artery during part of the arterial pressure cycle, a sound is then heard with each pulsation - these sounds are called Korotkoff sounds

In determining blood pressure first heard sounds are connected with a systolic pressure, last Korotkoff sounds are reserved for diastolic pressure.

## LITERATURE

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