ELECTRO MYO GRAPHY (EMG)

Electromyography is the science of recording and interpreting the electrical activity of muscle‘s action potential. The recording of peripheral nerve‘s action potentials is called electroneurography

Electrodes used

- EMG is usually recorded by using surface electrodes or needle electrodes, which are directly inserted into the muscles.
- Surface electrodes or needle electrodes pick up the potentials produced by contracting muscle fibers.
- The surface of the skin is cleaned and electrode paste is applied.
- The needle is inserted into the muscle to record the action potentials from a single nerve, microelectrodes are used.

Some symptoms which make to test EMG include:

- Pain or cramping Tingling or numbness Muscle weakness Setup of EMG
- The surface electrode or needle electrodes pick up the potentials produced by contracting muscle fibers.
- After an electrode has been inserted, patient may be asked to contract the muscle, for example, by lifting or bending your leg. The action potential (size and shape of the wave) that this creates on the oscilloscope provides information about the ability of the muscle to respond when the nerves are stimulated

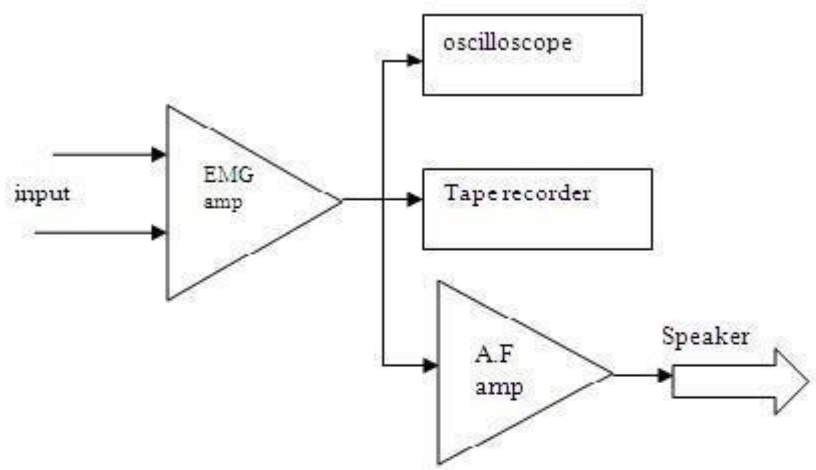


Fig:1.71 Block Diagram for EMG Recording Setup

[Source: Khandpur, R.S., ―Handbook of Biomedical Instrumentation]

- EMG recording instruments includes audio amplifier and loud speaker to permit the operator to hear.
- The audio presentation helpful in placement of needle or wire electrodes into a muscle.
- The oscilloscope displays EMG waveform.
- The tape recorder is used to study of EMG sound waveforms.
- Related procedure that may be performed is nerve conduction study (NCS) can be done by nerve conduction measurement.
- NCS is a measurement of the amount and speed of conduction of an electrical impulse through a nerve.
- The technician puts electrode patches on the skin over the nerve. A stimulating electrode sends a mild electrical impulse to the nerve. The other electrodes record the nerve's response.

- NCS can determine nerve damage and destruction, and is often performed at the same time as EMG.
- Both procedures help to detect the presence, location, and extent of diseases that damage the nerves and muscles.

EMG and NCS are helpful in diagnosing:

- Neuromuscular diseases, such as muscular dystrophy.
- Nerve problems in the spine, such as a herniated disk
- Nerve problems elsewhere in the body, such as carpal tunnel syndrome.
- Peripheral nerve problems in your arms or legs
- Pinched nerves.
- Guillain-Barré syndrome, a disease in which the immune system attacks the nerves in your legs and arms.

During this EMG measurement

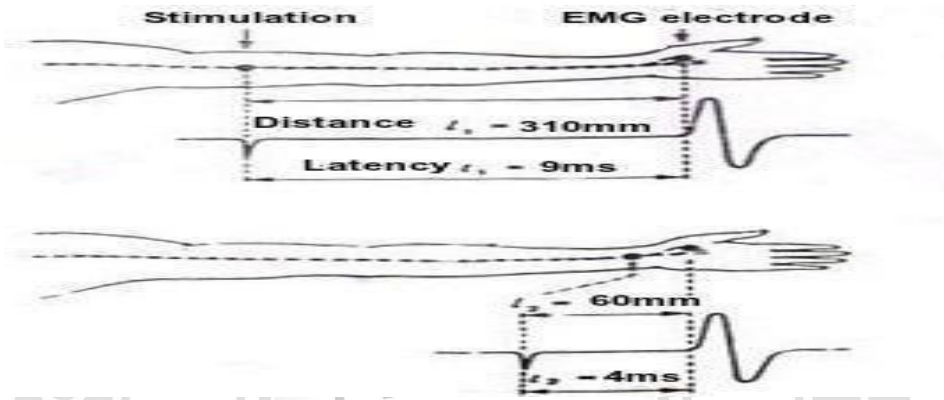
- When the study is underway, the surface electrodes will at times transmit a tiny electrical current that patient may feel as a twinge or spasm.
- The needle electrode may cause discomfort or pain that usually ends shortly after the needle is removed.

Determination of conduction velocities in motor nerves.

- The measurement of conduction velocity is used to indicate the location and type of nerve lesion
- The EMG electrode and stimulating electrode are placed at two points on the skin, separated by a known distance l1.An electrical pulse is applied through the stimulating electrode. The latency is now measured as ‗ t2‘seconds. The

conduction velocity is U = l1- l2 / t1 –t2

- The conduction velocity in peripheral nerves is normally 50 m/s. when it is below 40 m/s, there is some disorder in nerve conduction.



- **Fig 1.7.2 : Determination of Conduction Velocity in a Motor Nerve**

[Source: Khandpur, R.S., ―Handbook of Biomedical Instrumentation]

PHONOCARDIOGRAPHY (PCG):

The graphic record of the heart sounds is called ―Phonogram. Since the sound is from the heart, it is called phonocardiogram. The instrument used to measure the heart sounds is called phonocardiograph.

1) Heart sounds
2) Murmurs

Heart sounds have a transient character and are of short duration. Heart murmurs have a noisy characteristic and last for a longer time. Heart sounds are due to the closing and opening of valves whereas murmurs are due to turbulent flow of blood in the heart and large vessels.

Heart sounds

Heart sounds are classified into four groups based on their origin. They are

1) Valve closure sounds
2) Ventricular Filling sounds
3) Valve opening Sounds
4) Extra cardiac sounds

1) Valve Closure Sounds

The sounds occur at the beginning of systole (First heart sound) and the beginning of diastole (Second heart sound). The first heart sound is due to the closure of mitral and tricuspid valves. The second heart sound is due to the closure of aortic and pulmonary valves.

2) Ventricular filling sounds.

These sounds occur either at the period of rapid filling of the ventricles (Third heart sounds) or during the terminal phase of ventricular filling (ie) atrial contraction. These sounds are normally in audible.

3) Valve opening sounds

They occur at the time of opening of atrio – ventricular valves and semilunar valves.

4) Extra cardiac sounds

They occur in mid (or) late systole (or) early diastole. They are caused by thickened pericardium which limites ventricular distensibility.

Physical characteristics of sound

Heart sounds and murmurs are characterized by three physical properties.

They are

1) **Frequency**
2) **Amplitude**
3) **Quality**

1) Frequency: All heart sounds and murmurs are made up of frequencies between 10 and 1000 Hz. They are divided into low, medium and high- pitch frequencies

i)Low range: 10 – 60 Hz. It is represented by the third and fourth heart sounds.

ii) Medium range: 60 – 150 Hz. It is represented by the first and second heart sounds.

iii) High range: 150 – 1000 Hz. It is represented by snaps, clicks and diastolic murmurs of aortic and pulmonary insufficiency.

1) **Amplitude:** Low frequency heart sounds have the biggest amplitude while the high frequency murmurs have small amplitudes.

2) **Quality:** quality depends upon the overtones (or) harmonics accompanying the fundamental frequency and applies to tones.

Origin of the heart sounds.

There are four separate heart sounds that occur during the sequence of one complete cardiac cycle.

1) **First heart sound:** It is produced by a sudden closure of mitral and tricuspid valves associated with myocardial contraction.

a) Timing: The low frequency vibrations occur approximately 0.05 sec after the onset of QRS complex of ECG.

b) Duration: It lasts for 0.1 to 0.12 sec.

c) Frequency : The first heart sound range from 30 – 50 Hz

d) Asculatory area: The first heart sound is best heard at the apex of the mid pericardium.

Second heart sound: It is due to the closure of semi lunar valves (ie) the closure of aortic and pulmonary valves

a) Timing: The second heart sound start approximately 0.03 – 0.05 sec after the end of ‗T‘wave of ECG.

b) Duration : 0.08 – 0.14 sec

c) Frequency : 250 Hz

d) Asculatory Area: It is best heard in the aortic and pulmonary areas.

2) **Third heart sound:** It arises as the ventricles relax and the internal pressure drops well below the pressure in atrium.

a) Timing: It starts at 0.12 – 0.18 sec after onset of second heart sound.

b) Duration : 0.04 – 0.08 sec

c) Frequency : 10 – 100 Hz

d) Asculatory Area: It is best heard at the apex and left lateral position after lifting the legs.

3) **Fourth heart sound:** Also called as atrial sound. It is caused by an accelerated flow of blood into the ventricles or due to atrial contraction. It occurs immediately before the first heart sound.

a) Timing : it starts at 0.12-0.18 sec after the onset of p-wave

b) Duration :0.03-0.06 sec

c) Frequency :10-50 Hz

d) Ausculatory Area: Because of its low frequency, it is inaudible

Heart murmurs

Murmurs are sounds related to non – laminar flow of blood in the heart and the great vessels.

They are distinguished from heart sounds such that

1) They have noisy character.
2) They have longer duration
3) They are high frequency components upto 1000 Hz.

Typical conditions in cardiovascular system which cause turbulence in blood flow.

1) Local obstructions to blood flow
2) Abrupt change in blood stream diameter.
3) Pathologic communication in cardiovascular system.
4) Ruptured cardiac structures.
5) Valve insufficiency.

Transduction of heart sound

The sounds and murmurs originate from the heart which can be picked up from the chest using a stethoscope or by transduction of sound into electrical signals. The heart sounds are conducted from the heart to the cheat.

Recording setup:

The heart sounds are converted into electrical signals by means of a heart microphone. The electrical signals from microphone are amplified by a phonocardiographic preamplifier followed by suitable filters and recorder.

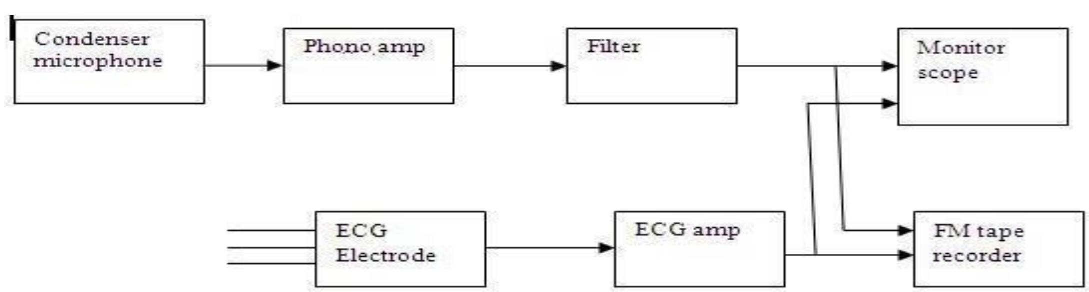


Fig.1.7.1: Block diagram of recording setup

[Source: Leslie Cromwell, ―Biomedical Instrumentation and Measurement‖, Prentice Hall of India, New Delhi, 2007. – Page: 227]

The electrodes are placed on the limbs to pickup the electrical activity of heart and these signals are amplified and recorded. This recorded ECG is used as a reference for PCG.

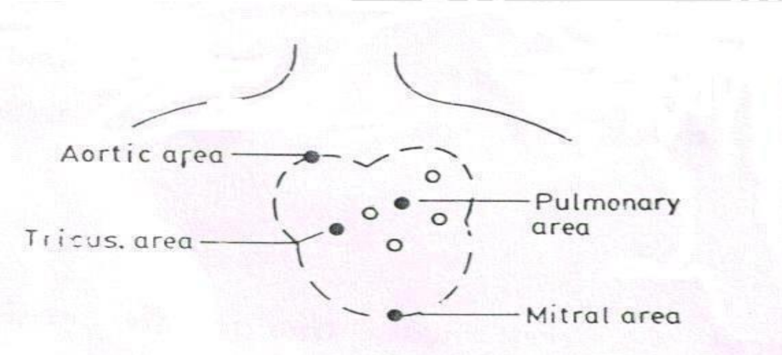


Fig1.7.2: Placement of Microphone on Different Areas of the chest for Recording PCG Heart Sound Microphone

[Source: Leslie Cromwell, ―Biomedical Instrumentation and Measurement‖, Prentice Hall of India, New Delhi, 2007. – Page: 228]

The conversion of heart sounds into electrical signals can be done using transducers. Via condenser microphone, moving coil microphone etc. The two main categories of microphones used in PCG are

1) The air coupled microphone
2) The contact microphone.

In the first case, the movement of chest is transferred via on air cushion and presents low mechanical impedance to chest.

C = Q/V

The vibrations produced by chest wall change the position of diaphragm which results in the change in voltage across electrode. The developed dc voltage is in the order of few mV.

Relationship between heart and function of cardiovascular system

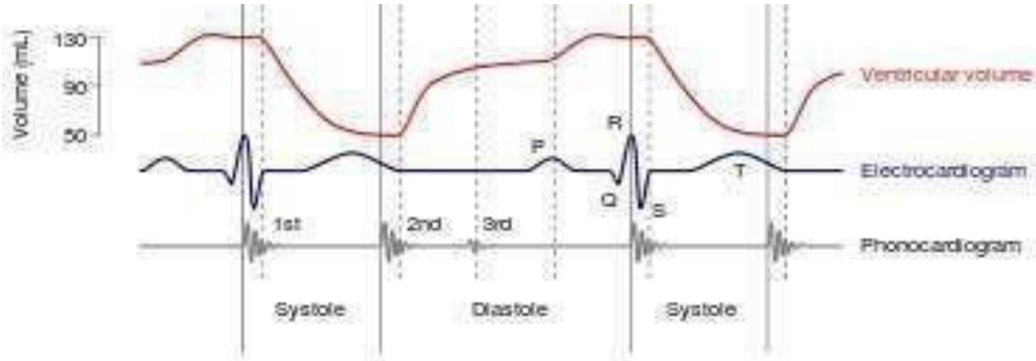


Fig 1.7.3: ECG waveform vs PCG waveform

[Source: Leslie Cromwell, ―Biomedical Instrumentation and Measurement‖, Prentice Hall of India, New Delhi, 2007. – Page: 229]

Medical Applications

Rheumatic Valvular Lesions

Valvular lesions results from rheumatic fever. Rheumatic fever is an allergic disease in which heart valves are damaged. This can be detected by phonocardiograph.

The valvular lesions cause the abnormal heart sounds as given below

1) The murmur of aortic steonosis
2) The murmur of aortic regurgitation
3) The murmur of mitral regurgitation
4) The murmur of mitral stenosis

Special applications of phonocardiogram

1) Fetal phonocardiogram
2) Esophageal phonocardiogram
3) Tracheal phonocardiogram

TYPICAL WAVEFORMS AND SIGNAL CHARACTERISTICS

P wave :

During normal atrial depolarization, the main electrical vector is directed from the SA node towards the AV node, and spreads from the right atrium to the left atrium. This turns into the P wave on the ECG, which is upright in II, III, and aVF (since the general electrical activity is going toward the positive electrode in those leads), and inverted in aVR (since it is going away from the positive electrode for that lead). A P wave must be upright in leads II and aVF and inverted in lead aVR to designate a cardiac rhythm as Sinus Rhythm.

- The relationship between P waves and QRS complexes helps distinguish various cardiac arrhythmias.
- The shape and duration of the P waves may indicate atrial enlargement.
- Absence of the P wave may indicate atrial fibrillation. A saw tooth formed P wave may indicate atrial flutter
- .The QRS complex is a structure on the ECG that corresponds to the depolarization of the ventricles.

  Because the ventricles contain more muscle mass than the atria, the QRS complex is larger than the P wave. In addition, because the His/Purkinje system coordinates the depolarization of the ventricles, the QRS complex tends to look "spiked" rather than rounded due to the increase in conduction velocity. A normal QRS complex is 0.08 to 0.12 sec (80 to 120 ms) in duration represented by three small squares or less, but any abnormality of conduction takes longer, and causes widened QRS complexes.

PR/PQ interval:

The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex. It is usually 120 to 200 ms long. On an ECG tracing, this corresponds to 3 to 5 small boxes. In case a Q wave was measured with a ECG the PR interval is also commonly named PQ interval instead

ST segment:

The ST segment connects the QRS complex and the T wave and has a duration of 0.08 to 0.12 sec (80 to 120 ms). It starts at the J point (junction between the QRS complex and ST segment) and ends at the beginning of the T wave. However, since it is usually difficult to determine exactly where the ST segment ends and the T wave begins, the relationship between the RT segment and T wave should be examined together. The typical ST segment duration is usually around 0.08 sec (80 ms). It should be essentially level with the PR and TP segment

T wave:

The T wave represents the repolarization (or recovery) of the ventricles. The interval from the beginning of the QRS complex to the apex of the T wave is referred to as the absolute refractory period. The last half of the T wave is referred to as the relative refractory period (or vulnerable period).

QT interval :

The QT interval is measured from the beginning of the QRS complex to the end of the T wave. Normal values for the QT interval are between 0.30 and 0.44 seconds. The QT interval as well as the corrected QT interval are important in the diagnosis of long QT syndrome and short QT syndrome. Long QT intervals may also be induced by antiarrythmic agents that block potassium channels in the cardiac myocyte. The QT interval varies based on the heart rate, and various correction factors have been developed to correct the QT interval for the heart rate. The QT interval represents on an ECG the total time needed for the ventricles to depolarize and repolarize.

U wave :

The U wave is not always seen. It is typically small, and, by definition, follows the T wave. U waves are thought to represent repolarization of the papillary muscles or Purkinje fibers. Prominent U waves are most often seen in hypokalemia, but may be present in hypercalcemia, thyrotoxicosis, or exposure to digitalis, epinephrine, and Class 1A and 3 antiarrhythmics, as well as in congenital long QT syndrome and in the setting of intracranial hemorrhage. An inverted U wave may represent myocardial ischemia or left ventricular volume overload.