PHONOCARDIOGRAPHY (PCG)

The technique of listening to sounds produced by the organs and vessels of the body is called auscultation. The areas at which the heart sounds are heard better are called auscultation area.

The graphic recording of the sounds connected with the pumping action of the heart is called phonocardiogram. These sounds are produced by vibrations set up in the blood inside the heart by the sudden closure of valves, movement of heart wall, closure of walls and turbulence and leakage of blood flow.

Heart sounds:

First heart sound (Lub):
It is due to closure of mitral and tricuspid valves which permit the flow of blood from atria into the ventricles i.e. it occur at the end of the atrial contraction and at beginning of the ventricular contraction. It occurs approximately 0.05 second after the onset of QRS complex and just before ventricular systole.

It has loud deep pitch and is booming in character. It is longer in duration, lower in frequency (30 - 45Hz) and greater in intensity than the second sound. The duration is 50 to 100msec. The auscultatory area i.e. it is best heard at the apex of mid pericardium.

Second heart sound (Dub):
It is occurs at the end of ventricular systole due to closure of semilunar valves (aortic and pulmonary aortic valves) in the arteries leading out of the ventricles. It occurs at 0.03-0.05 second after the end of T wave. It has higher pitch than the first sound and is snapping in character. It has frequency 50 - 70Hz. The duration is 25 to 50msec. The auscultatory area i.e. it is best heard in the aortic and pulmonary areas.

Third heart sound:
It is due to cessation of ventricular filling. It is heard in children and patient with left ventricular failure due to rapid inflow of blood from the atria into the ventricles. The accumulated blood from atria and veins causes the distention and vibration of ventricles. Frequency is below 30Hz. The duration is 0.1 to 0.2sec. It starts 0.12 – 0.18 second after the onset of second heart sound. The auscultatory area i.e. it is best heard at the apex and left lateral position after lifting the legs.

Fourth heart sound or atrial heart sound:
It is produced by the contraction of the atria. It is not audible due to low amplitude and frequency of vibrations. It occurs immediately before the first heart sound. It starts 0.12 – 0.18 second after the onset of P wave. The duration is 0.03 to 0.06 second. Frequency 10-50Hz.

The third and fourth sounds are called diastolic sounds and are generally inaudible in the normal adult but are commonly heard among children.

The figures shows the time relationships between the first, second and third heart sounds with respect to ECG.

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Uses: They provide indication of heart rate and its rhythmicity. They also give useful information regarding effectiveness of blood pumping and valve action.

Murmurs.

It occurs in abnormal hearts between normal heart sounds. They are higher pitched sounds in 100-600Hz range and are longer in duration compared to normal heart sounds.

The causes of murmurs are

1. High velocity blood flow that occurs through small opening when there is improper opening of valves.
2. Regurgitation which results when the valves do not close completely and allow some backward flow of blood.
3. Small opening in the septum that separates the left and right sides of the heart. This forces the blood through the opening from the left ventricle into right ventricle bypassing the systemic circulation.

The figure shows a record of normal heart sounds and several types of murmurs.

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Difference between heart sounds and murmurs.

Heart sound: Transient in character and are of shorter duration. Low frequency. It is mainly due to closing and opening of valves.

Murmurs: Noisy and higher pitched sounds in characteristic and long duration. Have high frequency (100 to 600Hz). It is due to turbulent flow of blood in the heart and large vessels.

Vibrocardiogram:

The vibrations produced by the side of the heart as it thumps against chest fall.

Apex cardiogram:

Produced when the tip or apex of the heart hits the rib cage.
Pulse:
It is felt with the finger tips at certain points on major arteries which approach the surface of the body.

Korotkoff sounds:
When an artery is partially occlude so that the blood velocity through the construction is increases sufficiently, identifiable sounds can be heard downstream through a stethoscope. These sounds are called Korotkoff sounds and are used in BP measurement.

Ballistocardiogram:
It is recording of the motions of the body due to the beating of the heart and the corresponding blood ejection into major arteries.

MEASUREMENT OF HEART SOUNDS

Acoustical stethoscope:
The principal instrument used for detection of heart sounds is acoustical stethoscope (stethos is greek word meaning chest and skopein means to examine). Stethoscope is a simple device that carries sound energy from the chest of the patient to the ear of the physician via a column of air. It has two earpieces connected to a common bell or chest piece. It has low fidelity and no amplification.

Electronic stethoscope:
An improvement over the acoustical stethoscope is electronic stethoscope consisting of microphone, amplifier and head set. It can detect very weak and high frequency heart sounds. It is not used often.

Phonocardiography:
Phonocardiography is an instrument used for recording waveforms of the heart sounds. The figure shows the block diagram of a recording setup used for PCG. The ECG is also measured for use as reference for PCG.

Microphone:
It has a microphone e.g. piezoelectric crystal microphone, condenser, moving coil, carbon and dynamic microphones with frequency response from below 5Hz to above
1000Hz, fastened to the chest wall by an adhesive strip, converts the heart sounds into electrical signals. The microphones are located at different areas shown in the figure below.

There are two main categories of microphones used in PCG. They are air coupled microphone and contact microphone. In the former, the movement of chest is transferred through an air cushion and presents low mechanical impedance to the chest. But the second one is directly coupled to the chest wall and presents a higher impedance, high sensitivity, low noise and light weight. Therefore the second one is more suitable. Sometimes special microphones are placed at the tips of catheters to pick up heart sounds from within the chambers of the heart or from the major blood vessels near the heart.

**CONDENSER MICROPHONE AND ITS CIRCUIT**
**Preamplifier:** The electrical signals from the microphone are amplified by a phonocardiographic preamplifier. The amplifier must have similar response characteristics. The preamplifier circuit is shown below.

![Preamplifier Circuit Diagram](image)

The preamplifier has two stages with gain 20 and 50 so that total gain is 1000. The gain is varied through potentiometer. The shunt capacitance in the output and the feedback loop capacitance of the second stage limit the response from 10Hz to 1000Hz. The amplifier must have wide bandwidth with frequency range of about 20 to 2000Hz.

**Filter:**

The high pass filters are used to separate the louder low frequency components from the medically interesting soft high frequency murmurs. For heart sounds, high pass filters with
gradual slope are required and for murmurs, high pass filters with sharper slopes are required.

The readout is high frequency chart recorder, oscilloscope, photographic or light-galvanometer recorders, optical or high velocity ink jet recorder. Some models use envelope recording technique in which the frequency components below 80Hz are recorded directly, but the frequency components above 80Hz are integrated (averaged) before recording. This allows use of low frequency thermal or ink pen type strip chart recorder.

Some times a digital computer with high speed analog to digital conversion capability and Fourier-transform software, is used for spectral analysis of heart sounds because presence of higher frequencies (murmurs) in the PCG indicates heart disorder.

Measurement of vibrocardiograph and apex cardiograph:

For measuring vibrocardiograph and apex cardiograph, the microphone must be a good force transducer with suitable low frequency coupling from the chest wall to the microphone element. For the apex cardiograph, the microphone must be coupled to a point between the ribs. Since the vibrocardiogram and apex cardiogram do not contain high frequency components of the heart sounds, these signals can be handled by amplifier and recorders used for ECG.

Measuring Korotkoff's sounds:

For measuring Korotkoff’s sounds from a partially occluded artery, a microphone is placed beneath the occluding cuff or over the artery immediately downstream from the cuff.

Measurement of ballistocardiogram:

Measurement of ballistocardiogram requires a platform mounted on a set of extremely flexible springs. When a person lies on the platform, the movement of his body in response to the beating of his heart and ejection of blood causes similar movement of the platform. The amount of movement can be measured by any of the displacement/velocity transducers or accelerometers.
APPLICATIONS OF PCG

1. Detection of Rheumatic valvular lesions: Occurs due to Rheumatic fever which is an autoimmune or allergic disease in which the heart valves are likely to be damaged or destroyed.

2. Murmur of Aortic stenosis: The blood is ejected from the left ventricle through a small opening of the aortic valve. Because of the resistance to the ejection, the pressure in the left ventricle rises sometimes to as high as 350mm of Hg. This causes turbulent blood flow. This turbulent blood impinging the aortic valve causes intense vibration it produces loud murmur. This sound can be heard several feet away from the patient.

3. Murmur of Mitral regurgitation: The blood flows backward through the mitral valve during systole.

4. Murmur of Aortic regurgitation: In aortic regurgitation, the blood flows backward from the aorta into the left ventricle causing “blowing murmur”, during diastole.

5. Murmur of Mitral stenosis: The blood passes with difficulty from the left atrium into the left ventricle due to the pressure difference.

SPECIAL APPLICATIONS OF PCG

1. Fetal PCG
2. Esophageal PCG
3. Tracheal PCG