

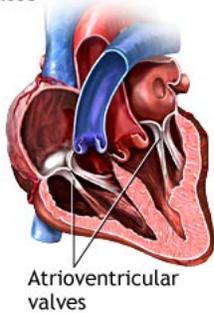
Heart Sounds. Phonocardiography ¹

Objectives

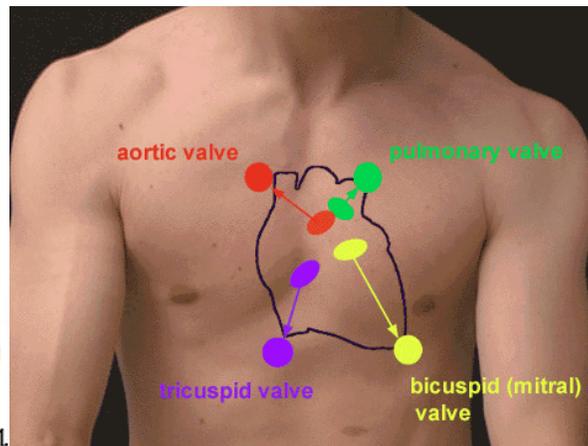
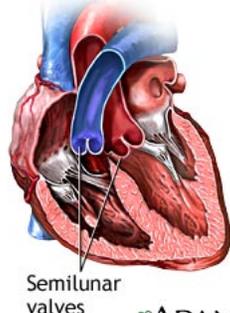
1. Phonocardiography - Definition
 2. What produces the heart sounds
 3. Where to listen for the heart sounds
 4. How to record a phonocardiogram
 5. Normal heart sounds
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1. Definition: diagnostic technique that creates a graphic record (phonocardiogram) of the sounds and murmurs produced by the heart, including its valves and associated great vessels.
 2. The heart sounds are produced by a summed series of mechanical events, as follows:
 - a. **Valvular events** = vibrations caused mostly by the closing of the heart valves; opening of the valves produces a vibration of lesser intensity.
 - b. **Muscular events** = vibrations of the myocardium during contraction.
 - c. **Vascular events** = vibration produced by the sudden distension of the arterial walls during ejection.
 - d. Vibrations caused by the **acceleration/deceleration of the blood flow**.
*Not every sound is composed of all these components, the most prominent component being the **closure of the valves**.*
 3. There are four primary areas of auscultation- areas where the sounds coming from a specific valve are best transmitted; the location of these areas are chosen to fit the direction of the blood flow through a specific valve; for example the blood column traveling from the left ventricle to the aorta has an upward and to the right direction; blood going to the pulmonary artery goes also upward but to the left, hence the location of the auscultatory areas for these valves as discussed below. For the atrioventricular valves the blood travels from atria to the ventricles downward, so the areas of auscultation will be located in the proximity of the apex.
 - a. The primary aortic area : second right interspace , adjacent to the sternum; there is a secondary aortic auscultation area in the third left interspace, also adjacent to the sternum (known as the Erb's point).
 - b. The pulmonary area : second left interspace
 - c. The tricuspid area: the fourth and fifth interspaces, adjacent to the left sternal border or on the xyphoid process.
 - d. The mitral area at the cardiac apex in the fifth left interspace, on the medioclavicular line.

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First heart sound, "lub", occurs when atrioventricular valves close



Second heart sound, "dup", occurs when semilunar valves close



4. The phonocardiogram is recorded using microphones placed on the thorax in the main auscultatory areas; these microphones filtrate the sounds in between 25 and 200 Hz. usually done together with the ECG.
5. There are two types of sounds: high frequency sounds associated with closing and opening of the valves and low frequency sounds related to early and late ventricular filling events.

High frequency sounds- better heard with the diaphragm of the stethoscope

- Related to closing and opening of the **AV valves**
 - a. Mitral (M1) and tricuspid (T1) closing sounds (**S1**)
 - b. Opening snaps-mitral and tricuspid (diastolic sounds)
 - c. Nonejection sounds –click caused by mitral valve prolapse (mid-late systolic sound)
- Related to closing and opening of the **semilunar valves**
 - a. Aortic (A2) and pulmonic (P2) closure sounds (**S2**)
 - b. Early valvular ejection sounds or clicks- aortic and pulmonic (systolic sounds)

Low frequency sounds- better heard with the bell of the stethoscope

- Physiologic third heart sound (**S3**), or in pathological conditions protodiastolic gallop
- Fourth heart sound (**S4**)

1) The first heart sound (S1) – systolic sound:

- appears at 0.02 – 0.04s after the QRS complex
- lasts 0.12-0.15s
- the “lub”
- frequency of 30-40Hz

- produced, in this order, by : closing of the mitral valve, closing of the tricuspid valve, opening of the pulmonary valve, opening of the aortic valve.
- Best heard in the mitral and tricuspid auscultatory areas
- Synchronous with the apex beat
- Shortly precedes the carotid pulse upstroke
- Starts after 30-35ms after mitral valve closure
- It has three components
 - S_{1a} –high frequency –caused by tension in the ventricle during izovolumetric contraction
 - S_{1b} –high frequency –appears right after aortic valve opening because of sudden acceleration of blood at the beginning of the ventricular ejection
 - S_{1c} –low amplitude – caused by the deceleration of the column of blood when rapid ejection slows down producing vibration of the aortic walls
- The intensity of the first heard sound depends on atrioventricular valve mobility; if the valves are fibrotic and have reduced excursions the sound will be diminished
- Loud S1 in :
 - Mitral stenosis (calcified but mobile valve)
 - Tachycardia –short diastole
 - Short PR interval –short interval between atrial and ventricular contraction
 - Complete AV block “canon sound” when the atria contract against a closed atrioventricular valve
- Reduced intensity of S1 in:
 - Thick chest wall, pericardial effusion, reduced contractility of the heart (all sounds have reduced intensity)
 - Long PR interval
 - Mitral regurgitation-imperfect closure
 - Mitral stenosis (immobile valve)
- Wide Splitting of S1- right bundle branch block

2) The second heart sound (S2) – diastolic sound

- appears in the terminal period of the T wave
- lasts 0.08 – 0.12s
- the “dub”
- frequency of 50-70 Hz
- produced, in this order, by: closing of the aortic valve, closing of the pulmonic valve, opening of the tricuspid valve, opening of the mitral valve.
- Best heard in the 2nd left interspace near the sternal border
- Starts after 5 ms after closure of the aortic valves

- Synchronous with the aortic notch
- Physiologic splitting that varies with respiration (wider splitting with inspiration); The aortic and pulmonary components of this sound are separated by 80-90 ms with inspiration and 40-50 ms with expiration.
- Pathological splitting:
 - Large variable splitting (A2 P2) with right bundle branch block (late systole of the right ventricle)
 - Fixed splitting- atrial septal defect (ASD)
 - Paradoxical splitting (P2 A2)- heard in expiration and disappears in inspiration- severe aortic stenosis (long left ventricle ejection); left bundle branch block (late left ventricular systole); severe pulmonary hypertension (early closure of pulmonary valve)
- Loud S2:
 - Systemic hypertension
 - Fibrous aortic valves
 - Pulmonary hypertension (louder P2)
- Reduced intensity of S2:
 - Aortic stenosis
 - Pulmonary stenosis

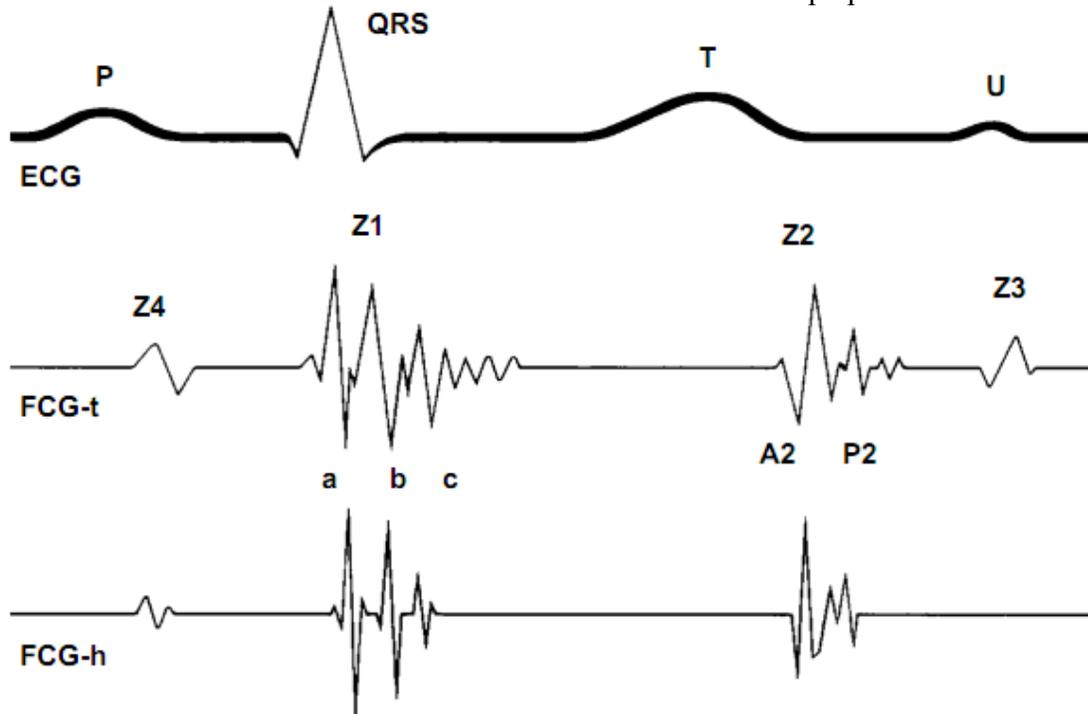
3) The third heart sound (S3) - *protodiastolic sound*:

- early diastolic, 100-150 ms after S2
- lasts 0.02-0.04 s
- low frequency
- it is normal in children and individuals with a thin thoracic wall
- it is produced by the blood flow that hits the ventricular wall during the rapid filling phase
- in pathologic conditions for example reduced ventricular compliance it is called *protodiastolic (ventricular) gallop*; if the heart is normal but the volume of blood coming from the atria is increased it is called a *filling sound*

4) The fourth heart sound (S4) – *presystolic sound*:

- appears at 0.04s after the P wave (late diastolic-just before S1)
- lasts 0.04-0.10s
- low frequency
- It is caused by the blood flow that hits the ventricular wall during the atrial systole, causing it to vibrate.
- It is physiological only in small children
- If heard otherwise it is a sign of reduced ventricular compliance.
- Is heard as a *presystolic (atrial) gallop*
- During tachycardia the two sounds can fuse, producing a summation gallop

Note that in normal auscultation only sound 1 and 2 should be heard, but on phonocardiogram we can record all four sounds. Sounds 3 and 4 can sometimes be palpated.



Heart murmurs

Heart murmurs are sounds that last longer than 150 ms, in contrast to heart sounds that are shorter. They are caused by turbulent blood flow through the heart or great vessels.

Types of heart murmurs:

- Systolic murmurs
 - Ejection murmurs- midsystolic
 - Aortic stenosis
 - Pulmonic stenosis
 - Regurgitation murmur- holosystolic
 - Mitral regurgitation
 - Tricuspid regurgitation
 - Other systolic murmurs
 - Vascular murmurs
 - Ventricular septal defect
- Diastolic murmurs
 - Mitral stenosis
 - Tricuspid stenosis
 - Aortic regurgitation
 - Pulmonary regurgitation
- Continuous murmurs –patent ductus arteriosus

Appendix to the heart sounds auscultation – the auscultation of the heart sounds is only part of the cardiac physical examination; one should follow, in order the following steps, auscultation being the last of them.

- **Inspection** of the chest- might show deformities or a visible apex beat.
- **Palpation** - the apex beat, thrills, pulsations of the heart and great arteries that are transmitted to the chest wall; evaluation of the cardiac size
- **Percussion** - determining cardiac size, especially in the absence of an apical beat.
- **Auscultation.** The modern binaural stethoscope - diaphragm for high frequencies, bell for low or lower frequencies.

When the bell is applied with just enough pressure to form a skin seal, low frequencies are accentuated; when the bell is pressed firmly, the stretched skin becomes a diaphragm, damping low frequencies. Variable pressure with the bell provides a range of frequencies from low to medium. The topographic areas for auscultation, irrespective of cardiac situs, are best designated by descriptive terms—cardiac apex, left and right sternal borders interspace by interspace, and subxiphoid.

During auscultation, the examiner is generally on the patient's right; three positions are routinely employed: left lateral decubitus (assuming left thoracic heart), supine, and sitting. Auscultation should begin by applying the stethoscope to the cardiac apex with the patient in the left lateral decubitus position.

Simultaneous palpation of the arterial pulse is necessary since the pulse wave is almost synchronous with the first heart sound.