Heart Sounds

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The detection and recognition of heart sounds play an important role in the diagnosis of various cardiac and valvular conditions. Because familiarity with heart sounds has such practical importance, students undertaking the USMLE are expected to have a good understanding of its theory and clinical applications.

Definition of Heart Sounds

On auscultation, there are two heart sounds that are heard from a normal heart, the **first and second heart sounds**. There are also extra heart sounds, namely the third and fourth heart sounds, and additional sounds called **murmurs**.

Murmur

A **murmur** is a sound that is produced by turbulent blood flow across a heart valve. Heart murmurs may be classified as **physiological or innocent murmurs** and **pathologic murmurs**.

A **physiological murmur** is heard when there is **increased turbulence of blood flow across a normal valve**, as can happen in the conditions thyrotoxicosis and anemia, as well as during fever and exercise. Physiologic murmurs are always systolic murmurs, as increased blood flow occurs during ventricular systole. They are more likely to be found in young people. As well as being systolic, innocent murmurs also have the qualities of being soft, short, early peaking, mostly confined to the base of the heart, have a normal second heart sound, and generally disappear with a change in position, with the rest of the cardiovascular exam being normal.

On the other hand, a **pathologic murmur** occurs when there is turbulence of blood flow across an abnormal valve. This can be due to stenosis or regurgitation.

Stenosis

Stenosis refers to **abnormal narrowing of a valve orifice**. Narrowing of a valve that prevents it from opening completely; as a result, stenosis murmurs can only occur when the valve is trying to open.

Regurgitation

Regurgitation refers to the **abnormal backward flow of blood from a high-pressure chamber to a low-pressure chamber**, often due to an incompetent valve (i.e. a valve that cannot shut properly).

Origins and Timing of the Heart Sounds

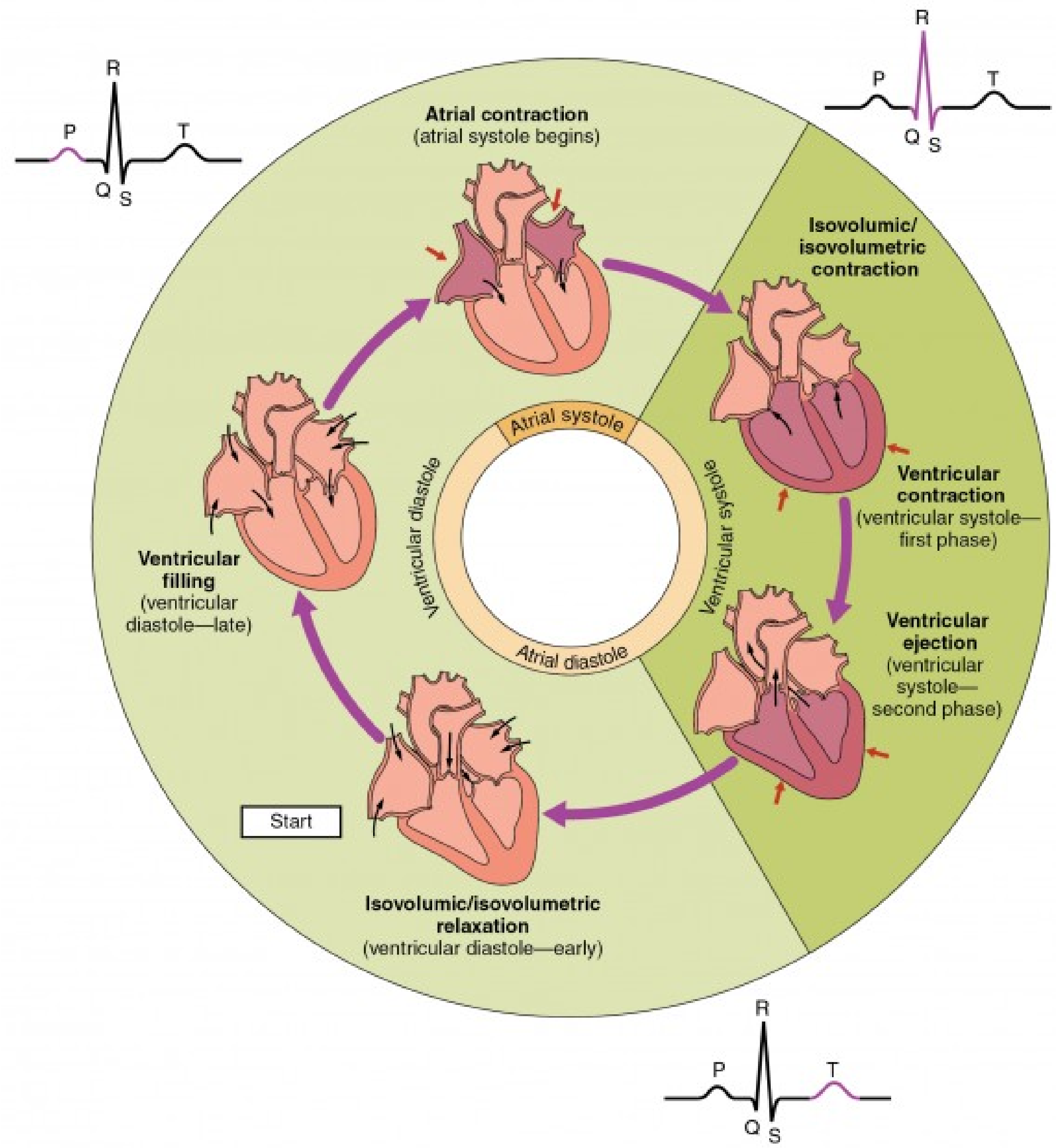
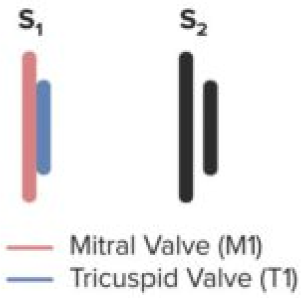


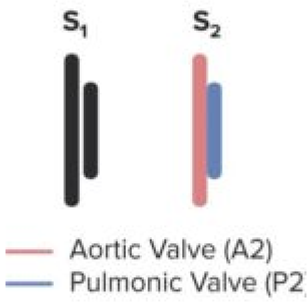
Image: “Overview of the Cardiac Cycle” by PhilSchatz. License: CC BY 4.0



“Heart Sound S1” Image created by Lecturio

The closure of the heart valves produces vibrations that are picked up as the two heart sounds.

The first heart sound, S1, corresponds with the **closure of the atrioventricular valves** – the tricuspid and mitral valves of the heart. S1 represents the **start of ventricular systole**. The closure of the mitral valves precedes the closure of the tricuspid valves, but this is only minimally different so that S1 is usually heard as only one sound. S1 is best at the apex of the heart.



“Heart Sound S2” Image created by Lecturio

The second heart sound, S2, corresponds with the **closure of the semilunar valves** – the aortic and pulmonary valves of the heart. S2 signifies the **end of ventricular systole** and the **beginning of diastole**. Compared to the first heart sound, S2 is shorter, softer and is slightly higher pitched. A reduced or absent S2 indicates pathology, due to an abnormal aortic or pulmonic valve.

The aortic valves shut before the pulmonary valves do. This is because of the lower pressures in the pulmonary circulation, which allows for blood to continue flowing into the pulmonary artery after systole ends in the left ventricle. In 70 % of normal adults, this difference can be heard as the splitting of the second heart sound.

The pulmonary component of S2 is referred to as P2, and the aortic component is called A2. The splitting is best heard in the pulmonary area (second left intercostal space) and the left sternal edge. Inspiration delays closure of the pulmonary valves by about 30 to 60 milliseconds, due to increased venous return and decrease pulmonary vascular resistance, and this is called **the physiological splitting of S2**. Persistent splitting of S2 occurs when there is delayed right ventricular emptying, in conditions such as pulmonary stenosis, right bundle branch block, mitral regurgitation and ventricular septal defect.

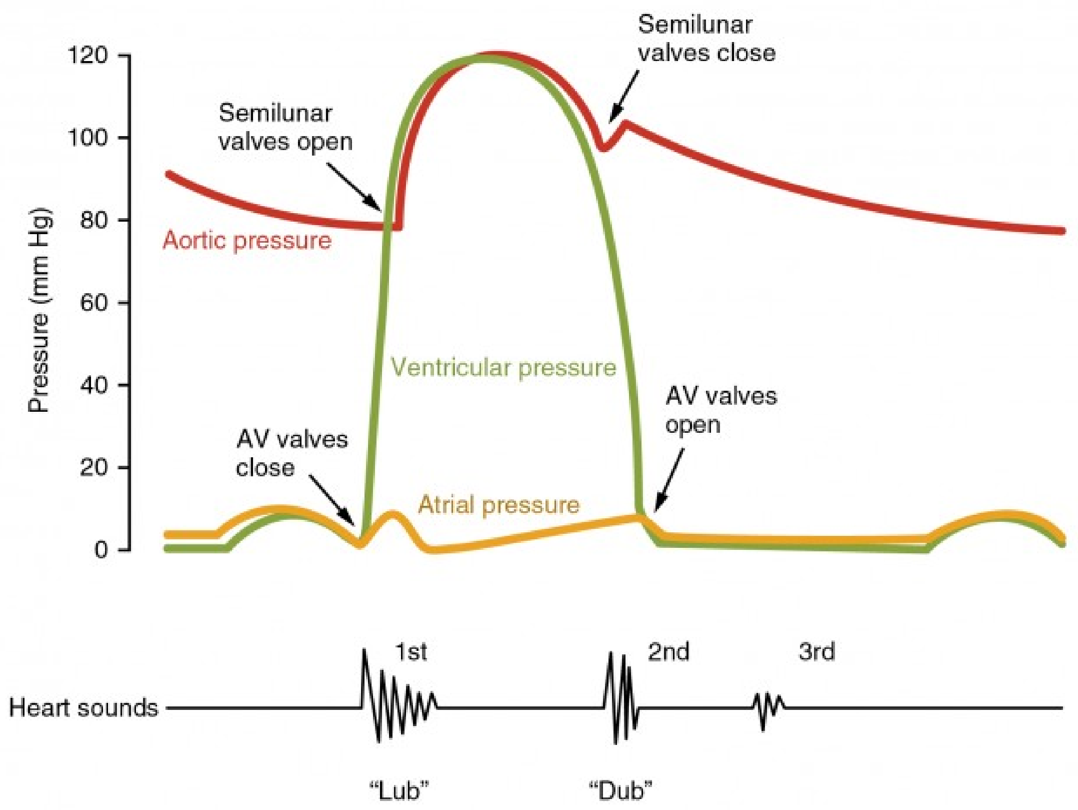


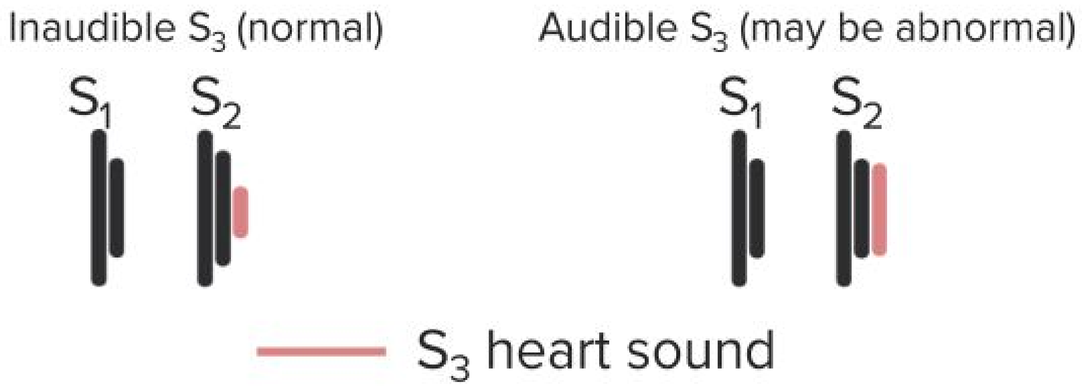
Image: "Heart Sounds and the Cardiac Cycle" by PhilSchatz. License: CC BY 4.0

Extra Heart Sounds

Extra heart sounds include the third and fourth heart sounds. The **third heart sound (S3) is a mid-diastolic, low-pitched sound**. With the presence of S3, the heart sounds are described as having a **gallop rhythm**, simply because its addition alongside S1 and S2 make it sound like a horse galloping. S3 occurs after S2, during the rapid passive filling of the ventricle.

A physiological S3 is produced when there is rapid filling during diastole, as can happen in conditions which increase cardiac output, such as thyrotoxicosis and pregnancy; or, it might be a finding in some children. On the other hand, **a pathological S3** is produced when there is decreased compliance of the ventricle (dilatation or overload), causing a filling sound.

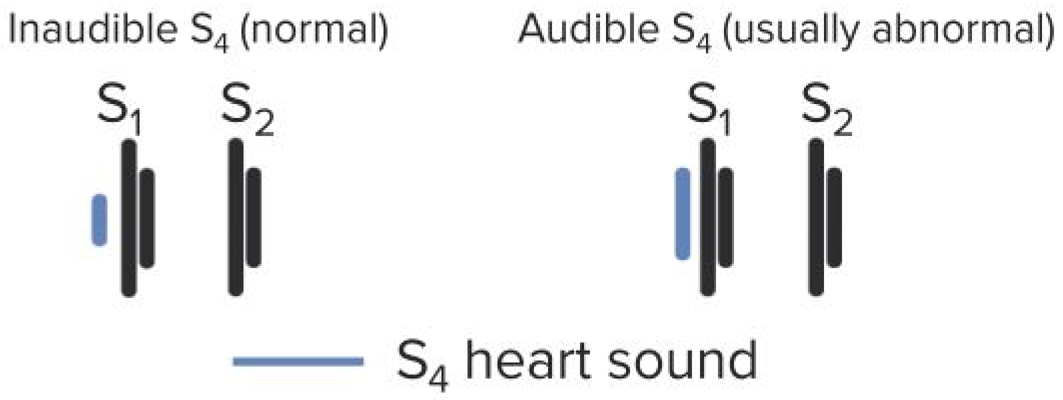
Causes of a pathological S3 include conditions that reduce left ventricular compliance, such as left ventricular failure, left ventricular dilation, aortic regurgitation, mitral regurgitation, patent ductus arteriosus and a ventricular septal defect. Conditions, where there is reduced right ventricular compliance and can also cause a pathological S3, include right ventricular failure and constrictive pericarditis.



“Heart Sound S3” Image created by Lecturio

The fourth heart sound (S4) is a late diastolic sound. It is a bit higher pitched than S3. S4 sounds like a **triple gallop rhythm** too. S4 happens slightly before S1 and is associated with atrial contraction and rapid active filling of the ventricle.

S4 is caused by decreased ventricular compliance. Reduced left ventricular compliance, as in aortic stenosis, mitral regurgitation, hypertension, angina, myocardial infarction and old age, can produce an S4. Reduced right ventricular compliance, as in pulmonary hypertension and pulmonary stenosis, can also cause an S4.



“Heart Sound S4” Image created by Lecturio

It is possible for the third and fourth heart sounds to co-exist, in which case it is called a **quadruple rhythm**. This indicates significantly impaired ventricular function. If S3 and S4 are superimposed when tachycardia is present, it produced a **summation gallop**.

Timing and Origin of Murmurs

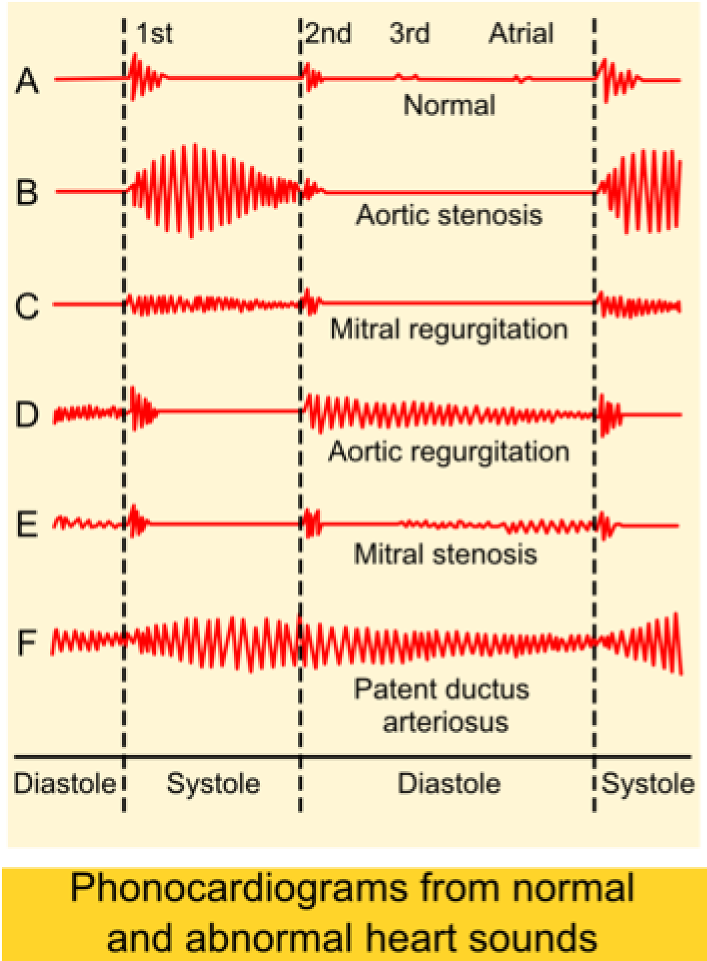


Image: “Phonocardiograms from normal and abnormal heart sounds” by Madhero88. License: CC BY-SA 3.0

Systolic murmurs

Systolic murmurs are murmurs that are **produced during systole** (contraction) of the ventricles, which is the period between S1 and S2. These murmurs can be midsystolic (ejection), late systolic and pansystolic murmurs. Systolic murmurs can be either normal or abnormal.

Midsystolic ejection murmurs have their highest intensity in the middle of systole. They are often described to have a crescendo-decrescendo quality. This can be a physiological murmur, caused by increased flow through a normal valve. Or it can indicate pathology, such as aortic stenosis or pulmonary stenosis. In cases of congenital aortic or pulmonary stenosis, an early high-pitched systolic ejection click may be heard, representing the sudden opening of these valves, which are still mobile.

A **late systolic murmur** is when there is a gap between hearing S1 and the murmur. This can be caused by mitral regurgitation, as in the case of papillary muscle dysfunction or mitral valve prolapse.

A **pansystolic murmur** extends from S1 to S2. The pitch and loudness of this murmur stay the same during systole. The murmur is caused by leakage from a high-pressure chamber to a low-pressure chamber. Causes of pansystolic murmurs include mitral or tricuspid regurgitation and ventricular septal defect.

Diastolic murmurs

Diastolic murmurs, as their name implies, **occur during diastole of the ventricles**. They are always pathological. Compared to systolic murmurs, they are softer and more difficult to hear.

An **early diastolic murmur** starts with S2 and is a decreasing murmur, loudest at its commencement. It produces a high-pitched sound. Causes of an early diastolic murmur include aortic regurgitation or pulmonary regurgitation. The decrescendo quality mirrors the peak in aortic and pulmonary pressures at the start of diastole.

Mid-diastolic murmurs occur in the later phases of diastole. Compared to early diastolic murmurs, they are lower pitched. Mid-diastolic murmurs can be caused by mitral or tricuspid stenosis or an atrial myxoma (rare). In mitral stenosis, the diastolic murmur may be preceded by a high-pitched **opening snap**, which represents the abrupt opening of the stenosed mitral valve.

Continuous murmurs are occur during both systole and diastole without a pause. The sound is created by unidirectional flow when there is a communication between a high-pressure and a low-pressure source. The constant pressure gradient results in a continuous flow. Causes include patent ductus arteriosus, an arteriovenous fistula and a venous hum.

Auscultation

There are **four chest areas** that the stethoscope is placed on to listen to heart sounds and any abnormal findings. Auscultation can be carried out in a clockwise manner, starting with the aortic then the pulmonic and mitral areas, followed by the tricuspid area.

To tell the difference between the two heart sounds on auscultation, palpation of the pulse (carotid or radial) while listening to the heart can be helpful. The pulse indicates systole, therefore corresponding to the first heart sound S1. Being aware of when systole and diastole occur is useful if an additional heart sound is heard, so that it can be timed in the cardiac cycle and accurately described.

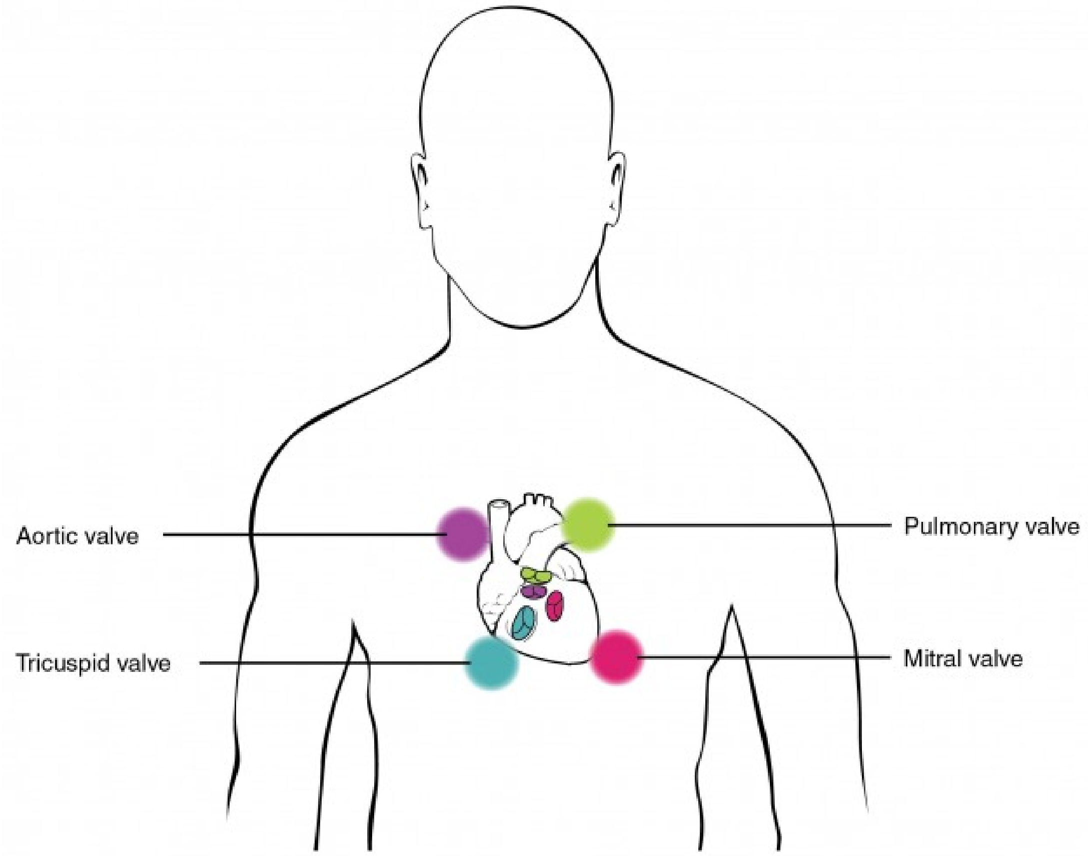


Image: "Stethoscope Placement for Auscultation" by Phil Schatz. License: CC BY 4.0

The **aortic area** is located in the second intercostal space, on the right sternal edge. The diaphragm of the stethoscope can be placed at this site to listen for aortic stenosis.

The **pulmonic area** is at the left second intercostal space, opposite the aortic area. The diaphragm is placed here to listen for a loud P2 and pulmonary flow murmurs.

The **mitral area** is also referred to as the apex of the heart. It is located in the fifth intercostal space, in the mid-clavicular line. This area is listened to with both the bell and diaphragm of the stethoscope. Low-pitched sounds, such as a diastolic mitral stenosis murmur and a third heart sound, can be better appreciated with the bell. The diaphragm can be used to detect high-pitched sounds, such as a fourth heart sound or mitral regurgitation.

The **tricuspid area** is also located in the fifth intercostal space but at the left sternal edge. The diaphragm is placed at this site to listen for tricuspid regurgitation.

Even when a murmur is heard more clearly at a certain part of the chest, this might not always be helpful in determining its origin. Because **murmurs can radiate**, they can be heard in other areas too. For example, a mitral regurgitation murmur is best heard in the mitral area, but it may also be heard anywhere else on the chest. This murmur is also characterized by its radiation to the axillae. An ejection systolic murmur that is of aortic valve origin may characteristically radiate to the carotid arteries.

Dynamic auscultation

Altering heart sounds by changing circulatory hemodynamics. This can be used to separate out the clinical cause of similar auscultatory findings and is frequently tested on board exams. If you understand the physiologic alterations caused by certain maneuvers, this is more simply understood.

Changing venous return is one such change that is useful.

Increasing venous return	Decreasing venous return
• Increased volume of blood into the RA/RV then LA/LV (increased preload) • Preload is the volume of blood in the ventricle	• Decreased volume of blood into RA/RV the LA/LV, thus decreasing preload (increased afterload) • Afterload is the effective pressure seen by the LV in the ascending aorta

Grading of murmurs

Using the **Levine system**, murmurs can be **graded on a scale from 1 to 6, reflecting the intensity of the murmur**. A greater intensity is usually due to increased turbulence of flow and suggests that the murmur is likely to be severe.

- Grade 1: murmur is very soft, and is initially not heard.
- Grade 2: murmur is soft, but can be readily heard by a skilled auscultator.
- Grade 3: murmur is easy to hear.
- Grade 4: murmur is slightly loud and accompanied by a palpable thrill (these murmurs are always pathological).
- Grade 5: murmur is very loud, and the accompanying thrill is easily palpable.
- Grade 6: murmur is so loud that it is audible even without direct placement of the stethoscope on the chest.

Dynamic maneuver

If a murmur is heard, various dynamic maneuver tests can be used to characterize it further. These maneuvers alter circulatory hemodynamics and, in doing so, change the emphasis with different murmurs.

Respiration can be used to differentiate between right-sided and left-sided murmurs. **Inspiration** has the effect of **increasing venous return**, and as there is an **increase in blood flow to the right side of the heart, right-sided murmurs are accentuated.** On the other hand, **expiration causes left-sided murmurs to become louder.** Another respiration maneuver is deep expiration. As the patient leans forward and is in deep expiration, the base of the heart is brought closer to the chest wall. In this maneuver, the murmur of aortic regurgitation can be appreciated.

The Valsalva maneuver is a well-known, often-used dynamic maneuver. It accentuates the murmurs of hypertrophic cardiomyopathy and mitral valve prolapse when listening over the left sternal edge. It involves getting the patient to expire fully against a closed glottis.

There are four phases to the Valsalva maneuver:

Phase I: this marks the start of the maneuver. Intrathoracic pressure increases, with a temporary rise in cardiac output and blood pressure.

Phase II: this is the **straining phase** of the maneuver. **Venous return decreases**, and so do cardiac output and stroke volume. There is a fall in blood pressure and an increase in heart rate. Most murmurs become softer, but the **systolic murmur of hypertrophic cardiomyopathy increases** and the **mitral valve prolapse murmur is heard**.

Phase III: this is when the maneuver is released. Right-sided murmurs are louder for a short interval and then follow the left-sided murmurs.

Phase IV: blood pressure rises with activation of the sympathetic nervous system.

Squatting is another dynamic maneuver, which causes an increase in venous return. In this test, the patient quickly moves from a standing position to a squat. This makes most murmurs louder, including aortic stenosis and mitral regurgitation murmurs, while the murmur of hypertrophic cardiomyopathy and mitral valve prolapse is softer or shorter. When the patient does the opposite – standing quickly from a squatting position – this has the opposite effects of the changes in murmurs.

Isometric exercise can also be used for eliciting certain types of murmurs. For this exercise, the patient sustains a **handgrip** for half a minute. This exercise **increases afterload** (or peripheral resistance). The **murmur of mitral regurgitation is accentuated.** But the murmur of aortic stenosis and hypertrophic cardiomyopathy are softer, while a mitral valve prolapse murmur is shorter.

Study Table

Heart Sound	Causes
Normal heart sounds https://d3uigcfkiiww0g.cloudfront.net/wordpress/blog/pics-en/uploads/Human_heart_beating_at_61_bpm_Cc-by-3.0.ogg.mp3	
First heart sound (S1)	Closure of the mitral and tricuspid valves
Second heart sound (S2)	Closure of the aortic and pulmonary valves
Extra heart sounds	
Third heart sound (S3)	A physiological S3 is caused by rapid diastolic filling (e.g. pregnancy, thyrotoxicosis, and some children). A pathological S3 is caused by reduced compliance of the left ventricle (e.g. left ventricular failure, aortic regurgitation, mitral regurgitation, patent ductus arteriosus, and a ventricular septal defect) or reduced compliance of the right ventricle (right ventricular failure, constrictive pericarditis)
Fourth heart sound (S4)	Decreased ventricular compliance of the left ventricle (aortic stenosis, mitral regurgitation, hypertension, angina, myocardial infarction, and old age) or the right ventricle (pulmonary hypertension, pulmonary stenosis)
Murmurs **Systolic murmurs**	
Midsystolic murmur	Increased flow through a normal valve (physiologic or innocent murmur), aortic stenosis, pulmonary stenosis, hypertrophic cardiomyopathy, atrial septal defect
Late systolic mumur	Mitral regurgitation (MR), due to papillary muscle dysfunction, mitral valve prolapse or infective endocarditis
Pansystolic murmur	Mitral regurgitation, tricuspid regurgitation, ventricular septal defect (VSD), aortopulmonary shunts
Diastolic murmurs	
Early diastolic murmur	Aortic regurgitation, pulmonary regurgitation
Mid-diastolic murmur	Mitral stenosis, tricuspid stenosis, atrial myxoma (rare), acute rheumatic fever murmur (Carey Coombs murmur)
Other	
Presystolic murmur	Mitral stenosis, tricuspid stenosis, atrial myxoma
Continuous murmur	Patent ductus arteriosus, arteriovenous fistula, venous hum

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Notes