

Approach to Cardiac Murmurs

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Introduction

What is a murmur?

A murmur is a sound generated when blood travels through vessels or valves in a turbulent or energy-dissipating manner. It can be an important clue to a structural abnormality of the cardiovascular system. However, over 50% of people have murmurs during childhood, but less than one percent are associated with congenital heart disease. Thus, the vast majority of murmurs are benign or innocent rather than pathological. Furthermore, although imaging modalities such as echocardiograms can detect many cardiac lesions, the final diagnosis of an innocent murmur is via a physician's clinical assessment.

Classification of murmurs

It is generally accepted that a cardiac murmur has several important characteristics that need to be discerned in order to classify them and reach a diagnosis. Most importantly, there are key differences among these characteristics that can help differentiate benign murmurs from pathologic ones. The following features should be described and considered:

Timing of the murmur relative to the cardiac cycle

- Most benign murmurs are early to mid systolic.
- Diastolic murmurs almost always indicate pathology.
- A systolic murmur is present between S1 and S2
- A diastolic murmur is present between S2 and S1
- A continuous murmur is present in systole and diastole

Configuration

- Crescendo: increases in intensity from start to finish
- Decrescendo: opposite of crescendo; decreases in intensity from start to finish
- Crescendo-decrescendo (if systolic, then also known as a systolic ejection murmur): increases then decreases in intensity; diamond shape.
- Decrescendo-crescendo: decreases then increases in intensity.

- Plateau (holosystolic or pansystolic); constant intensity; rectangular shape

Location

The site where the murmur originates from tends to correspond to where it is loudest or most intense. Timing and location tend to be the most important identifying characteristics of a murmur.

Classical descriptions of valve auscultation areas:

- Mitral area: cardiac apex, 5th intercostal space (ICS) in the midclavicular line
- Mitral valve prolapse, regurgitation, and stenosis; Still's murmur, aortic stenosis
- Tricuspid area: 4-5th ICS, left sternal edge
- Tricuspid regurgitation, ventricular septal defect (VSD), Still's murmur, hypertrophic cardiomyopathy.
- Pulmonary area: 2nd ICS, left sternal edge
- Pulmonary regurgitation and stenosis, ASD, TAPVR, PDA, and pulmonary flow murmurs.
- Aortic area: 2nd ICS, right sternal edge
- Aortic stenosis, benign aortic systolic murmur
- Using the bell and diaphragm, you should first perform a sweep at these locations for heart sounds and then a second sweep for murmurs.

Other sites of auscultation:

- Infra and supraclavicular areas
- auscultate for a venous hum
- Common carotid areas
- auscultate for supraclavicular or brachiocephalic systolic murmurs. Differentiating these from a radiating murmur of aortic stenosis is difficult.
- On the patients' back.
- aortic stenosis

Radiation

- A murmur can radiate to different locations from its origin, and this can be an important clue because it correlates with the direction of blood flow. For instance, when you are analyzing a systolic ejection murmur, keep in mind that the murmur of aortic stenosis tends to radiate to the common carotid arteries, whereas mitral regurgitation classically radiates to the left axilla. A VSD does not radiate to those areas.
- Auscultating the back and infraclavicular areas for a peripheral pulmonary arterial stenosis murmur and a venous hum, respectively.

Intensity

Intensity is synonymous with the loudness or amplitude of a sound wave, and it is inversely related to the size of the opening or vessel that blood travels through, and directly proportional to the pressure gradient and the amount of blood flow through that opening. It is graded on a 6-point scale:

- Grade 1: very soft and heard with difficulty
- Grade 2: soft but readily heard
- Grade 3: moderately loud, no thrill. Approximately the same intensity as the first and second heart sounds.
- Grade 4: Loud with thrill (palpable vibration of the chest wall) present. Louder than the first and second heart sounds.
- Grade 5: Thrill, very loud, but not audible without a stethoscope
- Grade 6: Thrill, audible without a stethoscope

Quality

Is the murmur musical or harmonic (vibratory)? Or is it noisy or dissonant (rough, non-vibratory)?

Pitch

The frequency of a murmur depends on the pressure gradient across a valve or narrowing. Low-pitched murmurs are heard best with a bell, and high-pitched murmurs are heard best with a diaphragm.

Some frequency ranges are inaudible by the human ear, and thus palpating for thrills is another means of detecting murmurs.

Maneuvers

Changes in position, such as squatting, sudden standing, the valsalva maneuver, and hand gripping can all influence the aforementioned characteristics of a murmur by changing the preload, afterload, and chamber size. This is an invaluable tool because murmur characteristics often overlap, and these maneuvers can result in predictable changes.

Examples of maneuvers:

Sudden standing from a supine position

When you stand suddenly, gravity will decrease venous return to the heart (decreases preload). This leads to a decrease in diastolic and stroke volumes, leading to a decrease in blood pressure (blood pressure = heart rate x stroke volume x systemic vascular resistance). The heart compensates by increasing the heart rate to maintain blood pressure. There are more heartbeats,

but less blood flow per beat, and thus most systolic murmurs will decrease in intensity (aortic and pulmonary stenosis, mitral and tricuspid regurgitation, ventricular septal defects without pulmonary hypertension). The important exception is hypertrophic cardiomyopathy, where the murmur increases in intensity. This occurs because the murmur is due to the narrowing of the left ventricular outflow tract, which is inversely proportional to the intensity of the murmur. Hence, the smaller end diastolic and stroke volumes cause a smaller outflow tract, and thus a more intense murmur.

Squatting from an erect/standing position

The muscle contractions caused by squatting literally squeeze venous blood to the heart, thus increasing preload. Moreover, the muscle contractions also compress arterioles and thus increase systemic vascular resistance (afterload). In this case, most systolic murmurs will increase in intensity because the ventricles will have a higher diastolic and stroke volume. A hypertrophic cardiomyopathy will decrease in intensity because the outflow tract becomes wider. However, the murmur of aortic stenosis may not become accentuated because squatting may increase afterload more so than preload, thereby dissipating its transvalvular pressure gradient. Furthermore, in tetralogy of fallot, an increased venous return will cause an increased pressure gradient through the pulmonary valve, increasing the intensity of its pulmonary stenosis murmur.

Valsalva maneuver

This maneuver has different phases; however, the straining phase of the valsalva is the best for analyzing murmurs. Specifically, it raises intrathoracic pressure, which compresses the caval veins and decreases venous return to the heart, and thus decreases stroke volume. This in turn leads to a compensatory increase in heart rate. This causes similar findings to sudden standing from a supine position.

Handgrip

Isometric handgrip for approximately 30 seconds is sufficient to increase afterload and preload; however, it appears as though afterload is increased proportionally more than preload. Hence, this maneuver is most useful for discerning mitral valve regurgitation from aortic stenosis. This maneuver decreases the pressure gradient across the aortic valve, and thus decreases the intensity of the aortic stenosis murmur; similarly, a regurgitant mitral valve will see increased backward blood flow because of the increased forward resistance encountered by the pumping left ventricle, and so its intensity will increase.

Patient in the lateral decubitus position

Tends to accentuate mitral murmurs because it brings the left ventricle closer to the stethoscope.

Patient sitting forward and exhaling completely

Tends to accentuate aortic murmurs because it decreases heart rate but increases stroke volume, thus more blood will flow through the aortic valve per heartbeat.

Supine to upright

This is an important examination technique when you discern benign murmurs. This maneuver decreases preload, and thus decreases right-sided stroke volume. Pulmonary flow and peripheral pulmonary arterial stenosis murmurs decrease in intensity because the various pressure gradients required are dissipated with the decreased preload. Moreover, Still's murmur also decreases in intensity although the pathophysiology is not fully understood. On the contrary, a venous hum increases its intensity in the upright position, and it disappears in the supine position, possibly due to the effects of gravity.

Examples of other maneuvers

Exercise can accentuate holosystolic murmurs such as mitral regurgitation and VSD, but not tricuspid regurgitation.

Inpiration can accentuate right-sided murmurs such as tricuspid regurgitation, but not left-sided murmurs.

Palpating continuous murmurs: a venous hum disappears with compression of the internal jugular vein; a mammary souffl é murmur disappears with pressure from a stethoscope.

Rapid shoulder extension can diminish a supraclavicular or brachiocephalic systolic murmur.

Benign versus pathological murmurs

A benign diagnosis should only be made in the context of a normal history and physical exam. Therefore, you must always look at the big picture. Assessing the characteristics of a murmur alone will not give you the answers you seek. You must ask yourself: does this child appear well or unwell? A murmur is more likely to be benign if the patient is asymptomatic. In neonates and infants, failure to thrive and problems feeding are important clues to pathology. On exam, tachypnea, tachycardia, and hepatomegaly are important signs of heart failure. Benign murmurs have normal peripheral pulses, without evidence of palpable ventricular enlargement (heaves/lifts or a laterally displaced point of maximal impulse) or thrills. Heart sounds are key: diagnosis of a benign murmur should be made in the context of normal splitting heart sounds, without gallops, clicks, or snaps. Furthermore, a systolic murmur is more likely to be benign, especially if it is early to mid systolic. A diastolic murmur is never benign. Furthermore, the higher the intensity (i.e. grade 4 or more) the more likely it is pathological. Benign murmurs change significantly with different patient positions. Finally, if investigations are performed they should reveal no abnormalities on ECG, CXR, echocardiogram, or other imaging modalities.

There are approximately eight benign murmurs:

Five systolic:

Still's (vibratory) murmur: Unknown cause, but possibly due to turbulent blood flow in the left or right ventricular outflow tract, or vibrations through the pulmonary valve leaflets.

- You will most often find it in two to six-year-old children, and rarely in infants.
- You will hear a grade 1-3 low to medium pitched early systolic murmur that is heard best at the tricuspid and mitral auscultation areas. It is never harsh, has a vibratory quality, and its intensity increases in the supine position.

Pulmonary flow murmur: turbulent blood flow through a physiologically normal pulmonary valve.

- You will hear this most often in young children, and up to young adulthood.
- You will hear a grade 2-3 systolic ejection murmur, heard at the pulmonary auscultation area, which is harsh, non-vibratory, and its intensity increases when in the supine position.

Peripheral pulmonary arterial stenosis murmur: turbulent flow through a narrowed left or right pulmonary artery.

- You will most often find it in newborns and children less than one year of age; you may also hear it in infants and young children recovering from respiratory viral illness.
- It is a grade 1-2 low to medium pitched early to mid systolic murmur, which can extend passed S2. It is heard best in the back and axilla, and louder in the supine position.

Supraclavicular or brachiocephalic systolic murmur: turbulent blood flow through a large diameter aorta into a smaller carotid or brachiocephalic artery.

- It can be present at any age.
- You will hear a low to medium pitched systolic murmur, which is heard best above the clavicles, and radiates to the neck; you will hear no change in intensity between the supine and upright positions, however, rapid shoulder extension can diminish its intensity.

Aortic systolic murmur: due to various high output physiological states such as anemia, hyperthyroidism, and fever, which cause turbulent flow through the ventricular outflow tract and aorta.

- You will hear a low-grade non-harsh systolic murmur that is heard best in the aortic auscultation area.

Three continuous:

Venous hum: possibly due to turbulent flow through slightly angulated internal jugular veins, or through the superior vena cava at the junction of the internal jugular and subclavian veins.

- You will most often find it in three to six-year-old children.
- It is best described as a grade 1-6 continuous murmur that is more intense in diastole, and heard best in the supra and infraclavicular areas. You will often find that it is louder on the patient's right side, and its intensity increases when the patient is sitting upright and

looking away from you. Furthermore, compression of the internal jugular vein may diminish its intensity.

Mammary souffl émurmur: originates from the plethoric arterioles during lactation.

Occurs in late pregnancy and lactating women.

It is a high-pitched continuous murmur, which is heard best over the breast anteriorly. There is a delay between S1 and its onset, and there are daily variations in its characteristics.

Patent ductus arteriosus (PDA): the connection between the aorta and pulmonary artery remains open.

It is physiologically innocent in newborns, but pathological if it persists.

PDA is a medium pitched high-grade continuous murmur heard best in the pulmonary area, which has a harsh machinelike quality and often radiates to the left clavicle. It is most intense during S2, with a crescendo pattern after S1 and a decrescendo pattern after S2 (diamond shaped).

Murmurs categorized by time in cardiac cycle

Early systolic murmurs

- Tend to have a decrescendo configuration
- Pathological examples include mitral valve regurgitation, tricuspid valve regurgitation, and ventricular septal defects (VSD). However, these are all classically described as holosystolic (described later in the holosystolic section). An early systolic murmur of VSD is consistent with a larger defect.

In the differential diagnosis for a benign early systolic murmur is a Still's, pulmonary flow, peripheral pulmonary arterial stenosis, and supraclavicular or brachiocephalic systolic murmur. The patient's age is a helpful clue, for instance, Still's is rare in adolescents and infants, whereas peripheral pulmonary arterial stenosis is rare in all people but infants and neonates, and pulmonary flow murmurs may occur in young adults. Nevertheless, a young child can present with anyone of these murmurs. You should look for the following clues: peripheral pulmonary arterial stenosis is heard best in the axilla and back, whereas Still's and pulmonary flow murmurs are heard best in the pulmonary auscultation area, however, they can be distinguished from one another by their differing qualities: Still's is vibratory, and pulmonary flow is not. Also note that a supraclavicular or brachiocephalic systolic murmur is heard best above the clavicles, and that rapid shoulder extension can diminish its intensity; the supine and upright positions do not change its intensity. On the contrary, the intensity of a Still's, pulmonary flow, and peripheral pulmonary arterial stenosis murmur will decrease in the upright position, and increase in the supine position.

Midsystolic

- Tend to have crescendo-decrescendo configuration
- Also called: systolic ejection murmur

- Pathological examples you should be aware of are aortic stenosis, mitral valve regurgitation, VSD, ASD, hypertrophic cardiomyopathy, pulmonary valve stenosis, coarctation of the aorta, and tetralogy of fallot.
- Benign examples are Still's, pulmonary flow, peripheral pulmonary arterial stenosis, supraclavicular/brachiocephalic stenosis, and aortic systolic murmurs.

You will often need to differentiate an aortic stenosis from a hypertrophic cardiomyopathy. Both have a harsh sounding quality. Aortic stenosis may have a preceding ejection click, a paradoxical split of S2 that narrows with inspiration if it is severe. It is also heard best in the aortic auscultation area, radiates to the carotids, and most importantly, maneuvers such as sudden standing and valsalva decrease its intensity. A hypertrophic cardiomyopathy is heard best in the tricuspid or mitral area, does not radiate, and sudden standing and valsalva increase its intensity. A benign aortic systolic murmur may mimic these two, but it tends to be of a lower grade, and it can be present in well-trained athletes (with or without an S3), or those with other high output states such as anemia, fever, pregnancy, and hyperthyroidism. A family history of sudden death is associated with hypertrophic cardiomyopathy and less commonly with aortic stenosis.

It is also important to differentiate mitral regurgitation (holosystolic) from aortic stenosis (crescendo-decrescendo) because the configurations at times may be difficult to discern from one another. As discussed earlier (refer to 8. Maneuvers), isometric handgrip can provide a means of differentiating the two, with aortic stenosis decreasing in intensity and mitral valve regurgitation increasing in intensity.

Pulmonary stenosis is a harsh high pitched and high-grade (may have a thrill) murmur best heard in the pulmonary area with radiation to the left common carotid. It has a widely split S2 with a decreased P2 intensity, and may or may not have an ejection click. Whereas the murmur of tetralogy of fallot (due to right ventricular outflow tract obstruction, not the VSD as it tends to be too large to cause turbulent flow) has a single S2. It is important to note that pulmonary stenosis at times may sound somewhat holosystolic and may mimic a VSD, but VSD does not have a widely split S2.

Also note that an ASD may present with a systolic ejection murmur with a widely split and fixed S2 heard best at the pulmonary area. It may also have an associated mid diastolic rumble heard best at the tricuspid area. Coarctation of the aorta is heard best in the back, but may also be a continuous murmur.

Late systolic murmurs

- Usually have a crescendo configuration.

Examples include mitral and tricuspid valve prolapse, and mitral regurgitation due to papillary muscle dysfunction.

Mitral and tricuspid valve prolapse are causes of mitral and tricuspid regurgitation, respectively, and so the findings are also similar (refer to holosystolic murmurs). However, they are associated with a midsystolic click and a late systolic murmur.

Although they may occur together, mitral valve prolapse and tricuspid valve prolapse can be differentiated from one another by their different auscultation locations, the mitral and tricuspid areas, respectively, and that tricuspid prolapse increases in intensity with the increased blood flow and transvalvular pressure gradients caused by inspiration. Mitral valve prolapse can be heard better when the patient is in the left lateral decubitus position.

You should note that sudden standing from a supine position will cause the midsystolic click of mitral valve prolapse to arrive earlier in systole because the valve leaflets will be closer together at the decreased ventricular volumes, and so the murmur will start sooner and last proportionally longer.

A late systolic murmur of mitral regurgitation is present in papillary dysfunction due to myocardial infarction (permanent) or ischemia (transient); it can transiently appear with increases in preload (isometric handgrip, sudden squatting, exercise).

Holosystolic murmurs

- Examples include mitral and tricuspid regurgitation, and ventricular septal defects.

Mitral and tricuspid regurgitation are medium pitched variably intense murmurs that have a blowing quality. However, mitral regurgitation is accentuated when the patient is in the left lateral decubitus position, and it classically radiates to the axilla and inferior to the left scapular tip; its intensity does not change with respiration. The latter point is most important in distinguishing it from tricuspid regurgitation, which increases its intensity with inspiration (you must wait a couple of cardiac cycles to appreciate the difference).

Furthermore, tricuspid regurgitation tends to radiate to the xiphoid area or epigastrum and right sternal border, but not to the axilla. Tricuspid regurgitation is often associated with pulmonary hypertension, and so signs such as a sternal heave (right ventricular hypertrophy) and a louder P2 may provide additional clues.

You should note that pulmonary atresia might present shortly after birth (after the closing of a PDA) with the murmur of tricuspid regurgitation but with a single S2.

Furthermore, the murmur of VSD is usually intense and is classically heard best over the tricuspid area, although it can also be heard loudest in the pulmonary area. Moreover, it does not radiate to a specific area and its intensity does not change with respiration. The murmurs of VSD and mitral regurgitation are enhanced by exercise.

Early diastolic murmur

- Decrescendo configuration
- Terminates before S1

Aortic and pulmonary regurgitation: both are high pitched with a blowing quality. However, aortic regurgitation starts with A2, is heard best along the left sternal border between the

pulmonary and tricuspid areas, may radiate to the apex (and you may hear an Austin-flint murmur of pure aortic regurgitation). Furthermore, if the patient leans forward and exhales completely the murmur of aortic regurgitation will be louder, and this is a useful maneuver to discern it from pulmonary regurgitation. Peripherally, a bounding pulse may be palpated, which signifies an abrupt down stroke due to regurgitation. On the other hand, pulmonary regurgitation starts after P2. It is heard best in the pulmonary area, and does not radiate to the extent of aortic regurgitation. Pulmonary regurgitation may be associated with a sternal heave—which is movement of the sternum suggesting right-sided heart failure and enlargement.

Mid diastolic murmur

- Decrescendo-crescendo configuration

The most common examples include mitral and tricuspid valve stenosis, and they are usually the sequelae of rheumatic fever. Both murmurs are associated with a preceding high-pitched opening snap, and a low-pitched diastolic rumble. The auscultation areas are different, where mitral stenosis is heard best over the mitral area, and tricuspid stenosis is heard best over the tricuspid area or closer to the sternum. Tricuspid stenosis is increased with inspiration and S1 is widely split, whereas mitral stenosis may be enhanced in the left lateral decubitus position. It is important to note that an Austin-flint murmur (pure aortic regurgitation; due to aortic regurgitant flow hitting the mitral valve) may sometimes be confused with that of mitral stenosis.

“Functional” mitral stenosis: due to severe mitral regurgitation where a mid diastolic rumble may be heard.

Carey-Coomb's murmur is due to acute rheumatic fever. It is caused by inflammation of the mitral valve or a first-degree atrioventricular block, which causes atrial systole to coincide with passive ventricular filling, thus causing greater flow and consequently turbulence across the mitral valve.

ASD (refer to midsystolic ejection murmurs and continuous murmurs).

Late diastolic (presystolic) murmurs

- Crescendo configuration
- Mitral valve stenosis and tricuspid stenosis if mild (refer to mid diastolic for details).
- Complete heart block, although the mechanism has not been fully elucidated.

Continuous Murmurs

Examples include a venous hum, patent ductus arteriosus, mammary souffl é. PDA can be pathological especially if it is large enough because it can cause left and right-sided heart failure.

PDA, venous hum, and mammary souffl é are all auscultated best in different areas: PDA is heard best in the pulmonary area; venous hum over the infra and supraclavicular areas; and mammary souffl é over the anterior breast. Mammary souffl é occurs in a distinct population (pregnant or lactating women) and can vary significantly from day to day. PDA tends to be louder, and a

venous hum is low grade. Whereas a PDA has a crescendo-decrescendo pattern encompassing the whole cardiac cycle with an accentuation of S2, a venous hum is holosystolic, and has a higher intensity during diastole. Moreover, a venous hum is low pitched and thus heard better with a bell, and its intensity can be increased with upright position and muted with compression of the internal jugular veins.

As mentioned earlier, you should note that an ASD might have two components: a systolic murmur at the pulmonary area and a diastolic rumble along the left sternal border. It has a widely split S2 that is fixed during respiration. Coarctation of the aorta may be heard in the back, it may also be continuous.

Investigations

Amyl nitrate or methoxamine are substances that can be given at the bedside that cause changes in arterial resistance, venous return, and stroke volume similar to the positional maneuvers described earlier. Imaging modalities such as a chest radiograph, ECG, and echocardiogram are all excellent ways to further provide clues to the etiology of a cardiac lesion. For instance, you may hear the systolic ejection murmur and the single S2 of a tetralogy of fallot, but the chest radiograph may also show a boot-shaped heart; the ECG may show right-sided heart failure and right axis deviation; and the echocardiogram will elicit a VSD and other anatomical clues—making the diagnosis of tetralogy of fallot almost definitive. Other imaging modalities include Doppler studies, which can help delineate transvalvular pressure gradients. Cardiac catheterization would be more invasive but much more definitive in providing etiological information.

Acknowledgements

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