Cardiac Examination and Evaluation of Murmurs

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EDUCATION GAPS

Murmurs are an exceedingly common physical examination finding in pediatric patients. It is imperative that all pediatricians know how to perform a complete cardiac examination and understand the components of benign versus pathologic murmurs.

OBJECTIVES *After completing this article, readers should be able to:*

1. Review and perform a complete cardiac examination in the pediatric patient.
2. Understand the various heart sounds and how they correlate with the underlying physiology of the cardiac cycle.
3. Accurately describe a murmur and be able to discern between innocent and pathologic murmur findings.

INTRODUCTION

The evaluation of murmurs in the pediatric patient has remained a subject of both interest and anxiety for decades. Murmurs are one of the most common physical examination findings in children, and most youth will have a murmur at some point in their life. Given that most murmurs are innocent, it is prudent to differentiate these benign murmurs from those representing underlying cardiac disease. However, with advancements in medical technology and the widespread availability of echocardiography, there is concern about a concomitant decline in cardiac examination skills. This not only has come at great financial expense to the health-care system but also may result in unnecessary increased parental or patient anxiety.

In addition to the physical examination, a targeted cardiac history is essential in determining whether to reassure or raise concern when evaluating the pediatric patient with a murmur. Special attention should be given to the family history; maternal pregnancy information, including the presence of gestational diabetes or drug/toxin exposures in utero, history of prematurity, growth, and feeding patterns; comorbid conditions; and developmental milestones. For older children it is also important to characterize any history of palpitations, presyncope or syncope, chest discomfort, and activity intolerance. Taking this into account, this review is designed to provide an overview of the cardiac physical examination in the context of a comprehensive history, focusing on the

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ABBREVIATIONS

PDA patent ductus arteriosus
VSD ventricular septal defect

importance of auscultation and differentiation of innocent versus pathologic murmurs.

PHYSICAL EXAMINATION

Examination of the pediatric patient is rarely performed in the standard head-to-toe manner and should be tailored to the age and development of the patient to maximize yield. This is of utmost importance in the cardiac examination, particularly auscultation, as a quiet and cooperative patient is essential for an accurate assessment of the cardiovascular system. Thus, although it may be helpful to have a routine examination sequence, it is also prudent that the provider take advantage of whichever portion of the physical examination that the child is willing to allow in a calm and comfortable state.

The cardiac physical examination involves 3 components: observation/inspection, palpation, and auscultation. The provider should have an accurate set of vital signs before the examination, including growth parameters, heart rate, blood pressure (ideally in all 4 extremities), oxygen saturation, and respiratory rate; these should be considered while observing and examining the patient.

Observation/Inspection

The examination begins the moment the provider enters the room. A baseline assessment of the child at rest is invaluable, and a substantial amount of information may be obtained during the interview portion of the examination, before ever laying hands on the patient. The nutritional status of the child, the presence of dysmorphic features, activity level, breathing pattern, and signs of cyanosis or pallor are particularly relevant. In addition to these general findings, a careful assessment of the chest wall (ideally in the supine position) for signs of asymmetry, the extremities for clubbing, and the neck veins for distention provides a more specific assessment of cardiac pathology.

Palpation

Examination of the extremities, peripheral pulses, chest wall, and abdomen by palpation is critical for a complete understanding of the cardiovascular system. Tissue perfusion via capillary refill (normal is <3 seconds), coupled with the temperature of the extremities, provides a rapid assessment of cardiac output. Pulses in the upper and lower extremities should be palpated simultaneously (brachial/radial and femoral), with specific attention to pulse regularity, strength, and delay between the upper and lower extremities; the pulses should be synchronous. For palpation of the chest wall, the provider should be positioned on the patient's right side and should use the palm of the hand and the pads of the fingers laid across the chest to allow an accurate assessment and localization of ventricular impulses, lifts or heaves, and thrills throughout the precordium. The point of maximal impulse should be beneath the left nipple. Although cardiac percussion is now rarely taught and is not high-yield for most providers, assessment of the liver for hepatomegaly by palpation and percussion provides insight into the patient's volume status and cardiac function. Percussion of the upper margin of the liver allows estimation of its span. Practicing these techniques on every patient builds comfort in one's skills such that when an abnormal examination finding is present, it will be reliably appreciated.

Auscultation

To accurately assess abnormal heart sounds, it is essential that the provider have the proper equipment. The stethoscope should have earpieces that are well-fitted; tubing that is intact, no longer than 18 inches, and uniform in diameter; and, ideally, a bell for low-pitched sounds and a diaphragm for high-pitched sounds. Digital stethoscopes are increasingly accurate and useful. Distracting noises should be eliminated or minimized. Traditional teaching of auscultation includes the 4 valvular areas along the sternal border and at the left midclavicular line. (1) However, in the pediatric patient, this should be expanded to include the right lower border, bilateral axillae, back, and, potentially, the anterior fontanelle in the newborn or neonate. This will provide a more complete assessment, as congenital heart lesions may cause extra heart sounds in atypical locations (eg, dextrocardia, coronary fistulae, vein of Galen malformation). Auscultation should also be performed in the supine, sitting, and standing positions in compliant patients.

HEART SOUNDS AND MURMUR CHARACTERIZATION

Heart Sounds

A thorough understanding of the cardiac cycle and normal heart sounds is essential when performing cardiac auscultation (Fig). This will allow better discernment of underlying anatomy and potential pathology. The first heart sound (S1) is a result of the atrioventricular (tricuspid and mitral) valves closing. The second heart sound (S2) occurs when the semilunar (pulmonary and aortic) valves close; the pulmonary valve closes just after the aortic valve because right ventricular contraction ends just after the left. This results in a normal "splitting" of S2. Inhalation

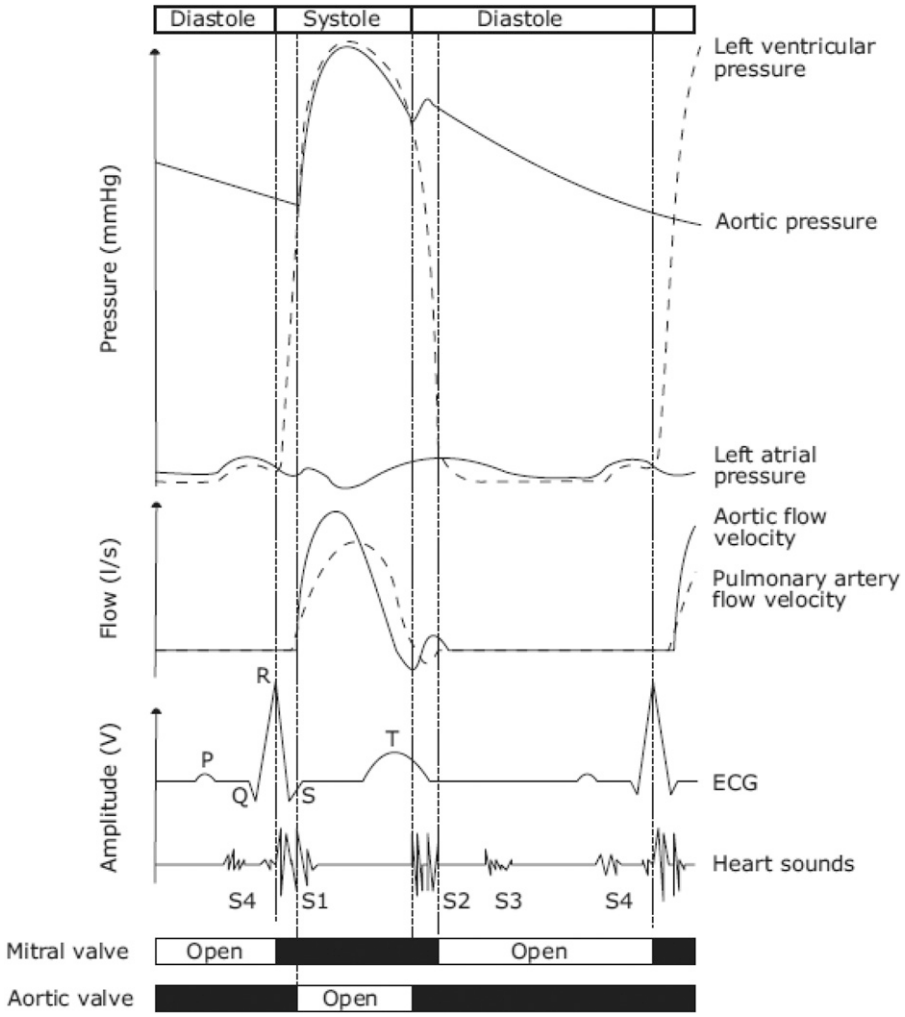

Figure. Wigger diagram of the cardiac cycle.
ECG=electrocardiography.

increases right-sided heart filling and widens the S2 split. Exhalation has the opposite effect.

The third heart sound (S3) is generated with rapid ventricular filling and can be heard early in diastole. It can be a normal finding in older children and athletic patients (2); however, in a tachycardic or ill-appearing patient, it should be considered pathologic until proved otherwise. The fourth heart sound (S4) is heard at the end of diastole just before S1 and is pathologic. It is produced during atrial contraction when additional blood is attempting to fill a poorly compliant ventricle, ultimately resulting in myocardial vibration heard as an S4.

Clicks are extra heart sounds that represent underlying valvar pathology. Ejection clicks can be heard in the setting of semilunar valve (pulmonic or aortic) stenosis and occur shortly after S1. They are best heard at the apex or right upper sternal border for the aortic valve, or along the left sternal border for the pulmonic valve; the pulmonic valve click will also increase in intensity with exhalation. Midsystolic clicks can be heard in patients with mitral valve prolapse and are often associated with a late systolic murmur of mitral regurgitation. They can be intensified by having the patient move from squatting to standing, thereby decreasing preload.

Murmur Characterization

When evaluating a heart murmur, it is important to provide a comprehensive description, including the murmur quality, intensity, duration/timing, location, and transmission/radiation. Taken together, the underlying etiology can often be accurately identified. Murmur quality is generally the most subjective component of the murmur characterization, using terms such as harsh, soft, blowing, crescendo/decrescendo, vibratory, or musical. These descriptors may also convey the examiner's impression of its etiology and whether it is thought to be benign. Table 1 lists descriptors with common etiologies.

Although the intensity of the murmur is a more objective parameter, there does remain some degree of subjectivity. Systolic murmurs should be graded on a scale from I to VI as follows (3):

Grade I: barely audible, often heard in only 1 location or intermittently with a quiet patient in a quiet room

Grade II: easily audible and heard consistently throughout cardiac cycles

Grade III: loud, audible throughout the precordium, of equal intensity to the heart sounds, without a thrill

Grade IV: loud, heard throughout and associated with a palpable thrill

Grade V: very loud, heard with only a small portion of the stethoscope touching the chest wall

Grade VI: very loud, heard with the stethoscope off the chest

Some murmurs change intensity with position or Valsalva maneuvers. An effective Valsalva maneuver is performed by having the patient strain against a closed glottis or blow against the thumb. In younger patients who cannot comply, Valsalva can be achieved as they transition from a supine to a sitting position. Because it is brief, this effort may need to be repeated in young patients to determine whether there is a change in murmur intensity.

The timing and duration of the murmur should be characterized with relation to the cardiac cycle and the heart sounds. Murmurs may generally be described as systolic (early/mid/late, S1-coincident, or ejection), diastolic (early/mid/late), or continuous. Finally, to complete the description, it is important to comment on murmur transmission or radiation to any other areas (eg, the back, axillae).

INNOCENT VERSUS PATHOLOGIC MURMURS

When performed thoroughly, a complete examination is often enough to determine the presence of underlying cardiac pathology. In general, murmurs that have a vibratory or musical quality or are quiet (grade I-II), located along the left middle or lower sternal border, short in duration, or midsystolic are benign or innocent in nature. Following are 4 examples of the most common innocent murmurs of childhood, followed by 4 examples of pathologic murmurs.

Innocent Murmurs

Still's Murmur (Audio 1). The Still's murmur is the most common benign murmur in children. (2) It is a soft (grade I-II) systolic ejection murmur that is best heard at the mid-left sternal border and is loudest in the supine position. It is often described as vibratory, buzzing, or musical in quality, and it decreases or extinguishes with the Valsalva maneuver. Although the etiology has not been determined, it is thought to result from turbulent flow through a relatively small left ventricular outflow tract. (4) The Still's murmur is generally heard in children aged 6 months through 6 years, but it can be present in infants and older children.

Pulmonary Flow Murmur of Infancy. Also known as peripheral pulmonic stenosis or peripheral pulmonary flow murmur, this murmur is soft (grade I-II), midsystolic, and heard along the left upper sternal border with radiation to the bilateral axillae and back. It is heard commonly in infancy, particularly in premature infants, and is thought to be due to the relatively small size of the branch pulmonary arteries in this age group. (5) As the pulmonary vascular bed grows, the murmur should disappear by age 6 months. If the murmur persists beyond 6 months of age, further investigation for underlying structural heart disease should be considered (eg, atrial septal defect).

Pulmonary Flow Murmur of Childhood. This is a grade I-III systolic ejection murmur that is heard best along the left upper sternal border, sometimes with radiation to the back, and is found in older children or adolescents. Although it resembles the murmur of pulmonary valve stenosis, it is not harsh in quality and should not have an associated click. It is most commonly heard in patients with increased cardiac output (eg, fever or anemia) and may disappear when cardiac output normalizes.

Table 1. Common Murmur Descriptors and Their Potential Underlying Etiologies

MURMUR QUALITY DESCRIPTOR	POTENTIAL UNDERLYING ETIOLOGY
Harsh	Ventricular septal defect, significant semilunar (pulmonary, aortic) valve stenosis
Soft	Mild semilunar (pulmonary, aortic) valve stenosis, mild atrioventricular (tricuspid, mitral) valve regurgitation
Crescendo/decrescendo	Semilunar valve (pulmonary, aortic) stenosis
Continuous	Patent ductus arteriosus, venous hum
Blowing	Patent ductus arteriosus, atrioventricular (tricuspid, mitral) valve regurgitation
Vibratory, musical, buzzing	Still's murmur (benign)

Venous Hum. This is the only innocent murmur that is not systolic ejection in timing. It is a low-pitched, soft (grade I-II), continuous murmur that is best heard in the infraclavicular region while sitting or standing. It may be heard in children of any age into young adulthood. The murmur is generated by blood flowing into the superior vena cava and should disappear when supine or with maneuvers that occlude the neck veins (eg, manual compression or turning the head). It can be differentiated from the murmur associated with a patent ductus arteriosus (PDA) in that it is less harsh in quality and should disappear while lying flat.

Pathologic Murmurs

S1-Coincident Murmurs. S1-coincident murmurs occur with the onset of systole and often obscure one's ability to hear S1. They are usually pansystolic and are generated when blood is ejected from a high- to low-pressure chamber. The murmur generated by a ventricular septal defect (VSD) is generally harsher in quality and located along the left sternal border, often with radiation to the right, depending on the VSD location (Audio 2). The murmurs associated with mitral or tricuspid regurgitation tend to be softer and more "blowing" in quality, located at their respective valvar locations, and radiate to either the mid-right sternal border (tricuspid) or apex (mitral) (Audio 3).

Continuous Murmurs. Aside from venous hum, any continuous murmur should be considered pathologic. They are generally vascular in origin and can be heard throughout the systolic and diastolic phases of the cardiac cycle. The PDA murmur is the most common pathologic continuous murmur and is classically described as "machine-like" in quality. It can usually be heard throughout the precordium, especially at the left upper sternal border and toward the infraclavicular area, with radiation to the midback (Audio 4). It is generated as a result of the constant high-pressure differential between the aorta and the pulmonary vascular bed. Other examples of continuous murmurs include arteriovenous fistulae, coronary-cameral fistulae, and surgical aortopulmonary shunts. (3)

Harsh Ejection Murmurs. Although similar in nature to some of the innocent murmurs noted previously herein, ejection murmurs that are harsh in quality or loud (grade III or higher) should be considered abnormal and investigated further. The murmur generated from pathologic semilunar valve stenosis will be early to midsystolic and have a crescendo-decrescendo quality (eg, aortic stenosis [Audio 5]). They may also be associated with other abnormal physical examination findings, such as a hyperdynamic precordium, ejection click, displaced or sustained apical impulse, or abnormal S2 splitting. Furthermore, depending on their etiology, they may be altered with various physical examination maneuvers (eg, hypertrophic cardiomyopathy murmur is louder with standing). Table 2 reviews common findings in pathologic ejection murmurs and associates them with the underlying level of obstruction.

Diastolic Murmurs. Although diastolic murmurs are generally the most difficult to hear, they are all considered pathologic and should be evaluated further. Their timing may help differentiate their potential etiology and should be classified as early or mid-to-late. As described later herein, early diastolic murmurs are caused by aortic or pulmonic regurgitation, whereas mid-to-late diastolic murmurs are caused by tricuspid or mitral valve stenosis, or in lesions with a large amount of shunting. Diastolic murmurs are usually lower-pitched, softer, and best appreciated with the bell of the stethoscope. Early diastolic murmurs, such as aortic regurgitation (Audio 6), occur immediately after S2, are located along the left lower sternal border or apex, and are decrescendo in quality due to the drop in pressure differential between the great artery and the ventricle throughout diastole. The aortic regurgitation murmur tends to be higher-pitched due to the higher-pressure difference, sometimes best heard with the diaphragm of the stethoscope, compared with the softer, lower-pitched

Table 2. Common Examination Findings with Pathologic Ejection Murmurs and Their Associated Underlying Level of Obstruction

LEVEL OF OBSTRUCTION (EXAMPLE)	SYSTOLIC EJECTION CLICK	SYSTOLIC EJECTION MURMUR	THRILL
Subvalvar (hypertrophic cardiomyopathy, subaortic or subpulmonary stenosis)	–	+	–
Valvar (aortic or pulmonary stenosis)	+	+	+
Supravalvar			
- Supravalvar aortic stenosis	–	+	+
- Branch pulmonary artery stenosis	–	+	–

pulmonary regurgitation murmur. Mid-to-late diastolic murmurs are generated due to ventricular filling during diastole and with atrial contraction. They are lower-pitched, often described as "rumbling" in quality, and result from tricuspid or mitral valve stenosis. A "mid-diastolic rumble" may also be appreciated in the patient with a large left-to-right shunt (ie, VSD or PDA), due to the increased volume return to the left atrium and mitral valve. (3) A rumble may be heard with a large left-to-right atrial-level shunt (eg, ASD) as well, with increased volume return to the right atrium and through the tricuspid valve.

Summary

- Although murmurs in children can be an important finding to suggest underlying cardiac disease, most are benign.
- Mastering the cardiac physical examination is a skill that requires practice and attention to detail but does allow one to differentiate between innocent and pathologic murmurs.
- Based on expert consensus, knowledge of the common traits of pathologic murmurs will lead to increased diagnostic accuracy.
- Based on expert consensus, maintaining cardiac examination skills allows a more judicious use of consultation and ancillary studies and helps prevent additional parental or patient anxiety.

Audio clips and references for this article can be found at http://pedsinreview.aappublications.org/content/42/No. 7/375.

PIR QUIZ

1. A 10-month-old boy is brought to the clinic for a follow-up visit. He is growing normally and developmentally meeting all his milestones. At 4 and 6 months of age the primary care provider noticed a soft (grade I-II), midsystolic murmur, which could be heard along the left upper sternal border with radiation to both axillary regions and the back. The second sound is constantly split. This murmur is still heard on today's visit. Which of the following is the most likely cause of this infant's murmur?

   A. Atrial septal defect.
   B. Mitral insufficiency.
   C. Patent ductus arteriosus.
   D. Peripheral pulmonic stenosis.
   E. Ventricular septal defect.

2. A 13-year-old boy is brought to your office by his parents for a sick visit. He missed school because he woke up in the morning with a sore throat. Apart from a few previous episodes of otitis media, he has had an unremarkable medical history. On physical examination his temperature is 103°F (39.4°C). He is breathing comfortably. His heart rate is 110 beats/min. There is no nuchal rigidity. His pharynx is injected. There are no tonsillar exudates. You note a grade II/VI systolic murmur along the left upper sternal border with radiation to the back. He does not have any abdominal tenderness or organomegaly. Which of the following is the most appropriate next step in evaluation of this murmur?

   A. Perform cardiac echocardiography to assess for pulmonic stenosis.
   B. Perform chest radiography to determine whether there is cardiomegaly.
   C. Perform electrocardiography.
   D. Reevaluate the child in a few weeks when well.
   E. Refer to pediatric cardiology.

3. You are seeing a 2-year-old boy with no significant medical history. He is growing normally and gaining weight appropriately. He has normal developmental milestones. On physical examination he has normal vital signs. You note that he has a low-pitched, soft (grade I-II), continuous murmur best heard in the infraclavicular region while sitting down. You are not able to hear the murmur when he is lying down or when you apply gentle pressure to the veins of the neck or ask him to turn his head. Which of the following best describes the cause of this child's murmur?

   A. Aortic stenosis.
   B. Arteriovenous fistula.
   C. Coronary-cameral fistula.
   D. Patent ductus arteriosus.
   E. Venous hum.

4. You are called to the well-baby nursery to evaluate a 2-day-old girl with dysmorphic facial features and a heart murmur. The infant has midfacial flattening with up-slanting palpebral fissures, epicanthal folds, bilateral transverse palmar creases, and hypotonia. The infant is comfortable at rest. On auscultation you hear a grade III/VI harsh S1-coincident systolic murmur along the lower left sternal border with radiation to the right. Which of the following is the most likely diagnosis in this patient?

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A. Down syndrome with atrial septal defect.
B. Down syndrome with patent ductus arteriosus.
C. Down syndrome with ventricular septal defect.
D. Turner syndrome with coarctation of the aorta.
E. Williams syndrome with supravalvular aortic stenosis.

5. You are evaluating a 15-year-old boy with a cardiac murmur. The murmur is heard best along the lower left sternal border during early diastole and is grade III/VI and follows S2. It is decrescendo in quality. The murmur is high-pitched and is best heard with the diaphragm of the stethoscope. Based on the cardiac auscultatory findings, which of the following is the most likely diagnosis in this patient?

A. Aortic regurgitation.
B. Atrial septal defect.
C. Mitral stenosis.
D. Still's murmur.
E. Tricuspid stenosis.