Emergency Cardiac Ultrasound

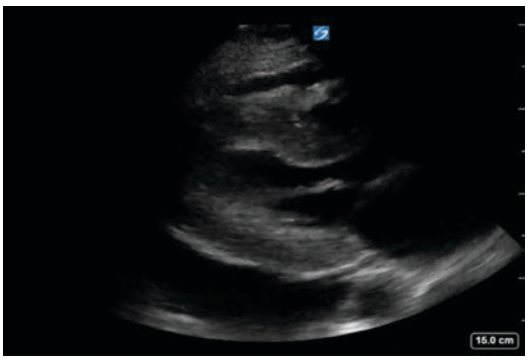
23

Christine Butts and Scott Mackey

Question 1

A 16-year-old boy presents to the emergency department because of chest pain. He states that he had "a cold" about a week ago, but that seemed to clear up. This morning he developed sharp stabbing chest pains that are worsened with movement, and improves while leaning forward. He denies shortness of breath or any other complaints. On arrival vital signs are as follows: temperature 98.0 °F, heart rate 79 beats/minute, respirator rate 16 breaths/minute, blood pressure 123/73 mm Hg, and oxygen saturation 100% on room air. Breath sounds are clear and equal throughout. Heart sounds are regular, with no murmurs, rubs, and gallops. His EKG shows diffuse ST elevation throughout.

An ultrasound of his heart is performed and is shown below. Which of the following is correct regarding this image?



A. It is impossible to assess the right ventricle from this view.
B. A pericardial effusion is present, but there are no indications of pericardial tamponade.
C. A pleural effusion is present.
D. A transesophageal echocardiogram (TEE) would be more sensitive for making the diagnosis in this patient.
E. All of the clinical signs of tamponade have to be present before the diagnosis can be suspected.

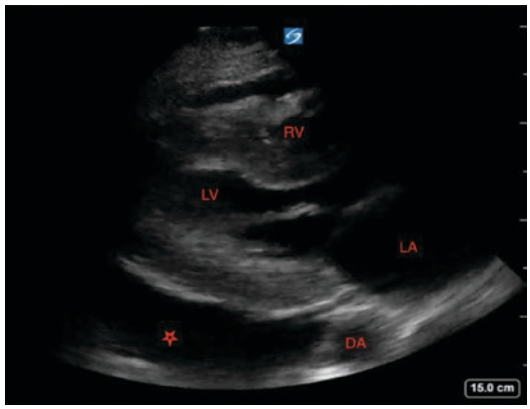
Correct Answer: B

This image shows a parasternal long axis view of the heart. This view, obtained by placing the transducer to the left of the patient's sternum with the indicator pointing towards the patient's left shoulder, yields an image that primarily evaluates

C. Butts (✉) · S. Mackey
Emergency Medicine, Louisiana State University, New Orleans, LA, USA
e-mail: cbutts@lsuhsc.edu; scott.mackey@lcmchealth.org

M. Waseem et al. (eds.), *Prepare for the Pediatric Emergency Medicine Board Examination*,
https://doi.org/10.1007/978-3-030-28372-8_23

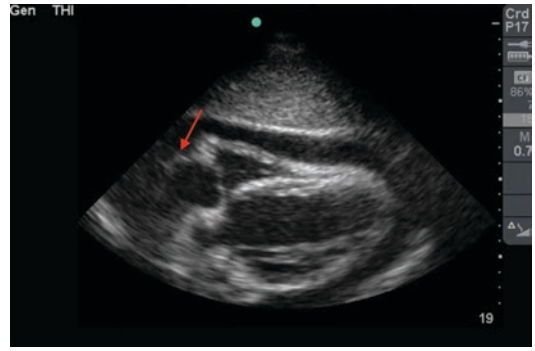
the left side of the heart. However, a small portion of the right ventricle is visible as well. A pericardial effusion is seen surrounding the heart (see image below). The descending aorta provides an important landmark in evaluating this image. Fluid collections anterior to the aorta are pericardial, versus fluid collections that are deep to (or posterior to) the aorta are pleural.



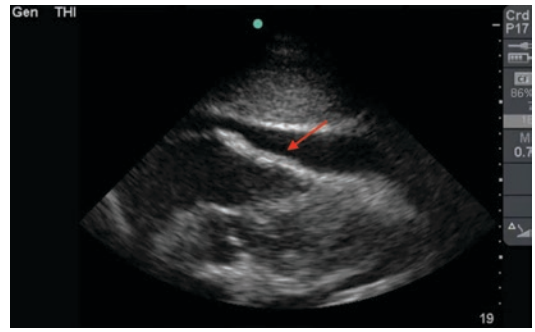
Annotated parasternal long axis view of the heart: RV (right ventricle), LV (left ventricle), LA (left atrium), DA (descending aorta), Star (pericardial effusion)

The patient's presentation of sharp, positional chest pain following a viral illness suggests pericarditis. EKG findings of diffuse ST segment elevation give further weight to this diagnosis. Determining the presence of an effusion is key in order to risk-stratify these patients. Additionally, once an effusion is identified, an assessment for factors suggesting cardiac tamponade is critical.

Beck triad of hypotension, muffled heart tones, and distended neck veins is often cited as the classical presentation of cardiac tamponade. However, these findings can be difficult to identify and may be variably present and a noisy room or obese patient may cause difficulty in assessing for these signs. Ultrasound provides an opportunity not only for the diagnosis of an effusion but also for signs of tamponade. One of the earliest signs that the pressure in the pericardial sac is building is a compressive effect on the right side of the heart. The right side of the heart is a lower pressure system when compared to the left and is the first to be affected by mounting pressure caused by a developing effusion. The right atrium is typically affected first, and the sonographer may note that the right atrium will appear to collapse or bow inward during systole. As the pressure increases, the right ventricle will be next affected and may be seen to collapse inward during diastole. Once diastolic filling of the right side of the heart is compromised, the examiner may note distention of the inferior vena cava as well. Any of these echocardiographic signs, even in the face of a normal blood pressure, should be concerning for impending tamponade.



This image, taken from a subxiphoid approach, shows bowing of the right atrium (arrow). Note that the tricuspid valve is closed, indicating that this is occurring during systole



This image, taken from a subxiphoid approach, shows bowing of the right ventricle. Note that the tricuspid valve, indicating that this is occurring during diastole

In this case, although there is a pericardial effusion present, there is no evidence of bowing of the right atrium or ventricle. Additionally, the patient's blood pressure is within normal limits. Choice A is incorrect due to the fact that, as noted above, the right ventricle can be seen in part in this image. Choice C is incorrect as the location of the descending aorta confirms this fluid collection as pericardial, not pleural. Choice D is incor-

rect as transesophageal echocardiogram is time consuming, requires sedation, and is not more sensitive in making the diagnosis of pericardial effusion and tamponade. Finally, choice E is incorrect as when a pericardial effusion is present, there should be concern for tamponade or impending tamponade, even when all of the clinical signs are not obviously present.

Take-Home Message

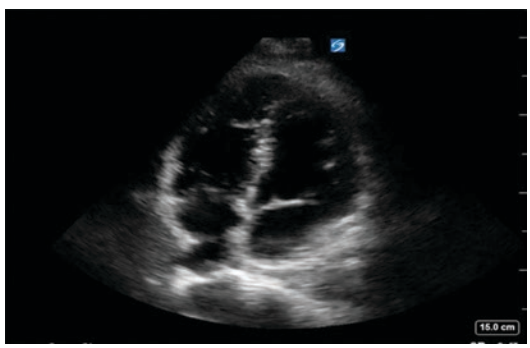
Ultrasound can be used to rapidly assess for the presence of a pericardial effusion and for signs of tamponade or impending tamponade.

ABP Content Specification

- Recognize cardiac tamponade based on clinical and laboratory manifestations. Recognize normal cardiac anatomy on echocardiography.

Question 2

A 12-year-old girl is brought into the ED by her mother with complaints that she is tiring easily. She notes that the patient has not been able to participate in gym class due to extreme fatigue. She has also noted that her daughter gets out of breath walking even short distances. Her vital signs are as follows: heart rate 110 beats/minute, respiratory rate 18 breaths/minute, blood pressure 100/60 mm Hg, and oxygen saturation 95% on room air. She is afebrile. Her examination is significant for tachycardia with an S3 and fine rales noted at both lung bases. A bedside echocardiogram is performed and is shown below. Which of the following is correct regarding this image and case?



A. This view of the heart is ideal for evaluating the flow across the mitral and tricuspid valves, as the direction of flow is parallel to the Doppler gate.
B. Assessing left ventricular contractility requires advanced Doppler calculations and is difficult to assess at the bedside.
C. This view of the heart is not adequate to assess right ventricular chamber size in comparison to the left.
D. Pericardial effusions cannot be assessed from this view.
E. The pressure gradient across a valve can be directly measured utilizing Doppler flow.

Correct Answer: A

Interpreting an echocardiogram at the bedside can be overwhelming. The amount of information measured and obtained can be enormous. However, evaluation of a few basic things is well within the scope of PEM physician. Ejection fraction refers to the volume of blood ejected from the left ventricle. It is calculated by measuring the end diastolic volume and the end systolic volume. These calculations can be cumbersome and intimidating. In contrast, the contractility, or muscular function, of the left ventricle, can be assessed quickly at the bedside by focusing on a few key factors. Specifically, the myocardium should be examined to determine if it is thickening during systole. The chamber size of the left ventricle should also decrease by one third in systole. By quickly assessing these two factors, the physician can rapidly determine if the contractility of the left ventricle is normal, decreased, or severely decreased. Taking a video clip of the heart and viewing it in slow motion can help if it is difficult to assess the contractility in real time. Often, with practice and experience, bedside sonographers can be as successful in this determination as cardiologists.

Additionally, other quick information can be obtained from a few views of the heart. The presence of a pericardial effusion can be noted on any view. Once left ventricular contractility has been assessed, the right heart should be examined for evidence of enlargement, or strain. The right heart should be smaller than the left ventricle, at a ratio of less than 0.60. The apical four-chamber

view, seen in this patient, is ideal for evaluating the two ventricles side by side.

Doppler flow is a complex subject, outside of the scope of this chapter. However, a basic knowledge of the concepts of Doppler can greatly aid the clinician that is attempting to interpret the pediatric heart. Doppler assesses the shift in frequency of an object as it moves in the body. By assessing this shift, the ultrasound is able to determine many factors, including the speed and direction of motion of the object. This information is obtained by placing the Doppler "gate" across the area of interest, such as across a valve. In order to obtain the strongest signal, with the least amount of interference, the gate should be positioned as parallel to the direction of flow as possible. An apical four-chamber view is ideal for this purpose when examining the flow across the mitral and tricuspid valves, as well as the aortic valve (see below).

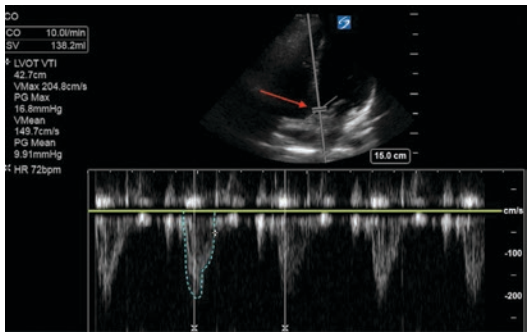


Image demonstrating the placement of the Doppler gate (arrow) parallel to the direction of flow in this apical view. Blood is flowing either from the bottom of the image towards the top (across the mitral and tricuspid valves) or from the top to the bottom (across the aortic valve)

Doppler can determine the velocity of motion of an object, but cannot directly determine the pressure gradient. Pressure gradient can be indirectly assessed once the velocity is determined.

When considering the above answers, option B is incorrect as a basic assessment of left ventricular contractility can be determined with a visual assessment. More complex measurements can be obtained to calculate the ejection fraction. Option C is incorrect as the apical four-chamber view is actually ideal to evaluate the right ventricular size in comparison to the left ventricular size. Option D is incorrect as a pericardial effusion can be seen on any cardiac view. Option E is incorrect as the Doppler function can calculate the velocity across an area, but can only assess the pressure gradient indirectly. Option A is the correct answer as the apical four chamber view allows the examiner to line up the Doppler gate as near to parallel to the direction of flow as possible.

Take-Home Message

Although echocardiography can be complicated, knowledge of basic anatomy, principles of echocardiography, and physics can enable the bedside sonographer to obtain a large amount of information.

ABP Content Specification

- Understand the principles of echocardiography.
- Understand the physics of echocardiography.
- Recognize normal cardiac anatomy on echocardiography.
- Know how Doppler-derived velocity measurements compare to direct-pressure gradient determinations.
- Assess systolic and diastolic function utilizing echocardiography.

Question 3

A mother brings her 8-week-old infant to the emergency department with concern for a change to his skin color. She reports he was born full term and had no complications at delivery. He has been slightly underweight at his office visits and she notes that he doesn't eat as much as he should. A physical exam shows an infant in no acute distress. A harsh systolic murmur is noted at the left upper sternal border and the lungs are clear.

Which of the following is correct concerning echocardiography for this patient?

A. Transesophageal echocardiography is the preferred initial method to examine a patient for suspected congenital heart disease.
B. Pediatric echocardiography is technically difficult when compared to adults due to differences in anatomy.

C. Doppler measurements are key in making the diagnosis of congenital heart disease.
D. Congenital heart disease is usually obvious on transthoracic echocardiography.
E. Congenital abnormalities are best noted on the apical view of the heart.

Correct Answer: C

Echocardiography is crucial in making the diagnosis of congenital heart disease (CHD). When the diagnosis is suspected by the clinical history or physical exam, a transthoracic echocardiogram should be performed first. Transthoracic echo (TTE) carries very little risk for even infants and can demonstrate a number of abnormalities. Transesophageal echocardiography (TEE) has its place in the evaluation of CHD, particularly when the initial echocardiogram is nondiagnostic, but carries inherent risks. Children must be sedated for TEE and this test should be considered as a second line diagnostic modality. It can also be used intraoperatively or in the cardiac catheterization lab to gain further information. Although many defects of CHD, such as a ventriculoseptal defect, can be visualized directly on TTE, findings may be subtle. At times, the sonographer may be looking for indirect evidence of a CHD. For example, right ventricular hypertrophy can be suggestive of the pulmonary stenosis of Tetralogy of Fallot. Additionally, the use of Doppler is crucial in looking for flow abnormalities. Blood flow within the pediatric heart should be predictable and the finding of turbulent flow or regurgitation across a valve should cause the examiner to be suspicious of an underlying CHD. For example, turbulent flow visualized within the right ventricle can suggest the presence of abnormal flow patterns, such as with the overriding aorta seen in Tetralogy of Fallot.

Pediatric patients may require slightly different technique than adults, but the TTE is not inherently more difficult. Pediatric echocardiography may actually be technically less challenging secondary to the absence of habitus complications that plague adult echocardiography.

Choice A is incorrect as transesophageal echocardiography should be reserved for cases in which the initial transthoracic echocardiogram is inconclusive or does not yield a diagnosis. It should not be the initial modality of evaluation. Choice B is incorrect as pediatric echocardiography is not more technically difficult than in adults. Choice D is incorrect as CHD may not be immediately obvious on echocardiography. Application of other techniques, such as Doppler or assessing for secondary findings (such as hypertrophy), will often suggest or prove the correct diagnosis. Choice E is incorrect as, depending on the nature of the defect, multiple views are likely needed to confirm the diagnosis. Choice C is correct as Doppler flow is essential in looking for regurgitant or turbulent flow that suggests a defect. Additionally, the use of Doppler flow allows for calculation of the velocity of flow and in turn, the pressure gradient across valves. This information is critical in identifying the presence of a lesion as well as in classifying its severity and need for intervention.

Take-Home Message

A large amount of information can be gained with transthoracic echocardiography in the evaluation of children with suspected congenital heart disease.

ABP Content Specification

- Know the indications and limitations of fetal echocardiography on the diagnosis of CHD. Know the indications for, risks of, and limitations of transesophageal, stress, and fetal echocardiography.
- Understand the principles of echocardiography.

Suggested Reading

Question 1

Jacob S, et al. Pericardial effusion impending tamponade: a look beyond Beck's triad. Am J Emerg Med. 2009;27(2):216–9.

Goodman A, et al. The role of bedside ultrasound in the diagnosis of pericardial effusion and cardiac tamponade. J Emerg Trauma Shock. 2012;5(1):72.

Question 2

Harris P, Kuppurao L. Quantitative Doppler echocardiography. BJA Educ. 2016;16(2):46–52.

Pershad J, et al. Bedside limited echocardiography by the emergency physician is accurate during evaluation of the critically ill patient. Pediatrics. 2004;114(6):e667–71.

Ciccone TJ, Grossman SA. Cardiac ultrasound. Emerg Med Clin North Am. 2004;22(3):621–40.

Question 3

Ayres NA, et al. Indications and guidelines for performance of transesophageal echocardiography in the patient with pediatric acquired or congenital heart disease: a report from the Task Force of the Pediatric Council of the American Society of Echocardiography. J Am Soc Echocardiogr. 2005;18(1):91–8.

Lai WW, et al. Guidelines and standards for performance of a pediatric echocardiogram: a report from the Task Force of the Pediatric Council of the American Society of Echocardiography. J Am Soc Echocardiogr. 2006;19(12):1413–30.