Julie R. Ingelfinger, M.D., *Editor*

Focused Cardiac Ultrasonography for Left Ventricular Systolic Function

Gabriel Prada, M.D., Ashley V. Fritz, D.O., Mariana Restrepo-Holguín, M.D., Pramod K. Guru, M.B., B.S., and José L. Díaz-Gómez, M.D.

OVERVIEW

Focused cardiac ultrasonography is a point-of-care, qualitative or semiquantitative means of assessing cardiac size, structure, and function that is performed and interpreted by the clinician at the same time that the physical examination is conducted. Multiple studies conducted in inpatient and outpatient settings have shown that focused cardiac ultrasonography is more reliable and accurate than physical examination for the diagnosis of left ventricular systolic dysfunction.[1,2] This video presents a practical method for conducting visual assessment of left ventricular systolic function with the use of focused cardiac ultrasonography.

From the Departments of Critical Care Medicine (G.P., P.K.G., J.L.D.-G.) and Anesthesiology and Perioperative Medicine (A.V.F., M.R.-H., J.L.D.-G.), Mayo Clinic, Jacksonville, FL. Address reprint requests to Dr. Díaz-Gómez at the Department of Critical Care Medicine, Mayo Clinic, 4500 San Pablo Rd. S., Jacksonville, FL 32224, or at diazgomez.jose@gmail.com.

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INDICATIONS AND APPLICATIONS

Focused cardiac ultrasonography is indicated in outpatient and inpatient settings for screening and diagnostic purposes. Diagnostic indications include acute critical cardiopulmonary conditions such as dyspnea, chest pain, trauma, arterial hypotension, shock, respiratory failure, and cardiac arrest. Focused cardiac ultrasonography should not replace physical examination or more advanced, comprehensive diagnostic measures such as formal echocardiography.[1]

Left ventricular systolic dysfunction is the most common pathologic condition evaluated with focused cardiac ultrasonography. Its goal is to identify findings that correlate with normal or severely reduced left ventricular systolic function through a qualitative visual assessment. Focused cardiac ultrasonography is more effective than physical examination for the identification of left ventricular systolic dysfunction, with a sensitivity of 73 to 100% and a specificity of 64 to 96%.[2] When performed by trained emergency medicine and critical care physicians, focused cardiac ultrasonography correlates well with quantitative assessment of left ventricular systolic function (e.g., Simpson's method and assessment of left ventricular fractional shortening) when performed by echocardiographers.[3-5]

The technique is more applicable for screening and diagnosis than for monitoring owing to the lack of quantitative measurements that can be followed over time. Focused cardiac ultrasonography is indicated in both outpatient and inpatient settings in persons with risk factors for atherosclerotic cardiovascular disease (e.g., advanced age, high blood pressure, dyslipidemia, diabetes mellitus, and tobacco smoking), an abnormal electrocardiogram, or elevated levels of brain natriuretic peptides.[1,2,6]

ANATOMY

The heart is a fibromuscular organ with an oblique orientation located in the middle mediastinum. The left ventricular cavity is enclosed by the endocardial border. On its long axis and on the apical four-chamber plane, the left ventricle has a bullet-shaped structure, with its long axis spanning from the apex to the base of the heart (Fig. 1). On its short axis, the left ventricle has a circular shape and an irregular inner surface owing to the presence of trabeculae and papillary muscles; the endocardial and epicardial borders surround the left ventricular wall (Fig. 2). The inflow portion of the left ventricle surrounds and contains the mitral apparatus. The components of the mitral apparatus include the annulus and the anterior and posterior leaflets. The outflow portion of the left ventricle lies between the anterior mitral-valve leaflet and the ventricular septum.

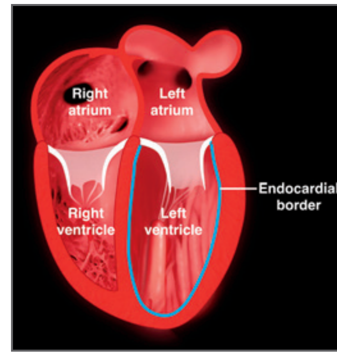

Figure 1. Anatomy of the Heart.

Shown is the heart in the apical four-chamber plane.

LEFT VENTRICULAR SYSTOLIC FUNCTION

Systolic function relies on shortening of the muscle fibers along the longitudinal and circumferential planes of the left ventricle. From the beginning to the end of systole, these changes are manifested by a displacement of the mitral annulus toward the apex, an increase in wall thickness, and a decrease in cavity size.[7,8]

EQUIPMENT

Focused cardiac ultrasonography requires an ultrasound system with two-dimensional imaging, a low-frequency (1 to 5 MHz) phased-array probe, ultrasound transmission gel, and gloves (Fig. 3).

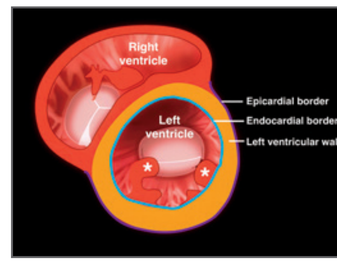

Figure 2. Short-Axis View of the Left Ventricle.

Shown is a cross-sectional view of the heart at the level of the papillary muscles (asterisks) of the left ventricle.

PREPARATION

Before beginning the procedure, wash or sanitize your hands. Explain the procedure to the patient, and mention that the procedure is not associated with risks or complications. Place the ultrasound machine at the head of the patient's bed, on the patient's right side. Put on a pair of gloves and expose the patient's thorax. If possible, place the patient in the left lateral decubitus position.

ECHOCARDIOGRAPHIC VIEWS

The most validated echocardiographic views for the visual assessment of left ventricular systolic function are the apical four-chamber view, the parasternal long-axis view, and the parasternal short-axis view. Table 1 describes and Figure S1 in the Supplementary Appendix (available at NEJM.org) illustrates the procurement of the echocardiographic views recommended for the visual assessment of left ventricular systolic function.

To obtain an image in the apical four-chamber view, set the field depth between 15 cm and 20 cm and place the probe at the point of maximal impulse. Alternatively, you can start scanning at the anterior axillary line and move toward the nipple using a zig-zag movement. Hold the probe at an angle of 60 degrees relative to the chest wall, facing the sternal notch, with the orientation marker pointing toward the 3 o'clock position. Since the orientation marker on the probe indicates the right side of the screen, the left ventricle and atrium will be seen on the right side of the screen.

Figure 3. Ultrasound Machine with Phased-Array Probe.

To obtain an image in the parasternal long-axis view, set the field depth between 12 cm and 20 cm and place the probe over the left third or fourth intercostal space, adjacent to the sternum. Point the orientation marker toward the 10 o'clock position (or the patient's right shoulder), and hold the probe perpendicular to the chest wall. The heart should be visualized in a horizontal orientation, showing the aortic and mitral valves but not the left ventricular apex.

To obtain an image in the parasternal short-axis view, first find the parasternal long-axis view. Then rotate the probe clockwise until the orientation marker points toward the 2 o'clock position (or the patient's left shoulder), and decrease the field

Table 1. Procurement of Echocardiographic Views.

View	Location of Probe	Approximate Orientation of Probe Marker	Depth (in cm)	Tips
Apical four-chamber view	Point of maximal impulse*	3 o'clock	15–20	Probe must be angled at approximately 60 degrees relative to chest wall, facing right upper hemithorax. If atria are not visible, tilt probe upward (with probe tail down). If left ventricular outflow tract is visible, tilt probe down (with probe tail up).
Parasternal long-axis view	Left third or fourth intercostal space, adjacent to sternum	10 o'clock	12–20	Heart should be visualized in horizontal orientation, showing aortic and mitral valves but not left ventricular apex.
Parasternal short-axis view	Left third or fourth intercostal space, adjacent to sternum	2 o'clock	10–14	At mitral-valve level, place probe perpendicular to chest wall; at midpapillary level, tilt probe downward and point toward patient's left flank.

* As an alternative to placing the probe at the point of maximal impulse, start from the anterior axillary line at the left fifth or sixth intercostal space and move toward the nipple, using a zig-zag movement, until the heart is seen. In female patients, place the probe under the breast crease.

depth to 10 to 14 cm. The left ventricle should be seen at the center of the screen as a circular structure in which the endocardial and epicardial borders can be consistently visualized.

Echocardiographic Measures of Left Ventricular Systolic Function

To evaluate the left ventricular systolic function by means of focused cardiac ultrasonography, use the following four echocardiographic measures: longitudinal shortening, anterior mitral-leaflet motion, thickening of wall segments, and change in the area of the cavity.[4,5,9,10]

Longitudinal Shortening

Longitudinal shortening is best evaluated in the apical four-chamber view. Identify the segment between the base and the apex of the heart, which corresponds to the left ventricular longitudinal plane. The lateral and septal mitral annuli can be used as anatomical reference points. The segment reaches its maximum length at end diastole. During systole, the base moves toward the apex, causing the segment to shorten until it reaches its minimum length at end systole. The difference between the maximum length and the minimum length during the same cardiac cycle yields the estimated longitudinal shortening. A difference of at least 1 cm indicates normal left ventricular systolic function, whereas a difference of less than 1 cm suggests severely reduced left ventricular systolic function (Fig. S2). Longitudinal shortening should also be evaluated in the parasternal long-axis view.

Anterior Mitral-Leaflet Motion

Anterior mitral-leaflet motion can be evaluated only in the parasternal long-axis view. Imagine drawing a line from the base to the apex of the heart, along the midline of the left ventricular cavity. In early diastole, the mitral-valve leaflets separate widely, with the anterior mitral leaflet moving toward the ventricular septum. Movement (or motion) of the anterior mitral leaflet beyond the midline indicates normal left ventricular systolic function, whereas movement that does not extend beyond the midline suggests severely reduced function (Fig. S3).

Thickening of Wall Segments

Thickening of wall segments is best evaluated in the parasternal short-axis view. Wall thickness is minimal at end diastole. During systole, the myocardium contracts, causing the wall to increase in thickness until it reaches its maximum thickness at end systole. The fractional increase in wall thickness from end diastole to end systole during the same cardiac cycle yields the estimated thickening of wall segments. Uniform thickening throughout most of the wall segments, with an increase in thickness of at least one third, indicates normal left ventricular systolic function, whereas an increase in thickness of less than one third suggests severely reduced function (Fig. S4). Thickening of wall segments should also be evaluated in the apical four-chamber and parasternal long-axis views.

Change in the Area of the Cavity

Change in the area of the cavity is best evaluated in the parasternal short-axis view. The space enclosed by the endocardial borders represents the area of the left ventricular cavity. The cavity reaches its maximum area at end diastole. During systole, the endocardial walls move closer to one another, thereby reducing the area of the cavity, until the cavity reaches its minimum area at end systole. The fractional decrease in the area from end diastole to end systole during the same cardiac cycle yields the estimated change in the area of the cavity. A decrease of at least one third indicates normal left ventricular systolic function, whereas a decrease of less than one third suggests severely reduced function (Fig. S5). The change in the area of the cavity should also be evaluated in the apical four-chamber and parasternal long-axis views.

PROCEDURE

Table 1 includes information on the procurement of echocardiographic views. To begin your evaluation of left ventricular systolic function, obtain images first in the apical four-chamber view, then in the parasternal long-axis view, and finally in the parasternal short-axis view. (The video shows images from two patients: Patient 1 has normal left ventricular systolic function, and Patient 2 has severely reduced left ventricular systolic function.)

In the apical four-chamber view, identify the structures of interest, including the lateral and septal mitral annuli, the apex, and the endocardial and epicardial borders. Using the ruler or M-mode vector line on the screen, evaluate the longitudinal shortening. (In Patient 1, the difference between the maximum length and the minimum length is more than 1 cm, whereas in Patient 2, the difference is less than 1 cm.) Next, evaluate the thickening of wall segments. (In Patient 1, the thickness is markedly increased by more than one third, whereas in Patient 2, the thickness is clearly increased by less than one third.) Finally, evaluate the change in the area of the cavity. (In Patient 1, the area is unmistakably decreased by more than one third, whereas in Patient 2, the area is decreased by less than one third.)

In the parasternal long-axis view, identify the structures of interest, including the anterior mitral-valve leaflet, the endocardial and epicardial borders, and the midline of the left ventricular cavity. Evaluate the anterior mitral-leaflet motion. (In Patient 1, the leaflet clearly extends beyond the midline of the left ventricular cavity during early diastole, but in Patient 2, the leaflet does not extend beyond the midline.) The results for the thickening of wall segments in this view are similar to the results in the apical four-chamber view, as are the results for the change in the area of the cavity and for the longitudinal shortening.

Obtain images in the parasternal short-axis view, first at the mitral-valve level and

Table 2. Echocardiographic Measures of Left Ventricular Ejection Fraction.*

Estimated LVSF or LVEF	Longitudinal Shortening	Anterior Mitral-Leaflet Motion	Thickening of Wall Segments	Change in Area of Cavity
Normal (>55%)	≥1 cm	Beyond midline	Increased by ≥1/3 from minimal thickness	Decreased by ≥1/3 from maximum area
Severely reduced (<30%)	<1 cm	Not beyond midline	Increased by <1/3 from minimal thickness	Decreased by <1/3 from maximum area

* LVEF denotes left ventricular ejection fraction, and LVSF left ventricular systolic function.

then at the midpapillary level. Identify the structures of interest, including the endocardial and epicardial borders. Again, the results for the thickening of wall segments in this view are similar to the results for the apical-four chamber and parasternal long-axis views, as are the results for the change in the area of the cavity.

As you perform the procedure, it is important to correlate and integrate the information collected in each view to complete the assessment of each echocardiographic measure. Consistency among all four measures and views is essential for an accurate visual assessment of the left ventricular systolic function. If all four measures are rated as normal, as in Patient 1, it is reasonable to grade the left ventricular systolic function as normal, which would correspond to an estimated ejection fraction of more than 55%. When all four measures are rated as abnormal, as in Patient 2, it is reasonable to grade the left ventricular systolic function as severely reduced, which would correspond to an estimated ejection fraction of less than 30% (Table 2). However, when some measures are rated as normal but others are rated as abnormal, or when some measures cannot be properly evaluated owing to difficulties in image acquisition or the inability to perform a clear assessment (e.g., a borderline result between normal and abnormal), it may not be possible to grade the left ventricular systolic function definitively. Finally, in every case, the focused cardiac ultrasonographic examination must be interpreted in a context-sensitive manner, taking into account available clinical information.

LIMITATIONS

Proper use of focused cardiac ultrasonography may be limited by patient-related factors such as obesity, obstructive pulmonary diseases, and the need for mechanical ventilation, and by measure-related factors, such as intrinsic mitral- or aortic-valve diseases, regional wall-motion abnormalities, and conditions that distort left ventricular anatomy. More importantly, proper use may be limited by the level of operator competence.

SUMMARY

Assessment of left ventricular systolic function is a cornerstone of management of the vast majority of cardiac diseases, and it can be evaluated well with appropriate use of focused cardiac ultrasonography. Obtaining four echocardiographic measures in the left ventricle — longitudinal shortening, anterior mitral-leaflet motion, thickening of wall segments, and change in the area of the cavity — can facilitate a qualitative or semiquantitative assessment of left ventricular systolic function.

No potential conflict of interest relevant to this article was reported.
Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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