Bedside Echocardiographic Assessment for Trauma/Critical Care: The BEAT Exam

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Recent evidence suggests that pulmonary artery catheter (PAC)-guided resuscitation may not improve outcomes in critically ill patients, creating heightened interest in minimally invasive or noninvasive methods of cardiac monitoring.[1,2] Transthoracic echocardiography offers a noninvasive way to evaluate both volume status and cardiac function. Traditionally, this has been performed solely by cardiologists with extensive training in advanced techniques of transthoracic echocardiography. But a growing body of evidence suggests that noncardiologist intensivists can effectively learn and apply the skills of focused, goal-directed transthoracic echocardiography in the intensive care setting.[3,4] Several curricula have been developed and evaluated, each consisting of 8 to 10 hours of both didactic and proctored hands-on training. Instruction focuses on image acquisition, normal and pathologic features of cardiac anatomy and function, and estimation of specific hemodynamic parameters.[5-7] Several recent publications showed that focused echocardiography can be used by intensivists to accurately predict volume status and cardiac function in critically ill patients.[8-10] Our group has developed a focused echocardiography examination and has demonstrated its accuracy in comparison with a PAC.[11,12] This report will detail the BEAT examination, the Bedside Echocardiographic Assessment in Trauma/Critical Care.

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Positioning and image orientation

All examinations are performed at the patient's bedside with a portable ultrasonography device using a low frequency, small footprint cardiac transducer. For most of the examination, the patient is placed in the left lateral decubitus position, which provides a more favorable cardiac orientation for image acquisition. All images are obtained using the cardiac software package available on the ultrasonography device. Because most surgeons are familiar with the abdominal software package (ie, for a Focused Assessment with Sonography for Trauma [FAST] examination), it must be recognized that the images obtained using the cardiac windows will be oriented 180° from FAST images. The letters in the name BEAT correspond to a specific step, each with a specific view and task (Table 1).

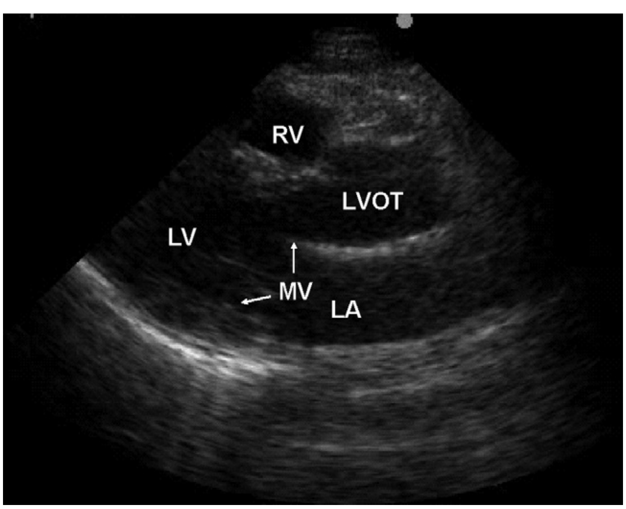

Figure 1. Parasternal long axis. LA, left atrium; LV, left ventricle; LVOT, left ventricular outflow tract; MV, mitral valve; RV, right ventricle.

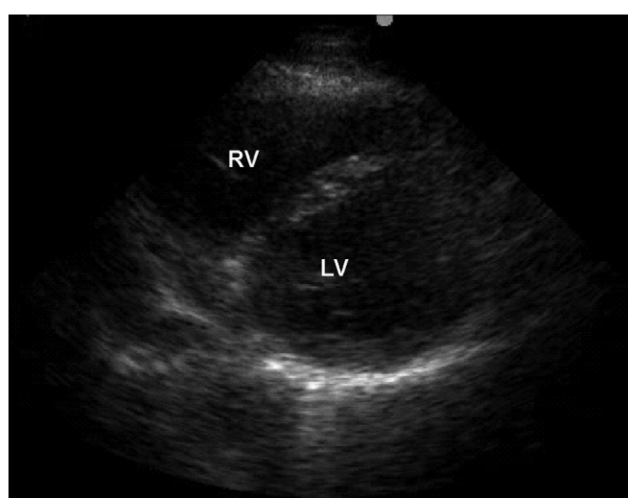

Figure 2. Parasternal short axis. LV, left ventricle; RV, right ventricle.

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Abbreviations and Acronyms

BEAT = Bedside Echocardiographic Assessment in Trauma/Critical Care
CI = cardiac index
FS = fractional shortening
PAC = pulmonary artery catheter

BEAT examination

B: beat/cardiac index

The patient is placed in the left lateral decubitus position and stroke volume is measured using the fractional shortening (FS) technique. The FS method was selected for the BEAT examination because of the consistency of image acquisition and accuracy of the stroke volume estimates. Two other techniques that may be used to measure stroke volume are the left ventricular outflow tract/velocity time integral method and Simpson's method.

Fractional shortening is calculated using a single view. In the left parasternal long axis view (Fig. 1), 2D and M-mode echocardiography are used to measure the left ventricular end-systolic and end-diastolic diameters. From these measurements, the SonoSite software package calculates the left ventricular end-systolic and end-diastolic volumes to derive left ventricular stroke volume. Cardiac output is calculated as the product of stroke volume and heart rate and adjusted for body surface area to obtain and record cardiac index (Table 2).

E: effusion

The patient is in the left lateral decubitus position. From the parasternal long axis view, the presence or absence of a pericardial or pleural effusion is noted and recorded. If a pericardial effusion is present, it is seen in a plane inside the pericardium and anterior to the aorta. A pleural effusion is best visualized at the costal-diaphragmatic recess outside the plane of the aorta.

A: area/ventricular size and function

The patient is imaged in the left lateral decubitus position. Subjective assessment (hypodynamic, normal, or hyperdynamic) of left ventricular function and size (decreased, normal, or increased) is done in the parasternal short axis view (Fig. 2). The apical four chamber view (Fig. 3) is the optimal view for assessing right ventricular size and function. In a normal heart, the size of the right ventricle is approximately 60% of the left ventricle. A large right ventricle may indicate pulmonary hypertension, right heart failure, or volume overload.

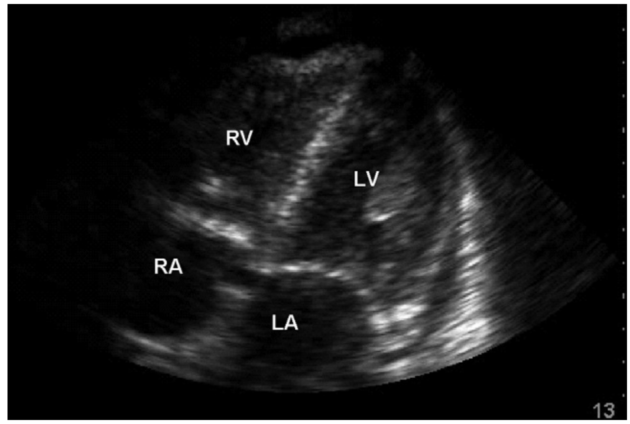

Figure 3. Apical four chamber. LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

T: tank/preload

Volume status is determined by the morphology of the mitral valve waveform and the IVC diameter and its percent collapse on inspiration. The former is assessed with the patient in the left lateral decubitus position. In the parasternal long axis view, either M-mode echocardiography or pulse-wave Doppler is used to trace the mitral valve waveform (Fig. 4). The relative sizes of the E and A waves (corresponding to early filling and atrial contraction in diastole) indicate whether the patient was hypo-, hyper-, or euvolemic. A patient who is volume overloaded will produce a prominent E wave; a dominating A wave may be an indication of hypovolemia.

The diameter of the IVC (Fig. 5) is measured at end inspiration and end expiration, with the patient in the supine position. This measurement is taken within 2 cm of its entrance into the right atrium. The percentage of IVC collapse is then manually calculated and used in determining the patient's volume status (Table 3).[13]

Training in focused bedside echocardiography is now offered as part of the "Ultrasound in the ICU" course at the annual Clinical Congress of the American College of Sur-

Table 1. The Bedside Echocardiographic Assessment in Trauma/Critical Care (BEAT) Examination

Meaning of BEAT acronym	Goal	View	Task
Beat	Cardiac function	Parasternal long	Stroke volume
Effusion	Pericardial effusion	Parasternal long	Subjective assessment
Area	Right and left ventricles	Parasternal short Apical 4 chamber	Subjective assessment
Tank	Volume status	M mode subcostal	IVC measurement

Table 2. Cardiac Index Using Fractional Shortening

Parameter	Calculation
Left ventricular end systolic volume	$(7/[2.4 + LVs]) \times LVs^3$
Left ventricular end diastolic volume	$(7/[2.4 + LVd]) \times LVd^3$
Stroke volume	LVEDV – LVESV
Cardiac output	SV × HR
Cardiac index	CO/BSA

BSA, body surface area; CO, cardiac output; HR, heart rate; LVd, left ventricular diastolic diameter; LVEDV, left ventricular end diastolic volume; LVESV, left ventricular end systolic volume; LVs, left ventricular systolic diameter; SV, stroke volume.

Table 3. Estimated Central Venous Pressure[13]

IVC diameter	% Collapse	Estimated CVP (mm H_2O)
< 20	> 50	5
< 20	< 50	10
> 20	< 50	15
> 20	0	20

CVP, central venous pressure.

geons. The curriculum consists of instruction on the basics of ultrasonographic imaging, cardiac physiology, image acquisition, and normal and pathologic cardiac anatomy. Detailed instruction on the elements of the BEAT examination is a component of both the didactic and practical portions of the course, and participants are able to perform the examination on human models. Bedside echocardiography provides a noninvasive cardiac assessment tool that surgeons can learn and use in the care of critically ill patients.

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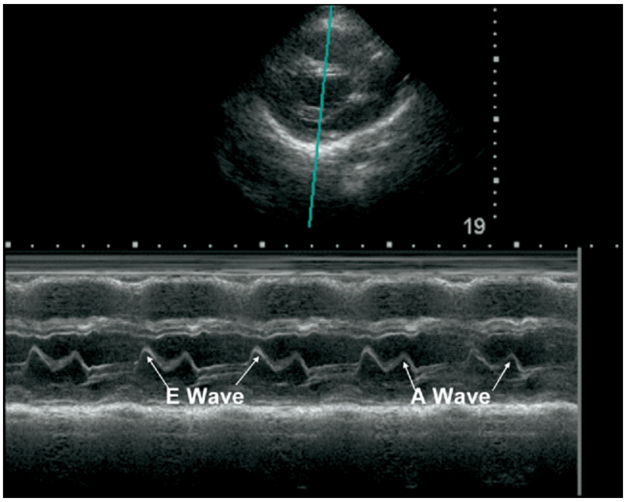

Figure 4. E/A waveform.

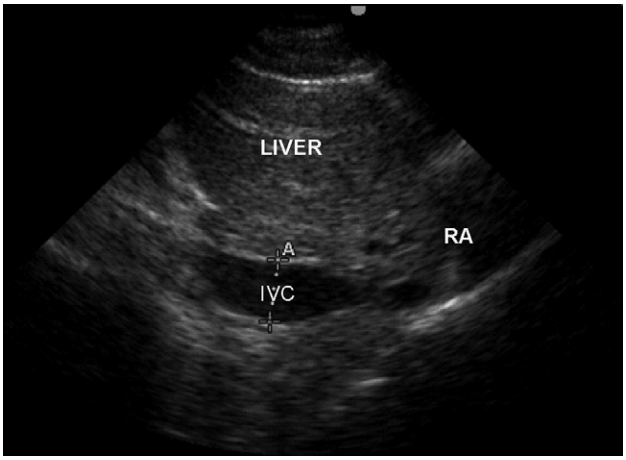

Figure 5. IVC diameter. RA, right atrium; IVC, inferior vena cava.