

Focus-Assessed Transthoracic Echocardiography: Implications in Perioperative and Intensive Care

Abstract

Transthoracic echocardiography is a potent and appealing diagnostic tool by virtue of rapidity, noninvasiveness, and repeatability. Focus-assessed transthoracic echocardiography (FATE) forms quick guidance to interpret the echocardiographic information and relates it to the clinical context. It can be applied in the perioperative period, intensive care units (ICUs), and emergency situations, in trauma and as resuscitation aids. FATE intends to assess cardiac function including contractility, chamber size and hypertrophy, valvular dysfunction, cardiac tamponade, and pericardial and pleural effusions. Thence, FATE has become a quintessential scanning tool perioperatively and in ICUs.

Keywords: Critical care, echocardiography, focus-assessed transthoracic echocardiography, focused transthoracic echocardiography, intensive care, ultrasonography

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Introduction

Ultrasound (US) is the only method which enables real-time bedside imaging of the heart.^[1] Focused cardiac US provides meritorious diagnostic information to usher changes in the perioperative management.^[2] Transthoracic echocardiography (TTE) allows rapid, noninvasive, point-of-care (POC) assessment of ventricular function, valvular integrity, volume status, and fluid responsiveness.^[3] Focus-assessed transthoracic echocardiography (FATE), an abbreviated TTE protocol, is an effective supplementary tool.^[4] In critically ill patients, it offers a systematic and focused approach to the echocardiographic examination and proposes a skill set that can be readily^[5] and quickly learned.^[6]

The objectives of FATE protocol are principally the exclusion of the obvious causative pathology, assessing contractility of the left ventricle (LV), estimation of wall thickness and chamber dimensions, exclusion of pleural pathology, and moreover relating the echocardiographic information to the clinical context.^[4,7,8]

While the basic FATE is done with the intentions mentioned above, advanced FATE examination aims at comprehensive

assessment of hemodynamics, Doppler US for cardiac output and pressure calculations, diastolic dysfunction, severity of valvular heart diseases, and more.^[9] This article addresses the basic FATE protocol.

The acumen to image acquisition and analysis ought to be precise and are done by procuring FATE protocol views. In this regard, familiarity with holding and movements of the transducer is essential. The transducer is held in two ways. For most of the images, transducer is held by “under-the-probe” technique like a pencil or “over-the-probe” technique with overhand grip for imaging, especially for subcostal views, which allows application of pressure against the abdominal muscles.

Transducer Movements

To ascertain effective imaging, the transducer is manipulated and the best images are obtained by the movements which include as follows:

- Sliding – also called as translation. The transducer is moved on the chest to any position to obtain the best window and in any direction; for instance, sliding the transducer from parasternal to apical area
- Tilting – also called as heel-toe movement. The transducer is kept at the same place on the chest and moved side to side to allow other planes in the same axis to come into view

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Quick Response Code:



- Angulation – The transducer is kept at the same place on the chest and moved cephalad or in caudal direction
- Rotation – The transducer is kept at the same place on the chest, and clockwise or counterclockwise movement is done for obtaining different views from the same echocardiographic window. Rotating the transducer approximately from 11 to 2 o' clock switches from long to short axis.

The basic FATE views are as follows:

1. Subcostal view
2. Apical four-chamber view
3. Parasternal long-axis view
4. Parasternal short-axis view
5. Pleura scanning.

Subcostal view [Figure 1]

The patient is positioned supine with both legs flexed at knees, abdomen relaxed. The transducer is placed in the subxiphoid area with the orientation marker pointing toward the patient's left shoulder. The subcostal four-chamber view is obtained to display left atrium (LA), LV, right atrium (RA), and right ventricle (RV). The interatrial septum (IAS) is best screened in this view as it is perpendicular to the echo signal. The interventricular septum (IVS), mitral valve (MV), and tricuspid valve (TV) are observed while the RV free wall thickness can also be estimated. A deep inspiration avails better imaging of this view. Furthermore, rotating the transducer counterclockwise exhibits short axis of the LV. The annex to the above findings is the inferior vena cava (IVC) diameter and collapsibility which can be determined by directing the probe to the right side to image the IVC entering the RA. In addition, chamber dimensions, contractility, wall thickness, and valvular function can be determined. Pericardial effusion can also be precluded. This view is applicable in particular during the cardiopulmonary resuscitation, patients with poor windows as in the obese, cardiac, or thoracic surgery patients.

Apical four-chamber view [Figure 2]

Patient is positioned supine with a left lateral tilt. The transducer is placed on the fifth intercostal space in the left midclavicular line or at the point of apex impulse with the orientation marker directing toward the patient's left shoulder. This view displays LA, MV, LV, RA, TV, RV, IAS, and IVS. The IVS should be perpendicular for an ideal view. Analysis of ventricular function, contractility, dilatation and hypertrophy is effected in this view. Pericardial effusion is evident if present.

Parasternal long-axis view [Figure 3]

Patient is positioned in the left lateral position; the transducer is placed in the left third to fifth intercostal space near the sternum. The orientation marker points toward patient's right shoulder. This view demonstrates LA,



Figure 1: Probe position for subcostal view



Figure 2: Probe position for apical four-chamber view



Figure 3: Probe position for parasternal long-axis view

MV, LV, AV, RV, and descending aorta. The LV apex is not imaged in this view. The LV systolic function, dilatation and hypertrophy of chambers, interventricular septal hypertrophy, mitral and aortic valve function, descending

aortic dilatation, pericardial and pleural effusion can be assessed. The pericardial effusion can be differentiated from pleural effusion by the fact that pericardial effusion lies anterior to the descending aorta while pleural effusion is seen posterior to descending aorta.

Parasternal short-axis view [Figure 4]

The transducer is rotated 90° clockwise from the parasternal long-axis view to visualize aorta, mitral valve apparatus and LV apex in short axis. The details are discussed in Extended FATE views.

Pleura scanning [Figure 5]

The FATE examination of the pleural cavity is performed with a cardiac probe. The pleural fluid is easy to differentiate from other tissue as it appears black. The transducer is placed on lateral thoracic wall at 10th rib approximately^[4] with the orientation marker directed upward, and scanning is initiated posteriorly in the upper abdomen and is progressed in cranial direction until the diaphragm is visible. Scan as inferior as possible.^[9] Pleural effusion, lung collapse, or atelectasis can be identified.

The extended FATE views are as follows:

1. Subcostal vena cava view
2. Apical two-chamber view
3. Apical three-chamber or long-axis view
4. Apical five-chamber view
5. Parasternal short-axis mitral plane view
6. Parasternal aortic short-axis view.

Subcostal vena cava view

The patient is positioned supine with both legs flexed at knees, abdomen relaxed. The transducer is placed in the subxiphoid area with the orientation marker pointing toward the patient's left shoulder. IVC diameter and collapsibility can be determined by directing the probe to right side to image the IVC entering the RA.

Apical two-chamber view

The transducer is rotated counterclockwise from the apical four-chamber position till RA and RV disappear. The LV and the LA are displayed. The anterior and inferior walls of LV are seen.

Apical three-chamber view

This view is also called as apical long-axis view. The transducer is rotated further counterclockwise from the previous position with slight anterior angulation. The LV, the LA, and the ascending aorta are displayed.

Apical five-chamber view

The apical four-chamber is first obtained, and then the transducer is angulated anteriorly towards the patient's head to display LV outflow tract, aortic valve, and ascending aorta in addition to the structures displayed in apical four-chamber view.

Parasternal short-axis mitral plane view

The transducer kept at the same place and tilted toward the left hip obtains the short-axis view of MV. This view displays the anterior mitral leaflet and the posterior mitral leaflet. The walls of LV, IVS, and part of RV are also seen. Further tilting of the transducer gives a view with anterolateral and posteromedial papillary muscles. The walls of LV can be visualized to diagnose RWMAs. Hypovolemia can also be diagnosed in this view. Further tilting of transducer shows the apical segments of LV.

Parasternal aortic short-axis view

The transducer is rotated 90° clockwise from the parasternal long-axis view to visualize aorta in short axis. The indicator should point toward the patient's left shoulder. The three aortic valve leaflets are seen namely the right coronary cusp adjacent to RV, the noncoronary cusp adjacent to the IAS, and the remaining the left coronary cusp. The other structures displayed in this view are the LA, IAS, RA, TV,



Figure 4: Probe position for parasternal short-axis view



Figure 5: Probe position for pleural scanning

RV, right ventricular outflow tract, pulmonary valve and the main pulmonary artery. Slight superior angulation displays left main coronary artery at 3–5 o'clock position and right coronary artery at 11 o'clock position.

Discussion

TTE is an inevitable and indispensable tool for anesthesiologist.^[10] Focused TTE performed in the preanesthetic clinic transmutes the management in a substantial proportion of patients, including the asymptomatic ones.^[11] It constitutes almost half of all cardiac imaging services.^[12] Focused TTE reveals real-time hemodynamics and physiological determinants and holds immediate diagnostic capability.^[10] Furthermore, experienced operators can perform FATE examination with patient in sitting position providing flexibility in different clinical scenarios.^[13]

FATE can be put to use as a screening and monitoring tool^[14] to appraise the effects of therapeutic interventions.^[15] The impetus is to screen for significant pathology^[5] and evaluate basic hemodynamic determinants such as preload, afterload, contractility, compliance, and relaxation.^[6] Studies have shown that clinicians can be trained in a short period of time to determine left ventricular function, determine intravascular fluid status, detect pericardial effusion, and identify valvular pathologies.^[14] Its application is distinct as a guide to pericardiocentesis and confirmation of transvenous pacing wire placement.^[16]

The characteristics features of various conditions that can be diagnosed by FATE are discussed here:

Chamber dilatation and hypertrophy can be diagnosed by the following indices.^[17]

- Normal ranges for LV internal dimension:
 - Diastolic dimension (mm): 50.2 ± 4.1 (males), 45.0 ± 3.6 (females)
 - Systolic dimension (mm): 32.4 ± 3.7 (males), 28.2 ± 3.3 (females).
- Normal ranges for LV indices:
 - Relative wall thickness (cm): 0.24–0.42 (males), 0.22–0.42 (females)
 - Septal thickness (cm): 0.6–1.0 (males), 0.6–0.9 (females)
 - Posterior wall thickness (cm): 0.6–1.0 (males), 0.6–0.9 (females).

Contractility and left ventricle function classification

- Normal – ejection fraction (EF) >55%
- Mild LV dysfunction – EF 45%–54%
- Moderate LV dysfunction – EF 30%–44%
- Severe LV dysfunction – EF <30%.^[18]

Evaluation of myocardial ischemia can also be done by focused TTE.^[19]

RWMAs may be present in patients with myocardial ischemia, infarction, or LV dysfunction. RWMAs are classified as:^[20]

- Normokinesia – Endocardium moves toward the center of LV during systole >30%
- Mild hypokinesia – Endocardium moves toward the center of LV during systole <30% but >10%
- Severe hypokinesia – Endocardium moves toward the center of LV during systole <10%
- Akinesia – Endocardium does not move or thicken
- Dyskinesia – Endocardium moves away from the center of LV.

Grading of myocardial contractility

- Normally the wall thickening is >30%–50%
- Mild Hypokinesia – 30%–50%
- Severe Hypokinesia – <30%
- Akinesia – <10%
- Dyskinesia – None.^[20]

Valvular dysfunctions can be diagnosed by inspecting the mitral and aortic valves essentially for stenosis and regurgitations. Restriction or immobility, thickening, calcification, vegetations, coaptation, prolapse, or flail scallops of the leaflets should be looked for.

Pericardial effusion appears as an echofree dark space between the two layers of the pericardium.

Pericardial effusion is classified as:^[21,22]

- Mild is <10 mm, present posterior to the heart
- Moderate is 10–20 mm, present laterally and apically
- Large is >20 mm, present circumferentially.

Cardiac tamponade is a life-threatening condition by cause of the accumulation of fluid in the pericardial space compressing the chambers and restricting their normal filling.^[21]

Echocardiographic findings of cardiac tamponade:^[21,23]

- RA or RV diastole collapse
- Septal bounce – An inspiratory “bounce” of the IVS toward the LV
- Diastolic ventricular size variability with respiration – An exaggerated ventricular interdependence shows increased RV diastolic diameter during inspiration with decreased diameter of the LV with the opposite changes happening on expiration
- Respiratory variation of mitral or tricuspid inflow velocities – On inspiration, decrease of mitral E wave >25% and decrease of tricuspid E wave >40%
- IVC plethora – IVC dilatation >21 mm with loss of respiratory collapse signifying elevated central venous pressure confirms tamponade
- Reversal of hepatic venous flow.

Hypovolemia

The standard criteria for diagnosing hypovolemia^[24] are:

- LV end-diastolic diameter <25 mm
- LV end-diastolic area (LVEDA) <10 cm² or
- LVEDA index (LVEDA/BSA) <5.5 cm²/m²
- Systolic obliteration of LV cavity.

In case of true hypovolemia, LV areas in both systole and diastole are small, whereas in case of vasodilatation with hypotension, only the systolic LV area is small.^[24]

Acute pulmonary embolism

The diagnosis can be made on the basis of following echocardiographic findings:

- Qualitatively
 - RV hypokinesis
 - McConnell's sign – Akinesia of the RV mid-free wall with normal motion at the apex^[25]
 - Paradoxical septal motion.
- Quantitatively
 - RV to LV end-diastolic ratio >1
 - RV to LV end-diastolic area >0.6
 - RV end-diastolic diameter >30 mm
 - Pulmonary artery systolic pressure >30 mmHg
 - Pulmonary artery mean pressure >20 mmHg
 - Right pulmonary artery dilatation >30 mm
 - Velocity of tricuspid regurgitation >2.8 m/s.

Pleural effusion

It emanates as a dark, anechoic area positioned in between visceral and parietal pleura. Small-to-moderate effusions are present in the dependent parts and the lateral regions, whereas large effusions exist in the anterior area. Large pleural effusions are often associated with compression atelectasis in the form of consolidated lung tissue seen as floating in the effusion^[26] [Figure 6].

POC US assessments of the pleural cavity should be incorporated into the primary survey of respiratory and circulatory unstable patients.^[13] Early diagnosis of large pleural effusion is crucial as it can culminate into cardiac tamponade-like physiology consequent to the increase in intrapleural pressure transmitting to the pericardium and causing diastolic chamber collapse.^[3,13] Regarding pericardial effusions, emergency physicians can reliably evaluate it.^[27] Melamed *et al.* in their study state that minimally trained intensivists using hand-held units have made LV function assessment reasonably accurate despite of challenges such as lung hyperinflation, dressings, drains, anasarca, and suboptimal positioning of the patients in intensive care units (ICUs).^[28] Further, the role of TTE in managing high-risk hemodynamically unstable patients for noncardiac surgery has been stressed by Kratz *et al.*, reason being TTE led to variation in the management by discovering the pathologic findings of hypovolemia, right-heart overload, or failure.^[29]

POC TTE in addition to diagnosing the causes of hypotension and shock facilitates life-saving interventions.^[30] Characterization of perioperative shock in conditions such as cardiac tamponade, hypovolemia, LV dysfunction, acute cor pulmonale, and acute respiratory failures such as pneumothorax, acute pulmonary edema,

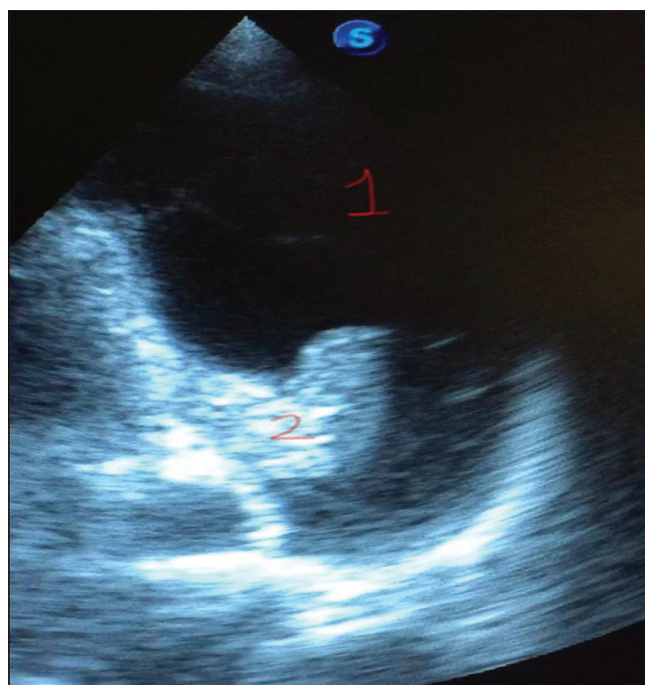


Figure 6: Pleural scan showing left-sided pleural effusion (1) along with the collapsed lung (2)

massive pleural effusion, and major atelectasis can be done.^[31]

Like FATE, many abbreviations and protocols have been standardized which define the preponderance of TTE and its efficacious implementation in clinical scenarios such as Focused Assessment with Sonography for Trauma^[8,13] protocol to evaluate penetrating chest injuries, cardiac contusions, and tamponade,^[30] The Abdominal and Cardiac Evaluation with Sonography in shock,^[13,32] and the Focused Echocardiographic Evaluation in Resuscitation.^[13,33] Focused Echocardiography in Emergency Life support^[34] is a limited echo protocol with limited training for catastrophic conditions.^[8] Focused ultrasonography in anesthesia^[31] and Rapid Ultrasound in Shock^[35] are few more.

Limitations of focused TTE are the challenging acoustic windows in patients with morbid obesity, edema, subcutaneous emphysema,^[20] chronic obstructive airway disease, surgical drains, positive pressure ventilation, and positive end-expiratory pressure^[36] making application of FATE difficult. Orme *et al.* stated that TTE could be performed with adequate or good views in mechanically ventilated patients.^[36] Further, successful use of focused US in the sitting position has been published.^[37] One or more acoustic windows, allowing clinical decision-making, could be obtained in 97% of the ICU patients.^[7]

FATE is extremely useful in all aspects of perioperative care.^[38] Furthermore, the focused approach can prove beneficial in extracorporeal membrane oxygenation (ECMO) patients as TTE has a role in cardiac screening to select patients, guide cannula insertion and

placement, monitoring, detect complications, determine cardiac recovery, and wean off ECMO.^[39] Moreover, the concept of focused POC US is promoted by the World Interactive Network Focused on Critical US in critical scenarios in and out of the hospital.^[15]

Conclusion

The FATE protocol is a comprehensive, rapid, and noninvasive approach contemplated to find the potential causes of hemodynamic instability. The fundamentals scanned are the chamber dimensions, wall thickness, ventricular function, pleura, and obvious pathology. Moreover, the information incurred from scanning is used analogously to the clinical context for better patient management. Hence, FATE protocol can be verily consolidated into routine as well as emergency clinical practice.

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Conflicts of interest

There are no conflicts of interest.

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