

# Limited Transthoracic Echocardiogram: So Easy Any Trauma Attending Can Do It

Paula Ferrada, MD, Rahul J. Anand, MD, James Whelan, MD, Michel A. Aboutanos, MD, Therese Duane, MD, Ajai Malhotra, MD, and Rao Ivatury, MD

**Background:** Limited transthoracic echocardiogram (LTTE) represents an attractive alternative to formal transthoracic echocardiogram (TTE), because it does not require an echocardiogram machine. Our hypothesis is that trauma attendings can learn LTTE effectively with minimal training.

**Methods:** Seven attendings at a Level I trauma center received didactic and hands-on training in LTTE and performed this test on hypotensive patients to evaluate for contractility, fluid status, and pericardial effusion. Therapy to improve perfusion (administration of fluids, ionotropes, or vasopressors) was guided by LTTE findings. Perfusion status was determined by serum lactate level before and 6 hours after LTTE. Findings were compared with cardiology-performed TTE.

**Results:** Range of postresidency training was 1 year to 29 years. LTTE teaching entailed 70 minutes of didactics and 25 minutes of hands-on. In all, 52 LTTEs were performed; two patients were excluded due to blunt trauma arrest. Age ranged from 22 years to 89 years with an average of 55 years. Admission diagnosis was blunt trauma (n = 34), penetrating trauma (n = 3), and intra-abdominal sepsis (n = 13). Average time for LTTE was 4 minutes 38 seconds. Cardiology-performed TTE was obtained in all patients, and correlation with LTTE was 100%. A total of 37 patients received intravenous fluid, 9 received vasopressors, and 4 received ionotropes as guided by LTTE findings, with lactate reduction in all patients ( $p < 0.00001$ ). Attendings scored a mean of 88% in a written test after training.

**Conclusions:** Trauma attendings can successfully learn LTTE with minimal training and use the technique as a resuscitation tool in the hypotensive patient.

**Key Words:** Fluid Status, Echocardiogram in trauma, Shock resuscitation.

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**T**ransthoracic echocardiogram (TTE) is an important tool for hemodynamic monitoring in the intensive care unit as it is a fast and noninvasive means to accurately assess hemodynamic status.<sup>1</sup>

A number of studies have previously demonstrated the usefulness of this technique in establishing cause of hypotension and management in critically ill patients.<sup>2–5</sup> Specifically,

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From the Department of Trauma, Critical Care and Emergency Surgery, Virginia Commonwealth University, Richmond, Virginia.

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Address for reprints: Paula Ferrada, MD, Trauma, Critical Care and Emergency Surgery, Virginia Commonwealth University, West Hospital, 15th Floor East, 1200 E. Broad Street, P.O. Box 980454, Richmond, VA 23298; email: pferrada@mcvh-vcu.edu.

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a few studies describe the use of focused, goal-directed transthoracic echocardiography in the critically ill patient at the bedside.<sup>3–6</sup> Moore and coworkers demonstrated how TTE can be used as part of a computerized decision support algorithm for traumatic shock resuscitation.<sup>2</sup> When performed by an intensivist, TTE has also been shown in most cases to be accurate in answering the clinical question at hand (87%), often resulting in a modification in the plan of care as a direct result of the test.<sup>3</sup>

There is a need for guidelines for the use of echocardiogram in the critical care setting as well as training and education.<sup>7,8</sup>

Performance of traditional TTE requires access to an echocardiography machine as well as formal training and calculations using M mode and the Doppler principle.<sup>7,9</sup> Handheld cardiac ultrasound, also known as limited transthoracic echocardiogram (LTTE), represents an attractive alternative to formal TTE, because it has the ability to provide meaningful information, without having to perform complicated calculations.<sup>10,11</sup>

Our hypothesis is that trauma attendings with simplified training in LTTE can use this test as a tool in the management of hypotensive critically ill patients.

## METHODS

Institutional review board approval was obtained. Seven attendings in the Division of Trauma, Critical Care and Emergency General Surgery at Virginia Commonwealth University Medical Center participated in this study. LTTE was taught using the SonoSite S-ICU (SonoSite, Bothell, WA) and a phased array probe. This machine did not have any Doppler or M mode capabilities. All tests were done using 2-D B mode ultrasound, the same mode used in Focus Assessment Sonography for the Trauma patient.<sup>12</sup>

All attendings received didactic and hands-on training in LTTE. The course was taught by a certified American College of Surgeons ultrasound instructor. The course entailed 70 minutes of didactics and 25 minutes of hands-on. For the hands-on session, live male models were used with an instructor to student ratio of 1:1. Windows taught during the course were the same views used in traditional TTE, as described in previous articles,<sup>3</sup> including:

1. Parasternal short and parasternal long windows.
2. Apical window.

Exam with answers:

1. IVC diameter and diameter change
    - a. **Is useful in the evaluation of fluid status**
    - b. Can not be use in patients on dialysis
    - c. Is unreliable in patient on the ventilator
    - d. none of the above
  
  2. IVC diameter and diameter change. Pair the correct statement with volume status.
    - a. IVC flat, 100% compressible
    - b. IVC full, somewhat compressible
    - c. IVC full, not compressible
- |                                 |          |
|---------------------------------|----------|
| CVP 10, pt euvolemic            | <b>B</b> |
| CVP less than 5 pat hypovolemic | <b>A</b> |
| CVP 25 pt in pulmonary edema    | <b>C</b> |

**Discussion:**

IVC diameter is a dynamic parameter; it changes with respiration, reflecting the elasticity of the vessel wall. Change in IVC diameter is an accurate predictor of fluid responsiveness in ventilated patients irrespective of the positive end-expiratory pressure, plateau pressure, or respiratory system compliance.

3. Which of the following are true regarding limited echocardiogram:
  - a. It allows for identification of pericardial fluid
  - b. It is useful for the management of fluid status
  - c. It is useful for the evaluation of adequate contractility
  - d. **All of the above**

**Discussion:**

Transthoracic echo has been validated in the past to accurately differentiate between different causes of shock in critically ill patients.

4. Compared to Low Frequency Probes, High Frequency allow for
  - a. Better tissue penetration.
  - b. **Better image detail.**
  - c. Faster imaging
  - d. Decreased attenuation.

**Discussion:**

The advantage of a high frequency transducer is better image detail. The disadvantage is increased tissue attenuation which reduces tissue penetration.

True or False:

5. Echocardiogram is best done with a low frequency phased array probe. This probe can also be used for abdominal ultrasound evaluation **TRUE**
6. Large pericardial effusion can be present without tamponade physiology **TRUE**
7. Pneumothorax, COPD, obesity and subcutaneous fluid will decrease visibility when performing an echocardiogram **TRUE**

**Figure 1.** Test performed after the didactic session. Answers are highlighted with bold. Discussions are provided below each question.

3. Subxyphoid window, including visualization of the inferior vena cava (IVC) and IVC diameter variation with respiration.

A posttest was given to the attendings after the training (Fig. 1).

The attendings performed LTTE on hypotensive patients to evaluate cardiac contractility and fluid status and for detecting pericardial effusion. Time to complete the examination and the various physiologic parameters were recorded and described below.

We use poor, normal, or hyperdynamic, LV short axis at papillary muscle level

**Contractility**

Contractility was rated as decreased or appropriate, evaluating decreased global heart function as a cause of hypotension.

**Fluid Status**

Fluid status was assessed by the size of the IVC and the collapsibility of the vessel with respiratory variation. Surgeons were instructed to recognize that a flat and collapsible IVC was present when the patient was under-resuscitated,

Remember more complicated than this, if spontaneous breathing, IVC should collapse if hypovolemic (30% or greater), if positive pressure breaths given will increase if hypovolemic (12% or greater)

and a full and not collapsible IVC was present when the patient was adequately resuscitated.

### Pericardial Effusion

Pericardial effusion was recorded as present or absent, evaluating the presence of pericardial effusion as a cause of hypotension.

Therapy to improve perfusion (administration of fluids, ionotropes, or vasopressors) was guided by findings on LTTE.

Cardiology-performed TTE was obtained within 24 hours of LTTE to compare LTTE findings regarding contractility. IVC measurements are not traditionally obtained by cardiology-performed TTE. Therefore, perfusion status was determined by serum lactate level before and 6 hours after LTTE.

## RESULTS

All trauma attendings had some previous training in Focus Assessment Sonography for the Trauma ultrasound but none in echocardiogram. The range of postresidency training was 1 year to 29 years. One attending was emergency medicine trained and six were general surgery trained.

In all, 52 LTTEs were performed on 51 hypotensive patients. Hypotension was defined as mean arterial pressure of 60 or less in more than one reading. Two patients were excluded due to blunt traumatic arrest. Two LTTEs were done in the trauma bay and the rest in the intensive care unit. All patients were subjected to one LTTE with the exception of one patient who was persistently hypotensive. This patient was imaged twice within a 3-hour period by the same attending (Fig. 2).

Patient age ranged from 22 years to 89 years with a mean of 55 years. Admission diagnosis was blunt trauma in 34 patients, penetrating trauma in 3 patients, and intra-abdominal sepsis unrelated to trauma in 13 patients. In all, 41 patients were intubated and receiving mechanical ventilation at the time of the test and ventilator settings were not recorded. Four patients had an open abdomen, six had chest tubes, one had a previous median sternotomy, and two had a recent left lateral thoracotomy. Subcutaneous emphysema was noted in one patient. Body mass index was not recorded. Parasternal, subxiphoid views, and IVC assessment were obtained in all studies. Apical views were obtained in only 43 patients. Average time for LTTE was 4 minutes 38 seconds.

Attending	Number of patients	Number of LTTE performed	Patients excluded
1	11	12	1
2	4	4	
3	9	9	
4	17	17	1
5	4	4	
6	3	3	
7	3	3	
Total		52	2

**Figure 2.** Attending breakdown of the LTTE studies performed. First column: attendings numbered; second column: number of patients that received LTTE; third column: numbers of LTTE performed; fourth column: number of patients excluded per attending.

In all, 41 patients had a central venous pressure recorded at time of LTTE, while 4 patients had vascular catheter-based assessment of cardiac output. One patient had a pulmonary artery catheter, and five patients did not have an alternative method of intravascular volume monitor at the time the LTTE was performed. Trauma attendings were not blinded to data provided by invasive monitoring at time of LTTE. Fifty LTTE studies were used to guide treatment. Therapy was guided by LTTE results as follows: 37 hypotensive patients received intravenous fluid, 9 received vasopressors, and 4 received ionotropes. Two patients were found to have effusions, which did not require a procedure or change in therapy. Forty-six patients were found to have adequate contractility; 32 of those patients were found to be hyperdynamic.

In 28 patients, therapy was modified as a result of the test. Eight hypotensive patients who were found euvolemic by LTTE were started on vasopressor therapy and fluid boluses were held. Three patients were found to be fluid resuscitated by LTTE with decreased ejection fraction—these patients received ionotropes. Seventeen patients were found to be persistently hypovolemic despite resuscitation—all of these patients received more aggressive resuscitation as a result of LTTE findings. Sixteen of these patients received only crystalloid as fluid of choice, while one patient received one unit of packed red blood cells in addition to the crystalloid resuscitation. Strikingly, blood lactate levels were reduced in all patients after initiation of therapy ( $p < 0.00001$ ) (Fig. 3).

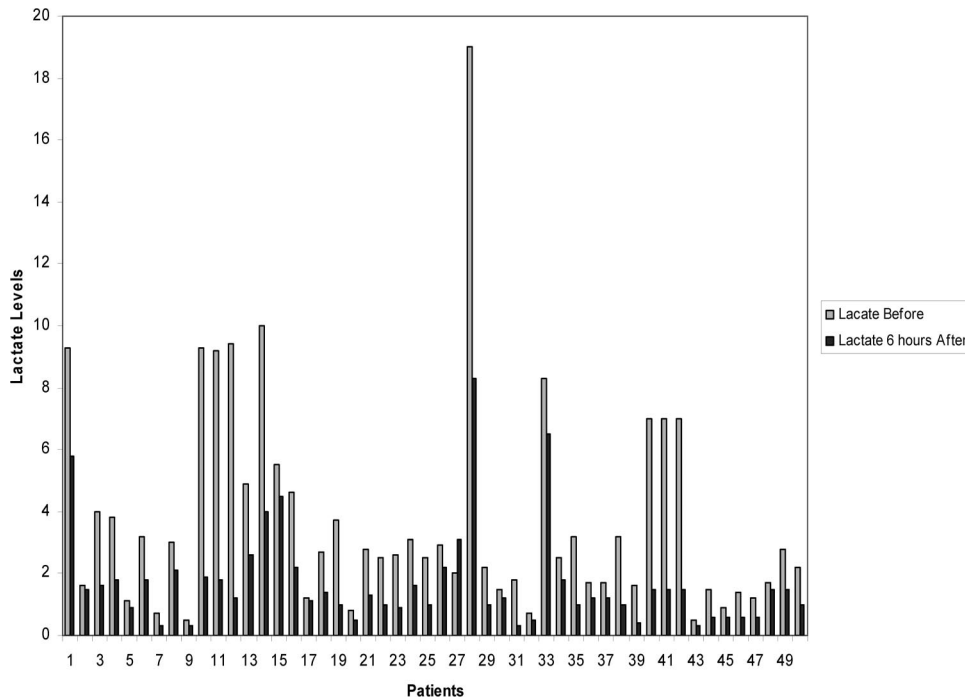
Cardiology-performed TTE was obtained in all patients within the first 24 hours (mean 8.5 hours) of performance of LTTE. Correlation between LTTE by attendings and cardiology-performed TTE with regards to global heart function assessment and contractility was 100%.

Scores on the written test ranged from 80% to 100%, with a mean of 88%. The kappa coefficient between surgeons was not considered. A test in a different setting would be the same for individual attendings.

The attendings who performed the therapy... there are no training guidelines for surgeons to incorporate TTE into critical care practice. The American Society of Echocardiography has some recommendations for physician training in echocardiography, suggesting performing 150 studies is appropriate for independent practice.<sup>13</sup> Recent data in the intensive care unit literature advocate that noncardiologists may acquire basic skills in focused critical care echocardiography with 10 hours of didactic and practical teaching.<sup>14,15</sup>

When compared with cardiology-performed echocardiography, critical care echocardiography has a different clinical emphasis.<sup>15</sup> The surgeon-intensivist does not require formal training in recognizing valvular disease, focal wall motion abnormalities, and the presence of anatomic variants or intramural clots. The surgeon-intensivist will be interested in answering

ACCP and SCCM have put out recs, that's what we follow, and hospital accreditation may be different; 16-24 hours of didactics per application and 25 'scans'; based on multiple societies' recs



**Figure 3.** Lactate levels immediately before (gray) and 6 hours after (black) establishing therapy of hypotension guided by LTTE results. On the x axis are the patients numbered 1 to 50. On the y axis is the lactate levels measured in mmol/L.  $p < 0.00001$

clinical questions concerning volume and filling status, fluid responsiveness, response to vasoactive and inotropic drugs, and hemodynamic explanations of cardiovascular collapse. Prompt acquisition of this specific diagnostic information does not require a comprehensive formal cardiology-based TTE,<sup>15</sup> and therefore the training and certification guidelines for LTTE should be different from cardiology-performed echocardiogram.

Echocardiography is a teachable technique. Kobal et al.<sup>16</sup> compared the accuracy of cardiovascular diagnoses by medical students operating a small hand-carried ultrasound device with that of board-certified cardiologists using standard examinations. The diagnostic accuracy of medical students using a hand-carried device after brief echocardiographic training to detect valvular disease, left ventricular dysfunction, enlargement, and hypertrophy was superior to that of experienced cardiologists performing cardiac examinations.<sup>16</sup>

This study confirms our hypothesis that LTTE is a technique that can be learned by trauma attendings after simplified training and can be applied in evaluation of hypotensive patients. Assessment of global heart function correlated 100% with the assessment of cardiologist-performed TTE, validating the findings of the trauma attendings regarding contractility.<sup>17</sup> Global heart function is assessed primarily by estimating left ventricular ejection fraction (EF). Several methods to calculate EF have been described including biplane contrast ventriculography, cubed M-mode formula, Teichholz M-mode formula, length-area method from the four-chamber view, Simpson's single plane formula, and subjective visual echocardiographic estimation.<sup>17-22</sup> In a double-blinded randomized trial, Mueller et al.<sup>23</sup> showed that subjective visual

echocardiographic estimate of EF is as reliable and less time-consuming method when compared with other techniques of EF evaluation. In this study, trauma attendings estimated global heart function as decreased or appropriate, subjectively without the use of formulas or calculations.

IVC diameter and collapsibility have been shown previously to provide an accurate assessment of fluid status.<sup>24,25</sup> TTE traditionally does not include IVC measurements. In this study, attendings were able to obtain IVC visualization in all patients. IVC diameter was not compared with CVP or other hemodynamic measurements. The volume status of the hypotensive patient was judged by the IVC diameter and therapy was based on this evaluation. The appropriateness of therapy was confirmed by improvement in serial lactate measurements.

Other studies have shown a correlation with IVC collapsibility. A study published a study showing a correlation with IVC and CVP.<sup>26</sup> Establishing IVC collapsibility is a useful tool to assess for the presence of hypovolemia and fluid overload.<sup>19</sup> Because not all patients had the same intravascular monitor and some patients had no intravascular monitor at the time of the test, we did not compare these findings with LTTE results.

Ventilation not documented

There are some limitations of the study. Serum lactate was used as a surrogate for fluid responsiveness solely, without comparing other hemodynamic parameters. Cardiologist-performed TTE was used to compare assessment of global heart function, not to evaluate for adequacy of resuscitation. The number of LTTE reported in this



article is small and it is not the same for each attending, some attendings performed four exams or less. The process to evaluate competency for performing and interpreting LTTE is still evolving. And finally, the attendings were not blinded to hemodynamic parameters measured in these patients.

Our preliminary observations, however, confirm the clinical applicability of bedside LTTE by trauma attendings in the evaluation of the hypotensive patient and provide the basis for future larger studies with concomitant assessment of other hemodynamic parameters and patient outcomes. LTTE is feasible, it is a teachable technique, and it is a useful tool to guide therapy in hypotensive patients. At the present time, a randomized control trial is being performed at this institution, to evaluate the impact of LTTE findings on resuscitation and patient outcome.

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## EDITORIAL COMMENT

I appreciate the opportunity to provide commentary regarding the continued work of the primary author in the field of focused echocardiography in critically ill and injured patients. In this article, the authors attempt to ensure us that any trauma surgeon can perform a bare-bone extremely limited bedside transthoracic echocardiogram.<sup>1</sup> The question is should he/she?

At the time of this study, it appears that Dr. Ferrada found herself resourced with a “lesser” ultrasound machine with neither Doppler nor M (motion) mode capabilities. Thus, the ability to calculate cardiac output using a standard echo methodology was not possible. Despite espousing the limited, but quantitative, “FREE” focused examination previously,<sup>2</sup> Dr. Ferrada used this work to ask: “Is an even more limited qualitative focused echo sufficient?” This is juxtaposed against an ever-burgeoning body of literature suggesting that intensivists and even trainees can use focused quantitative echocardiography on midrange machines with accuracy and success.<sup>3–6</sup>

The inherent difficulty with a study espousing a qualitative echo assessment to guide resuscitative therapy is how to report the data to convince us that the paradigm was efficacious. Most trauma patients show benefit from resuscitation—however monitored—clearing lactate in this study is not definitive evidence that echo guidance was responsible, particularly with small numbers. This is even

truer when the practitioners were not blinded to data from other sources—such as the central venous pressure readings. That the “confirmatory” cardiology-performed echo’s often happened many hours later (after ongoing resuscitation) is even more problematic.

Furthermore, to assert that any trauma attending can perform even the limited examination is bold. Half of the attendings in this study did four echo’s or less that were subject to data analysis. Finally, it seems that the training period in this study is insufficient to ensure proficiency or at least is inconsistent with guidelines regarding other frontline providers performing this examination.<sup>7</sup>

But before we throw the baby out with the bath water, it is of historical interest to remember as the case was being built against pulmonary artery catheters (PACs), investigators started in just this manner before protocol-driven National Institutes of Health-funded multicenter randomized controlled trials finally provided definitive data.<sup>8</sup> And, it is impressive that in this study, more than half of the patients reportedly had resuscitative therapy altered by use of the basic qualitative echo examination.

In conclusion, in most intensive care units, monitoring by PACs has all but vanished—and, for good reason—it did not alter outcome in most patients.<sup>9</sup> However, we must be just as assiduous with acquiring data on newer less invasive methods of monitoring as we were with PACs before enthusiastically adopting their use. At present, the literature includes data on fewer than 500 focused echo studies of injured patients, and it is uncontrolled and not outcome-based.<sup>2,5</sup> Surgeons must ensure that their training and proficiency mirrors that of other intensivists who perform focused echocardiography. Nonetheless, I congratulate the authors on their attempts to advance the science. We must encourage all practicing trauma surgeons to continue to move forward and learn this examination should be

Again, in our curriculum we have more hours of training, lots of self learning material, hands on (about 5 hours for each person with me each year), and testing (which we will do in May/June

sure we know yet based on this work. I would encourage the authors to acquire a midrange ultrasound machine to more accurately answer the question as to whether qualitative echo is sufficient while addressing the methodological flaws of the present study.

**Heidi L. Frankel, MD**  
 University of Maryland Shock  
 Trauma Center  
 Baltimore, Maryland

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