

Competence of Intensivists in Focused Transthoracic Echocardiography in Intensive Care Unit: A Prospective Observational Study

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Abstract

Objectives: Focused transthoracic echocardiography (fTTE) in critical care can be used to assess patient's volume status, ventricular contractility, right ventricle chamber size, and valvular abnormalities. The objective of the study was to assess the competency of intensivists in performing fTTE in Intensive Care Unit (ICU) patients after a brief training course by cardiologist using a specific ECHO protocol. **Methods:** One hundred and four patients in ICU were recruited for this prospective observational study over a period of 12 months. Intensivists were trained for 60 h (2 h/day for 30 days). Intensivists performed fTTE in 82 ICU patients using a specific ECHO protocol developed in consensus with cardiologists. Each patient was assessed by an intensivist and two blinded cardiologists. At the end of the study period, the competency of intensivists was compared with two cardiologists and analyzed using intraclass correlation coefficient (ICC). **Results:** There were excellent agreement between intensivists and cardiologists in terms of measuring ejection fraction (ICC estimate was 0.973–0.987), valvular function (ICC estimate for mitral valve was 0.940–0.972; ICC estimate for aortic valve was 0.872–0.940), and ICC estimate for pulmonary hypertension was 0.929–0.967. Good reliability has been found for the assessment of volume status with inferior vena cava diameter (ICC estimate for assessing hypovolemia was 0.790–0.902). **Conclusion:** Intensivists with requisite training in TTE were able to perform focused echocardiography with comparable accuracy to that of cardiologists. Further studies are required to elucidate the therapeutic implications of fTTE performed by the intensivists.

Keywords: Competence of intensivists, focused transthoracic echocardiography, intensivists and Doppler

INTRODUCTION

Focused transthoracic echocardiography (fTTE) in critical care can be used to assess patient's volume status, ventricular contractility, right ventricle (RV) chamber size, and valvular conditions.^[1,2] In addition, any pericardial collection can also be visualized. Being a noninvasive technique, the TTE can be used at the bedside and is available immediately even for the most unstable patients.^[3] It not only enables the intensivist to measure hemodynamic variables but also provides a morphological picture of various pathologies. Stanko *et al.* reported that with the use of TTE in Intensive Care Units (ICUs), diagnosis was changed in 29% of patients and in 41% of patients, it influenced the change in management.^[4] Albeit the versatility of echocardiography in the ICU, immediate nonavailability of cardiologists could be a deterring factor to the use of TTE to answer the hemodynamic questions. Studies have proven that with appropriate training, noncardiology residents with

minimal prior exposure to TTE, could perform TTE required to diagnose important, life-threatening conditions in the ICU.^[5] However, obtaining appropriate images and correct interpretation are of paramount importance to diagnose and treat the critical ill patients. This study was designed to compare the interpretation of TTE by intensivists after a short training course with blinded cardiologists. The primary objective of this study was to evaluate the competence of intensivists in TTE and the secondary objective was to identify areas where intensivists would need more extensive training.

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METHODS

This was a prospective observational study. Intensivists doing fellowship in critical care were trained in TTE by cardiologists for 2 hours everyday for 30 days. The training included real-time training in the echocardiography laboratory and video demonstrations. Patients who were admitted in the ICU with age above 18 years were recruited into the study after obtaining informed consent from their legal representatives. Patients with prior echocardiographic evaluation, poor echocardiographic window, hemodynamic instability, or when cardiologists were not available to perform TTE immediately were excluded from the study. Patients admitted in the tertiary care ICU were randomly (convenient sampling) recruited for the study. Echocardiographic probe with frequency of 1–5 Hz (Sonosite, S-ICU™, USA) was used in this study.

Patients were positioned in the left lateral posture and left arm abducted whenever possible; otherwise they were placed in the supine posture. Parasternal long-axis (PLAX) view was obtained by placing the probe in the left 3rd or 4th intercostal space in the left parasternal location with the orientation marker pointing toward the right shoulder (right shoulder to left flank). In this view, (RV and left ventricle (LV) were examined for contractility and movement of interventricular septum was assessed.^[1,2] In addition, mitral valve (MV) and aortic valve (AV) were also scanned for to detect the presence of any regurgitant lesions. Left ventricular ejection fraction (LVEF) was calculated by fractional shortening method in M-mode.^[1,2]

Parasternal short-axis was obtained by placing the probe at the same location as PLAX, but the pointer was turned by 90° to face the left shoulder to evaluate regional wall motion abnormalities (RWMAs) of LV, MV area (planimetry method).^[1,2]

Apical 4-chamber view was obtained by keeping the probe at the place where apical impulse was felt. LA, LV, right atrium (RA), RV, MV, tricuspid valve (TV), and pericardium were visualized. Regurgitant jets at MV and TV were analyzed with color Doppler. LVEF was calculated by modified Simpson's method. Presence of diastolic dysfunction was analyzed by measuring E/A ratio with pulse wave Doppler at MV level. Right ventricular systolic pressure (RVSP) was measured with continuous-wave Doppler at TV.^[1,2]

To obtain visualization of inferior vena cava (IVC), probe was placed longitudinally in the epigastric region and tilting toward right. Diameter of the IVC was measured 2 cm away from IVC and RA junction. IVC diameter of <2 cm or variation in IVC diameter of >50% with respiration was considered as hypovolemia in this study.^[6-8]

Intensivists had performed echocardiography in patients and findings were reported in a standard pro forma. Two independent blinded cardiologists performed echocardiography on the same patients within the time frame of 60 min and their reports were sealed. The agreement between the

intensivists and cardiologists in fTTE were analyzed using intraclass correlation coefficient (ICC), based on absolute agreement, two-way random model for all the independent variables such as ejection fraction, regional wall motion abnormality, diastolic dysfunction, RVSP, valvular function, IVC diameter, and pericardial sac collection.^[9] ICC estimate of <0.5 indicate poor agreement, ICC estimates between 0.5 and 0.75 indicate moderate agreement, values between 0.75 and 0.9 indicate good agreement and values >0.9 indicative of excellent agreement. Bland–Altman analysis was done for agreement between intensivists and cardiologists in measuring ejection fraction.^[10] The IBM SPSS® Statistics for Windows, version 19 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis.

RESULTS

One hundred and four patients were recruited into the study and 22 patients were excluded as they had poor echocardiographic window or due to nonavailability of cardiologists. Among these 22 patients, 6 (27.3%) patients had chronic obstructive pulmonary disease, 3 (13.6%) patients were obese, 9 (40.9%) were on positive-pressure ventilation, and cardiologists were not available to perform the study for 4 (18.2%) patients within the same time frame as the intensivists [Figure 1]. Mean acute physiology and chronic health evaluation II score of these patients was 44 ± 12 . Among the recruited patients, 67% were male and 70.7% were on positive-pressure ventilation [Table 1].

Both cardiologists 1 and 2 detected RWMA in 19.5% patients and the intensivists could detect RWMA in 18.2% patients indicative of excellent agreement (ICC estimate was 0.987–0.994) [Table 2]. There was excellent agreement in measuring LV ejection fraction among intensivists and cardiologists [Figures 2-4].

Cardiologists 1 and 2 detected mitral valvular abnormalities in 18.2% and 17% of patients, respectively [Table 3].

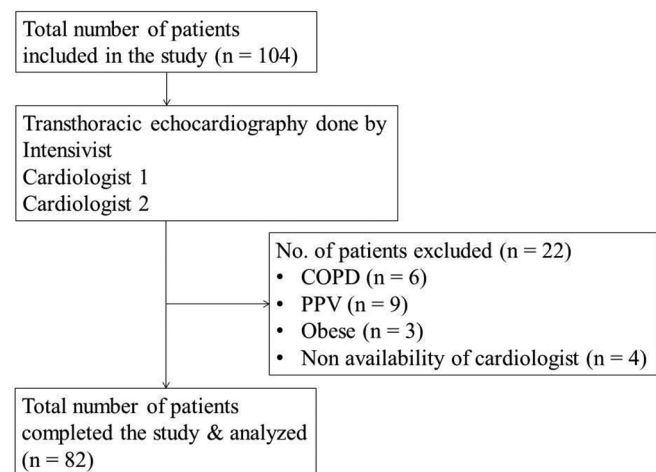


Figure 1: STROBE diagram for various phases of the study (STROBE: Strengthening the reporting of observational studies in epidemiology)

Table 1: Demographic variables

Parameter	Number of patients
Gender (%)	
Male	55 (67)
Female	27 (33)
Age (years) (%)	
20-40	32 (39)
40-60	38 (46)
>60	12 (15)
On positive pressure ventilation (%)	60 (73.1)
Mean APACHE II score	44±12
Reason for admission in ICU (%)	
Sepsis	39 (47.56)
Acute coronary syndrome	3 (3.66)
ARDS	11 (13.41)
Severe preeclampsia	4 (4.88)
Postpartum hemorrhage	3 (3.66)
Polytrauma	12 (14.63)
Traumatic brain injury	5 (6.1)
Acute pancreatitis	3 (3.66)
Pregnancy with acute liver failure	2 (2.44)

APACHE II: Acute Physiology and Chronic Health Evaluation II;
 ICU: Intensive Care Unit; ARDS: Acute respiratory distress syndrome

Table 2: Intraclass correlation coefficient for the study parameters

Parameter	95% CI of ICC estimate	
	Upper bound	Lower bound
LV contractility	0.987	0.994
LV ejection fraction	0.973	0.987
Diastolic dysfunction	0.940	0.972
Pulmonary hypertension	0.929	0.967
Valvular abnormalities		
Mitral valve	0.940	0.972
Tricuspid valve	0.884	0.946
Aortic valve	0.872	0.940
Pericardial effusion	0.933	0.969
Hypovolemia	0.790	0.902

LV: Left ventricle; ICC: Intraclass correlation coefficient; CI: Confidence interval

However, these intensivists were able to detect in 14.6% cases (ICC estimate was 0.940–0.972). Similarly, AV abnormalities were detected in 5 patients by the intensivists and the cardiologists 1 and 2 could detect them in 7 patients (ICC estimate was 0.872–0.940).

Intensivists detected tricuspid regurgitation (TR) in twenty patients. Cardiologists 1 and cardiologists 2 detected TR in 21 and 20 patients, respectively. The ICC estimate was 0.884–0.946 which was indicative of excellent agreement.

Cardiologists 1 and 2 detected diastolic dysfunction in ten patients and intensivists identified diastolic dysfunction in nine patients (ICC estimate was 0.940–0.972). Intensivists and cardiologist 2 detected pulmonary hypertension in

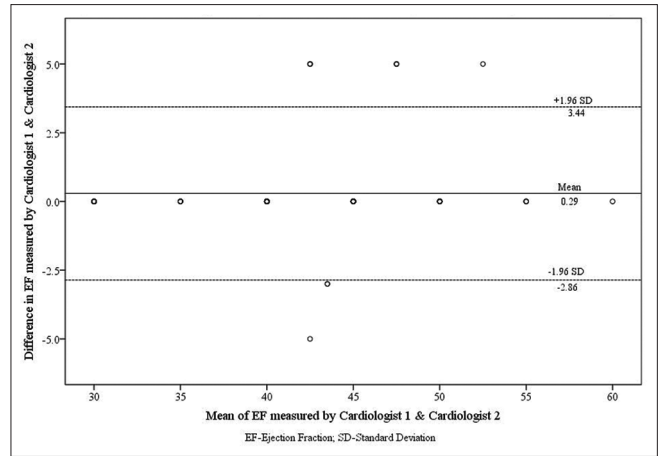


Figure 2: Bland–Altman plot for agreement between cardiologist 1 and cardiologist 2 in measuring ejection fraction

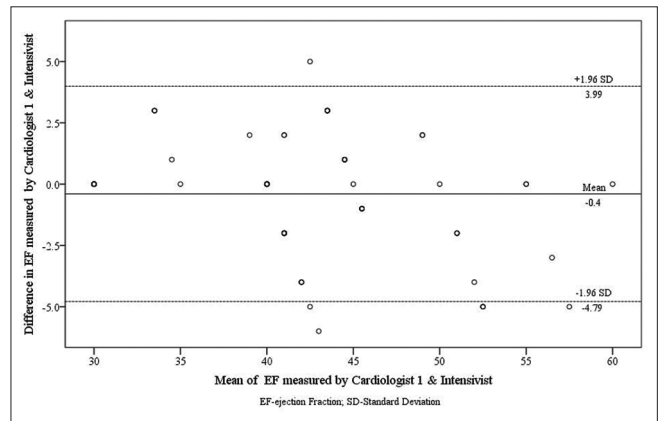


Figure 3: Bland–Altman plot for agreement between cardiologist 1 and intensivist in measuring ejection fraction

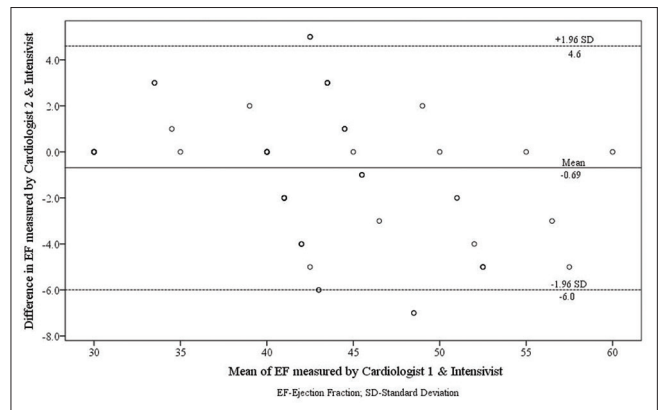


Figure 4: Bland–Altman plot for agreement between cardiologist 2 and intensivist in measuring ejection fraction

12 patients. Cardiologists 1 detected pulmonary hypertension in 11 patients (ICC estimate was 0.929–0.967).

Intensivists categorized 37 patients as hypovolemic using respiratory variation in IVC diameter. Cardiologist 1 identified 32 patients and cardiologist 2 identified 27 patients as having

Table 3: Abnormalities detected by intensivists, cardiologists 1, and cardiologists 2

Parameter	Intensivists (%)	Cardiologists 1 (%)	Cardiologists 2 (%)
RWMA	15 (18.2)	16 (19.5)	16 (19.5)
Diastolic dysfunction	9 (10.9)	10 (12.2)	10 (12.2)
Pulmonary hypertension (RVSP)	12 (14.6)	11 (13.4)	12 (14.6)
Mitral stenosis	7 (8.5)	7 (8.5)	7 (8.5)
Mitral regurgitation	5 (6.1)	8 (9.7)	7 (8.5)
Aortic stenosis	2 (2.4)	2 (2.4)	2 (2.4)
Aortic regurgitation	3 (3.7)	5 (6.1)	5 (6.1)
Tricuspid regurgitation	20 (24.4)	21 (25.6)	20 (24.4)
Pericardial effusion	3 (3.7)	3 (3.7)	3 (3.7)
Hypovolemia	37 (45.1)	32 (39)	27 (32.9)

RWMA: Regional wall motion abnormalities; RVSP: Right ventricular systolic pressure

hypovolemia (ICC estimate was 0.790–0.902). Three patients had pericardial effusion and all three were picked up by both cardiologists 1 and 2 and the intensivists.

DISCUSSION

This study has demonstrated that with requisite training, intensivists can perform fTTE and obtain corresponding results as cardiologists. Studies done to assess the ability of noncardiology residents to perform echocardiography after minimal training have also shown similar results previously.^[3,11,12] Majority of studies have assessed only the two-dimensional imaging techniques as using Doppler functions require more elaborate training. In our study, in addition to 2D imaging, we also included Doppler assessments as part of our fTTE.

Assessing LV contractility and ejection fraction is of particular importance as it will help to identify a cardiac cause in the presence of mixed shock states. It also helps in differentiating hydrostatic pulmonary edema secondary to cardiac etiology from other causes. LV systolic function (SV and CO) in the ICU is routinely assessed with invasive or semi-invasive methods;^[13-15] however, real-time echocardiographic assessment offers not only a noninvasive assessment of LV function but also helps in evaluating other possible cardiac causes which by routine methods are likely to be overlooked. In our study, there was an excellent agreement among the cardiologists and intensivists in the assessment of LV contractility and ejection fraction (ICC estimate was 0.987–0.994). Royse *et al.* conducted a study where the interpretative skills of 100 participants, after a limited TTE course were evaluated for assessment of hemodynamic state, left atrial pressure, LV volume, and systolic function.^[11] The authors concluded that with short training courses, noncardiology residents could show similar results as experts in terms of valvular and ventricular function. Similarly, Randazzo *et al.* reported a 86.1% overall agreement ($r^2 = 0.712$) among emergency physicians in assessing ejection fraction.^[12]

In addition to LV contractility and EF, examination of RWMA can help to diagnose myocardial perfusion insufficiency and identify the culprit vessels involved to plan for coronary

intervention.^[11] The intensivists in our study were able to detect the RWMA with ICC showing excellent agreement with the cardiologists. In previous studies, assessment of RWMA was considered difficult by residents with minimal training in echocardiography.^[16] In our study, we found that the agreement was excellent for detecting RWMA between cardiologists and intensivists. Hence, intensivists after short-term training can develop the competence in assessing LV systolic function can manage patients presenting with mixed shock conditions with more objective echocardiographic evidence corroborated with other clinical clues.

Assessment of RV size is of crucial role in assessing critically ill patients with acute onset respiratory distress with hemodynamic collapse.^[17] Bedside echocardiographic assessment of RV is the intervention of choice for patients suspected to have pulmonary embolism with a precarious hemodynamic state and facilities for immediate computed tomography angiography are not available. Dilated RV by a bedside echocardiographic assessment in a high-risk patient with typical clinical features suggests diagnosis of pulmonary embolism. However, the presence of RV dilation alone could be because of coexisting cardiac or pulmonary problems.^[17] Two patients had RV dilation and both cases were identified by the intensivists and the cardiologists (ICC estimate for pulmonary hypertension was 0.929–0.967). Pulmonary hypertension was diagnosed based on RVSP, calculated from TR jet velocity. There was excellent agreement between the cardiologists and intensivists in diagnosing pulmonary hypertension (ICC estimate was 0.929–0.967).

Assessing valvular functions in ICU patients can help in diagnosing acute valvular dysfunction caused by primary cardiac disease (myocardial infarction leading to acute mitral regurgitation).^[18] Identifying a mitral stenosis lesion presenting with acute pulmonary edema can be done easily using a bedside echocardiography. Two patients with mild MR and two patients with mild AR that were detected by cardiologists were missed by the intensivists. However, none of the severe lesions were missed.

Diagnosis of diastolic dysfunction has been gaining importance in the critically ill due to several associations with ICU

mortality and morbidity. Diastolic dysfunction has been found to be a key predictor of weaning failure and has also been associated with mortality in septic patients.^[19,20] However, most studies evaluating TTE training programs do not include diagnosis of diastolic dysfunction because of the need to use Doppler functions which have a steeper learning curve and may not be possible for noncardiology residents with minimal training.^[21] Ten patients were diagnosed to have diastolic dysfunction by the cardiologists in our study and one patient was missed by the intensivists.

There has been a recent surge in the use of dynamic indicators to assess volume responsiveness in the critically ill patients, one which has remained quite elusive to intensivists. Assessing respiratory variation in IVC diameter has become one of the commonly used methods because of the noninvasiveness, avoidance of complications associated with other techniques, suitability for both ventilated and nonventilated patients, and the immediate availability of an USG machine in the ICU. Recently, the dynamic predictors using invasive arterial blood pressure monitors have been in use for assessing fluid responsiveness in critically ill patients.^[22] Assessing the IVC diameter and its variability with respiration offers a noninvasive means of assessing fluid status in ICU patients.^[8] In addition, it also avoids other complications seen with invasive modalities such as bleeding, arrhythmias, and infections.^[23,24] In our study, intensivists could detect hypovolemia in 37 patients, whereas cardiologists 1 and 2 detected in 32 and 27 patients, respectively (ICC estimate for interpretation of hypovolemia was 0.790–0.902). This apparently better performance by the intensivists in assessing IVC diameter variation could probably be because of increased acquaintance with studying IVC diameter for diagnosing hypovolemia in the critically ill population which might not be the case with cardiologists.

Using bedside echocardiography, it is easier to diagnose a pericardial collection and also helps to perform real-time TTE-guided pericardiocentesis.^[25] Three patients had pericardial effusion in the study population and all three were picked up by the intensivists.

This study had the following limitations. The training program was not standardized. Therapeutic decisions were not made based on the results of the fTTE done by the intensivists. Hemodynamically unstable patients were excluded; the population in which this focused assessment by the intensivists would have had more implications.

CONCLUSION

This study has shown that intensivists with appropriate training in TTE were able to perform focused echocardiography with comparable accuracy to that of cardiologists. Nonetheless fTTE cannot replace comprehensive echocardiography and the short training may not suffice to perform Doppler studies efficiently. Further studies are required to elucidate the therapeutic implications of fTTE performed by the intensivists.

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Conflicts of interest

There are no conflicts of interest.

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