ORIGINAL ARTICLE

Assess the clinical applicability of transthoracic echocardiography in laparotomy patients in a general intensive care unit

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Background: Echocardiography is one of the diagnostic tools that can be applied at the bedside, along with avoiding transporting critically ill patients. This prospective observational study was designed to assess the clinical applicability of the transthoracic echocardiography (TTE) device by noncardiologist intensivists. **Materials and Methods:** Intensivists performed a limited TTE examination on critically ill patients admitted to the surgical intensive care unit (ICU). After initial cardiac clinical assessment in 85 critically ill adult patients, a limited TTE was performed by an intensivist to assess left ventricular (LV) function and LV volume status as well as valvular function and qualitative factors. Data were analyzed and presented in proportions using descriptive statistics. The setting was in surgical ICU of an academic medical center. **Results:** Valvular abnormalities (44.8%) as well as qualitative indices (68.3%) were the most frequently detected abnormalities. The ejection fraction was the only alteration, which was affected by the risk factors (P = 0.05, mean = 55.57). **Conclusion:** Transthoracic approach can provide useful information on cardiac anatomy and function in most ICU patients along with detecting severe previously unknown conditions in some patients.

Key words: Echocardiography, intensive care unit, transthoracic

How to cite this article: Abbasi S, Fazel K, Abdar Esfahani M, Kashefi P, Harandi SA. Assess the clinical applicability of transthoracic echocardiography in laparotomy patients in a general intensive care unit. J Res Med Sci 2014;19:398-403.

INTRODUCTION

Cardiovascular evaluation is very necessary in critically ill patients.[1] At present, there are some methods such as measuring capillary vein pressure, hypertension (HTN), urine output, body weight, heart rate, and arterial oxygen pressure, which are mostly invasive.[1-7] Echocardiography is one of the diagnostic tools that can be applied at the bedside, along with avoiding transporting critically ill patients.[8] In total, the indications of performing echocardiography for the patients in intensive care unit (ICU) include hemodynamic instability (such as hypovulemia, pulmonary embolism, and cardiac tamponade), infective endocarditis (IE), aortic dissection, and finding the source of embolism.[5]

Transesophageal echocardiography (TEE) has attracted more opinions in ICU,[9-15] because of high quality images and low failure rate of examinations performed. On the other hand, transthoracic echocardiography (TTE) is simpler and several practical approaches in the ICU are described on the bases of this technique.[16,17] At first, TEE was the main approach in ICU, but recently, as the technology developed, the TTE equipments could give us reliable images with high quality, which made it to be the main method of echocardiography in ICU.[2,18] The data gained by TTE can specify the reason of resistant hypotension to inotropic or vasopressor agents. It can also diagnose the other cardiovascular dysfunctions in a wide spectrum.[5]

TTE is noninvasive and more available than TEE. However, TTE has not been widely applied in ICU due to few intensivists who are trained in echocardiography. Moreover, very few intensivists can enterprise the time necessary for a comprehensive formal echocardiography training program as suggested by the American Society of Echocardiography. Unfortunately, it is not possible or practical to have a trained technologist or cardiologist available in every ICU on a 24-h basis.[19] Limited-scope, goal-directed TTE is defined as a TTE performed with specific limited objectives.[20,21]

Since there are some concerns about the safety of pulmonary arterial catheters and the data gained by them,[1] the purpose of this study was evaluating the diagnostic indices as well as their correlation with predisposing factors in laparotomy patients in ICU department.

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Received: 12-01-2014; **Revised:** 11-02-2014; **Accepted:** 07-03-2014

MATERIALS AND METHODS

This study was an observational descriptive analytical study, in which 85 patients were admitted to the ICU of Al-Zahra Hospital of Isfahan for being undergone for laparotomy operation during the summer of 2013.

At first, a checklist was filled out by the patients including of some information such as demographic traits, the underlying disease leading to laparotomy and medical and drug history. After initial diagnostic and therapeutic evaluation involving the examination of heart, lung, and abdomen, vital signs checking and arterial oxygen saturation, diagnostic TTE was performed for the patients at the position of supine via vivide3, probe 3v2, South Korea. Then the diagnostic indices were gathered according to the check list of criteria. The exclusion criteria were hypovolomia owning to severe dehydration and any type of shock (septic, hypovolomic etc.). Because the cardiac indexes are intensively influenced by hemodynamic indexes, and volume depression can destruct the cardiac indexes. The following parameters were checked during TTE performance: age, sex, the reason of laparotomy, medical history, drug history, stroke volume (SV), ejection fraction (EF), fractional shortening, end systolic diameter, end diastolic diameter (EDD), pericardial effusion (p-eff), pericardial tamponade (p-tamp), respiratory variation inferior vena cava diameter (IVC-diam) ratio, aortic insufficiency (AI), aortic stenosis (AS), mitral stenosis, mitral regurgitatin (MR), pulmonary stenosis, pulmonary regurgitation (PR), tricuspid stenosis, tricuspid regurgitation (TR) and the underlying risk factor. Furthermore, there were some risk factors in some patients that were considered in evaluating the results of TTE such as HTN, ischemic heart disease (IHD), diabetes mellitus (DM), convulsin, cerebrovascular accident, chronic obstructive pulmonary disease (COPD), acute renal failure (ARF) and hyperlipoproteinemia. Any alteration in TTE examination (alteration in cardiac anatomy or function) was considered to be an abnormality. It was assumed to be a severe condition whenever an emergent therapeutic intervention such as tamponade was needed like when a new diagnostic approach was required (a newly diagnosed severe left ventricular (LV) dysfunction, detection of endocarditis), or a cardiology consultation was requested because of a specific cardiac situation (detection of unsuspected valvular heart disease). These situations were considered unsuspected, if they were unknown prior to the examination. Data collected were analyzed using Chi-square, *t*-test, and Mann-Whitney test if normal distribution of variables could not be found. All descriptive data are presented as mean, standard deviation, and ICU stay were considered dependent variables, and echocardiographic data as the independent variables. The statistical program used was SPSS 15 (SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL, USA). $P < 0.05$ were considered to be statistically significant.

RESULTS

During the study period, 85 patients were enrolled with a mean age of 60.5 ± 21.5 years and a mean ICU stay of 15.1 ± 9.6 days. During the TTE examination, 46 (51.4%) patients were mechanically ventilated and 39 (20.3%) were hemodynamically unstable (hypotension as cause for admission). Main demographic and clinical characteristics are presented in Table 1.

Furthermore, echocardigraphic abnormalities are outlined in Table 2.

In one patient, it was not possible to obtain any data (impossible examinations). In four patients, cardiac chamber dimensions or LV function could not be quantified. In these patients, only qualitative, subjective information was obtained on such parameters. Information on cardiac chamber dimensions, LV function, and cardiac output were obtained in the majority of patients. In surgical patients, IVC

Table 1: Main demographic and clinical characteristics of patients on admission to ICU

	All patients	Percentage
n	85	100
Male	60	70.6
Female	25	29.4
RF	69	8.12
HTN	26	30.6
IHD	9	10.6
HLP	3	3.5
DM	14	16.5
COPD	14	16.5
Convulsion	1	1.2
ARF	13	15.3
CVA	1	1.2

RF = Renal failure; HTN = Hypertension; IHD = Ischemic heart disease; HLP = Hyperlipidemia; DM = Diabetes mellitus; COPD = Chronic obstructive pulmonary disease; ARF = Acute renal failure; CVA = Cerebrovascular accident; ICU = Intensive care unit

Table 2: Echocardiographic abnormalities in patients

	Frequency	Percentage
p-eff	2	2.35
p-tamp	2	2.35
AI	4	4.7
AS	1	1.2
MR	12	14.1
MS	1	1.2
PR	9	10.6
PS	0	0
TR	11	12.9
TS	0	0

p-eff = Pericardial effusion; p-tamp = Pericardial tamponade; IVC-diam = Inferior vena cava diameter ratio; AI = Aortic insufficiency; AS = Aortic stenosis; MS = Mitral stenosis; MR = Mitral regurgitatin; PS = Pulmonary stenosis; PR = Pulmonary regurgitation; TS = Tricuspid stenosis; TR = Tricuspid regurgitation

evaluation was particularly difficult, due to the presence of surgical bandages. The frequency of echochardiographic findings according to the type of risk factor in patients with no risk factor included 3 cases of mild p-eff, one severe p-eff, one severe p-tamp, two cases of mild AI, two cases of moderate MR, one PR, two cases of severe TR and two cases of moderate TR. Among the cases, there was a case of convulsion in which the findings were including severe p-eff, severe p-tamp, moderate AI, moderate AS and moderate TR. Also the results of Chi-square test for comparison of two alterations were representative of the meaningful correlations that are shown in Table 3. The distribution of frequency of the evaluated indices in patients with risk factors was more observed compared with those who had not any risk factors.

After evaluating the qualitative alterations and a comparison of mean of the evaluated indices in patients with and without risk factors using *t*-test, the EF was the only alteration which was affected by the risk factors (P = 0.05, mean = 55.57). These alterations had not any meaningful correlation with HTN, IHD, diabetes and ARF. But about COPD, IVC-diam and EDD had a statistically meaningful correlation (P = 0.02, mean = 57.14 and P = 0.005, mean = 4.32, respectively) [Table 4].

Table 3: The comparison between two alterations with the meaningful *P* values, analyzed by Chi-square

Alterations	*P* value
p-eff and RF	0.03
AI and ARF	0.01
AS and IHD	0.003
MR and IHD	0.01
MS and DM	0.02

RF = Renal failure; DM = Diabetes mellitus; ARF = Acute renal failure; p-eff = Pericardial effusion; AI = Aortic insufficiency; AS = Aortic stenosis; MS = Mitral stenosis; MR = Mitral regurgitatin; IHD = Ischemic heart disease; HTN = Hypertension; HLP = Hyperlipidemia; COPD = Chronic obstructive pulmonary disease; CVA = Cerebrovascular accident; p-tamp = Pericardial tamponade; IVC-diam = Inferior vena cava diameter; PS = Pulmonary stenosis; PR = Pulmonary regurgitation; TS = Tricuspid stenosis; TR = Tricuspid regurgitation

DISCUSSION

The management of critically ill patients with unknown hemodynamic position is on the basis of early diagnosis of the etiology and treatment. Time can save the lives. The international guidelines have recommended widely that according to the goal, the patient should be treated at the early stages.[4]

Routine use of TTE by all ICU physicians is not a common finding. In this survey, we presented and evaluated this practice to make possible in assessing important issues like data acquisition possibilities of TTE and the prevalence of specific cardiac abnormalities or diagnoses. TTE examination was reported to present a high failure rate in ICU. A study by Cook *et al*.[22] observed a failure of 38% in a surgical ICU, where TTE examinations were considered as "inadequate" or "poor." These scientists used TEE as a comparative examination. Conditions related to failure were found to be related to edema, high positive end expiratory pressures and presence of chest tube thoracostomies. The LV function could be evaluated in 64% of patients, but even easily diagnosed conditions by TTE, like tamponade, had a high failure rate. This failure rate described by Cook *et al*. seemed to be linked with specific situations such as those described above mainly in surgical patients. In this study, there were difficulties in evaluating surgical patients. Because patients with chest tubes thoracostomies were few, the main difficulty in surgical patients was detecting the IVC.

Another study by Stanko *et al*.,[23] which was performed in a medical or surgical ICU, observed a lower rate of "suboptimal studies." Bossone *et al*.[24] described two of 467 consecutive studies in which the TTE examinations were impossible to interpret.

This research was done in a general ICU, where most patients presented a medical clinical manifestation. It seemed that

Table 4: The comparison between qualitative alterations and the risk factors analyzed by *t*-test

	RF versus no RF (*P* value and mean ± SD)	HTN versus no HTN (*P* value and mean ± SD)	IHD versus no IHD (*P* value and mean ± SD)	DM versus no vDM (*P* value and mean ± SD)	COPD versus no COPD (*P* value and mean ± SD)	ARF versus no ARF (*P* value and mean ± SD)
SV	0.671 and 64.1±13.7 versus 65.6±8.8	0.492 and 66.1±16.7 versus 63.6±10.8	0.155 and 70.2±8.2 versus 63.7±13.2	0.325 and 67.5±11.1 versus 63.7±13.2	0.407 and 57.1±13.3 versus 65.8±12.4	0.464 and 64.5±8.3 versus 64.3±13.6
EF	0.050 and 57.57±8.2 versus 60.06±7.7	0.97 and 56.3±8.9 versus 56.4±8.0	0.618 and 55.1±7.1 versus 56.5±8.4	0.180 and 59.1±7.4 versus 55.8±8.3	0.072 and 52.7±6.8 versus 57.1±8.3	0.575 and 55.2±5.7 versus 56.6±8.6
FS	0.052 and 35.1±10.4 versus 29.7±7.3	0.503 and 35.2±9.8 versus 33.6±10.2	0.668 and 32.7±6.4 versus 34.3±10.4	0.587 and 35.5±8.8 versus 33.8±10.3	0.298 and 1.5±9.6 versus 34.6±10.1	0.221 and 38.6±14.5 versus 33.3±8.9
ESD	0.697 and 3.17±0.89 versus 3.2±0.44	0.980 and 3.1±0.58 versus 3.1±0.89	0.337 and 3.4±0.4 versus 3.1±0.8	0.742 and 3.1±035 versus 3.2±0.8	0.157 and 2.9±0.3 versus 3.2±0.8	0.703 and 3.3±1.8 versus 3.1±0.47
EDD	0.572 and 4.7±063 versus 4.6±0.43	0.327 and 4.8±0.73 versus 4.4±0.53	0.814 and 4.7±1.0 versus 4.7±0.5	0.186 and 4.9±0.46 versus 4.6±0.6	0.005* and 4.3±0.5 versus 4.8±0.59	0.829 and 4.7±0.66 versus 4.7±0.59
IVC-diam	0.058 and 1.4±0.5 versus 1.2±0.41	0.47 and 1.4±0.50 versus 1.3±0.48	0.105 and 1.1±0.3 versus 1.4±0.49	0.164 and 1.5±0.5 versus 1.3±0.4	0.020* and 1.5±0.51 versus 1.37±0.48	0.970 and 1.3±0.48 versus 1.4±0.49

ARF = Acute renal failure; COPD = Chronic obstructive pulmonary disease; DM = Diabetes mellitus; HTN = Hypertension; IHD = Ischemic heart disease; RF = Renal failure; SD = Standard deviation; SV = Stroke volume; EF = Ejection fraction; FS = Fractional shortening; ESD = End systolic diameter; EDD = End diastolic diameter; IVC-diameter = Inferior vena cava diameter; *Meaningful at 0.005 and 0.02

the characteristics of ICU patients are relevant in choosing the best echocardiographic tool (TTE or TEE). Moreover, the information needed may be also important. It is clear that TEE is superior to TTE in identifying a valvular disease (like in cardiac surgery patients) or a cardiac source of embolus.[9,12,25]

The second issue addressed was related to a routine use of TTE. This question involves several topics such as detecting and studying the prevalence of cardiac abnormalities in a general ICU, specific diagnoses, and the influence of these factors on the outcome.

Stanko *et al*.,[23] showed a high number of abnormalities (121 of 135). The main difference between these studies is in the methodology used. Stanko *et al*. enrolled patients on the basis of a specific request for TTE (selective TTE), whereas this study enlisted consecutive patients. It is possible that patients studied by those authors had a higher previous suspicion for cardiovascular abnormalities.

In the other study by Bossone *et al*.,[24] the rate of abnormalities was similar to the prevalence rate of abnormalities detected in the present study. Also, a number of severe conditions that required unblindedness of the study were detected in 11% of cases. It should be pointed out that these scientists excluded patients with "obvious cardiovascular disease," which was determined on admission. Differences between these studies should be mentioned.

Bossone *et al*. prospectively defined all the abnormalities such as LV dysfunction, and severe chamber dilatation, regardless of its clinical significance. In our study, TTE abnormalities were differentially analyzed including any anatomic or functional alteration and specific severe cardiac diagnoses. Right heart chamber dilatation and signs of right ventricular (RV) overload mostly presented in patients with respiratory diseases, were not identified in this study. However, in a patient's assessment, these findings are relevant.

Pericardial effusion is very common in ICU patients particularly after cardiac surgery on the cardiothoracic ICU. The apical, subcostal, parasternal long and short axis view will usually reveal the effusion. In many critically ill patients, the subcostal view will often be the only appropriate window to detect p-eff. It should be reminded that cardiac tamponade is a clinical diagnosis and echocardiography may suggest a hemodynamic abnormality that may be the stratum for tamponade, but this alone will not establish the diagnosis of tamponade. The signs of tamponade are directly relevant with actual elevation of intrapericardial pressure. The right atrial wall collapse is seen in late diastole in the apical view and RV free wall collapse is seen in early diastole in parasternal view.[18]

In our study, we investigated two cases of severe p-eff and severe p-tamp which one of them was found in a patient with no risk factor and one in a case of convulsion. Hence, it is demonstrating that the patients, who do not have any type of risk factor, may have prominent echochardiographic findings, which may not be important at the first glance of no TTE evaluation.

Significant valvular abnormalities can be present in the critically ill patient without being recognized.[24] An accurate evaluation of valvular pathologies requires to be identified in ICU. The common indications for bedside echocardiography in such group of patients are aortic and mitral valve disease, excluding native IE as well as prosthetic valve endocarditis. In the critical care setting, TTE can provide valuable information concerning valvular integrity and function, but it may not be optimal and sensitive for detecting vegetations of endocarditis, or evaluating a dysfunctional mitral valve and the assessment of the most prosthetic valves. In this regard, TEE is in advance for assessing valvular function.[26] In some cases, TTE can provide better imaging than TEE to evaluate anterior structures such as aortic valve and Doppler measurements.

Assessment of the mitral valve by TTE in ICU setting is difficult and may underestimate the severity of mitral valve disease. TEE provides high quality imaging for the assessment of the mitral valve in ICU patients, due to its close anatomic position to the esophagus. Mitral valve leaflet opening and prolapse can be noted in a parasternal long axis view and in short axis view.

In our study, valvular abnormalities were mostly correlated with the patients who had an underlying disease such as DM, IHD, or ARF. It means that TTE can be very effective to predict the prognosis of disease in patients who do not have any cardiovascular pathology.

Also, as it was mentioned before, EF in patients with no risk factor as well as SV and EDD in patients with underlying disease are the alterations which were statistically meaningful. It shows that there are many patients who have a poor level of qualitative echocardiographic criteria such as EDD and SV without any cardiovascular or critical manifestations that can be diagnosed at the initial steps to reduce the mortality and morbidity in ICU ward.

Finally, in addition to the information on the feasibility of bedside TTE in the ICU, the study can confirm to establish the training needed for ICU physicians. It is necessary to remember; however, that such training may differ according to patients' characteristics and ICU needs. Several limitations must be pointed out. First, this was an observational rather than a blinded study. Just patients with known diagnoses, previous to admission, were considered to have suspected

cardiac abnormalities. Moreover, all examinations were done by ICU physicians, and the information was immediately available. Hence, other diagnostic tests were not considered to be performed; we were not able to establish the clinical suspicion for more severe conditions. But even in this case, TTE was a reliable option to achieve success. We found a significant number of patients with lots of echocardiographic disorders. It is possible to state that echocardiography has a real impact on major outcomes, such as mortality.

AUTHORS' CONTRIBUTION

Saeed Abbasi: contributor for designing the work. Kamran Fazel: contributor for acquisition, analysis and interpretation of data for the work. Morteza Abdar Esfahani: corresponding author and contributor for revising the paper critically for important intellectual content. Parviz Kashefi: contributor for designing the work. Smaneh Alami Harandi: contributor for interpretation of data.

CONCLUSION

The TTE is a useful technique in a general ICU. The majority of echocardiographic parameters can be obtained and quantified. Specific cardiac abnormalities involving structural or functional, were detected in 73% of the patients. Valvular abnormalities as well as qualitative indices were the most frequently detected abnormalities. As much as 69% of the patients presented previously unknown critical conditions. These were manifested by severe structural cardiac diseases that could threaten the patient's life.

Echocardiography is a promising technique in the intensive care. ICU specialists can perform this technique perfectly after appropriate training in several noncardiological settings such as ICU.

This study demonstrates that the transthoracic approach can provide very useful information on cardiac anatomy and function in most ICU patients along with detecting severe previously unknown conditions in some patients.

ACKNOWLEDGMENTS

This research is affiliated by Isfahan University of Medical Science with the research project number of 393018.

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Source of Support: Nil, **Conflict of Interest:** None declared.