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Original Article

Transthoracic echocardiography for cardiopulmonary monitoring in intensive care

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Summary

Background and objective: To evaluate the feasibility of an abbreviated focus assessed transthoracic echocardiographic protocol, consisting of four standardized acoustic views for cardiopulmonary screening and monitoring.

Methods: The protocol was applied in 210 patients in a 20-bed multidisciplinary intensive care unit in a university hospital. When inconclusive, an additional transoesophageal echocardiographic examination was performed. Diagnosis, indication, acoustic window, position and value were recorded. Significant pathology, load, dimensions and contractility were assessed.

Results: Two-hundred-and-thirty-three transthoracic and four transoesophageal echoes were performed. The protocol provided usable images of the heart in 97% of the patients, 58% subcostal, 80% apical and 69% parasternal. Images through one window were obtainable in 23%, through two windows in 41% and through three windows in 34%. In 227 patients (97.4%) the focus assessed echo protocol contributed positively. In 24.5% of cases the information was decisive, in 37.3% supplemental and in 35.6% supportive.

Conclusions: By means of an abbreviated, focus assessed transthoracic echo protocol it is feasible to visualize the haemodynamic determinants for assessment and optimization. One or more useful images are obtainable in 97% of critically ill patients.

Keywords: ECHOCARDIOGRAPHY, transthoracic, transoesophageal; CRITICAL CARE, monitoring; HEART DISEASES, cardiac output low, heart failure, myocardial ischaemia.

Monitoring and treatment of the haemodynamically unstable patient in the intensive care unit (ICU) is a complex challenge. Often the time factor is a major concern and the outcome depends on a rational and problem focused approach. Two dimensional imaging of the heart, with the ability to characterize the individual haemodynamic determinants and exclude or confirm different conditions in a quick and non-invasive way, is an attractive thought. Ultrasound is, at present, the only method which can provide bedside real-time and dynamic imaging of the heart – either from the transthoracic echocardiographic (TTE) approach or by means of transoesophageal echocardiography (TOE). With these methods, the heart, the great vessels and the pleurae can be visualized, giving important information about cardiac morphology, systolic and diastolic function, and significant pathology [1–6]. Measurements of wall thickness and cavity dimensions are essential parameters for assessment of the major determinants of haemodynamics, namely preload, afterload and contractility. In addition, diastolic function as well as ventricular interdependency may be described by echocardiography. In this way the examination provides information of paramount importance for further therapeutic decisions. TOE has been claimed to be the method of choice in the ICU and many investigations have demonstrated

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a convincing diagnostic strength and impact of TOE in the perioperative as well as in the critical care setting [7–11]. By viewing the heart from the oesophagus, limited acoustic conditions can be surpassed [9–13]. Technical refinements however, including second harmonic imaging, have dramatically improved the imaging capabilities of TTE [14].

The value of a brief, focus assessed TTE (FATE) examination, performed by non-cardiologists compared to a comprehensive TTE examination has been demonstrated [15–18]. After more than 10 yr experience with transthoracic ultrasound, we propose a rapid and systematic protocol for cardiopulmonary screening and monitoring. This protocol is complementary to the thorough and much more time-consuming cardiologic diagnostic procedure from which it should be clearly distinguished.

We hypothesized that this protocol could be applied in a mixed ICU population and hereby contribute to cardiopulmonary optimization. The purpose of this study was therefore to present the principles of an abbreviated focus assessed protocol, to evaluate the frequency of successful TTE protocol procedures and to present illustrative clinical cases.

Methods

After institutional approval, data were collected between 1 May, 2001 and 2002. Patients who were not making clinical progress after cardiopulmonary evaluation based on conventional monitoring were selected for the TTE protocol. In each case, the following was recorded: patient characteristics, respiratory mode, location of acoustic window, patient diagnosis, clinical problem, echocardiographic finding and importance of findings on a four-level scale (see Table 1). Data were collected prospectively on a predefined data protocol.

Echocardiographic technique

Three different echo machines were used (System 5, Vivid 5 and Vivid 7, G.E. Vingmed, Horten, Norway). Second harmonic imaging was standard mode in all adult cases. All machines allowed images to be stored digitally and/or on video tape. A 2.5 MHz phased array transducer was used in adults and a 10 MHz probe in paediatric cases. TTE was initially performed with the patient in the supine position or on the left side. If the patient was placed on the right side prior to the examination a supine position was used. In case of sub-optimal image quality the patient was turned 30° or 60° to the left. An inconclusive TTE led to TOE examination.

Four scanning positions are of particular interest in the focus assessed TTE protocol (Fig. 1).

1. Subcostal view. A subcostal view offers imaging access to the heart in patients placed in the supine position (Fig. 1). The transducer should be placed parallel to the skin, inferior to the right costal curvature and the ultrasound image plane directed towards the heart. From this position a four-chamber view is attainable (Fig. 2a). By rotation, a short-axis view may be obtained. The subcostal projection is important for monitoring of pericardial effusions.

2. Apical view. The transducer is placed over the apex of the heart and the ultrasound beam directed parallel to the long axis of the heart, ending up with the apical four-chamber view (Figs 1 and 2b). From the four-chamber view, the transducer is rotated counter clockwise to obtain the two-chamber view of the left ventricle. The apical two-chamber view is used for evaluation of the anterior left ventricular

Table 1. The monitoring value of FATE.

I	No image/too poor information	6 (2.6%)
II	Support of available information	83 (35.6%)
III	Added new information	87 (37.3%)
IV	Added decisive information	57 (24.5%)
Total		233 (100%)

Graded by the investigator.

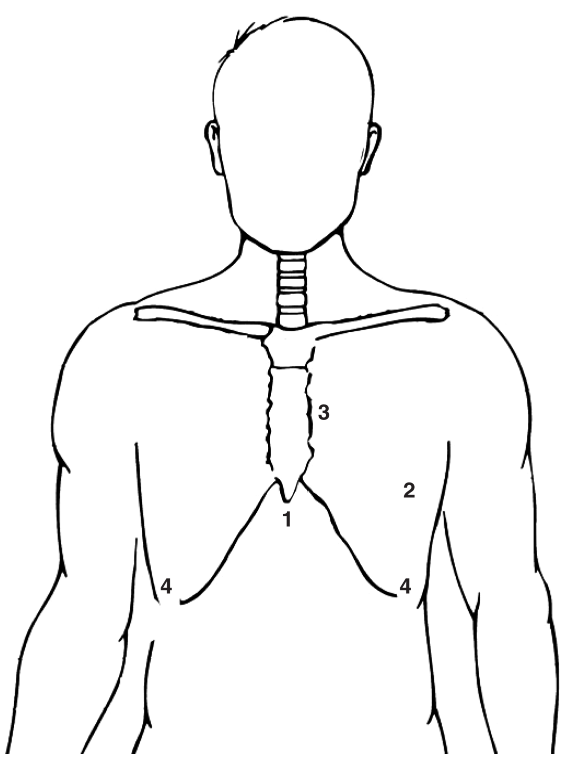

Figure 1.
Transducer positions in the FATE protocol. (1) subcostal view; (2) apical view; (3) parasternal view; (4) pleural view.

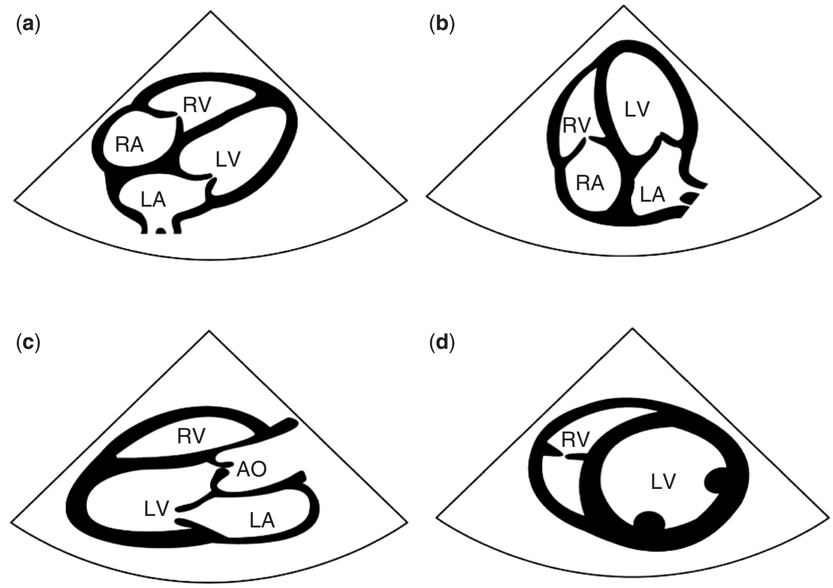

Figure 2.
*Schematic drawing of the four most important image planes as they appear on the monitor during TTE. (**a**)* Subcostal four-chamber view *(position 1, Fig. 1). The right ventricular free wall, the midsection of the interventricular septum and the posterolateral left ventricular wall are seen. (**b**)* Apical four-chamber view *(position 2, Fig. 1). The left-sided chambers are seen to the right, the right-sided to the left of the screen. (**c**)* Parasternal long-axis view *(position 3, Fig. 1). The right ventricular outflow tract is seen anteriorly. The aortic root and valve, the mitral valve, the interventricular septum and left ventricular posterior wall are further displayed. The left atrium is seen posterior to the aortic root with a similar antero-posterior dimension as the aortic root. (**d**)* Parasternal short-axis view *(position 3, Fig. 1). Left and right ventricles and papillary muscles. AO: aorta; LA: left atrium; LV: left ventricle; RA: right atrium; RV: right ventricle.*

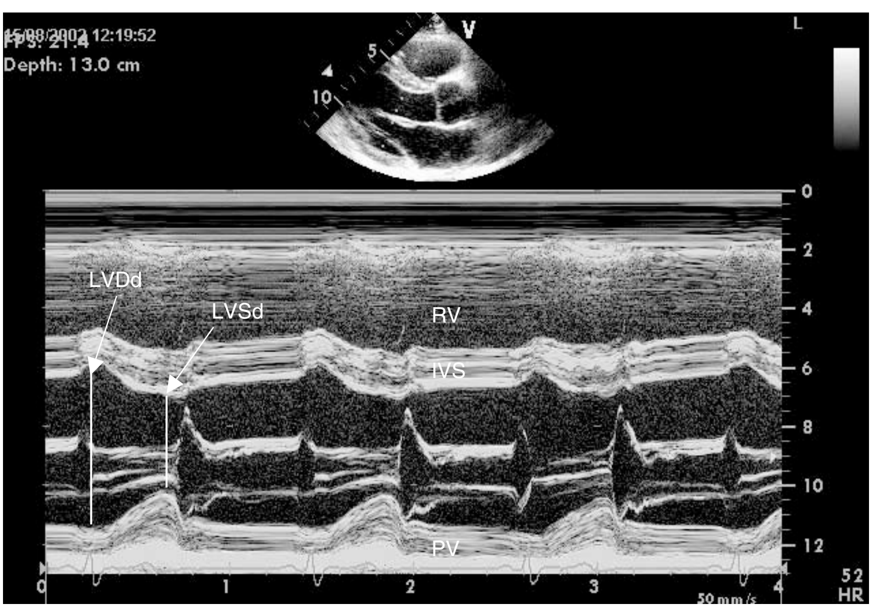

Figure 3.
M-mode scan of parasternal long-axis view with 2D image on top (cf. Fig. 2c). IVS: interventricular septum; LVDd: left ventricular diastolic diameter; LVSd: left ventricular systolic diameter; PV: posterior wall; RV: right ventricle.

wall (seen to the right on the screen) and the posterior wall (seen to the left). Further rotation of the transducer yields the long-axis view.

3. Parasternal view. The transducer is placed on a line connecting the apex with the middle of the right clavicle, adjacent to the left lateral margin of the sternum (Figs 1 and 2c). By rotation a short-axis view will be displayed (Fig. 2d). Image quality may be improved by turning the patient to the left side. From the parasternal long-axis view the classical M-mode scan is achieved, which is the basis for quantitative measurements of ventricular and myocardial dimensions (Fig. 3) [19].

4. Pleural view. The transducer is placed on the lateral thoracic wall (Fig. 1). By placing the indication knob cranially, caudal structures will be presented to

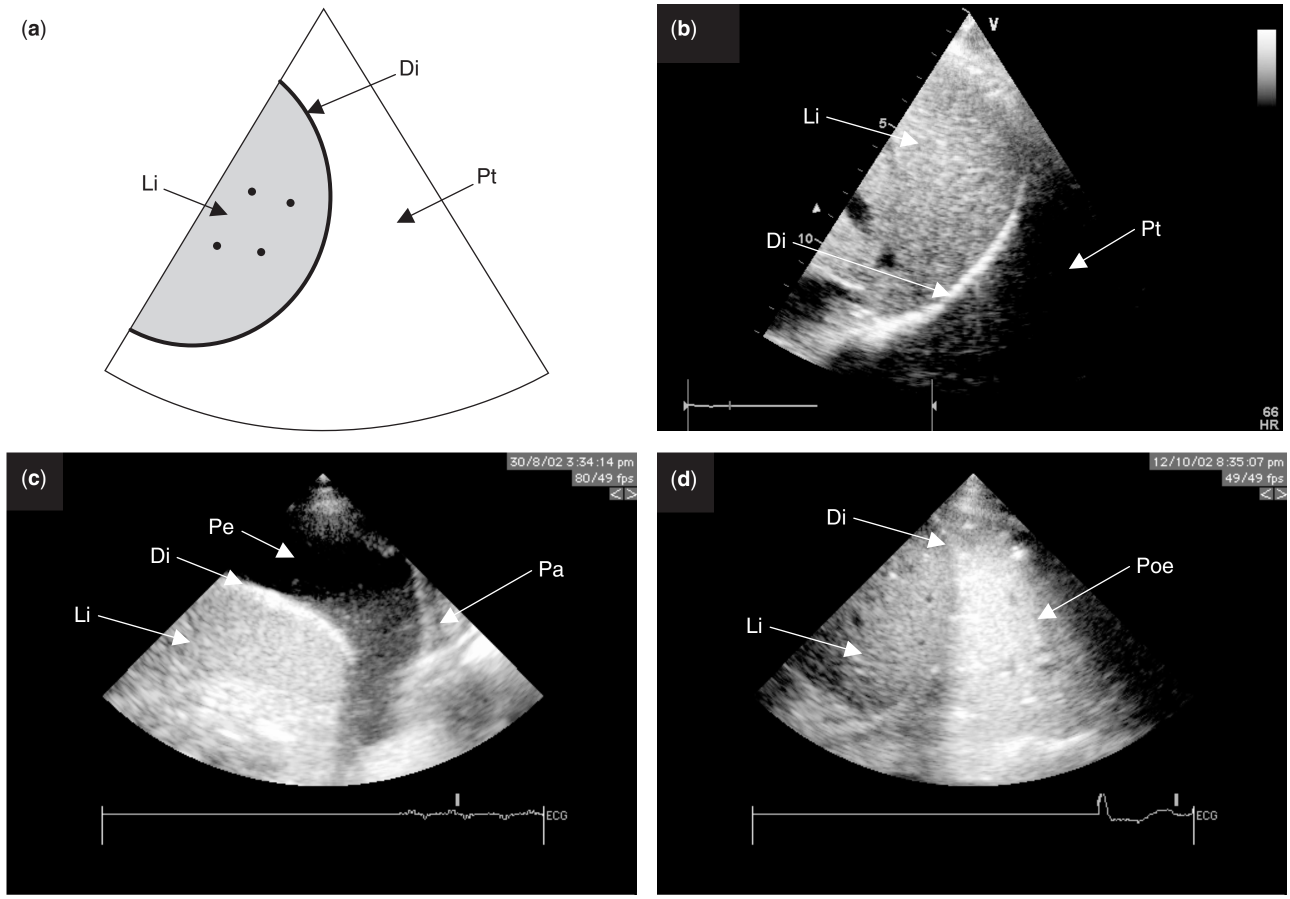

Figure 4.
*(**a**) Schematic drawing of pleural scan, right side (position 4, Fig. 1), (**b**) normal, aerated pulmonary tissue, (**c**) pleural effusion and pulmonary atelectasis, (**d**) pulmonary oedema, pulmonary tissue appears white due to water content. Di: diaphragm; Li: liver; Pa: pulmonary atelectasis; Pe: pleural effusion; Poe: pulmonary oedema; Pt: pulmonary tissue.*

the left on the screen (Fig. 4a) and vice versa, similar to standard TTE and TOE. It should be noticed that normal aerated pulmonary tissue will blur the image (Fig. 4b). This is in contrast to the presence of pleural effusion, pulmonary atelectasis (Fig. 4c) and even acute pulmonary oedema (Fig. 4d). The diaphragm (Fig. 4) is a fixed point and should always be clearly recognized on the screen especially if pleural puncture is intended. This will secure a proper drainage, avoiding trauma to sub-diaphragmatic organs.

The FATE protocol

The FATE is performed from the four positions listed above (Fig. 1) in a rapid sequence with the following objectives:

1. Exclude obvious pathology.
2. Assess wall thickness and dimensions of chambers.
3. Assess contractility.
4. Visualize pleura on both sides.
5. Relate the information to the clinical context.

The overall purpose is to screen for significant pathology and to obtain information about volume status and contractility of the heart. Quantitative measurements of dimensions and contractility are provided by utilizing the measurement and analysis functions of the echo machines. Appropriate Doppler modalities are applied as necessary, e.g. for pressure measurement, evaluation of valvular pathology, myocardial defects and assessment of cardiac output. The FATE may be interrupted as soon as the clinical problem/question has been solved. However, we recommend that all imaging positions be completed because of the possibility of further disorders, which would otherwise be missed. In addition, a specific finding may be better evaluated from a combination of different views.

Results

Patient characteristics data are presented in Table 2. Two-hundred-and-thirty-three TTE and four TOE examinations were performed in 210 patients. The

Table 2. Patient characteristics data.

Patient group	Age (years)	Number (*n*)	TTE (*n*)	TOE (*n*)
Children				
Cardiac postoperative	0–11 (1)	15	18	0
ECMO (RS-virus)	2	1	1	0
Adults				
Cardiac postoperative	40–85 (69)	108	118	2 (+2)
Non-cardiac postoperative	24–81 (63)	19	23	1
Sepsis	27–82 (58)	35	38	0
Cardiac failure	19–81 (64)	24	27	1
Miscellaneous	50–82 (62)	8	8	0
Total		210	233	4 (+2)

ECMO: extracorporeal membrane oxygenation; RS-virus: respiratory syncytial virus; *n*: number of patients; TTE: transthoracic echocardiography; TOE: transoesophageal echocardiography (numbers in parenthesis refer to cases where TOE was indicated but not possible). Values are numbers or range (median).

Table 3. Number of examinations with 0–3 usable windows for cardiac imaging (positions 1–3, Fig. 1).

Usable windows	Examinations (*n* (%))
0	4 (2)
1	54 (23)
2	96 (41)
3	79 (34)
Total	233 (100)

monitoring value of the TTE examinations, graded from I to IV, is shown in Table 1. In 227 TTE examinations (97.4%) images of sufficient quality were obtained. In six cases (2.6%) TOE was planned; it was not possible to obtain any images at all with TTE in four patients (1.8%) and in two patients the clinical problem was not solved by TTE. Two of the TOE examinations could not be performed because of contraindication and hardware problems.

Table 3 illustrates the number of examinations with 0–3 usable TTE windows for cardiac imaging (position 1–3). Usable images were achieved in 136 examinations (58.4%) with subcostal transducer position, in 186 (79.8%) with apical position and in 161 examinations (69.1%) with a left parasternal transducer position. One-hundred-and-ninety-six examinations were performed while the patient was supine, 26 cases with 30° and 11 cases with 60° inclination to the left. One-hundred-and-thirty-seven of the 210 patients (66%) were mechanically ventilated during the examination.

Case 1

A 60-yr-old male, without previous cardiac disease, was admitted after cardiac arrest for primary coronary intervention. Following this procedure the patient was supported by two inotropic infusions and an intra-aortic balloon pump due to low blood pressure and suspected cardiac failure. At the time of admission to the ICU the patient was increasingly hypotensive and tachycardic. A FATE showed extreme left ventricular hypertrophy. The presence of tachycardia without echocardiographic signs of impaired myocardial contractility indicated diastolic dysfunction and preserved contractile reserve. The strategy was therefore changed and inotropic support was replaced by beta-blockade and concomitant judicious volume loading. This opposite approach fully reversed the circulatory failure.

Case 2

A 70-yr-old female, with terminal renal insufficiency and 5 kg overweight was referred from a local hospital for dialysis. Before leaving the local hospital the patient was intubated due to low oxygen saturation. During transportation the patient was ventilated with 100% oxygen which was reduced to 60% on arrival. An infusion of dopamine (3 $\mu g\,kg^{-1}\,min^{-1}$) was supporting the circulation. An X-ray at the local hospital was reported to show no signs of pleural effusions. A FATE showed normal cardiac function but significant pleural effusions on both sides. Bilateral pleural drains were inserted immediately. 500 mL was drained on the left side and 600 mL on the right side. The inspired oxygen fraction could be reduced to 40%. Shortly thereafter the patient was extubated and dopamine was withdrawn.

Case 3

A 83-yr-old male, having had an acute coronary artery bypass grafting operation. Left ventricular ejection fraction was 50% prior to surgery. The patient was re-explored due to bleeding. Perioperative TOE showed good left ventricular function, but dilation and dysfunction of the right ventricle. The patient's postoperative course was complicated by haemodynamic instability with a heart rate (HR) of 133 beats min^{-1}, systolic blood pressure of 78 mmHg and decreasing urine production. The patient was supported with infusions of milrinone (0.5 $\mu g\,kg^{-1}\,min^{-1}$), dobutamine (15 $\mu g\,kg^{-1}\,min^{-1}$), epinephrine (0.1 $\mu g\,kg^{-1}\,min^{-1}$), and norepinephrine (0.2 $\mu g\,kg^{-1}\,min^{-1}$). A FATE showed a well-contracting and volume-depleted left ventricle, and a dilated and dysfunctioning right ventricle as could be expected from the perioperative TOE. Based on these findings the patient was treated with volume infusion under repeated echocardiographic monitoring. During the following hours, the inotropic infusions, except the milrinone, were gradually withdrawn. HR fell from

133 to 94 beats min^{-1}. Arterial pressure increased from 78/40 to 102/47 mmHg, pulmonary arterial pressure from 20/12 to 22/14 mmHg, and CVP from 16 to 19 mmHg. Mixed venous oxygen saturation decreased from 72 to 65%. Urine production returned and the patient was discharged from the ICU 1 week later in good condition.

Case 4

A 50-year-old female, without known cardiac disease, was admitted to the ICU due to meningitis. The temperature was 39°C, blood pressure was 80/40 mmHg and the patient had a tachycardia of 150 beats min^{-1}. The patient was in severe respiratory distress and needed immediate intubation. During this procedure, concomitant with volume loading and HR regulation with amiodarone, the patient had a cardiac arrest but was successfully resuscitated. A FATE showed severely compromised left ventricular contractility with left ventricular dilatation and ejection fraction about 10%. The patient was supported with inotropic medication. She was discharged from the ICU 1 month later without sequelae.

Discussion

This study shows that TTE used as a monitoring tool provides 2D images of acceptable quality to fulfil the requirements in 97% of the cases (Table 1). In more than one-third, all three cardiac windows were useful (Table 3). According to the literature, this is a very good result [9,11–13]. Our findings are supported by one large study [20], in which TTE was performed in 469 ICU patients and imaging was insufficient in only 0.4%. The number of ventilated patients was not reported, though. Ventilator treatment is one of the major reasons for limited acoustic access, especially during high levels of positive end expiratory pressure (PEEP) [13,21]. In our series, 137 of the 210 patients were mechanically ventilated but this seems not to have had a significant negative impact. The majority of earlier reports have deemed TTE less useful in this patient population due to the inferior image quality compared to TOE [9,11,13,22]. Two main differences between these reports and ours are the clinical stage at which the examination is performed and the purpose of the examination. Previously, echocardiography has been mainly used as a diagnostic tool in the ICU [11,12,21,22]. This must be clearly distinguished from the purpose of a FATE examination as a tool for monitoring and haemodynamic evaluation. A rough assessment of load, dimensions and contractility does not require the same quality of images as a comprehensive cardiological examination. As illustrated in our patients, the apical and parasternal transducer positions had the highest yields. With these views, substantial information about dimensions and contractility is obtainable. The subcostal transducer position gave acceptable images in only 58.4% of the cases, probably due to the fact that 50% were postoperative cardiac patients with subcostal chest tubes.

About 2200 patients, of whom 1200 are postoperative cardiac patients, are admitted to our department each year. A FATE was performed in about 10% (210/2200). The patient population was a mixed sample of cardiac, non-cardiac surgical and medical critically ill patients (Table 2). The majority of the examinations were performed in patients in whom the haemodynamic picture was not perfectly clear, e.g. patients receiving inotropic support and in whom the need for increase or reduction had to be distinguished from volume therapy. The echocardiographic evaluation of preload and afterload by visualization of left ventricular dimensions and wall thickness, and the immediate assessment of a volume challenge enabled a rational intervention.

This is illustrated by Case 1, which shows the difficulty in distinguishing left ventricular failure from hypovolaemia in a patient with left ventricular hypertrophy. While left ventricular systolic function may be normal, impaired ventricular relaxation and/or poor ventricular compliance may lead to pulmonary congestion and clinical heart failure [2,4]. If normal systolic left ventricular function is observed in a failing heart, attention must focus on the possibility of compromised diastolic function. In such cases, increased inotropic medication will not solve the problem; preload has to be restored.

Case 2 shows that pleural effusions can lead to respiratory failure in a marginal patient. The use of ultrasound for locating pleural collections is well established [6]. Pleural effusions are normally diagnosed by X-ray but ultrasound may be more sensitive [23]. In our case, the fluid collection was not revealed on a supine chest X-ray. When estimating the amount of fluid from an X-ray, ultrasound may help in the decision whether to drain or not and it will guide proper drainage. In comparisons of TTE vs. TOE, the advantage of pleural scanning with TTE has not been investigated.

Case 3 highlights the importance of a thorough evaluation of ventricular interdependency. Because of the close anatomic association of the ventricles – they are enclosed within the pericardium, share a common septum and are encircled by common muscle fibres – the volume and contraction of one ventricle affects the function of the other. In this case, the approach was changed from treatment of an initially well-functioning left ventricle to treatment of the failing right ventricle. Echocardiography is the only method for assessing ventricular interdependency.

In Case 4 a septic patient with meningitis had persistent tachycardia. Tachycardia is often caused by relative hypovolaemia, which accompanies septic conditions. Hyperthermia may be a contributing factor. However, we believe that the elevated HR in this case was part of a sympathetic compensatory response to the unsuspected and severe left ventricular dysfunction caused by the systemic infection. This illustrates the need for dynamic cardiac imaging in severe illness.

As with any other monitoring tools, the correct interpretation implies a thorough understanding of pitfalls in data acquisition and processing, together with an understanding of limitations related to patients, equipment and examiner. One major limitation of our abbreviated goal-directed TTE protocol is the subjective and qualitative character of the assessment. A more comprehensive examination would improve quantitative assessment of cardiac function. With experience and training, however, the ability to extract increasing amounts of data at a glance increases. The patient sample in this study is representative for our mixed ICU, but the selection of patients depended to some extent on the three investigators.

Conclusions

This study emphasizes the usefulness of an abbreviated focus assessed TTE-protocol in an ICU setting, for rapid evaluation of the major haemodynamic determinants including significant pathology. One or more acoustic windows, allowing clinical decision-making, were obtainable in 97% of the patients. Our data, supported by illustrative case reports, clearly indicate that this abbreviated protocol often can characterize the haemodynamic disorder and optimize intervention in a rational way. Although FATE supported information was obtained in other ways in 35.6% of our cases, this confirmation may be just as important as new information. Echocardiography offers non-invasiveness and speed, but whether it can replace existing monitoring techniques cannot be concluded from this study. We recommend physicians in daily contact with critically ill patients in ICUs to obtain the necessary skills for echocardiographic examinations.

References

1. Cahalan MK, Lurz FC, Schiller NB. Transoesophageal two-dimensional echocardiographic evaluation of anaesthetic effects on left ventricular function. *Br J Anaesth* 1988; **60**: 99S–106S.
2. Troianos CA, Porembka DT. Assessment of left ventricular function and hemodynamics with transesophageal echocardiography. *Crit Care Clin* 1996; **12**: 253–272.
3. Kuecherer HF, Foster E. Hemodynamics by transesophageal echocardiography. *Cardiol Clin* 1993; **11**: 475–487.
4. Garcia MJ, Thomas JD, Klein AL. New Doppler echocardiographic applications for the study of diastolic function. *J Am Coll Cardiol* 1998; **32**: 865–875.
5. Ribeiro JP, Marcelino P, Marum S, Fernandes AP. Echocardiography: a fundamental part of the intensive care curriculum. *Crit Care Forum* 2002; **6**: 175.
6. Hatfield A, Bodenham A. Ultrasound: an emerging role in anaesthesia and intensive care. *Br J Anaesth* 1999; **83**: 789–800.
7. ASA/SCA. Practice guidelines for perioperative transesophageal echocardiography. *Anesthesiology* 1996; **84**: 986–1006.
8. Denault AY, Couture P, McKenty S, *et al*. Perioperative use of transesophageal echocardiography by anesthesiologists: impact in non-cardiac surgery and in the intensive care unit. *Can J Anaesth* 2002; **49**: 287–293.
9. Hwang JJ, Shyu KG, Chen JJ, Tseng YZ, Kuan P, Lien WP. Usefulness of transesophageal echocardiography in the treatment of critically ill patients. *Chest* 1993; **104**: 861–866.
10. Foster E, Schiller NB. The role of transesophageal echocardiography in critical care: UCSF experience. *J Am Soc Echocardiogr* 1992; **5**: 368–374.
11. Khoury AF, Afridi I, Quinones MA, Zoghbi WA. Transesophageal echocardiography in critically ill patients: feasibility, safety and impact on management. *Am Heart J* 1994; **127**: 1363–1371.
12. Colreavy FB, Donovan K, Lee KY, Weekes J. Transesophageal echocardiography in critically ill patients. *Crit Care Med* 2002; **30**: 989–996.
13. Cook CH, Praba AC, Beery PR, Martin LC. Transthoracic echocardiography is not cost-effective in critically ill surgical patients. *J Trauma* 2002; **52**: 280–284.
14. Caidahl K, Kazzam E, Lidberg J, *et al*. New concept in echocardiography: harmonic imaging of tissue without use of contrast agent. *Lancet* 1998; **352**: 1264–1270.
15. Willenheimer RB, Israelsson BA, Cline CM, Erhardt LR. Simplified echocardiography in the diagnosis of heart failure. *Scand Cardiovasc J* 1997; **31**: 9–16.
16. Benjamin E, Griffin K, Leibowitz AB, *et al*. Goal-directed transesophageal echocardiography performed by intensivists to assess left ventricular function: Comparison with pulmonary artery catheterization. *J Cardiothorac Vasc Anesth* 1998; 12: 10–15.
17. Moore CL, Rose GA, Tayal VS, Sullivan M, Arrowood JA, Kline JA. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. *Acad Emerg Med* 2002; **9**: 186–193.
18. Kimura BJ, Pezeshki B, Frack S, DeMaria AN. Feasibility of 'limited' echo imaging: Characterization of incidental findings. *J Am Soc Echocardiog* 1998; **11**: 746–750.
19. Egeblad H. *Ekkokardiografi*. Copenhagen, Denmark: Lægeforeningens Forlag, 2001: 134.
20. Bossone E, DiGiovine B, Watts S, *et al*. Range and prevalence of cardiac abnormalities in patients hospitalized in a medical ICU. *Chest* 2002; **122**: 1370–1376.
21. Vignon P, Mentec H, Terre S, Gastinne H, Guéret P, Lemaire F. Diagnostic accuracy and therapeutic impact of transthoracic and transesophageal echocardiography in

mechanically ventilated patients in the ICU. *Chest* 1994; **106**: 1829–1834.
22. Sohn DW, Shin GJ, Oh JK, *et al*. Role of transesophageal echocardiography in hemodynamically unstable patients. *Mayo Clin Proc* 1995; **70**: 925–931.
23. Mattison LE, Coppage L, Alderman DF, Herlong JO, Sahn SA. Pleural effusions in the medical ICU. Prevalence, causes and clinical implications. *Chest* 1997; **111**: 1018–1023.