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CRITICAL CARE

Impact of echocardiography on patient management in the intensive care unit: an audit of district general hospital practice

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Background. Echocardiography has been shown to positively impact on the management of the critically ill patient. However, many published studies have a significant bias towards inclusion of cardiothoracic patients. We present an audit of the impact of echocardiography on the management of patients in a district general hospital intensive care unit (ICU).

Methods. We conducted a prospective audit of all echocardiograms, both transthoracic (TTE) and transoesophageal (TOE), performed on our ICU between October 1, 2005, and December 31, 2007. In addition to patient characteristics, we recorded the indication for the echocardiogram, and any change in management that occurred as a result of the study.

Results. Two hundred and fifty-eight echocardiograms were performed in 217 patients, of which 224 (86.8%) were performed by intensive care consultants. One hundred and eighty-seven studies (72.4%) were TTEs and 71 (27.8%) were TOEs. TTE provided diagnostic images in 91.3% of spontaneously breathing and 84.2% of mechanically ventilated patients. Management was changed directly as a result of information provided in 51.2% of studies. Changes included fluid administration, inotrope or drug therapy, and treatment limitation.

Conclusions. Echocardiography may have a significant impact on the management of patients in the general ICU. We recommend that appropriate training in echocardiography should be incorporated into the intensive care curriculum in the UK.

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The management of haemodynamic instability in patients on the intensive care unit (ICU) traditionally relies on a combination of clinical skills and measurement of physiological variables such as arterial and central venous pressure, urine output, acid–base balance, and frequently cardiac output. A variety of techniques, both invasive and non-invasive, are available to measure ventricular filling and function. However, echocardiography, either transthoracic (TTE) or transoesophageal (TOE), can identify the cause of shock and provide a guide to therapy,[1] and can accurately predict fluid responsiveness.[2] Previous studies have shown that echocardiography can significantly alter the management of up to 46% of critically ill patients.[3–7] Traditionally, TOE has been favoured in critically ill patients because of superior image quality, but improvements in imaging technology have altered this doctrine and the majority of patients can be adequately imaged using TTE.[6–8] In the past, although accepted as a valuable investigation, the widespread use of echocardiography in ICUs in the UK has been limited by the prohibitive costs of the machines, the lack of availability of trained echocardiographers able to provide immediate access to the service 24 h a day, and perhaps by a perceived lack of benefit.

To our knowledge, there are no published reports of the impact of echocardiography on critically ill patients from hospitals in the UK. In addition, the majority of published data originate from teaching hospitals with a significant cardiac surgical workload. We present an audit of our 2 yr experience of using echocardiography in a district general hospital ICU.

Methods

Cheltenham General Hospital is a 425 bed district general hospital with five adult intensive care (level 3) and four high dependency beds (level 2). The critical care unit receives

both elective and emergency admissions from a wide range of general medical and surgical specialities, including major vascular surgery, colorectal surgery, and oncology.

Our critical care unit purchased an Acuson CV70 ultrasound system (Siemens Medical Solutions, Camberley, UK) with both TTE and TOE probes in April 2005, allowing a wider use of echocardiography in patient management. The priority of all echocardiograms was to perform a focused examination depending upon the clinical question being asked. Where required and whenever possible, comprehensive examinations were performed according to current guidelines for both TTE[9] and TOE,[10] including the use of M-mode, colour Doppler, and continuous and pulsed-wave Doppler modalities. The studies were performed by intensive care consultants, cardiac physiologists, or cardiologists. The lead author was undertaking British Society of Echocardiography (BSE) accreditation during the study, and the other authors had previously undertaken a 2 day hands-on training course in TTE for intensivists before commencing practice and subsequently attended a 3 day course designed for cardiology registrars and cardiac physiologists. All studies were archived digitally to permit peer review. Where there was doubt about the findings, studies were reviewed either by the lead author or by a consultant cardiologist. Handwritten reports were entered in the patients' medical records.

We then conducted an audit of all echocardiograms performed on patients in either the intensive care or the high dependency unit between October 1, 2005, and December 31, 2007, to assess the impact of a wider use of echocardiography on patient management. Formal Research Ethics Committee approval, and thus informed patient consent, was deemed unnecessary after discussion with the local ethics committee chairperson who agreed that this was an audit of clinical practice. After each echocardiogram, information was recorded on patient characteristics, type of echocardiogram (TTE or TOE), whether the patient was mechanically ventilated, and person performing the study. The quality of images obtained was graded as good, with sufficient windows to allow a comprehensive study, adequate for a focused study, or poor. The indication for the echocardiogram was recorded as either assessment of left ventricular function, hypotension, evaluation for suspected infective endocarditis, pulmonary oedema, assessment of right ventricular function, diagnosis of pericardial effusion, or 'other'. Findings from the study were classed as either 'expected' or 'unexpected'. Any change in patient management that occurred as a result of the study was recorded. Therapeutic impact was defined as any significant change in management occurring as a result of echocardiography.

Results

Over the period of observation, 1576 patients were admitted to either the ICU or the high dependency unit. Of these, 859 were men (54.5%) and 717 were women (45.5%). During this period, we performed 258 echocardiograms in 217 patients with a median age of 70 yr (range 18–87 yr). Of these, 123 were men (54.1%) and 94 were women (45.9%). Twenty-eight of the 217 patients had two or more echocardiograms performed during their ICU stay. We performed 187 (72.4%) TTE and 71 (27.6%) TOE studies. Intensive care consultants performed 156 (83.4%) of the TTE examinations with the remainder being performed by doctors in training with prior echocardiography experience (16 studies), cardiac physiologists (14 studies), or a consultant cardiologist (one study). The lead author performed 95.8% of the transoesophageal examinations, the other operators being consultant cardiologists.

The recorded indications for all 258 studies are shown in Table 1. The most common reason for performing an echocardiogram was for assessment of left ventricular function (119 studies, 46.1%), followed by investigation for cause of hypotension (43 studies, 16.6%). In mechanically ventilated patients, 165 examinations (63.9%) were performed (95 TTE, 70 TOE). Of the TTE studies in ventilated patients, image quality was 'good' in 26 (27.4%) and 'adequate' views were achieved in 52 (62.1%). In spontaneously breathing patients, 'good' views were achieved in 25/92 (27.2%) and 'adequate' views were achieved in 59/92 (64.1%). Overall, TTE provided useful images in 84.2% of mechanically ventilated patients and 91.3% of spontaneously breathing patients. No significant complications as a result of echocardiography were observed.

After echocardiography, 112 patients had their management changed. Overall, 132 of the 258 studies (51.2%) led to a change in management, the details of which are shown in Table 2. TTE and TOE yielded similar therapeutic impact with a management change after 48.6% and 53.5% of studies, respectively. Of note, an immediate change in treatment, including changes in inotropic support, drug therapy, fluid management, cardiac intervention, and additional procedures on the ICU, occurred after

Table 1 Recorded indications for TTE and TOE

Indication	Type of study		
	TTE	TOE	Total (%)
Assessment of left ventricular function	100	19	119 (46.1)
Investigation of cause of hypotension	34	9	43 (16.6)
Pulmonary oedema	18	17	35 (13.6)
Suspected infective endocarditis	6	13	19 (7.4)
Pericardial effusion	15	0	15 (5.8)
Assessment of right ventricular function	6	1	7 (2.7)
Other			
Post-cardiac arrest	2	4	6 (2.3)
Suspected valvular disease	2	3	5 (1.9)
Refractory hypoxia	2	1	3 (1.2)
Investigation of systemic emboli	0	2	2 (0.8)
Assessment of pleural effusion	2	0	2 (0.8)
Aortic dissection	0	1	1 (0.4)
Organ donation	0	1	1 (0.4)
Total	187	71	258

Table 2 Details of changes in patient management after echocardiography. Data are presented for both TTE and TOE. ACEI, angiotensin-converting enzyme inhibitors

Change in management	Number of studies (%)
Altered drug therapy	
Initiation/increase of diuretics ± ACEI	11 (8.3)
Cessation of diuretics	5 (3.8)
Initiation of β-adrenoreceptor blockade	4 (3.0)
Cessation of antibiotics for endocarditis	3 (2.3)
Cessation of anticoagulation for thromboembolism	3 (2.3)
Sildenafil for pulmonary hypertension	2 (1.5)
Thrombolysis for pulmonary embolism	1 (0.8)
Initiation or increase of inotropic support	19 (14.3)
Reduction of inotropic support	2 (1.5)
Cardiac intervention	
Cardiac surgery	5 (3.8)
Percutaneous coronary intervention	4 (3.0)
Balloon valvotomy for mitral stenosis	1 (0.8)
Fluid management	
Fluid loading	28 (21.2)
Fluid withheld	4 (3.0)
Additional ICU procedure	
TOE for inadequate TTE examination	6 (4.5)
Intercostal drain for pleural effusion	6 (4.5)
Pericardial drain	2 (1.5)
Change of central venous catheter	1 (0.8)
Decision-making support	
Treatment limitation	17 (12.9)
CT pulmonary angiogram	2 (1.5)
Removal of pericardial drain	2 (1.5)
CT thorax for pulmonary consolidation	1 (0.8)
Cardiology referral	1 (0.8)
Initiation of renal replacement therapy	1 (0.8)
Initiation of mechanical ventilation	1 (0.8)
Total	132

107 studies (41.5%). Twenty-five studies (9.7%) help to support clinical decision-making, including the limitation of treatment.

Discussion

This audit of echocardiography in a general adult intensive care population demonstrated a significant therapeutic impact with a change in patient management after 51.2% of all echocardiograms. This is the first such report from a general ICU in the UK, where echocardiography is used extensively in cardiothoracic centres but is perhaps less readily available to intensivists in general hospitals.

Historically, TOE has been favoured over TTE in critically ill patients largely because of the challenges of obtaining images. In mechanically ventilated patients, lung inflation and PEEP interfere with TTE imaging, leading to reduced therapeutic impact when compared with TOE.[3] We were able to obtain adequate images with TTE in around 91.3% of spontaneously breathing patients. We also demonstrated that a focused TTE, performed to answer a specific clinical question, could be performed in the majority of mechanically ventilated patients, with 'adequate' or 'good' views being achieved in 84.2%. Suitable views for a comprehensive TTE study were only achieved in 27.4% of mechanically ventilated patients. Other studies that have investigated the diagnostic ability of TTE found similar results. Jensen and colleagues[7] were able to obtain at least one echocardiographic window in 98.2% of patients, with the majority of studies performed with the patient supine. In this study, 137 of the 210 patients (66%) were mechanically ventilated during echocardiography. Vignon and colleagues,[6] in comparing the diagnostic ability of a hand-held echocardiography system to a traditional system, were able to visualize 74% of all echocardiographic windows in mechanically ventilated patients. TTE is non-invasive and carries little, if any, risk to the patient and should therefore be used in preference to TOE, even in critically ill patients. We do not advocate altering ventilator settings, such as reducing the level of PEEP in order to perform a TTE, but occasionally it may be necessary to alter patient position in order to obtain views. TOE should be reserved for patients with a specific indication for TOE or with inadequate windows.

In our study, a significant change in management resulted after echocardiography in 51.2% of patients. This compares favourably with similar studies which have demonstrated therapeutic impact in 24%,[3] 32%,[4] 41%,[5] and 46%[6] of studies. In another report, echocardiography provided decisive information in 24.5% and supplemental information in 37.3% of studies.[7] We also observed no major differences between the impact of TTE and TOE. Major advances in ultrasound technology have improved the diagnostic ability of TTE in critically ill patients and have also reduced the costs of ultrasound systems, bringing echocardiography within the reach of intensivists. Recent publications that have focused on TTE[5–7] have demonstrated a similar therapeutic impact to older studies that relate to TOE.[3 4]

Not surprisingly, we found echocardiography particularly useful in haemodynamically unstable patients. The majority of our studies were performed to assess left ventricular function or to investigate the cause of hypotension, as was observed in similar studies.[4 5] All of our recorded indications in our audit were appropriate when compared with current criteria.[11] In terms of specific interventions that occurred as a result of echocardiography, we found that changes in the administration of fluids, inotropes, and medications were the most common. We observed left ventricular dysfunction in a number of patients with septic shock and subsequently commenced an inotrope such as dobutamine, which in turn led to an improvement in haemodynamics. This highlights the importance of assessing left ventricular function in such patients as the incidence of left ventricular dysfunction is up to 60%.[12] Echocardiography may therefore help to optimize the circulatory support of patients with septic shock and providing a means of detecting fluid reponsiveness.[3] As shown in Table 2, most changes in drug therapy involved the initiation, increase, or reduction of cardiovascular

drugs such as diuretics, angiotensin-converting enzyme inhibitors, and β-adrenoreceptor blocking drugs where the echocardiogram was used to evaluate left ventricular function in patients with known or suspected cardiac disease. In one study, the most common management changes that occurred were either the addition of discontinuation of medications, although the exact nature of these changes was not specified in detail.[5] In addition, 9.7% of studies provided information that supported our decision-making, either leading to additional imaging or helping to guide overall management decisions as to appropriate levels of organ support. The presence of ventricular disease in patients with unexplained hypotension is associated with a poorer prognosis.[13] In 17 patients, echocardiographic findings of severe left ventricular impairment helped to support the clinical decision not to increase organ support in patients failing to respond to treatment.

Inevitably, there are a number of limitations to our findings, common to the majority of previous studies of echocardiography in intensive care. Since we have conducted an audit of clinical practice, rather than a randomized or blinded study, it is impossible for us to say whether echocardiography can improve the outcomes for critically ill patients. There is also the possibility of bias, since the majority of echocardiograms were performed by the clinician caring for the patient. We have also not been able to identify those patients most likely to benefit, however with the most common indications for echocardiography being either hypotension or assessment of left ventricular function, it is perhaps the haemodynamically unstable patient who is most likely to benefit. We have also not assessed whether the echocardiogram produced new, clinically unsuspected information or whether it merely confirmed the findings from clinical assessment.

Historically, echocardiography has been the remit of cardiologists and cardiac physiologists. Generally, their training does not encompass the full range of rapidly changing pathophysiology that is seen in the ICU setting. In contrast, intensivists are fully trained in both physiology and pathology seen on the ICU and interventions that are commonly used. It is therefore increasingly recognized that intensivists should be trained in critical care echocardiography. This is apparent in areas of Europe where there are established training programmes[14–17] and in Australasia, where a training programme is currently being developed.[18] However, there is considerable debate as to the amount of training required in order to perform and interpret echocardiograms in critically ill patients and a pyramid of skills has been proposed (Fig. 1).[15] At the bottom of the pyramid are operators with specific training who are able to perform focused echocardiography in the peri-resuscitation setting to detect gross pathology such as a large pericardial effusion, severe left ventricular impairment, right ventricular dilatation, and gross hypovolaemia, relying on two-dimensional imaging only. Training to this level of competence is readily achieved within a short

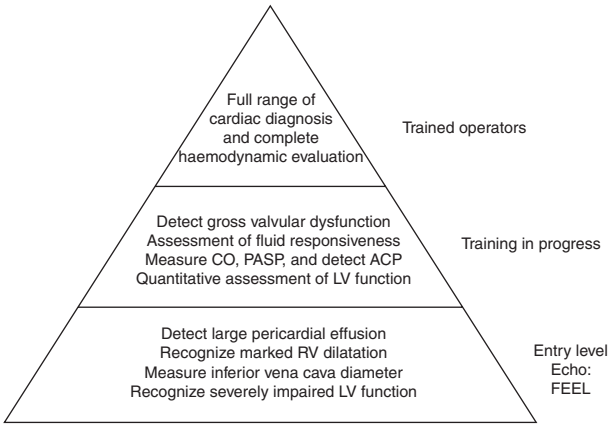

Fig 1 The 'pyramid' of echocardiography skills in the ICU, adapted from Vieillard-Baron and colleagues.[15] FEEL, Focused Echo Evaluation in Life support; CO, cardiac output; PASP, pulmonary artery systolic pressure; ACP, acute cor pulmonale; LV, left ventricular; RV, right ventricular.

time period.[19–21] At the top of the pyramid are operators fully trained and accredited in all aspects of critical care echocardiography who are able to utilize echocardiography for comprehensive evaluation of the critically ill patient.[22] Ideally, each ICU would have access to all levels of expertise, with the overall supervision of those with minimal training being provided by a local expert.

In the UK, the role of echocardiography in the management of critically ill patients has recently been recognized in a consensus statement developed by a collaborative working group of the BSE.[23] This statement strongly supports the use of focused echocardiography using a specific programme currently being developed—Focused Echo Evaluation in Life support (FEEL). It is proposed that operators would be trained using a combination of a 1 day course followed by local supervision to recognize pathology relevant to the peri-arrest setting. For those wishing to develop their skills in order to perform a comprehensive study, intensive care physicians currently have access to BSE accreditation processes for either TTE or TOE, both of which require the successful completion of a multiple choice exam, the submission of a logbook, and the support of a local supervisor, all of which requires a considerable investment of time and effort. However, echocardiography in the critically ill patient is complex and therefore a development of the existing accreditation processes specific to intensive care has also been proposed. In recommending that echocardiography is more readily available in UK ICUs, we feel there are the important issues to be considered of who is going to provide the training and supervision, and the impact on echocardiography services and their ability to train both technicians and other physicians. Beyond echocardiography, the problems of training and accreditation in ultrasound imaging for anaesthetists have been highlighted in a recent editorial in this journal.[24] The other major difficulty is access to

suitable equipment, although the falling cost of machines is making it easier for critical care units to purchase systems at least suitable for focused examinations. Perhaps, part of the problem for critical care units has been the lack of evidence supporting the introduction of echocardiography, which this paper in part addresses.

In conclusion, this study indicates that echocardiography may have a high therapeutic impact in critically ill patients, the majority of whom can be adequately imaged with TTE. While further studies are needed to look at the effects of echocardiography on patient outcomes, there would be major ethical issues that would almost certainly preclude a randomized controlled trial. Echocardiography should be readily accessible in all critical care units and therefore we recommend that basic training in echocardiography is incorporated into the training of intensive care physicians in the UK.

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References

1 Slama M, Maizel J. Echocardiographic measurement of ventricular function. *Curr Opin Crit Care* 2006; **12**: 241–8

2 Charron C, Caille V, Jardin F, Vieillard-Baron A. Echocardiographic assessment of fluid responsiveness. *Curr Opin Crit Care* 2006; **12**: 249–54

3 Vignon P, Mentec H, Terre S, Gastinne H, Gueret P, Lemaire F. Diagnostic accuracy and therapeutic impact of transthoracic and transoesophageal echocardiography in mechanically ventilated patients. *Chest* 1994; **106**: 1829–34

4 Colreavy FB, Donovan K, Lee KY, Weekes J. Transoesophageal echocardiography in critically ill patients. *Crit Care Med* 2002; **30**: 989–96

5 Stanko LK, Jacobsohn E, Tam JW, De Wet CJ, Avidan M. Transthoracic echocardiography: impact on diagnosis and management in tertiary intensive care units. *Anaesth Intensive Care* 2005; **33**: 492–6

6 Vignon P, Chastagner C, Francois B, *et al*. Diagnostic ability of hand-held echocardiography in ventilated critically ill patients. *Crit Care* 2003; **7**: R84–91

7 Jensen MB, Sloth E, Larsen KM, Schmidt MB. Transthoracic echocardiography for cardiopulmonary monitoring in intensive care. *Eur J Anaesthesiol* 2004; **21**: 700–7

8 Joseph MX, Disney PJS, Da Costa R, Hutchison SJ. Transthoracic echocardiography to identify or exclude cardiac cause of shock. *Chest* 2004; **126**: 1592–7

9 Chambers J, Masani N, Hancock J, Graham J, Wharton G, Ionescu A. A minimum dataset for an adult transthoracic echocardiogram. Available from http://www.bsecho.org/index.php?option=com_docman&task=doc_download&gid=33&&Itemid=6 (accessed May 7, 2008)

10 Shanewise JS, Cheung AT, Aronson S, *et al*. ASE/SCA guidelines for performing a comprehensive intraoperative multiplane transesophageal echocardiography examination: recommendations of the American Society of Echocardiography Council for Intraoperative Echocardiography and the Society of Cardiovascular Anesthesiologists Task Force for Certification in Perioperative Transesophageal Echocardiography. *Anesth Analg* 1999; **89**: 870–84

11 Douglas PS, Khandheria B, Stainback RF, *et al*. ACCF/ASE/ACEP/ASNC/SCAI/SCCT/SCMR 2007 appropriateness criteria for transthoracic and transoesophageal echocardiography: a report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American Society of Echocardiography, American College of Emergency Physicians, American Society of Nuclear Cardiology, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, and the Society for Cardiovascular Magnetic Resonance endorsed by the American College of Chest Physicians and the Society of Critical Care Medicine. *J Am Coll Cardiol* 2007; **50**: 187–204

12 Heidenreich PA, Stainback RF, Redberg RF, Schiller NB, Cohen NH, Foster E. Transesophageal echocardiography predicts mortality in critically ill patients with unexplained hypotension. *J Am Coll Cardiol* 1995; **26**: 152–8

13 Vieillard-Baron A, Caille V, Charron C, Belliard G, Page B, Jardin F. Actual incidence of global left ventricular hypokinesia in adult septic shock. *Crit Care Med* 2008; **36**: 1701–6

14 Cholley BP, Vieillard-Baron A, Mebazaa A. Echocardiography in the ICU: time for widespread use! *Intensive Care Med* 2006; **32**: 9–10

15 Vieillard-Baron A, Slama M, Cholley BP, Janvier G, Vignon P. Echocardiography in the intensive care unit: from evolution to revolution? *Intensive Care Med* 2008; **34**: 243–9

16 Jensen MB, Sloth E. Echocardiography for cardiopulmonary optimization in the intensive care unit: should we expand its use? *Acta Anaesthesiol Scand* 2004; **48**: 1069–70

17 Seppelt IM. All intensivists need echocardiography skills in the 21st century. *Crit Care Resusc* 2007; **9**: 286–8

18 McLean A, Yastrebov K. Echocardiography training for the intensivist. *Crit Care Resusc* 2007; **9**: 319–22

19 Breitkreutz R, Walcher F, Seeger F. Focused echocardiographic evaluation in resuscitation management: concept of an advanced life support-conformed algorithm. *Crit Care Med* 2007; **35**: S150–61

20 Manasia AR, Nagaraj HM, Kodali RB, *et al*. Feasibility and potential clinical utility of goal-directed echocardiography performed by noncardiologist intensivists using a small hand-carried device (SonoHeart) in critically ill patients. *J Cardiothorac Vasc Anesth* 2005; **19**: 155–9

21 Hellmann DB, Whiting-O'Keefe Q, Shapiro EP, Martin LD, Martire C, Ziegelstein RC. The rate at which residents learn to use hand-held echocardiography at the bedside. *Am J Med* 2005; **118**: 1010–8

22 Price S, Nicol E, Gibson DG, Evans TW. Echocardiography in the critically ill: current and potential roles. *Intensive Care Med* 2006; **32**: 48–59

23 Fox K on behalf of a Collaborative Working Group of the British Society of Echocardiography (BSE). A position statement: echocardiography in the critically ill. *J Intensive Care Soc* 2008; **9**: 197–8

24 Bodenham AR. Ultrasound imaging by anaesthetists: training and accreditation issues. *Br J Anaesth* 2006; **96**: 414–7