Review Article

Transthoracic and transoesophageal echocardiography: a systematic review of feasibility and impact on diagnosis, management and outcome after cardiac surgery

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Summary
Transthoracic and transoesophageal echocardiography are increasingly used as tools to improve clinical assessment following cardiac surgery. However, most physicians are not trained in echocardiography, and there is no widespread agreement on the feasibility, indications or effect on outcome of transthoracic or transoesophageal echocardiography for patients after cardiac surgery. We performed a systematic review of electronic databases for focused transthoracic and transoesophageal echocardiography after cardiac surgery which revealed 15 full-text articles. They consistently reported that echocardiography is feasible, whether performed by a novice or expert, and frequently resulted in important changes in diagnosis of cardiac abnormalities and their management. However, most were observational studies and there were no well-designed trials investigating the impact of echocardiography on outcome. We conclude that both transthoracic and transoesophageal echocardiography are useful following cardiac surgery.

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Introduction
The use of transthoracic and transoesophageal echocardiography by anaesthetists and critical care physicians in order to guide decision-making at the 'point-of-care' has increased rapidly over the last decade [1–6]. Persistent haemodynamic instability or shock are recognised indications for echocardiography, and transoesophageal echocardiography is currently the gold standard for diagnosis after cardiac surgery [7]. However, the increase in its use has been restricted due to lack of training and because it is an invasive procedure, usually requiring sedation and/or mechanical ventilation of the patients lungs, and there is a small risk of oesophageal injury, which is a potentially lethal complication [8]. Although previously reported to be more difficult than transoesophageal echocardiography in the postoperative cardiac surgical patient, transthoracic echocardiography is non-invasive and improved image quality has recently been reported [9].

Apart from improved ultrasound technology and availability, it has been realised that both transthoracic and transoesophageal echocardiography may be performed by the treating physician, in a focused form, at the patient's bedside as part of their routine assessment, rather than restricting its use to experts for a narrow range of indications [5]. Focused studies are based on the understanding that only a limited number of views are required to diagnose haemodynamically important cardiac pathology [10]. It is not the aim of focused echocardiography to replace conventional echocardiography but to enhance clinical assessment. This empowers the physician to increase their speed and confidence in diagnosing the cause of postoperative haemodynamic instability such as heart failure or pericardial effusion, and is usually obtainable in only a few minutes at the bedside or even during cardiac arrest [8]. Improved diagnostic information at the time of clinical assessment should lead to better informed management decisions, perhaps reducing the need to perform further diagnostic tests such as radiographs or CT scans, thereby avoiding transportation of the patient to another facility or their exposure to ionising radiation. As transthoracic echocardiography is non-invasive and provides more diagnostic information than current intravascular pressure-based flow monitors, it may be useful for haemodynamic monitoring [11]. However, as with transoesophageal echocardiography, there are a number of barriers to the widespread adoption of focused transthoracic echocardiography. Most physicians are not properly trained and they may believe that echocardiography leads to adverse outcomes by delaying, or otherwise interfering with, time-critical patient management. Furthermore, they may consider that an abbreviated examination may lead to an incorrect diagnosis being made, which will lead to an adverse clinical outcome. However, there are an increasing number of observational studies reporting the absence of missed diagnoses from focused transthoracic echocardiography compared with conventional transthoracic echocardiography [12], and consistent findings that focused transthoracic echocardiography yields diagnostic information that is substantially superior to conventional clinical assessment [13–16]. Overcoming this mindset, the significant cost of implementing echocardiography into clinical practice remains, such as training, quality assurance and equipment. Therefore, the clinical benefit should be justified by evidence of improved outcome.

The primary aim of this systematic review was to evaluate the feasibility and effect of focused transthoracic and transoesophageal echocardiography on diagnosis and management of clinically important cardiac disease following cardiac surgery, compared with conventional clinical assessment. The secondary aim was to determine the influence of transthoracic and transoesophageal echocardiography on patient outcome, including cardiovascular complications and death.

Methods

We performed a literature search protocol based on the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [17] for which no protocol had previously been registered or published for this study. In February 2016, after confirming that a similar systematic review was not already published, the principal researcher (JH) performed a detailed search of PubMed, Medline and EMBASE electronic databases using the following search terms: ("Point-of-Care Systems" OR "Echocardiography, Transesophageal" OR "Echocardiography") AND ("Postoperative Care" OR "Cardiac Surgical Procedures/standards" OR "Cardiac Surgical Procedures/adverse effects" OR "Critical Care" OR "Intensive Care Units") AND "Humans".

The search was restricted to peer-reviewed, original research, including prospective, retrospective cohort, case–control and cross-sectional studies; but excluded case reports, non-English language publications, studies published before 1 January 1995, or publications without an available full text. Participants were humans aged at least 18 y. The intervention was transthoracic or transoesophageal echocardiography performed after cardiac surgery. The outcomes included feasibility, changes in clinical diagnosis and management, cardiac complications and death. For each individual publication an outcome-level assessment of bias was performed including the following parameters: patient selection; sonographer expertise (novice or expert); and indication for transthoracic echocardiography or transoesophageal echocardiography. This bias assessment was considered in the synthesis of results but no scoring system was used and definitions of all criteria and end points were agreed by the researchers before performing the search (Appendix 1).

Results

The systematic review process is shown in Fig. 1. Our search identified 600 publications with a further 24 publications being found in the bibliographies, resulting in a total of 616 after duplicates were removed. After reviewing the titles and abstracts of these publications for eligibility, 596 were excluded, resulting in 20 publications that were checked for accuracy by two independent reviewers (DE and DC). Four full-text publications were excluded because they were in a non-cardiac surgery setting, and another one was excluded for not including echocardiography, resulting in 15 full-text publications for analysis. Data extracted included: year of publication; study design; aim; number of patients; mean patient age; echocardiographic modality (TTE or TOE); indications for echocardiography; and the influence of echocardiography on diagnosis, management and outcome (as defined in Appendix 1). All data were stored in Microsoft Excel for Mac 2015 (Version 14.5.8; Microsoft Corporation, Redmond, WA, USA) software. An overview of the included full-text publications with primary and secondary outcome measures is shown in Table 1. There were seven studies reporting the use of transthoracic echocardiography [9, 11, 18–22] and eight for transoesophageal echocardiography [23–30]. There were eight uncontrolled prospective observational studies [9, 11, 19, 21–23, 26, 28], and seven retrospective cohort studies [18, 20, 24, 25, 27], of which only two had a control group [29, 30]. There was considerable variability in the study aims, indications for echocardiography, patient populations and end-points used. Of the seven studies assessing the use of transthoracic echocardiography, the indication for transthoracic echocardiography followed recognised guidelines in only two studies, both for pericardial tamponade. The majority of studies reported the use of transthoracic echocardiography for routine screening (without a recognised indication). By contrast, all eight studies reporting the use of transoesophageal echocardiography after cardiac surgery were for recognised indications. Feasibility (image quality) of echocardiography after cardiac surgery was reported for transthoracic echocardiography in seven studies and for transoesophageal echocardiography in two studies (Table 2). However, the timing of echocardiography after surgery and method of assessment of image quality was inconsistent. Only three studies specified when echocardiography was performed, ranging from the day after surgery to 30 days postoperatively. For assessing interpretability, two studies used the same 5-point scale, and another two studies defined interpretability as the ability to demonstrate tamponade, whereas the remaining used different definitions of interpretability.

When transthoracic echocardiography was used to investigate the presence of pericardial tamponade [18, 22], the proportion of patients in whom transthoracic echocardiography was interpretable was lower (61–76%) compared with when transthoracic echocardiography was used for screening (83–100%) [9, 11, 19–21, 28, 29]. Jakobsen et al. [9] reported that the apical and parasternal windows were superior to the subcostal window in terms of image quality, presumably due to surgical dressings and drainage tubes in the subcostal position. Flynn et al. [20] demonstrated that inadequate assessment of left ventricular function with transthoracic echocardiography was associated with increasing age, male sex, mechanical ventilation of the lungs and the early postoperative period. Inadequate assessment of right ventricular function with transthoracic echocardiography was also associated with mechanical ventilation of the lungs and the early postoperative period. Christiansen et al. [19] showed that the mean (SD) time for a focused transthoracic echocardiography examination was 4.7 (1.2) min with no difference between the three time points (preoperative, day 4 and day 30 following surgery). In the two studies that reported feasibility of transoesophageal echocardiography following cardiac surgery, the proportion of patients in whom transoesophageal echocardiography was interpretable was very high (99% and 100%).

The impact of focused echocardiography on clinical diagnosis after cardiac surgery was reported in ten studies and is shown in Table 3. Seven of these studies were about the impact on diagnosis of transoesophageal echocardiography. Three studies compared diagnosis of pleural effusion between transthoracic echocardiography

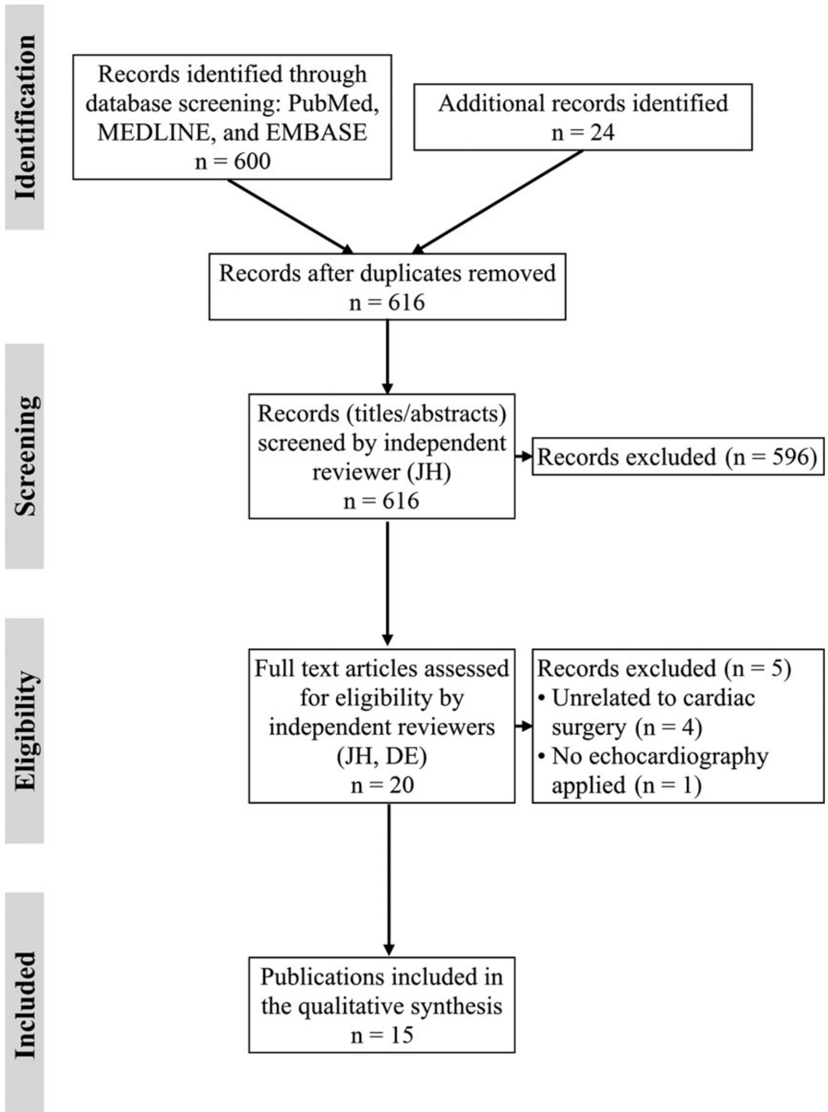

Figure 1 Flow diagram of the systematic review process.

and conventional clinical assessment (11–16%), and two studies compared diagnosis of pericardial effusion with conventional clinical assessment (2%). However, only the study by Alsaddique et al. [11] reported differences in diagnosis of left ventricular and right ventricular function, left ventricular volume, valvular function, pericardial effusion and pleural effusion, where they found a change in diagnosis in 51% of cases compared with conventional assessment and chest radiography. Transthoracic echocardiography frequently identified cardiac dysfunction in 36% of patients in whom it was not suspected clinically, even though transthoracic echocardiography was used as a screening tool, rather than for an indication such as haemodynamic instability. There were three studies that reported a change in diagnosis between transoesophageal echocardiography and clinical assessment (25–59%) [25, 29, 30]. Pericardial effusion was detected with transoesophageal echocardiography more frequently (6–48%) than transthoracic echocardiography (2%). Buyukbayrak et al. [18] reported sensitivity and specificity of detecting tamponade with transthoracic echocardiography of 65% and 91%, respectively, in patients who had received transthoracic echocardiography before re-sternotomy for pericardial tamponade. The use of transoesophageal echocardiography also frequently changed the diagnosis of LV

Table 1 Overview of publications reporting the impact of transoesophageal or transthoracic echocardiography on feasibility, diagnosis, management and outcome of patients after cardiac surgery compared with conventional clinical management.

Authors (evidence level)	Year	Study design	Aim	Indication for echocardiography	Number of patients	Main findings
Transthoracic						
Alsaddique et al. [11] (level 4)	2015	Prospective cohort	Determine whether routine and repeated monitoring with echocardiography after cardiac surgery is feasible and changes diagnoses	Screening (100%)	91	100% interpretable imaging, 51% diagnosis change
Buyukbayrak et al. [18] (level 4)	2013	Retrospective cohort	Determine diagnostic sensitivity of echocardiography in diagnosis of postcardiac surgery tamponade	Screening of patients requiring reoperations (100%)	118	76% interpretable imaging
Christiansen et al. [19] (level 4)	2013	Prospective cohort	Determine the incidence of pericardial effusion, pleural effusion and cardiac function after open heart surgery	Screening (100%)	80	100% interpretable imaging, 13% surgical management change
Flynn et al. [20] (level 4)	2010	Retrospective cohort	Determine the risk factors that affect the visualisation and reporting of LV and RV function	–	300	83% interpretable imaging
Jakobsen et al. [9] (level 4)	2007	Prospective cohort	Determine the echocardiography image quality in postcardiac surgery patients	Screening (100%)	35	93% interpretable imaging
Jensen et al. [21] (level 4)	2004	Prospective cohort	Determine the frequency of successful echocardiography procedures	Screening (100%)	108	98% interpretable imaging
Price et al. [22] (level 4)	2004	Prospective cohort	Determine the nature and magnitude of the diagnostic challenge posed by cardiac surgery	Suspected pericardial effusion (100%)	80	61% interpretable imaging
Transoesophageal						
Bruch et al. [23] (level 4)	2003	Prospective cohort	Determine the role of echocardiography in critically ill postcardiac surgery patients	Haemodynamic instability (67%), suspected pulmonary embolism (17%), endocarditis (16%), valve dysfunction (11%) or aortic dissection (11%), or other (10%)	117	32% surgical management change

(continued)

Table 1 (*continued*)

Authors (evidence level)	Year	Study design	Aim	Indication for echocardiography	Number of patients	Main findings
Cicek et al. [24] (level 4)	1995	Retrospective cohort	Determine the utility and safety of echocardiography and its impact on diagnosis in cardiac surgical patients	Suspected cardiac dysfunction (84%), haemodynamic instability (16%)	119	7–26% change in diagnoses
Colreavy et al. [25] (level 4)	2002	Retrospective cohort	Determine the effectiveness and safety of echocardiography performed by intensive care physicians	Haemodynamic instability (40%), suspected endocarditis (27%) or cardiac dysfunction (20%), or other (13%)	255	25% diagnosis change, 49% management change
Costachescu et al. [26] (level 4)	2002	Prospective cohort	Determine whether echocardiography can yield additional information to the haemodynamic appraisal and the echocardiographic evaluation	Haemodynamic instability (100%)	20	10% in-hospital mortality, 35% 1-y mortality
Hirose et al. [27] (level 4)	2013	Retrospective cohort	Determine the feasibility of diagnosing tamponade in postcardiac surgery patients	Haemodynamic instability (86%) or suspected bleeding (14%)	21	48% change in pericardial effusion, 32% surgical management change
Maltais et al. [28] (level 4)	2013	Prospective cohort	Determine whether echocardiography guides assessment of intravascular/myocardial volume, inotrope need, vasopressor use and assessment of pericardial effusions in critically ill cardiac patients	Haemodynamic instability (100%)	35	100% interpretable imaging, 10% surgical management change
Schmidlin et al. [29] (level 3)	2001	Retrospective cohort with controls	Determine impact of echocardiography on patient management and outcomes following cardiac surgery	Haemodynamic instability (29%), suspected pericardial effusion (14%) or cardiac dysfunction (43%), or other (14%)	162	99% interpretable imaging, 45% diagnosis change, 34% medical management change
Wake et al. [30] (level 3)	2001	Retrospective cohort with controls	Determine whether urgent echocardiography changes diagnosis and patient outcome in post-cardiac surgery	Suspected cardiac dysfunction (40%), pericardial effusion (27%), valve dysfunction (16%), endocarditis (9%) or aortic dissection (4%), or other (4%)	130	59% diagnosis change, 59% management change

TTE, transthoracic echocardiography; TOE, transoesophageal; echo, TTE or TOE; LV, left ventricle; RV, right ventricle.

Table 2 Feasibility of TTE or TOE compared with conventional clinical assessment.

Authors	Sonographer expertise	Interpretable imaging	Comments
Transthoracic			
Alsaddique et al. [11]	Novice focused TTE	99% day after surgery, 100% after extubation, 100% at discharge	3-point scale; (1) good, (2) interpretable, (3) uninterpretable
Buyukbayrak et al. [18]	Expert TTE	76% (time point not reported)	Defined as the ability to demonstrate tamponade
Christiansen et al. [19]	Novice focused TTE	99% 4 d after surgery, 100% 30 d after surgery	5-point scale; (1) no image, (2) poor and un-usable image, (3) usable image, (4) good image, (5) perfect image
Flynn et al. [20]	Expert TTE	83% within 7 d of surgery	2-point scale; (1) no visualisation of LV, (2) visualisation of LV
Jakobsen et al. [9]	Expert focused TTE	88% day after surgery, 97% at discharge	5-point scale; (1) no image, (2) poor or un-usable image, (3) usable image, (4) good image, (5) perfect image
Jensen et al. [21]	Novice focused TTE	98% (time point not reported)	4-point scale; (1) no image, (2) supported available information, (3) added new information, (4) added decisive information
Price et al. [22]	Expert TTE	61% (time point not reported)	Defined as the ability to demonstrate tamponade
Transoesophageal			
Maltais et al. [28]	Expert TOE	100% (time point not reported)	Not defined
Schmidlin et al. [29]	Expert TOE	99% (time point not reported)	3-point scale; (1) good, (2) moderate, (3) insufficient

TTE, transthoracic echocardiography; TOE, transoesophageal; LV, left ventricular; –, not reported.

Table 3 Changes in diagnosis of cardiac pathology after echocardiography compared with conventional clinical assessment.

Authors	Diagnoses, total	LV dysfunction	RV dysfunction	Valve disease	Hypovolaemia	Hypervolaemia	Pleural effusion	Pericardial effusion
Transthoracic								
Alsaddique et al. [11]	51%	36%	–	3%	0%	–	16%	2%
Christiansen et al. [19]	–	–	–	–	–	–	13%	2%
Jakobsen et al. [9]	–	–	–	–	–	–	11%	–
Transoesophageal								
Bruch et al. [23]	–	–	–	–	–	–	–	7%
Cicek et al. [24]	–	12%	7%	14%	12%	–	–	26%
Colreavy et al. [25]	25%	–	–	–	–	–	–	–
Hirose et al. [27]	–	–	–	–	–	–	–	48%
Maltais et al. [28]	–	–	–	–	55%	35%	–	10%
Schmidlin et al. [29]	45%	9%	–	–	–	–	–	11%
Wake et al. [30]	59%	–	–	12%	12%	–	–	6%

LV, left ventricular; RV, right ventricular; –, not reported.

dysfunction (9–36%), right ventricular dysfunction (7%), valve disease (3–14%), hypovolaemia (0–55%), and hypervolaemia (35%).

The changes in management owing to echocardiography after cardiac surgery were reported in seven of the 15 studies included in this review and are shown in Table 4. Six of these were for transoesophageal echocardiography and one for transthoracic echocardiography. Two studies reported the overall proportion of patients in whom transoesophageal echocardiography resulted in a change in diagnosis compared with conventional clinical assessment (49% vs. 59%) [25, 30]. The most commonly reported change in patient management due to transoesophageal echocardiography was to drain pleural effusions (10–38%) or to re-operate for pericardial tamponade (6–38%). In one report by Bruch et al. [23], surgical management changes included coronary artery bypass grafting, valvular surgery and surgery for aortic dissection. Two studies on transoesophageal echocardiography and one on transthoracic echocardiography reported changes in medical management, such as intravascular fluid therapy, use of inotropic agents or a decision to insert an intra-aortic balloon pump

There were no randomised controlled trials comparing the outcome of patients who received echocardiography with those who did not. One of the transthoracic echocardiography studies and seven of the transoesophageal echocardiography studies reported postoperative mortality rates. Two retrospective studies compared patients who received transoesophageal echocardiography with controls, and both studies demonstrated a worse outcome with transoesophageal echocardiography. However, transoesophageal echocardiography was positively biased because, unlike those in the control group, patients who received transoesophageal echocardiography were haemodynamically unstable, placing them at greater risk for mortality. Schmidlin et al. [29] showed an in-hospital mortality rate of 24% in their transoesophageal echocardiography group compared with 3% in the control group. They also demonstrated a higher risk of adverse neurological outcome (13%) in the transoesophageal echocardiography group compared with 3% in the control group, as well as a median (range) ICU stay of 7 (5.6–8.4) days and 1 (0.8–1.2) days, respectively. Wake et al. [30] performed the other retrospective outcome study and demonstrated a 24% mortality in the transoesophageal echocardiography group compared with 2% in the standard treatment group during their 36-month study period. Six studies reported mortality and adverse events without a comparator. The most commonly reported was in-hospital mortality and ranged from 1% to 38% [19, 25–28], whereas one

Table 4 Changes in management of patients after echocardiography compared with conventional clinical assessment.

Authors	Management total	Medical management	Medical management details	Surgical management	Surgical management details
Transthoracic					
Christiansen et al. [19]	–	–	–	13%	Pleural fluid drainage (10%), exploration for bleeding (3%)
Transoesophageal					
Bruch et al. [23]	–	–	–	32%	Exploration for bleeding (10%), pleural fluid drainage (10%), valve replacement (8%), aortic arch repair (8%), CABG (4%)
Colreavy et al. [25]	49%	–	–	–	–
Hirose et al. [27]	–	–	–	38%	Exploration for bleeding (38%)
Maltais et al. [28]	–	–	–	10%	Exploration for bleeding (10%)
Schmidlin et al. [29]	–	34%	Fluids or drugs (34%), IABP (1%)	15%	–
Wake et al. [30]	59%	43%	IABP (4%)	15%	Exploration for bleeding (6%), other (5%)

IABP, intra-aortic balloon pump; CABG, coronary artery bypass grafting; –, not reported.

study reported a 12-month mortality of 35% [26]. Other outcomes reported were total complication rate (61%), heart failure (29–53%) [23, 30], aortic dissection (10%) [23], pulmonary embolus (8%) [23] and length of ICU stay (9 days) [26, 28].

Discussion

The studies we included in this review demonstrate that both conventional and focused transthoracic and transoesophageal echocardiography are feasible after cardiac surgery and can result in frequent changes in diagnosis of significant cardiac pathology as well as influencing clinical decision-making. Despite this, there are no reported studies that adequately test the hypothesis that echocardiography may positively influence outcome and there is a need for prospective randomised studies. Before 1996, transoesophageal echocardiography was consistently reported to provide good imaging and has been the gold standard for investigating unexplained persistent circulatory failure, and this is supported by two studies in our review. By contrast, the quality of transthoracic echocardiography imaging was considered poor after cardiac surgery [31, 32], but more recent reports demonstrate improved rates of interpretable image quality approaching that of transoesophageal echocardiography [11, 19, 21]. This is important because transoesophageal echocardiography is invasive, with a small risk of oesophageal perforation, a potentially lethal complication [8]. Other advantages are that transthoracic echocardiography is associated with less patient discomfort and is usually less time consuming than transoesophageal echocardiography. It is therefore possible that transthoracic echocardiography may replace transoesophageal echocardiography for some indications, such as investigation for haemodynamic instability, and may be used as a screening tool and monitor. However, transoesophageal echocardiography is still superior in terms of assessing posterior heart structures, such as the mitral valve, left atrium and aorta, and is likely to be more useful in the small proportion of patients in whom transthoracic echocardiography is impossible such as patients that are either obese or whose lungs are being mechanically ventilated. The most likely reasons for improvement in the image quality of transthoracic echocardiography include advances in ultrasound technology, such as harmonic imaging, and the increasing use of transthoracic echocardiography by intensive care physicians. Other limitations of transthoracic echocardiography include worse imaging soon after surgery [9, 20] and difficulty using the subcostal window [33–36]. This is shown by three studies in our review that reported lower rates of interpretability on the first postoperative day compared with later [9, 11, 21] and may be due to the presence of dressings and drainage tubes, or patient discomfort.

The use of transoesophageal echocardiography after cardiac surgery not only influenced the decision as to whether or not to surgically re-explore the chest due to suspected pericardial tamponade but also prompted drainage of pleural effusions. More recent studies reported the role of both transoesophageal and transthoracic echocardiography in influencing haemodynamic management. Transthoracic echocardiography is non-invasive, and this has led to five studies investigating the utility of transthoracic echocardiography as a screening tool and, in more recent studies, as an intermittent haemodynamic monitor.

The most frequently reported diagnostic change using transoesophageal echocardiography was pericardial tamponade, which frequently leads to surgical re-exploration. This was far more commonly performed when using transoesophageal echocardiography than transthoracic echocardiography. However, the three studies reporting diagnostic changes after transthoracic echocardiography were at lower risk of tamponade than the six transoesophageal echocardiography studies because, in the transthoracic echocardiography studies, transthoracic echocardiography was used as a screening tool. By contrast, tamponade was suspected in three of the six studies reporting the diagnostic impact of transoesophageal echocardiography, and in all six studies the patients had at least one recognised indication for transoesophageal echocardiography, placing them at greater risk of pericardial tamponade. Several investigators previously demonstrated that transoesophageal echocardiography is superior to transthoracic echocardiography in detecting intrapericardial haematoma [37–39]. More recently, Buyukbayrak et al. [18] reported the sensitivity and specificity of detecting tamponade with transthoracic echocardiography as 65% and 91%, respectively. The study by Bruch et al.

[23] reported a high number of surgical interventions prompted by transoesophageal echocardiography for reasons other than pericardial tamponade and these included revision of occluded coronary artery bypass grafts, aortic and valve surgery.

Two transthoracic echocardiography studies frequently reported clinically significant pleural effusions, which is not unexpected because ultrasonography is recognised as being more accurate than radiography and comparable to CT scanning for detecting pleural effusion [40]. No transoesophageal echocardiography studies showed pleural effusions, which is not surprising because pleural effusion is not usually an indication for transoesophageal echocardiography.

Haemodynamic instability or shock is a recognised indication for both transoesophageal and transthoracic echocardiography in order to assess volume status, prediction of fluid responsiveness [41–44] and response to initiated therapy [21, 45–47]. In five transoesophageal echocardiography studies and one transthoracic echocardiography study, there were frequent changes in diagnosis of the haemodynamic status, however management changes were only reported in two of the transoesophageal echocardiography studies and none in the transthoracic echocardiography studies; this is an area that we believe deserves further study. The most frequent change in patient management was administration of intravenous fluids or inotropic agents, but there were also some patients in whom a new echocardiographic diagnosis of cardiac failure led to the insertion of an intra-aortic balloon pump. We feel that it is important to note that a change in patient management following echocardiography did not always result in a step-up in treatment and it is not uncommon that the reassurance of normal echocardiography, in the presence of a previously suspected haemodynamic problem, can lead to a step-down in treatment [16].

Following major surgery, cardiac adverse events are a leading cause of morbidity and mortality [48–50]. In our review, only two were outcome studies conducted in order to compare mortality after cardiac surgery in patients who did, or did not, have postoperative echocardiography. Both these studies were retrospective in design and at risk of selection bias. In a study by Schmidlin et al. [29], transoesophageal echocardiography was chosen mainly in haemodynamically unstable patients, and in a study by Wake et al. [30] the main indication for transoesophageal echocardiography was suspected cardiac dysfunction. By contrast, their control groups consisted of all the other patients thereby placing the intervention group at higher risk of mortality than their control groups. The lack of any attempt to case-match patients in these studies means that conclusions regarding the impact of transoesophageal echocardiography are difficult. Randomised controlled trials are required to determine whether postoperative echocardiography affects patient outcome.

The studies included in this review represent a wide variety of study designs and have limitations. Firstly, the indications for transthoracic or transoesophageal echocardiography were different between studies, and the studies are skewed towards transoesophageal echocardiography having a recognised indication more often than is transthoracic echocardiography. There is likely less pathology and thereby less impact when echocardiography is used for screening compared with when it is indicated due to haemodynamic instability or suspected pericardial effusion. Nevertheless, a focused ultrasound assessment seems to have a positive effect in a large proportion of patients.

Nine studies reported that focused transthoracic and transoesophageal echocardiography is generally feasible, and ten studies reported substantial diagnostic impact of focused echocardiography. This resulted in frequent changes to patient management in seven studies. It has been claimed that focused ultrasound examination is a potentially life-saving diagnostic tool following cardiac surgery. We therefore believe that there is a requirement for well-designed, sufficiently powered, randomised controlled trials to determine whether echocardiography can improve clinical outcome, and whether this potential benefit justifies the significant cost of training and equipment purchase.

In conclusion, focused transthoracic and transoesophageal echocardiography are increasingly utilised following cardiac surgery, where it leads to frequent changes in diagnosis and management of pericardial and pleural effusions, as well as influencing haemodynamic management. However, transoesophageal echocardiography is invasive and routine use of transthoracic echocardiography is not without cost and randomised controlled trials have not yet been performed in order to determine whether echocardiography improves patient outcome.

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Competing interests

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Appendix 1: Definitions

Term	Definition
Feasibility	
Interpretable imaging	Defined in each paper
Changes in clinical diagnoses	
Diagnoses, total	Diagnoses accumulated
LV dysfunction	Change in grade of LV dysfunction (normal, subnormal, moderate or severe)*
RV dysfunction	Increased RV size or decreased RV systolic function†
Valve disease	New moderate or severe valve dysfunction
Hypovolaemia	Defined by each paper
Hypervolaemia	Defined by each paper
Pleural effusion	New demonstration of more than 2.5 cm (equivalent to 500 ml)
Pericardial effusion	New demonstration of more than 0.5 cm
Changes in clinical management	
Management, total	Medical + surgical management
Medical management	Change in type or amount of fluids or drugs, or insertion of intra-aortic balloon pump
Surgical management	Exploration for bleeding, pleural drainage, valve replacement, aortic arch repair, coronary artery bypass grafting

LV, left ventricular; RV, right ventricular.

