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Original Article

The impact of pre-operative focused transthoracic echocardiography in emergency non-cardiac surgery patients with known or risk of cardiac disease

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Summary

This prospective observational study investigated the effect of focused transthoracic echocardiography in 99 patients who had suspected cardiac disease or were ≥ 65 years old, and were scheduled for emergency non-cardiac surgery. The treating anaesthetist completed a diagnosis and management plan before and after transthoracic echocardiography, which was performed by an independent operator. Clinical examination rated cardiac disease present in 75%; the remainder were asymptomatic. The cardiac diagnosis was changed in 67% and the management plan in 44% of patients after echocardiography. Cardiac disease was identified by echocardiography in 64% of patients, which led to a step-up of treatment in 36% (4% delay for cardiology referral, 2% altered surgery, 4% intensive care and 26% intra-operative haemodynamic management changes). Absence of cardiac disease in 36% resulted in a step-down of treatment in 8% (no referral 3%, intensive care 1% or haemodynamic treatment 4%). Pre-operative focused transthoracic echocardiography in patients admitted for emergency surgery and with known cardiac disease or suspected to be at risk of cardiac disease frequently alters diagnosis and management.

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Cardiac complications are a leading cause of peri-operative mortality [1, 2]. Patients with cardiac disease requiring emergency surgery have a higher incidence of peri-operative complications [2], especially if surgery is performed after hours [3] or if patients are elderly [4]. Accurate pre-operative cardiac assessment is important to devise the most appropriate anaesthetic plan [2]. Aortic stenosis, common in the hip fracture population [5], and pulmonary hypertension are significant risk factors for mortality [6, 7], but diagnosis is unreliable without echocardiography [8, 9]. In addition, other abnormal haemodynamic states such as hypovolaemia, left ventricular systolic and/or diastolic failure, right heart failure and vasodilatation (for example, in sepsis) often accompany acute surgical disease, and may contribute to impaired cardiac output and tissue

perfusion peri-operatively if not adequately treated. Pre-operative transthoracic echocardiography (TTE) can determine haemodynamic state [10] and valvular abnormalities and assist in estimation of cardiac risk [11, 12], thus facilitating assessment and treatment changes before surgery.

Focused TTE is a truncated ultrasound cardiac examination that does not attempt to replace comprehensive TTE, but provides more accurate assessment than physical examination alone. It is usually performed at the patient's bedside or 'point of care' [13], and can be considered as 'ultrasound-assisted examination' [14]. The aim of this study was to determine whether focused TTE changes the cardiovascular diagnosis and management in patients requiring emergency non-cardiac surgery.

Methods

This study was conducted with approval from the Melbourne Health Human Ethics Committee and written consent was obtained from all participants between March 2010 and May 2011. Patients were screened for eligibility if they were admitted to the Royal Melbourne Hospital and required emergency non-cardiac surgery within 24 h. Inclusion criteria included all patients aged ≥ 65 years, or patients with symptoms, signs or clinical investigations suggestive of cardiac disease, including a history of previous peri-operative cardiac complications or haemodynamic instability (defined as a systolic blood pressure persistently less than 90 mmHg). Patients were excluded if planned surgery was brief (≤ 30 min) or minor (could be performed under local anaesthesia infiltration or light sedation), or if they had received TTE in the 12 months before surgery without any change in symptoms. This study represents the initial or pilot phase of a longer term project to identify the benefit of anaesthetist-performed TTE.

Diagnosis of Cardiac disease by either clinical or TTE assessment was defined as that which could result in haemodynamic instability during or after anaesthesia and surgery. This included one or more of the following: an abnormal haemodynamic state (empty, vasodilated, left ventricular systolic and/or diastolic failure, or right ventricular failure, as described previously [10]); valve stenosis or regurgitation of at least moderate severity (according to recognised guidelines [15, 16]); a pericardial effusion greater than 0.5 cm; or pulmonary hypertension (estimated pulmonary artery systolic pressure > 60 mmHg). Clinical assessment may be poor at discriminating between the sub-types of ventricular failure (primary diastolic failure, systolic failure, systolic and diastolic failure, and right ventricular failure) which may present with similar symptoms and signs. These were therefore grouped together as 'cardiac failure' to enable a comparison with the echocardiography diagnosis. Non-haemodynamically significant findings on clinical or TTE examination included mild valvular stenosis or regurgitation, and normal haemodynamic state.

Clinical assessment was performed by the treating anaesthetist or consultant rostered on-call for emergency cases, who completed a research form that detailed their diagnosis and management plan. An independent investigator, trained in focused TTE, then performed the echocardiographic study according to the HEART scan protocol (Haemodynamic Echocardiography Assessment in Real Time), with the addition of right-ventricular systolic pressure estimation when possible [17]. A standardised focused TTE report was then given to the treating anaesthetist. The echocardiography anaesthetist was not precluded from discussing the echocardiography findings with the treating anaesthetist, but was asked not to provide any management advice. The treating anaesthetist then completed a second diagnosis and management plan. The pre- and post-TTE data sheets used identical fields, and differences between the first and second forms were recorded as changes. TTE was performed using an iE33 (Phillips Medical Systems, Andover, MA, USA), a Vivid 7 Pro (General Electric Healthcare, Milwaukee, WI, USA), an M-turbo (Sonosite, Bothwell, Andover, MA, USA) or a LogiQ (General Electric Healthcare) echocardiography machine with a 1.5–3.6 MHz transthoracic probe.

The primary endpoint was any change in the original cardiac diagnosis (haemodynamic state, valve pathology or pulmonary hypertension) or any change in the management plan after TTE had been performed. These included both step-up (delay in surgery for cardiology referral, change in surgical technique, request for intensive care postoperatively, use of invasive monitoring including arterial and central venous catheters, fluid infusion or restriction before anaesthesia), or step-down in treatment (such as cancellation of planned

cardiology referral or ICU admission, not using inotropes, vasopressor or change in fluid management). Secondary endpoints included the incidence of cardiac pathology identified by TTE, and the comparison of the findings between focused and comprehensive TTE when performed after surgery. Descriptive data were analysed using SPSS V17 (SPSS Inc, Chicago, IL, USA).

Results

During the study period, 574 patients were screened and 412 did not meet the inclusion criteria. Of the 162 eligible patients, 57 were not enrolled due to patient refusal or other logistic reasons, including echocardiographer unavailability (eight patients). One-hundred and five patients were enrolled, but five patients were excluded after recruitment because the TTE was not completed (2); data sheets were not completed (2); or the operation was cancelled by the surgeon (1). One hundred patients therefore completed the study protocol, but one patient subsequently withdrew consent, leaving 99 for analysis. Mean (SD) age was 77 (11) years, there were 41 men, and mean (SD) left ventricular ejection fraction was 54 (16) %. The median (IQR [range]) ASA physical status and NYHA functional status were 3 (2–3 [2–4]) and 2 (1–3 [2–4]), respectively. Surgical specialties included orthopaedic (67), vascular (8), neurosurgery (8), upper gastrointestinal (5), haemodialysis venous access (5), general (1), urology (1), thoracic (1), plastics (1), head and neck (1) and ophthalmology (1). Forty-two patients required surgery for fractured neck of femur.

Clinical assessment before TTE reported that 75% of patients were suspected of having cardiac disease (abnormal haemodynamic state or valvular disease capable of resulting in peri-operative haemodynamic instability). The remaining 25% were asymptomatic and their only risk factor for cardiac disease was age ≥ 65 years. Following focused TTE, the anaesthetist changed the cardiac diagnosis in 67% of patients, which led to a change in management in 44% of patients (Fig. 1). The management changes were classified into procedural/postoperative care changes (14%, compris-

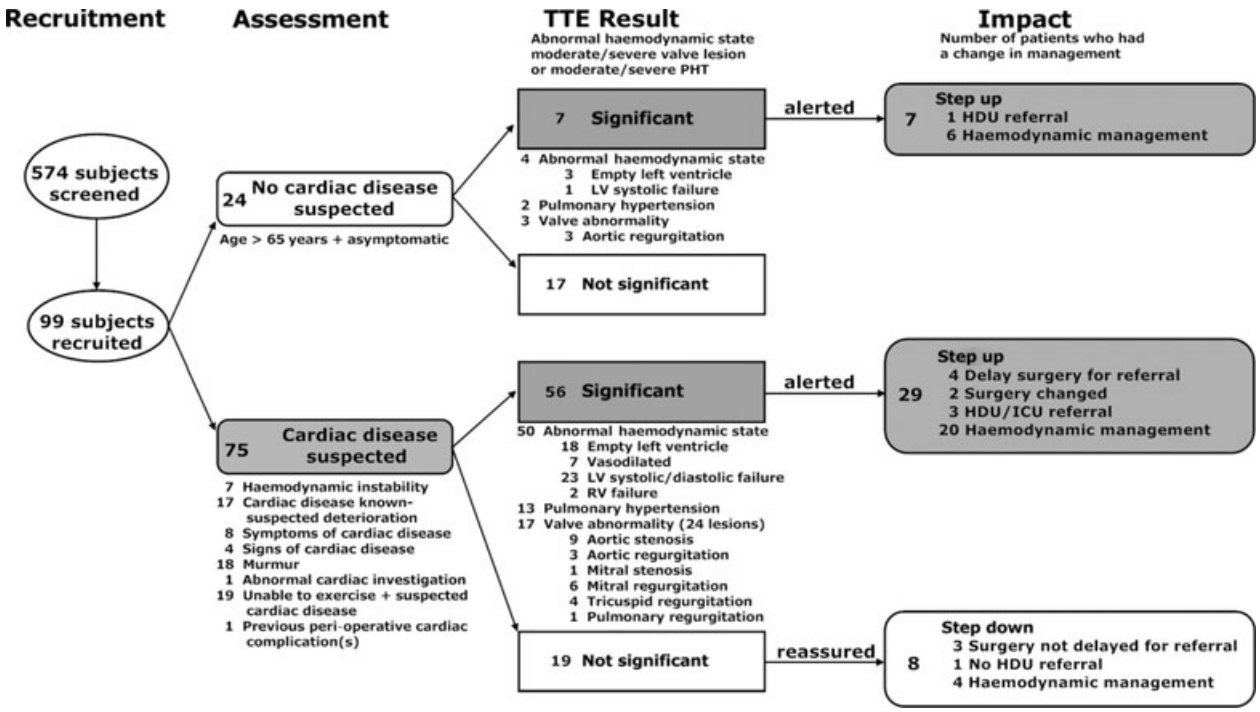

Figure 1 Summary of findings of clinical assessment, pre-operative transthoracic echocardiography (TTE) and changes to diagnosis and management plans in 99 emergency surgery patients at risk of cardiac disease. More than one change in management occurred in 13 patients. PHT, pulmonary hypertension; LV, left ventricular; RV, right ventricular; HDU/ICU, high dependency/intensive care unit.

ing 10% step-up and 4% step-down) or intra-operative haemodynamic changes (30%, comprising step up 26% and step down 4%) (Tables 1 and 2). In patients with suspected cardiac disease, cardiac pathology was confirmed by TTE in 75%, and no clinically important cardiac pathology was found in the remaining 25%.

Agreement for haemodynamic state diagnoses between clinical assessment and echocardiography occurred in only 39% of all patients (normal in 27 patients; empty 7; and cardiac failure 5). Transthoracic echocardiography diagnosed 79 patients with no significant valve pathology, and there were 27 moderate or severe valve lesions in 20 patients. The most common valve abnormality found on TTE was aortic stenosis (9), of which seven were diagnosed by clinical examination. Clinical assessment missed valve abnormalities that were diagnosed with TTE in 10 patients

Table 2 Negative or reassuring transthoracic echocardiographic (TTE) findings that led to a step-down in management in 8 out of 99 patients.

Clinical findings	TTE findings	Change in Management
Aortic stenosis (3)	Normal	Not cancelled
	Normal	No HDU referral
	Cardiac failure, PHT	Not cancelled
Cardiac failure (3)	Normal	Not cancelled, no HDU referral, no central venous catheter
	Normal	No central venous catheter
	Vasodilated	No arterial catheter
Unsure (2)	Normal (2)	No arterial catheter (2)

HDU, high dependency unit; PHT, pulmonary hypertension.

Table 1 Positive transthoracic echocardiographic (TTE) findings that led to a step-up in management in 36 out of 99 patients. The number in parentheses refers to the number of patients.

Clinical findings	TTE findings	Change in management
Aortic stenosis (5)	Aortic stenosis, cardiac failure	Surgery cancelled for cardiology referral, pulmonary artery and central venous catheters
	Aortic stenosis, cardiac failure	Surgery cancelled, cardiology referral
	Aortic stenosis, cardiac failure	Vasopressor infusion
	Aortic stenosis, empty, vasodilated	Surgery cancelled for cardiology referral, vasopressor infusion
	Aortic stenosis, PHT, empty	Fluid bolus
Cardiac failure (4)	Cardiac failure, mitral regurgitation	Central venous catheter
	Empty (2)	Fluid bolus (2)
	Vasodilated	Vasopressor infusion (no inotrope or fluid bolus)
Empty (5)	Empty, PHT	Fluid bolus
	Cardiac failure (3)	No fluid bolus – fluid restriction (2), vasodilator changed to vasopressor infusion (1)
	Aortic stenosis	Vasopressor infusion
Unsure (6)	Critical aortic stenosis + cardiac failure	Surgery changed, GA to local anaesthesia
	Cardiac failure	HDU referral
	Empty (4) PHT (1)	HDU changed to ICU (1), fluid bolus (4)
Cardiac tamponade	Tamponade confirmed, cardiac failure	Surgery changed, pericardial window added, HDU referral
Normal (15)	Empty (6)	Fluid bolus (6)
	PHT, mitral regurgitation, TR, empty	HDU referral, arterial catheter, fluid bolus
	Cardiac failure	HDU referral
	Aortic regurgitation, PHT, empty	Arterial catheter, vasopressor infusion
	Aortic regurgitation	Arterial catheter
	Aortic regurgitation, PHT	Vasopressor infusion
	Aortic regurgitation, vasodilated	Arterial catheter, no fluid bolus – fluid restriction
	Empty, mitral regurgitation	Vasopressor infusion
	Cardiac mass (2)	Surgery cancelled for cardiology referral (1), arterial catheter (1)

PHT, pulmonary hypertension; GA, general anaesthesia; HDU, high dependency unit; ICU, intensive care unit; TR, tricuspid regurgitation.

(one aortic stenosis, three aortic regurgitation, one mitral stenosis, five mitral regurgitation, two tricuspid regurgitation and one pulmonary regurgitation). Out of the 20 patients with significant valvular abnormalities diagnosed by TTE, clinical assessment agreed in only seven patients (35%), all of which were aortic stenosis. In addition, TTE revealed a cardiac mass in four patients and pulmonary hypertension in 15 patients.

There were 18 patients who subsequently received a comprehensive TTE by the cardiology service. There were no significant valve pathologies missed using the focused TTE examination. Differences between focused and formal TTE in the severity of the valve or haemodynamic state assessment occurred in 4 patients. Focused TTE reported significant aortic stenosis and regurgitation in one patient, but subsequent transoesophageal echocardiography (TOE) under general anaesthesia for aortic valve replacement (124 days later) failed to report regurgitation, which may have been explained by differences in loading conditions and was not thought to be clinically important. There were three patients with an abnormal haemodynamic state which was not reported on a subsequent comprehensive TTE (two empty and one right ventricular failure). These differences may have been due to changes in the patients' medical condition (the comprehensive study was performed 71, 3 and 31 days later, respectively), and were judged not to be clinically important.

Discussion

We have shown proof of concept that pre-operative focused TTE, performed in the emergency-surgery setting by an anaesthetist in patients at risk of cardiac disease, resulted in a change in the cardiac diagnosis and management in a high proportion of patients. When a clinically important haemodynamic or valvular abnormality was diagnosed with TTE, the predominant effect was to alert the anaesthetist to increased cardiac risk, leading to a step-up in the level of intra-operative haemodynamic monitoring and treatment or of postoperative care. Conversely, a clinically unimportant finding or normal TTE had the effect of reassuring the anaesthetist, leading to a reduced requirement for further investigation, reduced invasive peri-operative monitoring and reduced postoperative level of care. The proportions of management changes were less than in three previous reports of peri-operative focused TTE [14, 18, 19], which could be due to differences in management definitions and patient cohorts.

It was not surprising to us that in patients with cardiac disease diagnosed after clinical examination, a high proportion would have cardiac disease confirmed with TTE. What was surprising is the lack of concordance in the type of cardiac disease between clinical assessment and TTE. Clinical assessment was less than 50% accurate in determining the exact nature of clinically important cardiac disease. Haemodynamic state is the integration of the cardiac and vascular systems, and abnormalities present as specific patterns on echocardiography, allowing more accurate diagnosis and categorisation. Another important finding was that one third of patients rated as not having cardiac disease (asymptomatic patients aged ≥ 65 years) had clinically important cardiac pathology diagnosed with TTE, confirming that occult cardiac disease is prevalent in elderly patients.

Many of the changes in management were intra-operative haemodynamic management changes, and some could be considered to be 'fine tuning' of the anaesthetic rather than fundamentally changing patient management. However, improved diagnosis should lead to better management and provide a potential avenue for improved outcomes. This study was not designed to examine patient outcomes, and our data relate only to diagnosis and management plan changes.

In this study, 18 patients underwent comprehensive TTE following surgery, and there were no instances of important pathology being missed. Agreement between focused and comprehensive TTE has also been reported to be satisfactory in other studies (over 90%) [14, 19, 20], which is similar to agreement of echocardiography reports between cardiologists. Successful use of focused TTE by emergency [21], intensive care [22] and trainee physicians [23] has also been demonstrated. The ability to discriminate haemodynamically significant from non-significant aortic stenosis is important as it is a significant risk factor for postoperative mortality [6], is relatively common [5], is often poorly assessed clinically [8, 9] and may be asymptomatic even if severe [24]. This has been achieved by focused TTE without the use of quantitative Doppler (standard with comprehensive

TTE) in this study, and by others [25–28] by using 2D assessment of cusp separation. This significantly reduces the time and knowledge required for a novice operator. Conventional practice is to refer selected patients for inpatient comprehensive TTE, which may lead to an undesirable delay in surgery, or pressure anaesthetists to proceed without echocardiography.

An advantage of TTE over TOE or other cardiac investigations is that it is non-invasive and can be performed on the awake patient before anaesthesia. Thoracic surface ultrasound can be performed at the same time to identify acute lung pathology including pneumothorax, pleural effusion, pulmonary oedema and consolidation [29]. Transthoracic echocardiography is possible in mechanical ventilation [18, 30], is more portable, and does not require disposable equipment or lengthy disinfection. Disadvantages of TTE include user variability in expertise, training and equipment considerations, and limited patient access during surgery for use as a haemodynamic monitor.

Limitations of this study include the observational nature of the design, which was aimed at establishing proof of concept rather than the effect on patient outcome. Bias was reduced by using a different anaesthetist to perform the TTE from the anaesthetist who filled in data fields in the diagnosis and management plans before and after TTE. The primary method of communicating the TTE results was via a written report, but we did not preclude verbal discussion of the findings. This could introduce a potential bias towards management changes, but to minimise this, the echocardiographers were requested not to discuss or offer management advice. There is also the potential for a wide range of anaesthetic management decisions following the same TTE findings. A more junior anaesthetist may have diagnostic skills that are less honed and be more influenced by the TTE findings, but departmental policy at the study institution is for direct supervision of trainee anaesthetists by a consultant. Consultants completed 85% of the study assessments and trainees under supervision by a consultant completed the remaining 15%.

In summary, we have shown that, in patients at risk of cardiac disease, pre-operative anaesthetist-performed focused TTE in emergency surgery changes clinical diagnosis and anaesthetic management plans in a substantial proportion of patients.

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References

1. Warden J, Horan B. Deaths attributed to anaesthesia in New South Wales, 1984–1990. *Anaesthesia and Intensive Care* 1996; **24**: 66–73.
2. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 Guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery. *Circulation* 2007; **116**: e418–500.
3. Neary WD, Foy C, Heather BP, Earnshaw JJ. Identifying high-risk patients undergoing urgent and emergency surgery. *Annals of the Royal College of Surgeons of England* 2006; **88**: 151–6.
4. Story DA, Leslie K, Myles PS, et al. Complications and mortality in older surgical patients in Australia and New Zealand (the REASON study): a multicentre, prospective, observational study. *Anaesthesia* 2010; **65**: 1022–30.
5. McBrien ME, Heyburn G, Stevenson M, et al. Previously undiagnosed aortic stenosis revealed by auscultation in the hip fracture population - echocardiographic findings, management and outcome. *Anaesthesia* 2009; **64**: 863–70.
6. Kertai MD, Bountioukos M, Boersma E. Aortic stenosis: an underestimated risk factor for perioperative complications in patients undergoing noncardiac surgery. *American Journal of Medicine* 2004; **116**: 8–13.
7. Ramakrishna G, Sprung J, Ravi BS, Chandrasekaran K, McGoon MD. Impact of pulmonary hypertension on the outcomes of noncardiac surgery: Predictors of perioperative morbidity and mortality. *Journal of American College of Cardiology* 2005; **45**: 1691–9.
8. Van Klei WA, Kalkman CJ, Tolsma M, Rutten CL, Moons KG. Preoperative detection of valvular heart disease by anaesthetists. *Anaesthesia* 2006; **61**: 127–32.
9. Das P, Pocock C, Chambers J. The patient with a systolic murmur: severe aortic stenosis may be missed during cardiovascular examination. *International Journal of Medicine* 2000; **93**: 685–8.
10. Royse CF. Ultrasound-guided haemodynamic state assessment. *Best Practice & Research Clinical Anaesthesiology* 2009; **23**: 273–83.
11. Christ M, Sharkova Y, Geldner G, Maisch B. Preoperative and perioperative care for patients with suspected or established aortic stenosis facing noncardiac surgery. *Chest* 2005; **128**: 2944–53.
12. Rohde LE, Polanczyk CA, Goldman L, Cook EF, Lee RT, Lee TH. Usefulness of transthoracic echocardiography as a tool for risk stratification of patients undergoing major noncardiac surgery. *American Journal of Cardiology* 2001; **87**: 505–9.
13. Moore CL, Copel JA. Point-of-care ultrasonography. *New England Journal of Medicine* 2011; **364**: 749–57.

14. Canty D, Royse C, Kilpatrick D, Bowman L, Royse A. The impact of focused transthoracic echocardiography in the pre-operative clinic. *Anaesthesia* 2012; 21 Feb doi:10.1111/j.1365-2044.2012.07074.x.
15. Baumgartner H, Hung J, Bermejo J, et al. Echocardiographic Assessment of Valve Stenosis: EAE/ASE Recommendations for Clinical Practice. *Journal of the American Society of Echocardiography* 2009; **22**: 1–23.
16. Zoghbi WA, Enriquez-Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and doppler echocardiography. *Journal of the American Society of Echocardiography* 2003; **16**: 777–802.
17. Faris J, Veltman M, Royse CF. Limited transthoracic echocardiography assessment in anaesthesia and critical care. *Best Practice & Research Clinical Anaesthesiology* 2009; **23**: 296.
18. Canty DJ, Royse CF. Audit of anaesthetist-performed echocardiography on perioperative management decisions for non-cardiac surgery. *British Journal of Anaesthesia* 2009; **103**: 352–8.
19. Cowie B. Three years' experience of focused cardiovascular ultrasound in the peri-operative period. *Anaesthesia* 2011; **66**: 268–73.
20. Cowie B, R K. Evaluation of systolic murmurs using transthoracic echocardiography by anaesthetic trainees. *Anaesthesia* 2011; **66**: 785–90.
21. Labovitz AJ, Noble VE, Bierig M, et al. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *Journal of the American Society of Echocardiography* 2010; **23**: 1225–30.
22. Lau G, Swanevelder J. Echocardiography in intensive care – where we are heading? *Anaesthesia* 2011; **66**: 649–52.
23. Decara J, Lang M, Koch R, Bala J, Penzotti J, Spencer K. The use of small personal ultrasound devices by internists without formal training in echocardiography. *European Journal of Echocardiography* 2003; **4**: 141–7.
24. Dal-Bianco JP, Sengupta PP, Khandheria BK. Role of echocardiography in the diagnosis and management of asymptomatic severe aortic stenosis. *Expert Review of Cardiovascular Therapy* 2008; **6**: 223–33.
25. Lesbre J, Scheuble C, Kalisa A. Echocardiography in the diagnosis of severe aortic valve stenosis in adults. *Archives des maladies du coeur et des vaisseaux* 1983; **76**: 1–12.
26. Weyman A, Feigebaum H, Dillon J, Chang S. Cross-sectional echocardiography in assessing the severity of valvular aortic stenosis. *Circulation* 1975; **52**: 828–34.
27. Godley RW, Green D, Dillon JC, Rogers EW, Feigenbaum H, Weyman AE. Reliability of two-dimensional echocardiography in assessing the severity of valvular aortic stenosis. *Chest* 1981; **79**: 657–62.
28. Chang S, Clements S, Chang J. Aortic stenosis: echocardiographic cusp separation and surgical description of aortic valve in 22 patients. *American Journal of Cardiology* 1977; **39**: 499–504.
29. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest* 2008; **134**: 117–25.
30. Jakobsen CJ, Torp P, Sloth E. Perioperative feasibility of imaging the heart and pleura in patients with aortic stenosis undergoing aortic valve replacement. *European Journal of Anaesthesiology* 2007; **24**: 589–95.

