

CLINICAL PRACTICE

Audit of anaesthetist-performed echocardiography on perioperative management decisions for non-cardiac surgery

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Background. Intraoperative transoesophageal echocardiography is increasingly used for guiding intraoperative management decisions during non-cardiac surgery. Transthoracic echocardiography (TTE) equipment and training is becoming more available to anaesthetists, and its point-of-care application may facilitate real-time haemodynamic management and preoperative screening.

Methods. We conducted an audit of transthoracic and transoesophageal echocardiograms, performed by an anaesthetist at a tertiary referral centre over a 9-month period, to identify the effect of echocardiography on clinical decision-making in patients undergoing non-cardiac surgery. The indications for echocardiography followed published guidelines.

Results. Echocardiographic examinations of 97 patients included 87 transthoracic, and 14 transoesophageal studies. Of 36 studies conducted in the preoperative clinic, eight revealed significant cardiac pathology, necessitating cardiology referral or admission before surgery. Preoperative transthoracic echocardiograms performed on the day of surgery ($n=39$) led to two cancellations of surgery owing to end-stage cardiac disease, the institution of two unplanned surgical procedures (drainage of pleural and pericardial effusions), and to significant changes in anaesthetic and haemodynamic management, or both in 18 patients. Greater influence on management occurred with emergency surgery (75%) than elective surgery (43%). Intraoperative transthoracic ($n=10$) and transoesophageal ($n=14$) echocardiography also altered management (altered surgery in two patients, cancellation in one, and altered haemodynamic management in 18 patients).

Conclusions. Anaesthetist-performed point-of-care TTE and thoracic ultrasound may have a high clinical impact on the perioperative management of patients scheduled for non-cardiac surgery.

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Transoesophageal echocardiography (TOE) is used extensively in cardiac surgery where it has been shown to be useful in guiding surgical decision-making,¹ and as a valuable haemodynamic monitor.² It is also useful in non-cardiac surgery by providing greater diagnostic information

than invasive pressure-based monitoring, facilitating more accurate haemodynamic management.³ There is increasing interest in whether transthoracic echocardiography (TTE) may have similar impact in the perioperative assessment and management of non-cardiac surgical patients.

TOE has advantages over conventional pressure-based monitoring, including the direct assessment of preload, ventricles, valves, pericardium, aorta, pleura, and guiding device placement.⁴ Oesophageal Doppler-directed fluid titration has been shown to reduce morbidity in non-cardiac surgery.⁵ Aortic Doppler-guided fluid titration is possible utilizing TOE or TTE. Persistent haemodynamic instability and risk of instability are Category I and Category IIa indications for use of intraoperative TOE, respectively.⁴ TTE can also be used to evaluate hypotension or haemodynamic instability.⁶ TOE and TTE are useful in the diagnosis and management of cardiac arrest^{7,8} and TTE has been incorporated into an advanced cardiac life support algorithm.⁹ Echocardiography training courses for anaesthetic and critical care physicians are becoming established¹⁰ and introduced into critical care training requirements. Interest in the application of TTE to anaesthesia is developing, but few data are available, and these are mostly limited to case studies.¹¹

The aim of this audit was to identify the clinical impact of TTE and TOE on the perioperative management of patients undergoing non-cardiac anaesthesia when performed by an anaesthetist trained in echocardiography at a tertiary referral centre.

Methods

This audit was conducted with Ethics approval from the Royal Hobart Hospital from August 2007 to 31 May 2008, in non-cardiac surgery patients in a tertiary referral hospital setting. Echocardiography and interpretation were performed by a single anaesthetist trained in both TTE and TOE, at the discretion of the operator, or as requested by another anaesthetist or surgeon. In all cases the indication was consistent with the published guidelines for preoperative⁶ and intraoperative echocardiography.⁴ Indications included known structural heart disease with possible clinical deterioration, murmur, unexplained dyspnoea, chest pain or syncope with evidence of cardiac disease, or haemodynamic disturbance. Surface thoracic ultrasound was used to examine the pleura in addition to echocardiography in two patients before surgery.¹²

A standard echocardiogram was performed for each patient using a Vivid I² echocardiography machine (General Electric Healthcare, Milwaukee, WI, USA) with either a transthoracic (P17/5–1 MHz) or a multiplane transoesophageal probe (TEE/8–3 MHz). A formal report was documented, which included clinical utility.

Data recorded included patient characteristic data, place, type and indication for echocardiogram, surgical procedure, haemodynamic state, clinically important echocardiography findings, and management changes. The haemodynamic state was classified into one of seven states (Table 1) according to the HEARTscan course (Haemodynamic Echochardiographic Assessment in Real Time, Melbourne University, Australia)¹⁰ based on echocardiography assessment of left ventricular (LV) volume, LV systolic function, and left atrial pressure estimation. LV volume measurements were obtained from either the parasternal long-axis view or the parasternal short-axis view of the LV at the mid-papillary level. Left atrial pressure was assessed by observation of the shape and movement of the interatrial septum¹³ and the change in left atrial size. Similar measurements were made with TOE.

New findings were considered clinically important if they could lead to haemodynamic instability during or after anaesthesia and surgery, such as severe valve or ventricular dysfunction, pulmonary hypertension or cardiac tamponade, or if there was progression in severity of pathology (moderate to severe) when compared with a previous echocardiogram. Findings were also considered important if they led to a change in, or cancellation of surgery.

Results

Eighty-seven TTE and 14 TOE studies were performed in 97 patients. Four patients were examined using both TTE and an intra-operative TOE. Examples of important positive and negative findings are shown in Tables 2 and 3. Haemodynamic state and anatomical findings are shown in Table 4, influence on clinical management in Table 5, and a summary in Figure 1.

Preoperative assessment clinic

Of the 36 TTE studies performed in the preoperative assessment clinic (PAC), significant new findings included severe aortic stenosis (two), aortic regurgitation (two), mitral regurgitation (two), LV systolic dysfunction (three), and severe pulmonary hypertension (one). Twelve patients had an abnormal haemodynamic state. TTE findings in seven patients required cardiology outpatient referral and a delay in surgery, and peri-prosthetic aortic regurgitation prompted hospital admission in one patient. The remaining

Table 1 Basic Haemodynamic State Classification. Haemodynamic state is constructed from echocardiography assessment of ventricular volume, ventricular systolic function, and left atrial pressure estimation. N is normal, ↑ is increased, and ↓ is decreased. Described by Royse¹⁰

Echo measurement	Normal	Empty	Diastolic heart failure	Systolic failure	Systolic and diastolic failure	Vasodilation	Right ventricular failure
LV volume	N	↓	N or ↓	↑	↑	N	RV ↑
LV systolic function	N	N or ↑	N or ↑	↓	↓	↑	RV ↓
Left atrial filling pressure	N	↓	↑	N	↑	N	↑

Table 2 Examples of positive findings affecting management decisions. Haemodynamic state: N, normal; SF, systolic failure; DHF, diastolic heart failure; E, empty; V, vasodilated; RVF, right ventricular failure; AS, aortic stenosis; ASD, atrial septal defect; EF, ejection fraction; GA, general anaesthesia; HOCM, hypertrophic obstructive cardiomyopathy; IABP, intra-aortic balloon pump; LV, left ventricle; LVOT, left ventricular outflow tract; MR, mitral regurgitation; ORIF, open reduction and internal fixation; OSA, obstructive sleep apnoea; NOF, neck of femur; PHT, pulmonary hypertension; PFO, patent foramen ovale; RAP, right atrial pressure; RWMA, regional wall motion abnormality; RV, right ventricle; SAM, systolic anterior motion of the anterior mitral leaflet; SOBOE, shortness of breath on exertion; TR, tricuspid regurgitation; #, fracture

Surgical procedure	Clinical information	Indication for echo	Haemodynamic state	New findings	Influence of echo
Preadmission clinic TTE					
1 Inguinal hernia repair	AVR/MVR/CABG 6 months ago	Exertional breathlessness	SF	Periprosthetic AR	Cardiology admission
2 Total knee replacement	Exercise limited by knee pain	Exertional breathlessness	DHF	Mod/severe AS	Cardiology referral preop
3 Excision tumour arm	Previous coronary stent	Chest pain	SF	Inf and lateral hypokinesis	Sestamibi scan and cardiology referral
4 Total hip replacement	Previous CABG	LV function assessment	SF	Mod/severe MR-reduced EF	Cardiology referral preop
5 Carotid endarterectomy	Chest pain	Worsening SOB	N	RWMAs	Cardiology referral preop
6 Leg amputation	PHx mod AS	Severity of AS	DHF	Severe AS	Cardiology referral preop
7 Total hip replacement	PHx CABG	Exertional breathlessness	RVF	Severe PHT	Cardiology referral preop
Preop TTE					
8 Hemi-arthroplasty #NOF	Murmur	Exertional breathlessness	SF+DHF	Critical AS PHT	Cancel surgery palliative care
9 Eye surgery under GA	Angina at rest	LV function	SF+DHF	mod MR PHT RWMA's	Cancel surgery radiation therapy
10 Endoluminal aortic stent	Severe IHd awaiting CABG	Exertional breathlessness	SF+DHF	Severe MR-reduced EF	Haemodynamic, TOE, mitral surgery
11 Pericardial window	Malignant pericardial effusion	Breathlessness at rest	DHF	Pleural effusions RWMA	Effusions drained TOE requested
12 Decortication empyema	Febrile tachycardia	Haemodynamic instability	N	Moderate pericardial effusion	Surgical drainage
13 Laparoscopic hemicolectomy	Severe HOCM awaiting coronary stent	LV function	DHF	No SAM concentric LVH	Influenced induction technique TOE requested
14 ORIF #NOF	Hypotension, liver+respiratory failure	LV function	E	Pericardial+pleural effusion	Changed anaesthetic technique
15 ORIF #femur	Hypotension hypoxia	Haemodynamic instability	E	Severe TR RVF+LVF	Fluid resuscitation
16 ORIF #NOF	Fall, tender ribs	Exclude pneumothorax	N	Pneumothorax	Change from GA to spinal
17 ORIF #NOF	Raised jugular venous pulse	Haemodynamic instability	E+RVF	Severe TR, PHT, mod MR	Haemodynamic and anaesthetic technique
18 Emergency laparotomy	Acute abdomen hypotensive tachycardia	Haemodynamic instability	V+E		Guided volume replacement and vasopressor
Intraoperative TTE					
19 Laparoscopic tubal ligation		Haemodynamic instability	N	Aortic gas emboli	Terminated procedure
20 ORIF C-Spine	Blunt trauma, cervical cord compression	Haemodynamic instability	V		Haemodynamic management (vasopressor)
21 Craniotomy debulking tumour+portacath insertion	2-yr-old with severe cachexia	Haemodynamic instability	RVF	(Iatrogenic prosthesis embolus)	Haemodynamic management cardiac surgery not indicated
22 Bifrontal craniectomies	Severe intracranial hypertension	Haemodynamic instability	E		Fluid resuscitation
23 Removal IABP (TOE)	Instability postop cardiac surgery	Exclude LVOT obstruction	RVF	L pleural effusion severe TR PHT	Effusion-drained haemodynamic management
Postoperative TTE					
24 ORIF Humerus	Persistent tachycardia (heart rate 130)	Haemodynamic ?Pulmonary embolus	V	No evidence of pulmonary embolus	Vasopressor

Table 3 Some examples of negative findings

Surgical procedure	Clinical information	Indication for echo	Haemodynamic state	New findings	Influence of echocardiography
1. Colectomy	Presyncope, chest pain	Presyncope, chest pain	N	Normal study	Proceed
2. Lumbar laminectomy	Severe OSA	?Cor pulmonale	N	Normal	Proceed
3. Tonsillectomy	Severe OSA, SOBOE, LV hypertrophy	?Cor pulmonale	N	Normal	Proceed
4. Laparoscopic hemicolectomy	LV hypertrophy	Murmur	N	Mild AS	Proceed
5. Redo ORIF ankle	Prior CABG AVR	Exertional breathlessness	N	Normal TTE	Proceed
6. Colonoscopy	Severe PHT recent heat failure	?RVF ?PHT	RVF	Systolic failure	Proceed
7. Arterio-venous fistula formation	Prior pericardial effusion and AR	?Effusion, ?AR	N	High RAP, no effusion, mild AR	Proceed
8. MRI brain (under GA)	Restrictive pericarditis systemic lupus erythematosus	?Restrictive cardiomyopathy ?cor pulmonale	N	Non-restrictive	Proceed
9. Cholecystectomy	Worsening SOBOE mod/severe COPD	?PHT	RVF	LVH, dilated RV, no PHT	Proceed
10. ORIF #NOF hemiarthroplasty	LVH on ECG exertional breathlessness	?AS	E	mild AS, mod LVH	Proceed
11. Gastrectomy	Breathlessness, palpitations	LV function assessment	N	Normal	Proceed
12. Craniotomy	Cardiomyopathy ECG LBBB	LV function assessment	SF+DHF	No worsening	Proceed
13. Craniotomy in sitting position		Screen for ASD/PFO	N	Interatrial septum intact	Proceed

Table 4 Haemodynamic state and new findings summary

	Total TTE+TOE	TOE	TTE PAC	TTE preop	TTE intraop	TTE postop
Primary haemodynamic state						
Normal	50	8	24	15	2	1
Empty	10	0	0	6	4	
Vasodilation	7	2	0	2	2	1
Systolic failure	11		6	4	1	
Primary diastolic failure	10	2	3	5	0	
Systolic and diastolic failure	7	1	1	5	0	
RV failure	6	1	2	2	1	
Total	101	14	36	39	10	2
New findings						
Significant AS	9		2	7		
Significant AR	3	1	2			
Significant MR	6	1	2	3		
Significant LV dysfunction	6	1	2	3		
Severe TR/RVF	5	1		3	1	
Pericardial effusion	2			2		
Pleural effusion	3	1		2		
Pneumothorax	1			1		
RWMAs	6		1	4	1	
Gas embolus	1				1	
Severe PR	1				1	
Severe PHT	1		1			

Table 5 Influence of echocardiography on management decisions. *Indicates adjustment as four patients had both transthoracic echocardiography and transoesophageal echocardiography imaging

Outcome	Total	TOE	TTE	TTE PAC	TTE preop	TTE intraop	TTE postop
Cancel surgery	3	0	3	0	2	1	NA
Defer surgery	8	0	8	8	0	0	NA
Alter surgery	4	2	2	0	2	0	NA
Alter anaesthesia*	*34 (38)	10	28	0	18	8	2
No influence	48	2	46	28	17	1	0
Total	*97 (101)	14	87	36	39	10	2

28 patients proceeded to surgery without further investigation or referral.

Transthoracic echocardiography before anaesthesia and surgery

In 39 patients TTE was performed immediately before anaesthesia and surgery and new findings included aortic stenosis (seven), mitral regurgitation (three), LV failure (three), right ventricular (RV) failure (three), pleural effusions (two), pericardial effusions (two), and pneumothorax (one). The haemodynamic state was abnormal in 24 patients: hypovolaemia (six), vasodilation (two), systolic failure (four), diastolic heart failure (five), combined systolic and diastolic failure (five), and RV failure (two).

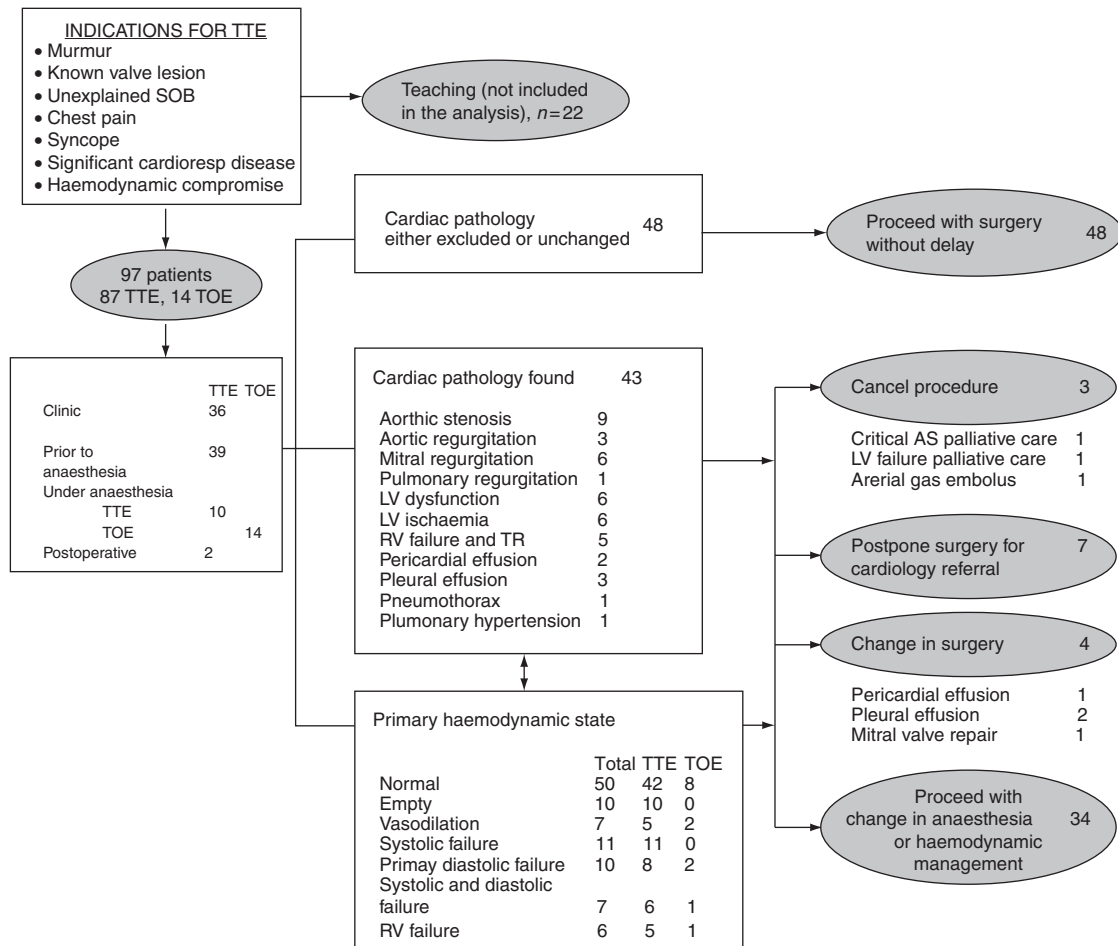


Fig 1 Summary of indications and outcomes for transthoracic echocardiography and transoesophageal echocardiography.

Several patients with clinical findings of raised jugular venous pulse had significant tricuspid regurgitation and hypovolaemia demonstrated on TTE. Eighteen echocardiograms contributed to significant changes in anaesthetic or haemodynamic management, for example changing from regional to general anaesthesia (or *vice versa*); placement of invasive monitoring devices; guiding i.v. fluid titration, inotropic or vasopressor drugs. In two patients, pathology was so severe that surgery was cancelled in favour of medical therapy (end-stage aortic stenosis in a patient scheduled for fractured neck of femur surgery, and severe heart failure in a patient for eyelid tumour surgery). Thoracic surface ultrasound in two patients led to unplanned surgical procedures (surgical drainage of a large pleural effusion and pericardial effusion). Management changes occurred more frequently in patients presenting for emergency surgery (12 of 16 patients) compared with elective surgery (10 of 23).

Under anaesthesia and during surgery

The image quality was adequate in all 10 patients examined by TTE during anaesthesia. Abnormal findings

included hypovolaemia (four), vasodilation (two), systolic failure (one), RV failure (one), and severe pulmonary regurgitation (one), which influenced haemodynamic management in eight patients. Other causes of persistent hypotension were also excluded by echocardiography, for example cardiac ischaemia, heart failure, and tamponade. During a laparoscopic tubal ligation, aortic gas emboli were seen and the surgical procedure was expedited. In a 2-yr-old child, severe hypotension and raised central venous pressure occurred during a portacath insertion into the right internal jugular vein. TTE revealed RV failure (consistent with an embolized portacath fragment in the pulmonary artery), which guided medical and surgical decision-making. The influence of TTE on management was similar in the emergency surgery group (five of six patients) and the elective surgery group (three of four).

The 14 TOE studies were performed in patients at risk of intraoperative haemodynamic instability (eight), to exclude an atrial septal defect before neurosurgery in the sitting position (one), to exclude left atrial appendage thrombus before emergency defibrillation for atrial fibrillation (one), to look for cardiac source of recurrent arterial emboli (one), and pericardial window procedures (two). In

one patient TOE was requested after a brief asystolic arrest after induction of anaesthesia. The study was normal and surgery was allowed to proceed. The new significant findings were aortic regurgitation (one), mitral regurgitation (one), pleural effusion (one), LV failure (one), and RV failure (one). The haemodynamic state was normal (eight), vasodilation (two), diastolic heart failure (two), systolic and diastolic heart failure (one), and RV failure (one). In one patient undergoing a pericardial window procedure, a large pleural effusion was identified by TOE and drained surgically. In another patient severe mitral regurgitation was identified during endoluminal abdominal aortic aneurysm stent deployment resulting in subsequent mitral valve surgery. Haemodynamic management was altered in 10 out of 14 patients.

Postoperative studies

Two TTE studies were performed postoperatively, to investigate persistent tachycardia in a young male after open humerus surgery (shown to be caused by vasodilation) and to exclude a possible pneumothorax by surface thoracic ultrasound (in a patient with reduced oxygen saturation and shallow respiration after a thoracoscopic sympathectomy, allowing safe institution of CPAP).

Discussion

This audit demonstrates that echocardiography performed by an anaesthetist in the preoperative assessment clinic or in the operating room environment is feasible, and can identify clinically important anatomical and haemodynamic disorders leading to important changes in clinical management. There was a higher impact of TTE in patients examined immediately before emergency surgery than before elective surgery, probably reflecting acute illness.

TTE has traditionally been within the remit of cardiologists and has been used primarily to guide long-term medical management. Improved image quality, reduced size and cost of equipment, together with increased awareness of its benefits by anaesthetists and critical care physicians has encouraged point-of-care applications of echocardiography. This enables time-critical decisions to be facilitated by focused echocardiography performed at the bedside in urgent situations.

The use of TTE by anaesthetists in the PAC is a promising development. Important cardiac pathology may be identified by TTE that could lead to further investigation or optimization of the patient before surgery. TTE may also be used to exclude significant pathology, potentially saving unnecessary investigations, consultations (and delay), invasive monitoring, and postoperative intensive care.¹⁴ This could reduce the burden on cardiology and intensive care departments. TTE can be used as a screening tool for conditions such as severe pulmonary

hypertension and aortic stenosis, both of which are associated with higher perioperative mortality.^{15 16} If identified by TTE then important changes to perioperative management may ensue. The anaesthetist echocardiographer does not assume the role of the cardiologist, but obtains more accurate and detailed cardiovascular assessment than physical examination alone at the time of initial assessment.¹⁷

The use of echocardiography in the operating room facilitates real-time cardiovascular assessment and adds a further level of diagnostic and monitoring ability. In this audit, significant cardiac pathology and abnormal haemodynamic state were identified using TTE in many patients, though there was no attempt to measure any effect on outcome, and further specific research is required. Surface thoracic ultrasound was used to identify important thoracic pathology immediately before and after surgery in three patients (effusion and pneumothorax).

Without echocardiography, hypotension or tachycardia may alert the anaesthetist to haemodynamic disturbances, but these signs do not indicate the cause. The use of pressure-based invasive monitoring may improve diagnostic accuracy, but cannot differentiate between systolic and diastolic heart failure or right from LV failure. Echocardiography provides direct assessment of ventricular volume and function, and when combined with assessment of left atrial pressure, can be used to estimate ventricular compliance. Accurate haemodynamic state diagnosis facilitates rational management interventions. Unlike TOE, it may be used in nonintubated patients during surgery and is less likely to interfere with airway management or other resuscitation procedures. TTE is noninvasive, quicker, and does not require sedation or lengthy cleaning procedures. It is also more reliable for the estimation of intracardiac pressures, transvalvular gradients, and imaging the LV apex. However, unlike TOE, TTE can only be used as an intermittent monitor. Other disadvantages of TTE include difficulty in obtaining adequate imaging during surgery from the effects of mechanical ventilation, and inaccessibility to all possible cardiac windows in some instances. However, the ability of the anaesthetist to support spontaneous ventilation, temporarily deflate the lungs and control patient posture assists in improving image quality. Adequate imaging was obtained in all of the intraoperative TTEs (all patients were intubated). TOE was used in four patients during surgery for haemodynamic monitoring to avoid interrupting the surgical field. Clinicians should consider attempting TTE (if feasible) before using TOE which may add additional risk. Compared with a pulmonary artery catheter, TTE provides additional information and is non-invasive.

Intraoperative TOE was used electively in patients prone to instability and to examine the interatrial septum and left atrial appendage (not as well seen on TTE). Use of intraoperative TOE is well developed but is still uncommon in non-cardiac surgery. The trained anaesthetist may perform the TOE on behalf of the cardiologist (who can

be consulted with the results if required) who may not be immediately available, or who may not be experienced in echocardiographic haemodynamic assessment or the dynamic situation during surgery and anaesthesia.

There are several important limitations to this audit. It is a single person, single-centre audit with many potential confounding factors. The images and their influence were not reviewed by a second observer and the indications for echocardiography were not prospectively defined. However, as TTE is non-invasive, additional information was gained without risk to the patient. It is feasible that the findings may have been identified clinically, but TTE has been shown to be more accurate than clinical examination in detecting cardiac pathology.¹⁷ The high incidence of abnormalities found by preoperative TTE may reflect inadequate preoperative assessment. However, it may also result from the high proportion of emergency surgical patients in the study, or may reflect a high proportion of old and sick patients one expects at the principal tertiary referral centre of Tasmania. The issue of echocardiography training and credentialing is important, but is beyond the scope of this audit.

Despite these limitations, both TTE and TOE performed by a suitably trained anaesthetist for non-cardiac surgery is feasible, and the study identified clinically important anatomical and haemodynamic abnormalities in real-time which contributed to changes in clinical management.

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