

# Peri-operative transoesophageal echocardiography

SUSAN WRIGHT

## Abstract

**P**eri-operative transoesophageal echocardiography (TOE) has become part of the routine management of patients undergoing cardiac surgery. Its use in guiding not only surgery, but also the haemodynamic management of the patient, has made TOE an indispensable tool in the cardiac operating theatre. Practical aspects of intra-operative TOE are outlined and its application in differing clinical situations is reviewed.

**Key words:** echocardiography, transoesophageal, peri-operative procedures, intraoperative care.

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## Introduction

The last decade has seen the rapid emergence of peri-operative transoesophageal echocardiography (TOE) as a fundamental part of the peri-operative care of the cardiac surgical patient in the UK.

Building on experience from the US, which has led the field, cardiologists and increasing numbers of anaesthetists have developed the TOE skills necessary to guide both the surgical procedure and the haemodynamic management of these patients. Intra-operative TOE is now available in most, if not all, cardiac surgical units in the UK. In approximately half of these, TOE is performed by anaesthetists, and most of the remaining units provide a joint anaesthesia/cardiology-led service. Anaesthetists are well placed to perform intra-operative TOE, its use requires an understanding of the sequence of surgical events and their haemodynamic sequelae, and the real-time information gained on both the patient's volume status and cardiac function facilitates rapid manipulation of haemodynamics.

In this country, anaesthetists have embraced the role enthusiastically; more than 10% of UK cardiac anaesthetists so far have acquired formal accreditation in peri-operative TOE.<sup>1</sup> The US National Board of Echocardiography established certification in peri-operative TOE in 1997. Since then certification has

Susan Wright



evolved into an accreditation process involving both a written examination and log book submission. Accreditation processes in the UK (overseen by the British Society of Echocardiography and the Association of Cardiothoracic Anaesthetists) and in Europe (by their European equivalents) have recently emerged and will also help to safeguard standards of clinical practice.

A significant obstacle to the introduction of peri-operative TOE has been the substantial cost involved. Purchase of expensive echocardiography equipment can represent major capital expenditure that UK healthcare trusts are unwilling to support in today's strained financial environment. However, Fanshawe *et al.* have analysed the cost implications of the introduction of a routine peri-operative TOE service in the US, finding a mean financial saving of US\$ 230 per patient undergoing adult cardiac surgery.<sup>2</sup>

## Practical considerations

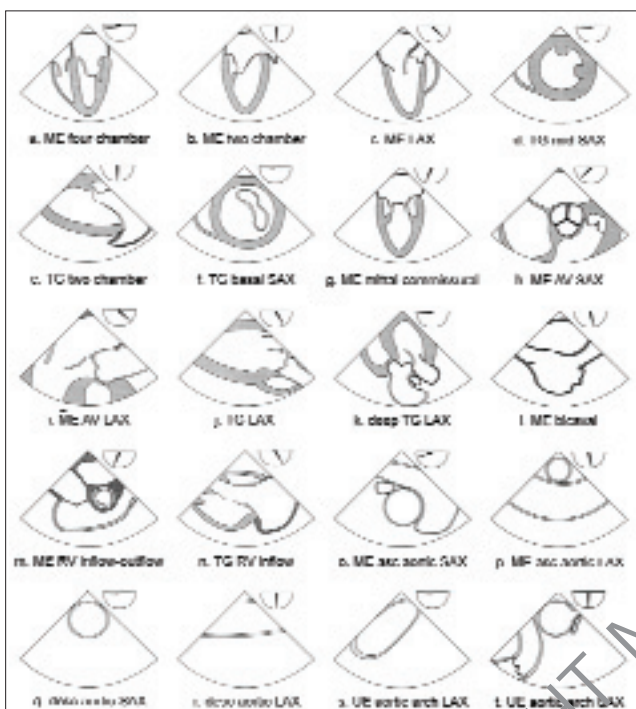
Shanewise *et al.* described 20 conventional TOE imaging planes that together constitute a comprehensive peri-operative TOE examination<sup>3</sup> (figure 1). It is acknowledged that most practitioners use 10–12 of the described planes in their routine intra-operative studies.

For non-anaesthetist echocardiographers visiting the operating theatre, there are numerous pitfalls attached to TOE in this setting. A short summary of the relevant practical considerations and tips for intraoperative TOE can be found in the appendix to

Department of Anaesthetics, The Heart Hospital, University College London Hospitals, 16-18 Westmoreland Street, London, W1G 8PH.  
Susan Wright, Consultant Anaesthetist

Correspondence to: Dr S Wright  
(E-mail: sue.wright@uclh.nhs.uk)

**Figure 1.** The 20 multi-plane views of a comprehensive intra-operative multi-plane transoesophageal examination, as described by Shanewise *et al.*<sup>3</sup>



**Key:** ME = midesophageal, LAX = long axis, TG = transgastric, SAX = short axis, mid = midpapillary, AV = aortic valve, RV = right ventricle, asc = ascending, desc = descending, UE = upper oesophageal

this article. A knowledge of the surgical and anaesthetic sequence of events is important to the accurate assessment of the patient.

### Complications and safety

The complications of intra-operative TOE (table 1) include all of those familiar to the out-patient TOE service setting. In addition, however, the intra-operative environment introduces the potential for inadvertent extubation of the patient (particularly in children) when the TOE probe is manipulated in the pharynx. Similarly, central venous catheters, monitoring and drug infusion lines can easily be dislodged or disconnected by the unwary. Of primary concern is the distraction from anaesthesia introduced by intra-operative TOE (figure 2); anaesthetist echocardiographers are advised to delegate the task of anaesthesia and monitoring vigilance to a second individual while the TOE study is being performed.

### Indications for intra-operative TOE

The need to allocate limited resources in terms of expensive TOE equipment in the operating theatre led to the development of a system of prioritisation of surgical procedures

**Figure 2.** The clinical setting, showing intra-operative transoesophageal echocardiography could distract the anaesthetist from anaesthesia and other monitoring



**Table 1.** Complications of intra-operative transoesophageal echocardiography

#### General complications

- **Direct mechanical trauma** - chipped teeth, pharyngeal abrasion, oesophageal perforation or haemorrhage, aneurysm rupture, mucosal thermal injury
- **Displacement or traction on contiguous structures** - recurrent laryngeal nerve injury, hypotension from great vessel compression
- **Stimulation of visceral reflexes** - dysrhythmias, vomiting
- **Bacteraemia**

#### Complications specific to the peri-operative setting

- Distraction from anaesthesia and other monitoring
- Accidental extubation
- Inadvertent removal of intravascular catheters and cannulae

according to the usefulness of TOE during the operation (table 2).<sup>4</sup> Disappointingly, but perhaps unsurprisingly, there is little or no evidence that the use of intra-operative TOE alters outcome. The categorisation of procedures was therefore based on the opinions of a panel of experts within the US Society of Cardiovascular Anesthesiologists (SCA). The resulting indications for intra-operative TOE were based primarily on its application as a diagnostic tool. During the rapid development of this field, however, it has become apparent that TOE during cardiac surgery is a haemodynamic monitor of unsurpassed value and its use is desirable in *all* patients undergoing cardiac surgery. In this respect, peri-operative TOE differs significantly from diagnostic cardiological TOE, which provides a diagnostic snapshot of the patient's pathology. With TOE monitoring, anaesthetic management of haemodynamic compromise can be carried out on a far better informed basis. As the avail-

**Table 2.** Summary of indications for intraoperative transoesophageal echocardiography (TOE), as described in Society of Cardiovascular Anesthesiologists Guidelines<sup>c</sup>

<p><b>CATEGORY I</b> Indications in which TOE is frequently useful in improving clinical outcome (strongest evidence or expert opinion)</p>	<p><b>Pre-operatively</b> Persistent haemodynamic instability not responding to treatment Unstable patients with suspected thoracic aortic pathology</p> <p><b>Intra-operatively</b> Persistent haemodynamic instability not responding to treatment Valve and hypertrophic obstructive cardiomyopathy (HOCM) repair Congenital heart surgery requiring cardiopulmonary bypass Endocarditis surgery Pericardial window surgery Aortic dissection surgery for aortic valve evaluation</p> <p><b>Post-operatively</b> Haemodynamic instability of unknown aetiology</p>
<p><b>CATEGORY II</b> Indications in which TOE may be useful in improving clinical outcome (weaker evidence or expert opinion)</p>	<p><b>Pre-operatively</b> Assessment of acute aortic pathology</p> <p><b>Intra-operatively</b> Patients with increased risk of myocardial ischaemia, infarction or haemodynamic instability Assessment of:</p> <ul style="list-style-type: none"> <li>- valve replacement</li> <li>- repair of cardiac aneurysms</li> <li>- removal of cardiac tumours</li> <li>- intra-operative detection of foreign bodies</li> <li>- detection of air emboli</li> <li>- cardiac thrombectomy</li> <li>- pulmonary embolectomy</li> <li>- cardiac trauma</li> <li>- thoracic aortic dissections</li> <li>- aortic atheroma and other source of aortic emboli</li> <li>- pericardial surgery</li> <li>- anastomotic sites during heart and lung transplantation</li> <li>- placement of ventricular assist devices</li> </ul>
<p><b>CATEGORY III</b> Indications in which TOE is infrequently useful in improving clinical outcome (little evidence or expert support)</p>	<p>Evaluation of myocardial perfusion, coronary artery anatomy, or graft patency Repair of cardiomyopathies other than HOCM Uncomplicated endocarditis in non-cardiac surgery Monitoring for emboli during orthopaedic procedures Assessment of repair of thoracic injuries Uncomplicated pericarditis Evaluation of pleuropulmonary disease Placement of balloon pumps, internal cardiac defibrillators, pulmonary artery catheters Monitoring of cardioplegia administration</p>

ability of equipment for intra-operative TOE increases, many units in the UK are now achieving the ideal of being able to provide intra-operative TOE for all of their cardiac surgical patients.

In fact, the incidence of unexpected findings on TOE that actually change the surgical procedure is surprisingly high, being approximately 12% for adult cardiac surgical all-comers, and rising to 33% for high-risk coronary artery bypass surgery.<sup>2,5-8</sup>

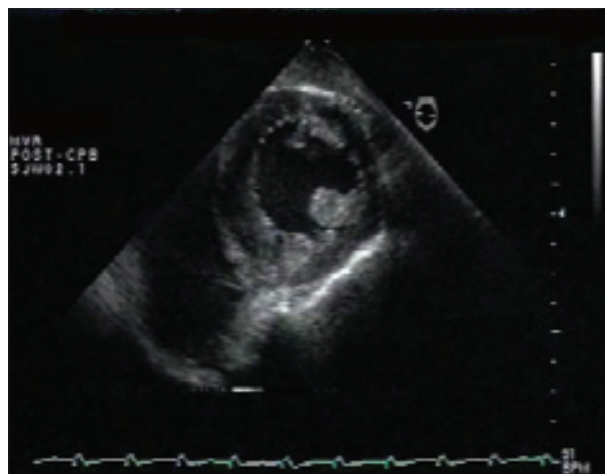
Support for the ranking of indications by the SCA has been provided by several studies,<sup>9,10</sup> which have confirmed that in terms of its influence on clinical decision-making and changes to management, the impact of TOE monitoring is greater for category 1 than for category 2 indications.

### Usefulness of peri-operative TOE and effect on clinical outcome

The usefulness of intra-operative TOE is difficult to refute despite the lack of incontrovertible evidence for a beneficial effect on patient outcome. It is intuitive that the ability to identify and correct complications before the patient leaves the operating theatre, and the ability to make an informed choice of inotrope therapy and volume replacement, means that the patient is less likely to suffer a damaging cardiovascular or vital organ insult.

As an instantaneous indicator of haemodynamic status and response to therapy, TOE exceeds the accuracy and capabilities of all other clinically available haemodynamic monitors. Both function and volume status can be rapidly visually assessed;

**Figure 3.** Transgastric short axis mid-papillary view of the left ventricle, the most informative view for initial assessment of the patient's intra-operative haemodynamic status



indeed visual real-time assessment of left ventricular ejection fraction (LVEF) by experienced operators has been shown to be at least equal in accuracy to offline echocardiographic measurement using Teicholz or Simpson's methods.<sup>11</sup> Preload is easily determined by estimation of left ventricular end-diastolic area.<sup>12</sup> Measurement of transmitral E wave deceleration time and transmitral colour M mode can further refine estimation of left ventricular filling and ventricular diastolic function.<sup>13</sup> Ventricular function, both global and regional, is also readily apparent from standard 2-dimensional imaging. Fractional area change (FAC) measured in the transgastric midpapillary short axis view of the left ventricle (LV) (figure 3) correlates closely with LVEF even in the presence of segmental wall motion abnormalities (SWMAs).<sup>12</sup> Furthermore, the sensitivity of TOE in the detection of regional ischaemia far exceeds that of 12-lead electrocardiogram (ECG) monitoring and ischaemia-induced SWMAs appear much earlier than ECG changes,<sup>14</sup> although it should be borne in mind in the operative setting that acute changes in loading conditions and rhythm can interfere with the interpretation of SWMA.<sup>15</sup> Use of longitudinal imaging planes enhances the sensitivity of TOE in detection of SWMAs.<sup>16</sup> Persistence of new SWMAs to the end of surgery is associated with a likelihood of myocardial damage.<sup>17</sup> These rapid diagnostic capabilities make TOE invaluable for monitoring patients undergoing coronary artery bypass grafting, as a guide for anti-ischaemia therapy<sup>18</sup> and by facilitating early graft revision in the event of inadequate revascularisation.

Although it can be assessed by calculation of ventricular wall stress, because this is a laborious process, afterload is more frequently inferred in the intra-operative setting by consideration of echo appearances and knowledge of arterial and central venous pressures. Cardiac output can be measured by Doppler assessment of aortic or pulmonary artery flow.<sup>19-21</sup>

The observations of Couture *et al.*<sup>22</sup> suggest that the use of

intra-operative TOE in cardiac surgery has the greatest impact on haemodynamic management, leading to alteration of medical management in 53% of patients. In this study, TOE was reported to lead to modification of the planned surgical procedure in 30% and provided useful confirmation of diagnosis in 27%. Utility of TOE was greatest in complex surgical procedures (39%), having less influence on valve replacement (19%) and revascularisation surgery (10%). Other studies report similarly impressive rates of intervention on the basis of intra-operative TOE findings in cardiac surgical patients.<sup>2,5-8</sup>

### Limited data

There are few data on the effectiveness of peri-operative TOE in the UK clinical setting. Data from Papworth Hospital<sup>23</sup> suggest that in 20% of patients there was a change of surgical procedure as a result of on-table TOE, which is much higher than the rate reported from the US. The investigators propose that this figure reflects the lower likelihood of pre-operative TOE examinations in the UK cardiac surgical population. It is suboptimal for the surgical team to be making clinical decisions regarding the nature of the surgical procedure after the induction of anaesthesia for surgery, since this practice precludes the possibility of fully informed discussion with the patient before surgery and is clouded by the difficulty of having to take into account the haemodynamic effects of anaesthesia on the lesion in question.

In particular, mitral regurgitation (MR) is notoriously difficult to assess on table, because the severity of regurgitation is profoundly sensitive to the effects of general anaesthesia and there is a real danger of underestimating the degree of MR in the anaesthetised patient.<sup>24-26</sup> To some extent, this can be counteracted by administering vasoconstrictors prior to echo assessment, but it is impossible to reproduce the awake haemodynamic state accurately. The role of intra-operative TOE in mitral valve surgery is, however, well supported by several large series. While the pre-cardiopulmonary bypass (CPB) TOE study leads to modifications to the planned surgical procedure in 9–14% of patients undergoing mitral valve surgery,<sup>5,6,27,28</sup> the rate of immediate return to CPB for surgical revision of a persistent valve abnormality post-CPB has been reported to be 5–12%.<sup>27,28</sup>

Several studies have examined the impact of TOE monitoring on the peri-operative management of patients undergoing non-cardiac surgery.<sup>29,30</sup> TOE has been found to influence management in more than 80% of patients studied<sup>30</sup> and its impact has been described as 'major' in 15% (i.e. resulting in a change to surgical procedure, anaesthetic management or in guiding the treatment of life-threatening events), although this high yield does, in part, reflect the highly selective use of TOE in non-cardiac surgery. The influence of TOE has been observed to be greatest in patients who have SCA category 1 indications for intra-operative TOE (most commonly haemodynamic instability).<sup>29</sup>

In the post-operative period, TOE has much to offer the patient. Transthoracic ultrasound signals are obstructed by dressings, drains and by the lungs in patients receiving positive pressure ventilation, making transthoracic echo (TTE) studies difficult



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**CONTRA-INDICATIONS:** Hypersensitivity to ezetimibe, simvastatin, or to any of the excipients. Pregnancy and lactation. Active liver disease or unexplained persistent elevations in serum transaminases. Concomitant administration of potent CYP3A4 inhibitors (e.g., itraconazole, ketoconazole, erythromycin, clarithromycin, telithromycin, HIV protease inhibitors and nefazodone).

**PRECAUTIONS:** *Myopathy/Rhabdomyolysis:* In post-marketing experience with ezetimibe, cases of myopathy and rhabdomyolysis have been reported. Most patients who developed rhabdomyolysis were taking a statin concomitantly with ezetimibe. However, rhabdomyolysis has been reported very rarely with ezetimibe monotherapy and very rarely with the addition of ezetimibe to other agents known to be associated with increased risk of rhabdomyolysis. Simvastatin, like other HMG-CoA reductase inhibitors, occasionally causes myopathy manifested as muscle pain, tenderness or weakness with creatine kinase (CK) above 10 X the upper limit of normal (ULN). Myopathy sometimes takes the form of rhabdomyolysis with or without acute renal failure secondary to myoglobinuria, and very rare fatalities have occurred. The risk of myopathy/rhabdomyolysis is dose related for simvastatin. *CK measurement:* CK should not be measured following strenuous exercise or in the presence of any plausible alternative cause of CK increase. If CK levels are significantly elevated at baseline ( $>5$  X ULN), measure levels again within 5 to 7 days. *Before treatment:* Advise all patients starting therapy, or in whom the dose is being increased, of the risk of myopathy and to report promptly any unexplained muscle pain, tenderness or weakness. Exercise caution in patients with pre-disposing factors for rhabdomyolysis. Measure CK level before starting treatment in the following: elderly (age  $>70$  years); renal impairment; uncontrolled hypothyroidism; personal or familial history of hereditary muscular disorders; previous history of muscular toxicity with a statin or fibrate; alcohol abuse. In these situations, clinical monitoring is recommended. If a patient has previously experienced a muscle disorder on a fibrate or a statin, initiate treatment with caution. If CK levels are significantly elevated at baseline ( $>5$  X ULN), treatment should not be started. Whilst on treatment: If muscle pain, weakness or cramps occur measure CK levels and stop treatment if found to be significantly elevated ( $>5$  X ULN). If muscular symptoms are severe even if CK levels are  $<5$  X ULN, consider discontinuation. Discontinue if myopathy is suspected for any other reason. If symptoms resolve and CK levels return to normal, then re-introduction of INEGY or another statin-containing product may be considered at the lowest dose and with close monitoring. Stop therapy temporarily a few days prior to elective major surgery and when any major medical or surgical condition supervenes. *Measures to reduce the risk of myopathy caused by interactions:* The risk of myopathy and rhabdomyolysis is significantly increased by concomitant use with potent inhibitors of CYP3A4 (such as itraconazole, ketoconazole, erythromycin, clarithromycin, telithromycin, HIV protease inhibitors, nefazodone, whose concomitant use is contra-indicated), as well as ciclosporin, danazol and gemfibrozil. If treatment with itraconazole, ketoconazole, erythromycin, clarithromycin or telithromycin is unavoidable, suspend therapy with INEGY during the course of treatment. The risk of

myopathy and rhabdomyolysis is also increased by concomitant use of other fibrates, lipid-lowering doses ( $\geq 1$  g/day) of niacin or by concomitant use of amiodarone or verapamil with higher doses of INEGY. There is also a slight increase in risk when diltiazem is used with the 10/80 mg dose. Concomitant intake with grapefruit juice should be avoided. Do not exceed 10/10 mg\* daily in patients receiving concomitant medication with ciclosporin, danazol or lipid-lowering doses ( $\geq 1$  g/day) of niacin. Weigh the benefits of the combined use with ciclosporin, danazol or niacin carefully against the potential risks of these combinations. Monitor ciclosporin concentrations in patients receiving INEGY and ciclosporin. The combined use of INEGY at doses higher than 10/20 mg daily with amiodarone or verapamil should be avoided unless the clinical benefit outweighs the increased risk of myopathy. Liver enzymes: Perform liver function tests before treatment and thereafter when clinically indicated. Patients titrated to the 10/80 mg dose should receive an additional test prior to titration, 3 months after titration to the 10/80 mg dose, and periodically thereafter (e.g., semi-annually) for the first year of treatment. Pay special attention to patients who develop elevated serum transaminase levels. Use cautiously in patients who consume substantial quantities of alcohol. *Hepatic insufficiency:* Not recommended in patients with moderate or severe hepatic insufficiency. *Other interactions:* *Cholestyramine:* Concomitant cholestyramine administration decreased the mean AUC of total ezetimibe approximately 55%. The incremental low-density lipoprotein cholesterol (LDL-C) reduction due to adding INEGY to cholestyramine may be lessened by this interaction. *Warfarin and other coumarin anticoagulants:* Very rare cases of elevated INR have been reported. Prothrombin time should be determined before starting INEGY and frequently enough to ensure that no significant alteration of prothrombin time occurs. *Fibrates:* concomitant use not recommended. \*The 10/10 mg tablet is not marketed in the UK. This dose can be met by co-administering 10 mg of each of ezetimibe and simvastatin.

**SIDE EFFECTS:** Refer to SPC for complete information on side effects. **Clinical Studies:** The frequencies of adverse events are ranked according to the following: Very common ( $\geq 1/10$ ), Common ( $\geq 1/100$ ,  $< 1/10$ ), Uncommon ( $\geq 1/1000$ ,  $< 1/100$ ), Rare ( $\geq 1/10,000$ ,  $< 1/1000$ ), Very rare ( $< 1/10,000$ ) including isolated reports. *INEGY: Nervous system disorders:* Common: headache. *Gastro-intestinal disorders:* Common: flatulence. *Musculoskeletal, connective tissue, and bone disorders:* Common: myalgia. *Laboratory values:* The incidence of clinically important elevations in serum transaminases (ALT and/or AST  $\geq 3$  X ULN, consecutive) was 1.7% for patients treated with INEGY. Clinically important elevations of CK ( $\geq 10$  X ULN) were seen in 0.2% of the patients treated with INEGY. *Post-marketing experience:* Adverse reactions reported for INEGY are consistent with those previously reported with ezetimibe and/or simvastatin. In addition to the above, other side effects reported with one of the individual components may be potential undesirable effects with INEGY. *Ezetimibe:* Blood and lymphatic system disorders: Very rare: thrombocytopenia. *Gastro-intestinal disorders:* Common: abdominal pain, diarrhoea. Rare: nausea. Very rare: pancreatitis. *Hepato-biliary disorders:* Rare: hepatitis. Very rare: cholelithiasis, cholecystitis. *Skin and subcutaneous tissue disorders:* Rare: hypersensitivity reactions, including rash, urticaria and very rarely, angioedema. *Musculoskeletal, connective tissue disorders:* Rare: arthralgia. Very rare: myopathy/rhabdomyolysis. *General disorders and administration site conditions:* Common: fatigue. *Laboratory values:* Rare: increased transaminases, increased CK. *Simvastatin: Blood and lymphatic system disorders:* Rare: anaemia. *Nervous system disorders:* Rare: dizziness, paraesthesia, peripheral neuropathy. *Gastro-intestinal disorders:* Rare: constipation, abdominal pain, dyspepsia, diarrhoea, nausea, vomiting, pancreatitis. *Hepato-biliary disorders:* Rare: hepatitis/jaundice. *Skin and subcutaneous tissue disorders:* Rare: rash, pruritus, alopecia. *Musculoskeletal, connective tissue and bone disorders:* Rare: myopathy, rhabdomyolysis, muscle cramps. *General disorders and administration site conditions:* Rare: asthenia. A hypersensitivity syndrome has been reported rarely which includes some of the following features: angioedema, lupus-like syndrome, polyarthralgia, rheumatism, dermatomyositis, vasculitis, thrombocytopenia, eosinophilia, red blood cell sedimentation rate increased, arthritis and arthralgia, urticaria, photosensitivity reaction, pyrexia, flushing, dyspnoea and malaise. *Laboratory values:* Rare: increases in  $\gamma$ -glutamyl transaminase, elevated alkaline phosphatase.

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### Key messages

- Intra-operative TOE influences anaesthetic decision-making as much as it influences the surgical procedure
- The operating theatre environment presents several challenges to the echocardiographer; knowledge of the sequence and significance of surgical and anaesthetic events is vital to accurate image interpretation
- The use of TOE in cardiac surgery has been validated in terms of its impact on intra-operative decision-making during a variety of cardiac surgical procedures. It has not been shown to improve outcome from cardiac surgery

and uninformative. A number of studies examining the use of TOE in ITU have reported unexpected findings in up to 59% of patients studied, and TOE findings have influenced clinical decision-making directly in 8–24%.<sup>31-37</sup>

Although it is often difficult to achieve adequate acoustic windows with TTE post-operatively, demonstration of a single view (parasternal short-axis) view of the LV) will often provide a considerable amount of information as part of routine assessment of post-operative patients on the ITU to exclude pericardial effusions and prosthetic dysfunction at an early stage. Subsequent selective use of TOE may further clarify haemodynamic status if required.

### Summary

The introduction of intra-operative TOE has transformed decision-making in the cardiac surgical theatre. It has also changed the working relationship between surgeons, anaesthetists and cardiologists, and has elevated teamwork, communication and mutual understanding to a new level.

There is no evidence, however, that TOE-led changes to surgical procedures or medical management of patients influence eventual clinical outcome. The widespread acceptance of TOE as an invaluable peri-operative tool means that the required prospective randomised trial may prove ethically impossible to perform.

### Conflict of interest

None declared.

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**Table showing practical considerations and tips for non-anaesthetic echocardiographers visiting the operating theatre****Pre-bypass period**

- Transoesophageal echocardiography (TOE) can be very distracting to others involved in patient care and can also obstruct anaesthetic access to infusion pumps etc
- General anaesthesia is usually associated with mild myocardial depression and significant vasodilatation, both systemic and pulmonary. This will affect the appearance and severity of many lesions, e.g. mitral regurgitation (MR), hypertrophic obstructive cardiomyopathy (HOCM) mitral systolic anterior motion (SAM)
- The operating theatre environment has high ambient light and the temptation is to set gain too high
- Diathermy interferes with imaging to varying degrees and may make imaging impossible for a while. The busiest time for diathermy is dissection at the start of surgery.
- During redo surgery it is worthwhile to image the right ventricle during sternotomy because sawing into an adherent right ventricle (RV) will be accompanied by the immediate appearance of air in the RV cavity
- Pre-cardiopulmonary bypass (CPB) time is limited. It is, however, desirable still to perform a complete examination pre-CPB because the incidence of significant unexpected findings is high (see text)
- The pericardium is opened early in the procedure. Effusions should therefore be assessed early (feedback on estimations of volume can be gained from volume in the surgical suction bottle)
- If bicaval cannulation is to be performed, central venous catheter tip position should be checked early in the examination sequence so that, if necessary, the line can be withdrawn from the right atrium before the superior vena cava is cannulated and snared (obstructing pressure measurement and drug administration through the catheter)
- It is rarely (if ever) possible to image the aortic cannulation site with TOE; it lies in the TOE 'blind spot' obscured by the intervening carina
- Moderate/severe arch or descending aortic atheroma should prompt consideration of epiaortic scanning of the proposed aortic cannulation site by the surgeon to exclude the presence of significant atheroma prior to insertion of the cannula
- Anaesthetists frequently vasodilate patients in order to reduce aortic pressure to facilitate safe aortic cannulation. This manipulation may influence TOE assessment of severity of lesions
- Preload may be compromised profoundly when surgeons lift the pericardium to improve exposure (allow time for administration of intravenous fluids and spontaneous recovery before making haemodynamic assessments)
- Continuous administration of aprotinin causes a steady stream of micro bubbles to pass through the right heart
- During off-pump cardiac surgery, extreme cardiac contortion can make imaging impossible or difficult to interpret
- If cardioplegia is going to be used to arrest the heart on CPB, the degree of aortic insufficiency (if any) should be assessed pre-CPB to aid decision-making on the method of cardioplegia administration (via aortic root or via coronary ostia)
- Transgastric imaging is much easier (because it is tolerated) in anaesthetised, paralysed patients

**Cardiopulmonary bypass (CPB)**

- Having assessed an intracardiac lesion pre-CPB, it is vital to stay and observe the lesion by direct vision when the heart is opened (the best feedback and learning tool available)
- There is potential for oesophageal mucosal burns if the TOE probe is left emitting sound (and heat) in the patient during the low-pressure state of CPB. This predisposes the patient to oesophageal perforation. The probe/machine should be turned off when not in use on CPB
- TOE can help to identify passage of cardioplegia through an incompetent aortic valve into the LV and can monitor surgical intervention to avoid LV distension
- It is not possible to assess prosthetic or ventricular function while the patient is still on cardiopulmonary bypass as it is virtually impossible to reproduce normal loading conditions while on CPB
- A satisfactorily de-aired left heart may refill with air that has been resting in the pulmonary veins when the heart is refilled or the pulmonary veins manipulated at the end of bypass

**Post-bypass period**

- The transgastric midpapillary short axis view of the left ventricle (LV) is the 'haemodynamic home page'; it is the best view to acquire during separation from bypass because it is the most reliable plane for detection of ischaemia-related segmental wall motion abnormalities (SWMAs), while also allowing rapid assessment of global LV function and volume status of the patient. Sensitivity for detection of SWMAs is further increased by subsequent use of multiple plane images of the LV
- Residual air in the left heart after open procedures is likely to flow into the right coronary artery (RCA) when the heart starts to eject because the right coronary artery ostium is most superior in the supine patient. Air is frequently visible by TOE in the affected area of myocardium as a fine white speckled appearance. The resulting SWMAs in the inferior wall usually take 30–40 minutes to resolve. Distinction from ischaemia due to an obstructed coronary anastomosis can be difficult
- Surgical swabs placed behind the heart will compromise image quality
- The appearance of SAM of the anterior mitral leaflet e.g. post MV repair should only be considered significant once haemodynamic predisposing factors have been eliminated (i.e. hypovolaemia has been corrected, inotropes and vasodilators reduced or switched off. Vasoconstrictor administration may help)
- Protamine, which is given routinely to reverse the heparinisation required for CPB, can cause idiosyncratic pulmonary vasoconstriction which can cause catastrophic RV failure and dilatation
- Epicardial ventricular pacing is commonly used in the post-CPB period (particularly if cardioplegia has been used); septal wall motion abnormalities may result