Peri-operative transoesophageal echocardiography

SUSAN WRIGHT

Abstract

Peri-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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Susan Wright

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.[1] The US National Board of Echocardiography established certification in peri-operative TOE in 1997. Since then certification has 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.[2]

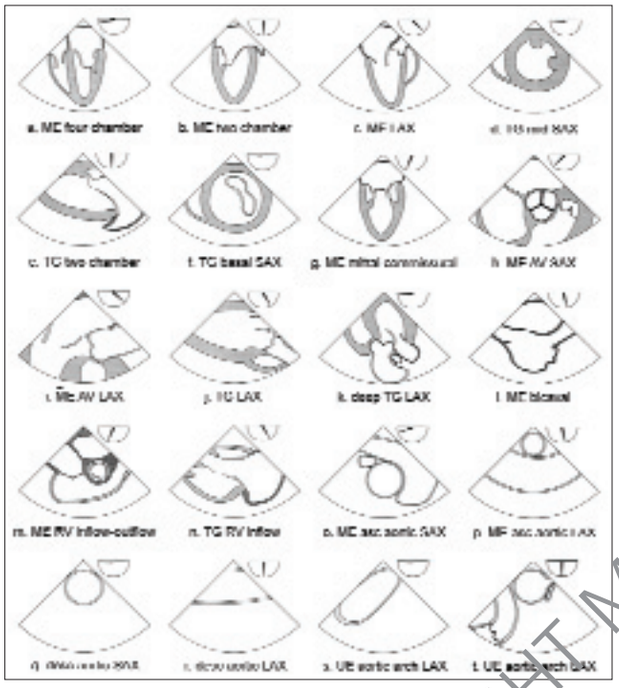
Practical considerations

Shanewise *et al*. described 20 conventional TOE imaging planes that together constitute a comprehensive peri-operative TOE examination[3] (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*.[3]



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

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

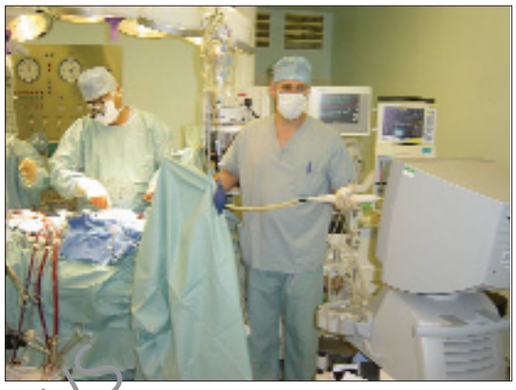


Table 1. Complications of intra-operative transoesophageal echocardiography

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

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 according to the usefulness of TOE during the operation (table 2).[4] 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[c]

CATEGORY I **Indications in which TOE is frequently useful in improving clinical outcome (strongest evidence or expert opinion)**	**Pre-operatively** Persistent haemodynamic instability not responding to treatment Unstable patients with suspected thoracic aortic pathology **Intra-operatively** 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 **Post-operatively** Haemodynamic instability of unknown aetiology
CATEGORY II **Indications in which TOE may be useful in improving clinical outcome (weaker evidence or expert opinion)**	**Pre-operatively** Assessment of acute aortic pathology **Intra-operatively** Patients with increased risk of myocardial ischaemia, infarction or haemodynamic instability Assessment of: - valve replacement - repair of cardiac aneurysms - removal of cardiac tumours - intra-operative detection of foreign bodies - detection of air emboli - cardiac thrombectomy - pulmonary embolectomy - cardiac trauma thoracic aortic dissections - aortic atheroma and other source of aortic emboli - pericardial surgery - anastomotic sites during heart and lung transplantation - placement of ventricular assist devices
CATEGORY III **Indications in which TOE is infrequently useful in improving clinical outcome (little evidence or expert support)**	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

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.[2,5-8]

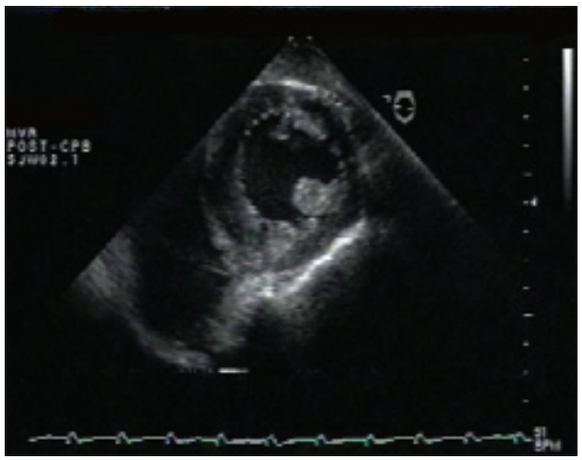
Support for the ranking of indications by the SCA has been provided by several studies,[9,10] which have confirmed that in terms of its influence on clinical decision-making and changes to management, the impact of TOE monitoring is greater for category 1 than for category 2 indications.

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.[11] Preload is easily determined by estimation of left ventricular end-diastolic area.[12] Measurement of transmitral E wave deceleration time and transmitral colour M mode can further refine estimation of left ventricular filling and ventricular diastolic function.[13] 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).[12] 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,[14] 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.[15] Use of longitudinal imaging planes enhances the sensitivity of TOE in detection of SWMAs.[16] Persistence of new SWMAs to the end of surgery is associated with a likelihood of myocardial damage.[17] These rapid diagnostic capabilities make TOE invaluable for monitoring patients undergoing coronary artery bypass grafting, as a guide for anti-ischaemia therapy[18] 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.[19-21]

The observations of Couture *et al*.[22] 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.[2,5-8]

Limited data

There are few data on the effectiveness of peri-operative TOE in the UK clinical setting. Data from Papworth Hospital[23] 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.[24-26] 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,[5,6,27,28] the rate of immediate return to CPB for surgical revision of a persistent valve abnormality post-CPB has been reported to be 5–12%.[27,28]

Several studies have examined the impact of TOE monitoring on the peri-operative management of patients undergoing non-cardiac surgery.[29,30] TOE has been found to influence management in more than 80% of patients studied[30] 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).[29]

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

References:
1. Ballantyne CM, Abate N, Yuan Z, et al. Dose-comparison study of the combination of ezetimibe and simvastatin (Vytorin®) versus atorvastatin in patients with hypercholesterolaemia: The Vytorin Versus Atorvastatin (VYVA) Study. *Am Heart J* 2005;149:464-473. * Vytorin is the trade name of INEGY in the USA.
2. Data on file, Merck Sharp & Dohme Limited and Schering-Plough Limited.
3. Goldberg AC, Sapre A, Liu J, et al. Efficacy and safety of ezetimibe coadministered with simvastatin in patients with primary hypercholesterolaemia: A randomised, double-blind, placebo controlled trial. *Mayo Clin Proc* 2004;79:620-629.
4. Feldman T, Koren M, Insull W Jr, et al. Treatment of high risk patients with ezetimibe plus simvastatin co-administration versus simvastatin alone to attain National Cholesterol Education Program Adult Treatment Panel III low-density lipoprotein cholesterol goals. *Am J Cardiol* 2004;93:1481-1486.
5. Masana L, Mata P, Gagné C, et al. Long-term safety and tolerability profiles and lipid-modifying efficacy of ezetimibe coadministered with ongoing simvastatin treatment: A multicenter, randomised, double-blind, placebo-controlled, 48-week extension study. *Clin Ther* 2005;27(2):174-184.

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%.[3,4,5,7]

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.

References

1. Bennnett S. Personal communication, 2006.
2. Fanshawe M, Ellis C, Habib S *et al*. A retrospective analysis of the costs and benefits related to alterations in cardiac surgery from routine intra-operative Transoesophageal echocardiography. *Anesth Analg* 2002;**95**: 824-7.
3 Shanewise JS, Cheung AT, Aronson S *et al*. ASE/SCA Guidelines for Performing a Comprehensive Intraoperative Multiplane Transesophageal Echocardiography Examination: Recommendations of the American Society of Echocardiography Council for Intraoperative Echocardiography and the Society of Cardiovascular Anesthesiologists Task Force for Certification in Perioperative Transesophageal

Echocardiography. *Anesth Analg* 1999;**89**:870-84.
4. American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography. Practice guidelines for perioperative transesophageal echocardiography. A report by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography. *Anesthesiology* 1996;**84**:986-1006.
5. Click RL, Abel MD, Schaff HV. Intraoperative transesophageal echocardiography: 5 year prospective review of impact on surgical management. *Mayo Clin Proc* 2000;**75**:241-7.
6. Michel-Cherqui M, Ceddaha A, Liu N *et al*. Assessment of systematic use of intraoperative transesophageal echocardiography during cardiac surgery in adults: a prospective study of 203 patients. *J Cardiothorac Vasc Anesth* 2000;14:45-50.
7. Savage RM, Lytle BW, Aronson S *et al*. Intraoperative echo is indicated in high risk coronary artery bypass surgery. *Ann Thorac Surgery* 1997;**64**: 368-73.
8. Mishra M, Chauhan R, Sharma KK *et al*. Real-time intraoperative echocardiography – how useful? Experience of 5,016 cases. *J Cardiothorac Vasc Anesth* 1998:**12**;625-32.
9. Pierre Couture P, Denault AY, McKenty S *et al*. Impact of routine use of intraoperative transesophageal echocardiography during cardiac surgery. *Can J Anesthesia* 2000;**47**:20-6.
10. Kolev N, Brase R, Swanevelder J *et al*. The influence of transesophageal echocardiography on intra-operative decision making. A European multicentre study. *Anaesthesia* 1998;**53**:767-73.
11. Amico AF, Lichtenberg GS, Reisner SA *et al*. Superiority of visual versus computerized echocardiographic estimation of radionuclide left ventricular ejection fraction. *Am Heart J* 1989;**118**:1259-65.
12. Clements FM, Harpole DH, Quill T *et al*. Estimation of left ventricular volume and ejection fraction by two dimensional transesophageal echocardiography: comparison of short axis imaging and simultaneous radionuclide angiography. *Br J Anaesth* 1990;**64**:331-6.
13. Garcia M, Thomas J, Klein A. New Doppler echocardiographic applications for the study of diastolic function. *J Am Coll Cardiol* 1998;**32**:865.
14. Seeberger MD, Cahalan MK, Chu E *et al*. Rapid atrial pacing for detecting provokable demand ischemia in anesthetized patients. *Anesth Analg* 1997;**84**:1180-5.
15. Seeberger M, Cahalan M, Rouine-Rapp K *et al*. Acute hypovolaemia may cause segmental wall motion abnormalities in the absence of myocardial ischemia. *Anesth Analg* 1997;**86**:1252-7.
16. Rouine-Rapp K, Ionescu P, Balea M *et al*. Detection of intraoperative segmental wall-motion abnormalities by transesophageal echocardiography: the incremental value of additional cross sections in the transverse and longitudinal planes. *Anesth Analg* 1996;**83**:1141.
17. Smith J, Cahalan M, Benefiel D *et al*. Intraoperative detection of myocardial ischemia in high-risk patients: electrocardiography versus two-dimensional transesophageal echocardiography. *Circulation* 1985;**72**: 1015-21.
18. Bergquist BD, Bellows WH, Leung JM. Transesophageal echocardiography in myocardial revascularization: II. Influence on intraoperative decision making. *Anesth Analg* 1996;**82**:1139-45.
19. Perrino A, Harris S, Luther M. Intraoperative determination of cardiac output using multiplane transesophageal echocardiography: a comparison to thermodilution. *Anesthesiology* 1998;**89**:350-7.
20. Maslow A, Communale M, Haering J *et al*. Pulsed wave Doppler Measurement of cardiac output from the right ventricular outflow tract. *Anesth Analg* 1996;**83**:466-71.
21. Darmon P, Hillel Z, Mogtader A *et al*. Cardiac output by transesophageal echocardiography using continuous wave Doppler across the aortic valve. *Anesthesiology* 1994;**80**:796-805.
22. Pierre Couture P, Denault AY, McKenty S *et al*. Impact of routine use of intraoperative transesophageal echocardiography during cardiac surgery *Can J Anesthesia* 2000;**47**:20-6.
23. Kneeshaw J, Canty D, Roscoe A *et al*. Perioperative TOE – Does it have an effect on surgical practice? *Echo* 2006;**55**:7-8.
24. Aklog L, Filsoufi F, Flores KQ *et al*. Does coronary artery bypass grafting alone correct moderate ischemic mitral regurgitation? *Circulation* 2001;**104**(suppl I):I68-75.
25. Grewal KS, Malkowski MJ, Kramer CM *et al*. Multiplane transesophageal echocardiographic identification of the involved scallop in patients with flail mitral valve leaflet: intraoperative correlation. *J Am Soc Echocardiogr* 1998;**11**:966-71.
26. Bach DS, Gee JDM. Accuracy of intraoperative transesophageal echocardiography for estimating the severity of functional mitral regurgitation. *Am J Cardiol* 1995;**76**:508-12.
27. Sheikh KH, de Bruijn NP, Rankin JS *et al*. The utility of transesophageal echocardiography and Doppler color-flow imaging in patients undergoing cardiac valve surgery. *J Am Coll Cardiol* 1990;**15**:363-7.
28. Stewart WJ, Currie PJ, Salcedo EE *et al*. Intraoperative Doppler color flow mapping for decision-making in valve repair for mitral regurgitation. Technique and results in 100 patients. *Circulation* 1990;**81**:556-66.
29. Denault AY, Couture P, McKenty S *et al*. Perioperative use of transesophageal echocardiography by anesthesiologists: impact in noncardiac surgery and in the intensive care unit. *Can J Anesthesia* 2002;**49**:287-93.
30. Suriani RJ, Neustein S, Shore-Lesserson L, Konstadt S. Intraoperative transesophageal echocardiography during noncardiac surgery. *J Cardiothorac Vasc Anesth* 1998;**12**:274-80.
31. Font VE, Obarski TP, Klein AL *et al*. Transesophageal echocardiography in the critical care unit. *Cleve Clin J Med* 1991;**58**:315-22.
32. Foster E, Schiller NB. The role of transesophageal echocardiography in critical care: UCSF experience. *J Am Soc Echocardiogr* 1992;**5**:368-74.
33. Chenzbraun A, Pinto FJ, Schnittger I. Transesophageal echocardiography in the intensive care unit: impact on diagnosis and decision-making. *Clin Cardiol* 1994;**17**:438-44.
34. Oh JK, Seward JB, Khandheria BK *et al*. Transesophageal echocardiography in critically ill patients. *Am J Cardiol* 1990;**66**:1492-5.
35. Pearson AC, Castello R, Labovitz AJ. Safety and utility of transesophageal echocardiography in the critically ill patient. *Am Heart J* 1990;**119**:1083-9.
36. Hwang JJ, Shyu KG, Chen JJ *et al*. Usefulness of transesophageal echocardiography in the treatment of critically ill patients. *Chest* 1993; **104**:861-6.
37. Alam M. Transesophageal echocardiography in critical care units: Henry Ford Hospital experience and review of the literature. *Prog Cardiovasc Dis* 1996;**38**:315-28.

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 sub sequent 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 anastamosis 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