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Transesophageal Echocardiography for the Noncardiac Surgical Patient

Annette Rebel, Oksana Klimkina, Zaki-Udin Hassan

Department of Anesthesiology, University of Kentucky Medical Center, Lexington, Kentucky, USA

Transesophageal echocardiography (TEE) has been established as a very valuable asset for patient monitoring during cardiac surgery. The value of perioperative TEE for patients undergoing noncardiac surgery is less clear. This article reviews the technical aspects of TEE and comments on the potential benefit of using TEE as a monitoring modality apart from cardiac surgery. Based on patient's comorbidities and/or injury pattern, TEE is a fast and minimally invasive approach to obtain important hemodynamic information, especially useful in a hemodynamically unstable patient. However, certain requirements for the use of the technique are necessary, most important the development of sufficient echocardiographic skills by the anesthesiologists. Indications, skill requirements, and possible complications of the technique are reviewed.

Key words: Transesophageal echocardiography – TEE – Noncardiac surgery – Perioperative monitoring – Perioperative risk

The value of transesophageal echocardiography (TEE) as diagnostic and monitoring tool during cardiac surgery has been established during the past 2 decades.[1] Although not all patients benefit from TEE during cardiac surgery and its use for cardiac surgery varies among institutions, guidelines have been established to assist with patient selection.[2,3] Recently, the American Society of Anesthesiologists updated their practice guidelines for perioperative TEE use.[4] Recommendations for TEE use for noncardiac surgery were established. TEE can be an important tool during the perioperative period for monitoring patients with significant comorbidities or if hemodynamic instability is anticipated or occurs intraoperatively. Patients with potential benefit of TEE monitoring include those with known or suspected cardiovascular compromise, patients with unexplained persistent hypotension, or unexplained persistent hypoxemia, as well as patients with major thoracic or abdominal trauma. The goal of this article is to review and discuss TEE technique, application, and perioperative use for noncardiac surgical patients. It seems logical that with increased applications of TEE the number of perioperative physicians using TEE will increase as well. Therefore, this article provides introductory information about this excellent

Reprint requests: Annette Rebel, MD, Department of Anesthesiology, University of Kentucky Medical Center, 800 Rose Street, Lexington, KY 40536.
Tel.: 859 323 5956; Fax: 859 323 1080; E-mail: arebe2@email.uky.edu

monitoring tool, including the limitations and contraindications for its use.

TEE Technique and Information

The TEE probe is inserted through the mouth and gently advanced into the esophagus. Depending on the insertion depth, the heart and vasculature can be examined at several levels: upper esophageal, midesophageal, and transgastric.

In addition to insertion depth, other probe manipulations are possible (Fig. 1).

For a standard examination, several views should be obtained (Fig. 2).[5] Views depict cardiac structures at certain angles and depth of probe insertion. Because a 3-dimensional structure (heart chambers/vasculature/heart valves) have a 2-dimensional appearance on the TEE screen, several views are needed to examine one aspect of the heart, and therefore the views shown in Fig. 2 are grouped by evaluation (*e.g.*, ventricle walls, mitral valve, aortic valve). A complete examination should be performed to fully evaluate the heart and vasculature. In an emergency situation, time might only allow a limited examination, focusing on a specific area. However, any attempt should be made to obtain several views to reduce the possibility of artifacts or false information. TEE examination provides information about several structural, functional, and hemodynamic parameters.

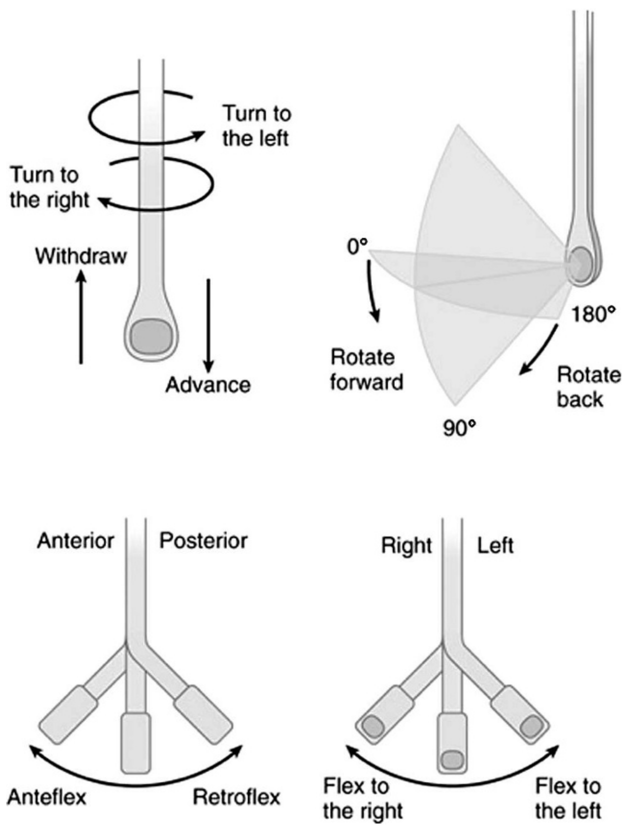

Fig. 1 Transesophageal echocardiography probe manipulations.[5]

Left Ventricle

Left ventricle preload

The filling status of the left ventricle (LV) can be assessed by direct visualization, and can be quantified through estimation of the left atrial pressure or measurements of the LV cavity cross-sectional area.

LV function

The global LV function/ejection fraction can be estimated by measurements of systolic and diastolic cross-sectional area. Several surrogates for ejection fraction can be used and are shown in Fig. 3 (*e.g.*, fractional shortening, fractional area change, or method of discs [modified Simpson's method]). Doppler TEE measurements of flow velocity of left ventricular outflow tract (LVOT) or aortic valve in addition to the size of LVOT obstruction or aortic valve allow for the calculation of the cardiac output.

Contrary to other techniques measuring cardiac output (*e.g.*, Flotrac, pulmonary artery catheter [PAC]), TEE allows visualization of the LV and therefore the evaluation for regional wall motion abnormalities. The heart receives blood through 3 different coronary arteries (right coronary artery, left anterior descending artery, circumflex artery). If hemodynamic instability is related to an acute decrease in myocardial blood flow, it is essential that the cause be identified as early as possible. Actions have to be taken to restore blood supply or to decrease oxygen consumption immediately to avoid permanent loss of function. Hypotension related to regional wall motion abnormalities can be identified instantly by TEE and actions can be taken to restore blood flow. The optimization of myocardial oxygen delivery and consumption can be evaluated immediately.

Although rare, LV outflow tract obstruction can cause a severe hemodynamic instability. The conventional approach to hypotension (vasopressor therapy) worsens the hypotension as it increases the LV afterload and therefore worsens the obstruction. TEE can quickly identify a LVOT obstruction-related hypotension and can guide the restoration of hemodynamics.

Diastolic dysfunction can contribute to hemodynamic instability but rarely is the sole cause.

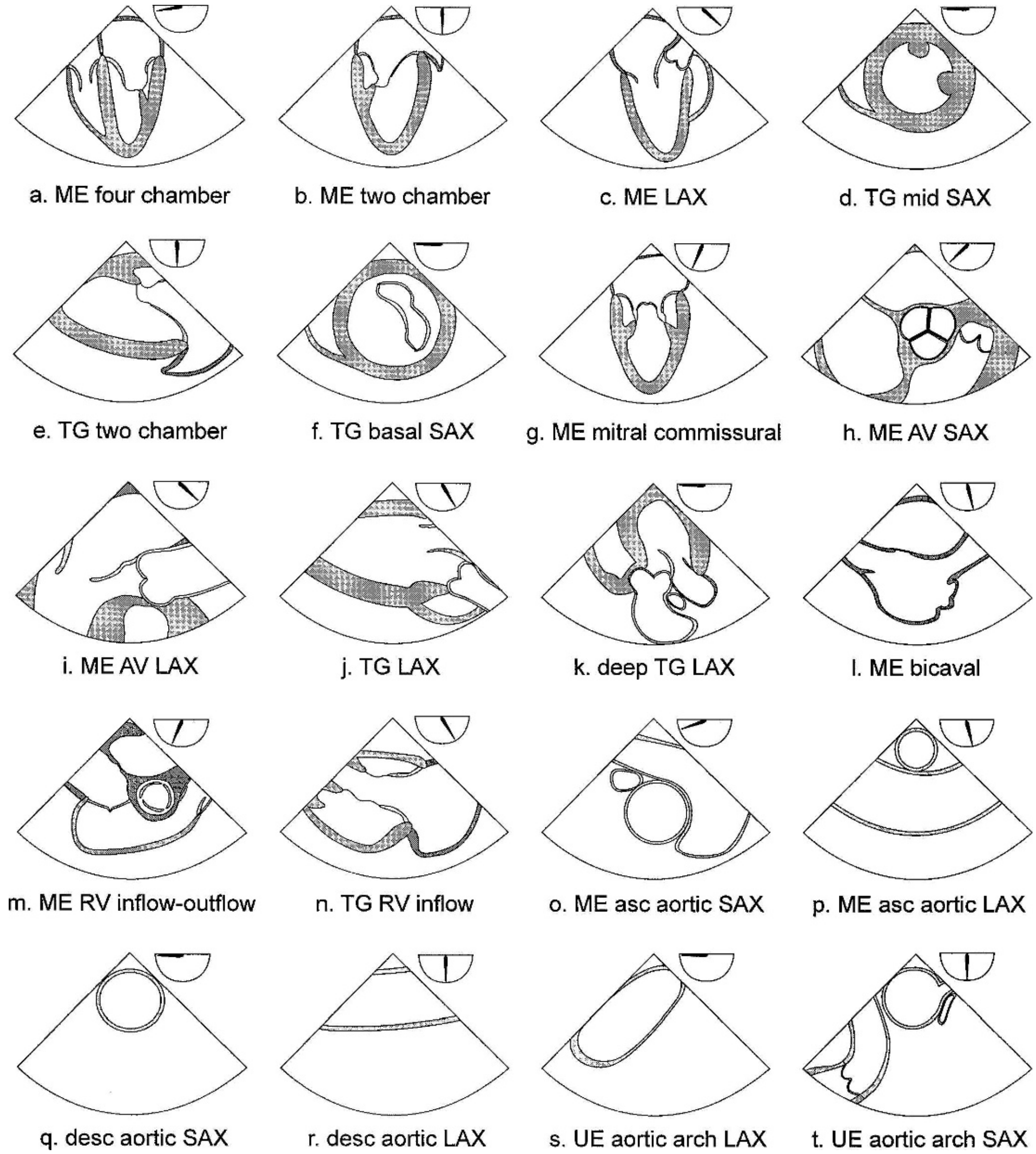

Fig. 2 Standard TEE examination views recommendations.[5] ME, midesophageal; TG, transgastric; UE, upper esophageal; SAX, short axis; LAX, long axis.

However, because it reveals a filling disturbance, the presence of diastolic dysfunction might call for reconsideration of pharmacotherapy and fluid management. TEE can assess the heart for diastolic dysfunction by Doppler measurements of mitral valve velocity and pulmonary venous flow.

Valve Function

All heart valves can be visualized by TEE. The examination of the pulmonary valve can be quite challenging and requires experience and visualization in several views. The other heart valves are usually easy to find. In addition to anatomic information (valve leaflets and valve opening area), valve function can be assessed with Doppler flow measurements. If hypotension is related to valve insufficiency or stenosis, fluid management and vasoactive medication therapy can be guided by TEE monitoring.

Right Heart Evaluation

Function and size of the right ventricle (RV) is more difficult to measure than the LV because of its

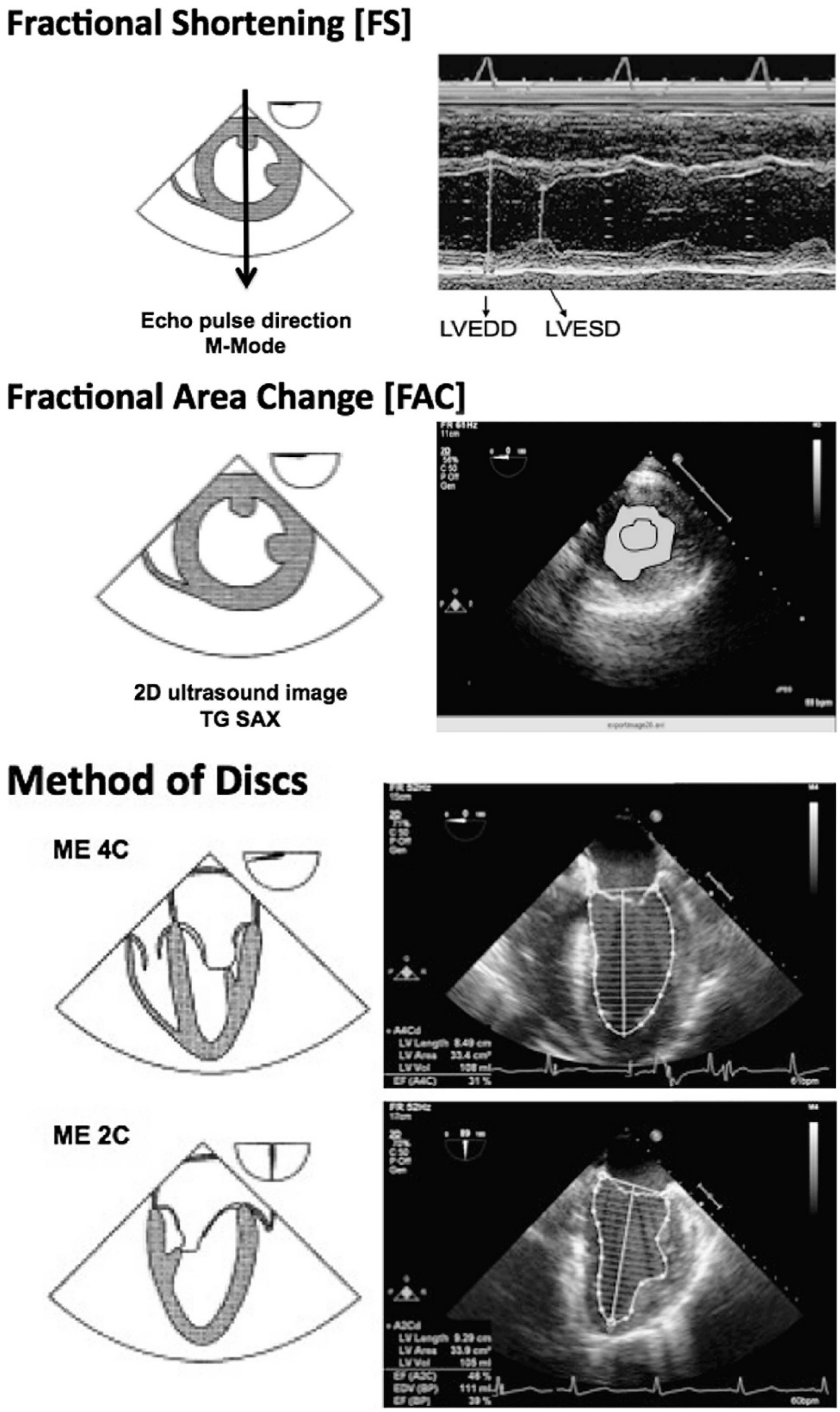

Fig. 3 Assessment of LV function. The graph describes the most common TEE methods to assess global LV function. Fractional Shortening: using the M-Mode (motion mode) modified ejection fraction is estimated as a percentage derived from the midleft ventricular internal diameters measured in end-diastole (LVEDD) and end-systole (LVESD) and is expressed as fractional shortening (%

triangular shape. Therefore, the competency of the right heart can be difficult to assess. Acute right heart dysfunction is easily missed as it rarely causes anatomic changes and the functional changes are subtle. Abnormal motion of the intraventricular septum can indicate a right-sided pressure overload. Tricuspid insufficiency can worsen with acute right heart failure.

The right heart TEE examination can provide valuable information about pulmonary resistance and the severity of pulmonary hypertension. Systolic pulmonary artery pressures can be estimated using the Doppler velocity through the tricuspid valve as the right ventricular pressure equilibrates with the pulmonary systolic pressure when the pulmonary valve is open.

A pulmonary embolus (PE) is rarely seen directly during the TEE examination. However, if a TEE probe is in place during the embolism passage, it can be followed and attempts can be made to prevent embolism movement into the pulmonary artery. If the TEE probe is placed after hypotension occurred secondary to PE, the absence of thrombus in the pulmonary artery does not exclude the diagnosis. PE is strongly considered if acute right heart dysfunction, increased systolic pulmonary artery pressures, and underfilled LV are observed additional to oxygenation/ventilation difficulties. TEE has a 70% sensitivity and 81% specificity for the confirmation of pulmonary embolism and is therefore an acceptable rapid bedside method to assess the possibility for PE.[6]

Vasculature

The portion of the ascending aorta directly after the aortic valve can be examined. However, a small area of the ascending aorta is not accessible to the TEE because of the black-out caused by the trachea or left mainstem bronchus. Aortic arch and descending aorta can be examined until deep below the diaphragm. If a detailed examination of the aorta is needed, epiaortic echocardiography can be performed intraoperatively.

The inferior vena cava (IVC) can be followed into the liver vasculature. IVC respiratory variations have been used to assess volume status and right heart preload.[7] IVC Doppler flow can provide information about right heart function.

Pericardial/Pleural Effusion

TEE examination allows assessment of possible external compression of the heart. Especially in a patient with history of chest trauma, hemodynamic deterioration can be caused by pericardial compression or external compression related to tension pneumothorax.

TEE can be used to guide intravascular device placement, as it directly visualizes right heart inflow tract and intracardiac structures. PAC placement with TEE guidance has been reported.[8] Using the right ventricular inflow/outflow tract view, the PAC can be guided through the right heart into the pulmonary artery without using fluoroscopy. Other devices (pacemaker, biventricular pacemaker lead, and intra-aortic balloon pump) can benefit from TEE guidance.

Patient Selection for Intraoperative TEE Use

Guidelines for the intraoperative TEE use during cardiac surgery are available (Table 1).[3] However, using TEE for perioperative patient management of noncardiac surgery is dependent on patient-based or surgical factors. The decision to use TEE is dependent on the TEE experience of the anesthesia team and the institutional TEE availability. Clinical and surgical factors identifying patient with possible benefit of TEE monitoring are shown in Table 2.

Based on recent guidelines,[4] risk stratification classifies patients with (1) unstable coronary syndrome,

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LV shortening): FS = [(LVEDD − LVESD)/LVEDD] × 100. The measurement can be obtained in the transgastric short axis view (TG SAX) as shown in the graph or in the transgastric long axis view (TG LAX). Fractional Area Change: using the 2-dimensional view of the diameter of the LV in the transgastric short axis view (TG SAX), the diameter of the endocardium is traced in the diastole (end-diastole area, EDA) and systole (end-systole area, ESA) and the fractional area change (FAC) is calculated and used as surrogate index of the LV ejection fraction: FAC = [(EDA − ESA)/EDA] × 100. Method of Discs (also called modified Simpson method): LV volume is calculated in 2 TEE views: the midesophageal 4-chamber (ME 4C) and 2-chamber view (ME 2C). After tracing the endocardial border and defining the mitral annulus and LV apex, the software function calculates the systolic and diastolic LV volume and LV volume change = ejection fraction.

Table 1 Recommendations for the use of intraoperative transesophageal echocardiography use during cardiac surgery[3]

Class I: Conditions for which there is evidence and/or general agreement that intraoperative echocardiography is useful and effective
Evaluation of acute hemodynamic disturbances of uncertain etiology
Surgical repair of valvular lesions, hypertrophic obstructive cardiomyopathy, and aortic dissection
Surgical repair of congenital heart lesions
Surgery for endocarditis
Placement of intracardiac devices
Minimally invasive cardiac surgery
Class IIa: Conditions for which there is conflicting evidence and/or a divergence of opinion: weight of evidence/opinion is in favor of usefulness/efficacy
Valve replacement, cardiac aneurysm repair, cardiac tumors, and pulmonary thromboembolectomy
Heart transplant and ventricular assist device
Coronary artery bypass graft surgery in patients with severely impaired left ventricular function
Class IIb/III: Usefulness/efficacy is less well established by evidence/opinion and in some cases may be harmful
Surgical repair of uncomplicated secundum atrial septal defect repair
Pericardiectomy, pericardial fluid drainage
Coronary artery bypass graft surgery in patients with preserved left ventricular function

(2) decompensated heart failure, (3) significant arrhythmias, and (4) severe valvular disease at high risk for perioperative cardiovascular events. Patients with high perioperative risk should undergo preoperative evaluation to optimize medical condition and possible risk reduction before elective noncardiac surgery. However, depending on comorbidities and clinical condition in combination with surgical invasiveness, intraoperative TEE can help to optimize perioperative care with assessing LV function and volume load, recognize regional wall motion abnormalities early, and guide vasopressor therapy.[9,10]

Although it is questionable whether patients with intermediate risk or low risk benefit from TEE monitoring during noncardiac procedures, the invasiveness or urgency of the surgical procedure will affect the need for TEE monitoring. If a patient presents for an emergent surgical procedure and it is unclear whether the heart failure is compensated or not, TEE assessment and monitoring can help to optimize heart performance.

Anesthesia and the surgical procedure can influence cardiac performance in several ways. Decreased cardiac preload (blood loss, fluid shifts, compressing venous blood flow), afterload changes (anesthetic agents, bowel manipulation, pulmonary emboli), and stress on cardiac compensation (stress, pain, tachycardia, anemia) can affect intraoperative hemodynamics. TEE provides selective functional and anatomic information to differentiate the underlying disturbance and therefore might be superior to other invasive monitors.

The American Society of Anesthesiologists practice guidelines recommend that TEE be used when

Table 2 Predictors for increased perioperative cardiovascular risk[15]

Patient-based risk factors	High risk	Intermediate risk	Low risk
	Unstable coronary syndrome Acute or recent MI Unstable or severe angina	Mild angina or previous MI	Advanced age
	Decompensated heart failure	Compensated heart failure	Low functional capacity
	Significant arrhythmias	Insulin dependent diabetes mellitus	Abnormal ECG, rhythm other than sinus rhythm
	Severe valvular disease	Advanced renal insufficiency	History of CVA, uncontrolled HTN
Surgical factors	Risk >5%	Risk <5%	Risk <1%
	Emergent major operation	Carotid endarterectomy	Endoscopic procedures
	Aortic or major vascular surgery	Head and neck surgery	Superficial procedures
	Peripheral vascular surgery	Intraperitoneal and intrathoracic surgery	Cataract surgery
	Procedure with anticipated large volume shifts and/or blood loss	Orthopedic and prostate surgery	Breast surgery

CVA, cardiovascular accident; ECG, electrocardiogram; HTN, hypertension; MI, myocardial infarction.

the nature of the surgery or the patient's known or suspected cardiovascular pathology might result in severe hemodynamic, pulmonary, or neurologic compromise.[4] TEE should be used when unexplained life-threatening hemodynamic instability persists despite corrective therapy if equipment and expertise is available.

TEE and Hemodynamic Instability

Intraoperative hemodynamic instability can occur unexpectedly. Survival and avoidance of neurologic deficit will depend on how long it took to restore acceptable organ blood flow. Actions to restore and stabilize acceptable hemodynamics as soon as possible will depend on an accurate diagnosis of the underlying cause. TEE can be placed quickly (<5 minutes) and can immediately provide information about heart pump function (acute myocardial infarction [MI] or PE), heart filling status (hypovolemia, PE), or obstructive flow patterns, which would not have been easily diagnosed (cardiac tamponade, LVOT). Examples of LVOT obstruction and pericardial effusion are shown in Figs. 4 and 5. Situations like this can occur in any patient at any time perioperatively. Because the management of MI, pulmonary embolism, hypovolemia, or obstruction is fundamentally different, the early placement of TEE can significantly assist in forming and optimize the treatment plan.[4,11,12]

Case examples

Case 1

A 83-year-old patient without any preexisting cardiac or pulmonary problems is brought to the operating room from the emergency department for hip arthroplasty because of traumatic femoral neck fracture. Despite aggressive fluid resuscitation with 3 L of intravenous fluid the patient remained hypotensive. After anesthesia induction a TEE probe is placed to evaluate the cause of persistent hypotension. The TEE examination demonstrates severe global hypokinesis of the LV with estimated ejection fraction of 10%. Inotropic support is initiated and surgery is postponed to the next day after optimization of the cardiac status. Placement of a PAC with cardiac output measurement would have been another option to evaluate cardiac preload/volume status and cardiac performance of this patient. However, it would not supersede TEE by invasiveness and timeliness of the data acquisition.

Case 2

A 50-year-old patient with a history of coronary artery disease presents for elective bronchoscopy and mediastinoscopy. After induction of general anesthesia the patient remains profoundly hypotensive despite intravenous fluid administration and without response to vasoactive medications. A TEE probe is inserted to evaluate the cause of the refractory hypotension. Based on assessment of ventricle size and respiratory variation of IVC diameter, the patient appears hypovolemic. The assessment of the LV shows severe septal hypertrophy causing a dynamic LVOT obstruction. An example of LVOT seen with TEE is demonstrated in Fig. 4. With further aggressive volume resuscitation (2 L) and small doses of beta blocker under TEE guidance, the hemodynamic condition improves and the planned surgery can proceed. After recovery, the patient is advised to contact a cardiologist for evaluation and management of the hypertrophic obstructive cardiomyopathy. The TEE use in this case has been the only option for fast and accurate diagnosis of the cause of persistent hypotension. Not only has the TEE use in this case improved the patient's condition; it also has diagnosed a new cardiac pathology with significant implication for future patient care.

TEE and the Trauma Patient

When a trauma patient is brought to the operating room or critical care unit, basic medical information is usually not available. If hemodynamic instability does not respond to volume resuscitation and obvious blood loss is not present, cardiac performance can be quickly assessed using TEE. Information about pre-existing disease can be obtained (previous or acute MI, valvular dysfunction, or intracardiac devices). Traumatic injuries can be examined and TEE information can help with surgical decisions (thoracic aortic dissection, cardiac tamponade, tension pneumothorax, myocardial contusion).[12,13] However, because the stability of the cervical spine is commonly still in question when the trauma patient is taken to the operating room, the placement of the TEE probe must be done as carefully as possible (see Table 4 on Contraindications). In addition, it should be remembered that all ''trauma patients'' are considered to have high gastric volumes (''full stomach'') and therefore are at higher risk for viscous rupture. If there is any suspicion for viscous rupture, TEE probe placement should be withheld. Utilization of TEE should only

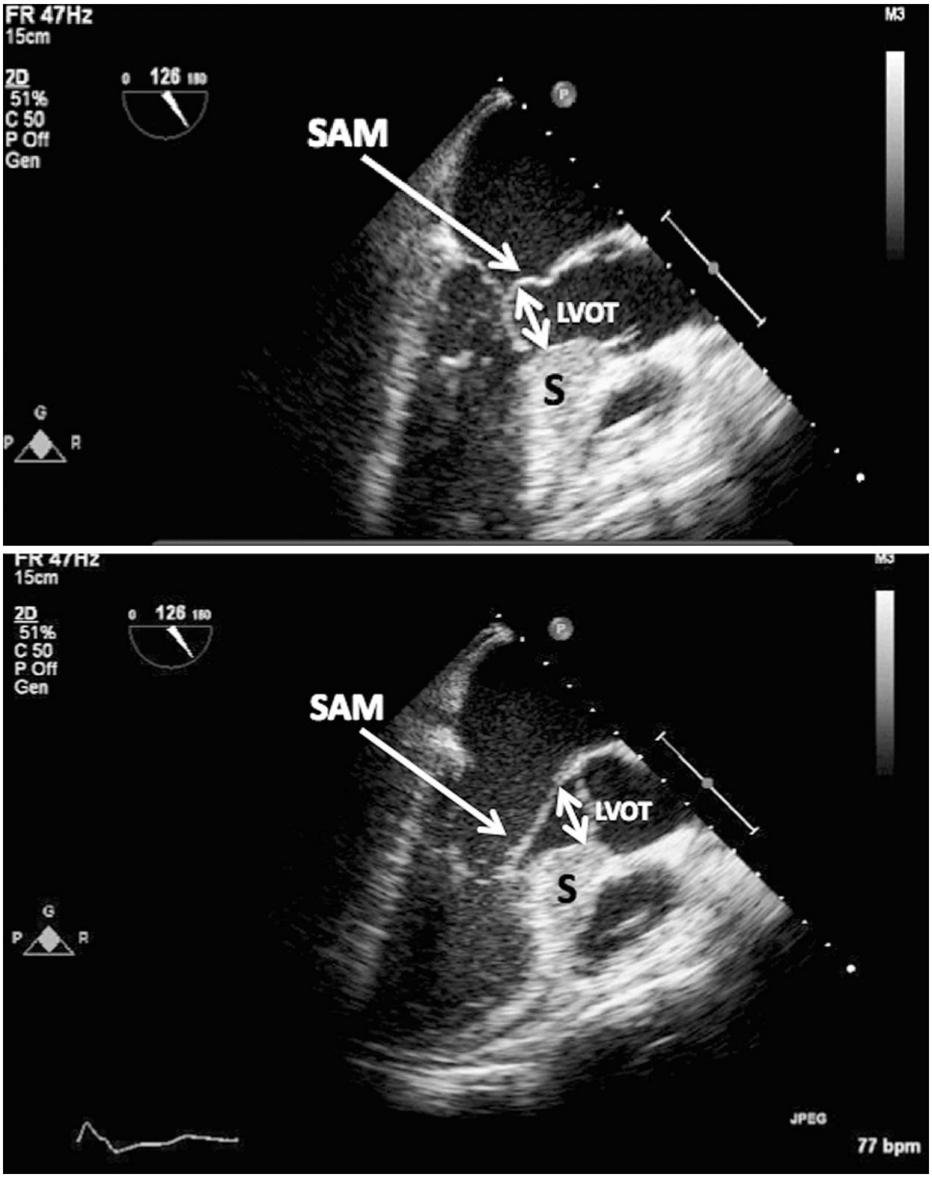

Fig. 4 Left ventricular outflow tract obstruction. In midesophageal long axis view (ME LAX), the left ventricular outflow tract is assessed. The image shows septum hypertrophy (S) and systolic anterior motion of the anterior mitral valve leaflet (SAM), causing a narrowing of the left ventricular outflow tract (LVOT). In the lower image the LVOT is completely occluded by SAM.

be considered in a trauma patient if severe hemodynamic instability is present and TEE information is crucial for the medical/surgical management.

After blunt chest trauma, injury to heart and great vessel can occur.[13] Blunt aortic injuries occur in less than 1% of all motor vehicle collisions (MVC) but cause about 16% of MVC-related deaths.[14] Plain chest radiography is highly insensitive in detecting blunt aortic injuries. This injury can be easily missed when a patient is taken to the operating room for another surgical procedure. Traumatic aortic injury can range from an intimal tear, intramural hematoma, to complete dissection. Because progression from small injury to life-threatening pathology can occur rather rapidly, trauma patients with widened mediastinum or suspicious trauma pattern should be assess early to rule out thoracic aortic injury. If other diagnostic options are not accessible or the patient is unstable, TEE can be a useful tool for the rapid evaluation of the thoracic organs.[9] An example of TEE images of an ascending aortic dissection is shown in Fig. 6.

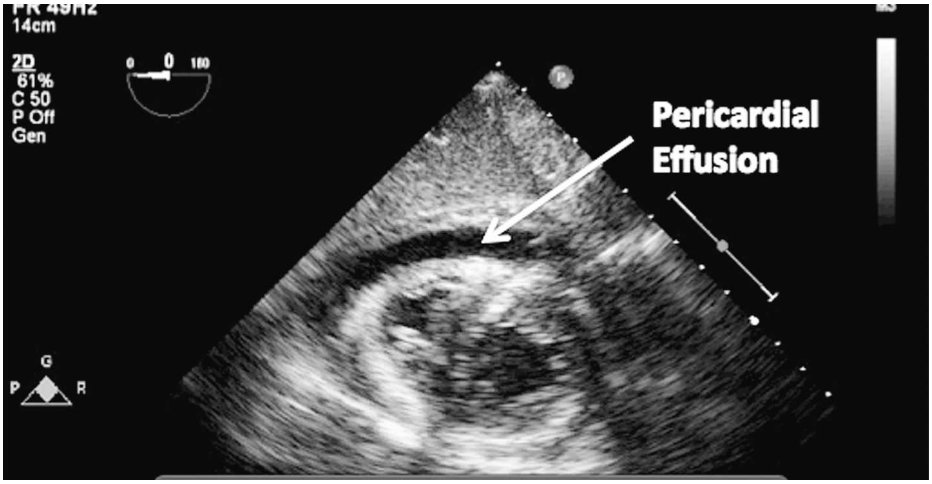

Fig. 5 Pericardial effusion. In transgastric short axis view (TG SAX), fluid accumulation around the heart in the pericardial space is shown.

However, the nonelective situation can also complicate the use of TEE in trauma patients. Visualization of cardiac and vascular structures can be more difficult with full stomach or nasogastric tube in place. The possibility of hidden viscous rupture of the esophagus might expose the trauma patient to increased risk for TEE-related complications.

Case examples

Case 3

A 30-year-old patient is brought to the operating room after MVC for open reduction and internal fixation (ORIF) of an open femur fracture. Shortly after the surgery starts, the radiologist calls into the operating room because of finding a widening mediastinum on the chest X-ray taken in the emergency room. The anesthesiologist performs a TEE examination while the orthopedic surgery proceeds and finds a traumatic aortic dissection. Because the patient is hemodynamically stable and the orthopedic procedure is of short duration, the ORIF of the femur is completed and then the patient undergoes a thoracic aortic repair. The utilization of TEE in this case definitely has optimized the patient management and saved time. Another option would have been to abort the orthopedic procedure and to transport the patient to the radiology department for angiography or intravenous contrast computed tomography (CT) scan for thoracic aorta assessment.

Case 4

A 30-year-old patient after an MVC is brought emergently to the operating room because of hemodynamic instability with chest trauma, suspecting a traumatic aortic injury. Simultaneously, while the surgeon opens the left thorax, ligates bleeding pleural vessels, and evacuates blood, the anesthesiologist performs a TEE examination. The TEE examination does not show signs of aortic injury. However, not all parts of the thoracic aorta can be examined. Therefore the surgeon decides to perform an epiaortic examination in conjunction with the TEE. The epiaortic study includes using an echocardio probe in a sterile sleeve directly applied to the ascending aorta and aortic arch. In this patient, the epiaortic study confirms the diagnosis of traumatic thoracic aortic dissection. The alternatives, a contract CT of the chest or angiography, would not have been a good diagnostic option because of the hemodynamic instability and ongoing hemothorax. The TEE examination by itself has not been helpful for the diagnosis, therefore additional echocardiographic options (*e.g.*, epiaortic exam) might have to be added.

TEE and Comorbidities

Right heart disease/pulmonary hypertension

Because TEE allows monitoring of right heart function and systolic pulmonary artery pressures, patients with significant pulmonary hypertension might not need PAC monitoring perioperatively if TEE is available. Depending on the invasiveness of the surgical procedure and the hemodynamic stability, both methods might be used. Although PAC offers continuous pulmonary artery pressure monitoring perioperatively, TEE can provide additional information about filling status, left heart performance, and

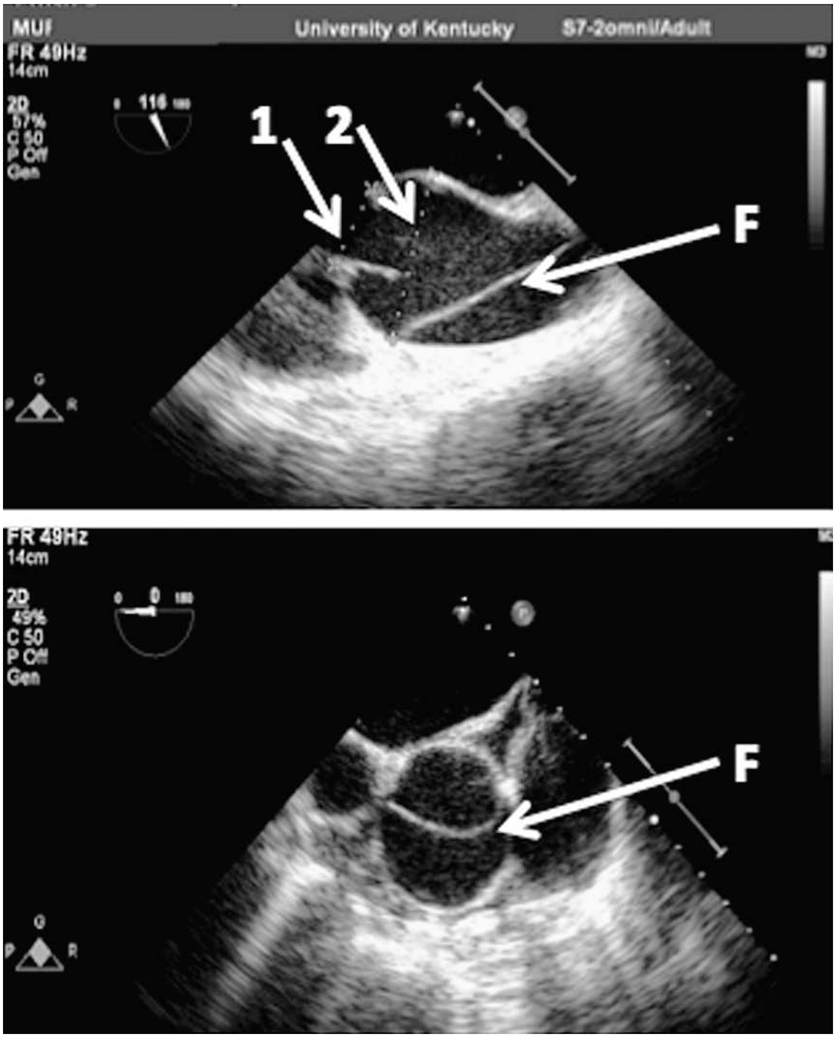

Fig. 6 Ascending aortic dissection. The ascending aorta is assessed in the midesophageal aortic valve long axis view (ME AV LAX, upper picture) and midesophageal ascending aortic short axis view (ME asc. Aortic SAX, lower picture). The diameter of the aortic valve opening is marked (1). The aortic diameter at the sinotubular junction is marked (2). The flap (F) indicates the ascending aorta dissection in both graphs.

tricuspid valve function. However, the TEE probe has to be removed before extubation.

Case examples

Case 5

A 75- year-old patient with known moderate pulmonary hypertension is undergoing a complicated endoluminal thoracoabdominal aneurysm repair using general anesthesia. A PAC and a TEE probe are in place to monitor cardiac function and pulmonary blood flow. After several hours into the surgery, an increase in pulmonary artery pressures and mild hypotension are noted. The cardiac performance remains unchanged (cardiac index 2.2–2.5). On TEE examination the right ventricle appears dilated with diminished contractility and worsened tricuspid regurgitation. Therefore, inotropic support is initiated. With repeated TEE examinations, the right ventricular function is restored and the surgery proceeds uneventfully. Using TEE monitoring has allowed early diagnosing of right ventricular failure. In the combination of pulmonary hypertension, PAC alone might have not indicated right ventricular failure as early in this situation as if combined with TEE.

Renal Carcinoma With IVC Thrombus

In situations with high embolization risk, TEE examination of IVC and the right atrium can determine the presence and distance of IVC invasion. During the thrombus/tumor removal, TEE monitoring can alert the surgical team if embolization occurs.

Liver Transplantation

During liver transplantation, patients are at high risk for hemodynamic instability related to several causes: hypovolemia secondary to blood loss, decreased preload secondary to obstructed IVC flow, myocardial dysfunction secondary to increased work load, reduced systemic vascular resistance, or increased pulmonary artery pressures secondary to embolization. TEE allows online monitoring of myocardial function to differentiate the several components causing hypotension and is helpful in guiding the treatment approach.[15]

Laparoscopic Surgery and Cardiomyopathy

During laparoscopy the increased intra-abdominal pressure affects the myocardial pressure–volume relationship and causes a shift in myocardial compliance.[16] The monitoring of right and left heart pressures becomes unreliable for monitoring heart volume status. In patients with advanced heart disease depending on optimization of preload and afterload, TEE is the preferred monitor to achieve and maintain hemodynamic stability.

Case example

Case 6
A 60-year-old patient with end-stage ischemic cardiomyopathy, with ejection fraction of 15% and history of ventricular tachycardia presents to the operating room for laparoscopic cholecystectomy. After induction of general anesthesia, a TEE probe is placed to monitor and optimize cardiac performance during the surgical procedure. This high-risk patient is in need for close cardiac monitoring during the intra-abdominal surgery. TEE is preferred to PAC in this situation because of several reasons: (1) TEE is less invasive, (2) TEE has less complications and less risk of arrhythmia, (3) TEE allows for a more specific assessment of cardiac performance than PAC, and (4) with increased intraabdominal pressure PAC measurements might be less reliable than TEE monitoring.[17]

Open Aortic Surgery With Aortic Cross-clamping

In patients with intact left ventricular function and absence of coronary artery disease, TEE monitoring is most likely not needed during infrarenal abdominal aortic aneurysm repair. However, if there is a question whether the LV can sustain a significant afterload increase or whether significant hypotension not responding to conventional therapy occurs, TEE can help with assessment and treatment approach.

Unexplained Hypoxemia

The intraoperative occurrence of unexplained hypoxemia is a relative new TEE indication. The value of TEE for the assessment of unexplained hypoxemia cannot be overemphasized. Intraoperative hypoxemia can be caused by (1) cardiopulmonary failure, (2) shunts, allowing desaturated blood to enter arterial circulation, or (3) mediastinal/thoracic structures. TEE is a very valuable tool in diagnosing the underlying pathophysiology for hypoxemia.[18] Hypoxemia secondary to cardiopulmonary failure might be related to pulmonary hypertension or left heart failure with pulmonary edema. With TEE assessment, pulmonary hypertension can be assessed for acute versus chronic onset and graded for severity. Based on the information treatment decisions can be made and impact on cardiac performance can be directly observed with TEE. Intracardiac shunts can cause new-onset hypoxemia after anesthesia induction. Patent foramen ovale, other atrial septal defects, or ventricular septal defects can gain hemodynamic importance after pulmonary vascular resistance increase, therefore allowing deoxygenated blood to bypass pulmonary circulation. Mediastinal/thoracic causes diagnosed by TEE include cardiac tamponade, pericardial, or pleural effusions. The use of TEE has to be balanced with the severity and urgency of the disturbance. Methemoglobinemia secondary to local anesthetic has been reported as a TEE-related complication resulting in hypoxemia.[19]

TEE Complications

Compared with other invasive hemodynamic monitoring options, TEE has a relative low invasiveness and complication rate.[20] Despite the ease of probe placement, TEE should be considered a semi-invasive technique and consent should be obtained, if possible. Severe complications are rare (Table 3).[21,22] The most common complications with TEE use are associated with pre-existing esophageal disease. However, according to the most recent American Society of Anesthesiologists practice guideline, there is no consensus among experts whether there really is an absolute contraindication for TEE use (Table 4).[4] TEE may be used for patients with oral, esophageal, or gastric disease if the expected benefit outweighs the potential risk. Consider other imaging studies if available (*e.g.*, transthoracic echocardiography). The most important step to minimize TEE complications is a cautious passage of the TEE probe with adequate training level of the practitioner. If the TEE probe is placed on a nonanesthetized patient, appropriate sedation and analgesia should be provided to avoid hemodynamic disturbances.

The most common problem associated with intraoperative TEE is distraction. Although monitoring just a few views might provide enough information to rapidly diagnose many hemodynamic and ischemic disturbances, it takes time to perform a complete TEE examination. In a rapidly deteriorating patient, additional personal will be necessary to provide patient care while the TEE examination is performed.

Required Skills

The use and interpretation of the TEE information is dependent on the training level and experience of the echocardiographer. Accreditation of echocardiographic skills is offered by several organizations. Based on the recommendations of the Royal College of Radiologists and British Society of Echocardiography, European Association of Echocardiography, and American Society of Echocardiography, the World Interactive Network Focused on Critical Ultrasound has outlined the specific requirements of clinical training.[23]

Although the technique is somewhat easy to learn and the acquired information can be interpreted immediately, there is a significant amount of training required to develop a sufficient skill level to perform an adequate TEE examination. Because the obtained TEE information is used for diagnosis and treatment, the TEE practitioner must have a solid understanding of TEE technique, intrathoracic anatomy, and TEE information to ensure that correct information is obtained. Several organizations offer teaching tools, classes, and online review courses.

Table 3 Complications associated with intraoperative transesophageal echocardiography use[20,21]

Complication	Incidence (%)
Odynophagia	0.10
Swallowing abnormality	0.01
Esophageal abrasions	0.06
No associated pathology	0.03
Upper gastrointestinal bleeding	0.03
Esophageal perforation	0.01
Dental injury	0.03
Endotracheal tube malposition	0.03
Total	0.2

Table 4 Transesophageal echocardiography contraindications[20,21]

Absolute	Relative
Perforated viscus	Prior radiation to the chest
Unstable cervical spine	Atlantoaxial joint disease
	Active upper GI bleeding
	Esophageal stricture
	Esophageal diverticulum
	Esophageal tumor
	Esophageal scleroderma
	Esophageal varices
	Recent upper GI surgery

GI, gastrointestinal.

Three levels of knowledge and competence are recognized:

1. The basic level provides that the TEE performer is capable of obtaining a standard TEE examination, interpreting the data from normal to abnormal structures, and is able to diagnose the most common abnormalities.
2. With the second level the physician should be able to use the full diagnostic TEE potential. In addition, the advanced TEE practitioner can function as a consultant for basic level TEE practitioners and can teach TEE to others.
3. At the most advanced level of competency, the physician is able to perform a high-level TEE examination (3-dimensional, 4- dimensional TEE), can be consulted by level 1 and 2 TEE practitioners, and can conduct research in the field of echocardiography.

Conclusions

In summary, TEE information can be very valuable in the perioperative period to provide or restore hemodynamic stability. In the situation of a hemodynamically unstable patient, TEE information can provide life-saving information very accurately and quickly. However, risks and benefits must be carefully weighted before TEE probe placement, as TEE is a semi-invasive method. Therefore, patient selection is very important. In addition, equipment and expertise must be available. Anesthesiologists should strive to have adequate training and knowledge to be able to use TEE.

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