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

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Echocardiography was introduced in the operating room in the 1970s, with its initial applications involving epicardial echocardiography (EE). The use of transesophageal echocardiography (TEE) during surgery was first described in 1980 and did not become commonplace until high-frequency transducers and color Doppler imaging became available in the mid-1980s. The improved quality of the acoustic image enabled anesthesiologists and surgeons to use TEE intraoperatively to diagnose myocardial ischemia, confirm the adequacy of valve reconstruction and other surgical repairs, determine the cause of hemodynamic disorders and other intraoperative complications, and provide diagnostic information that could not be obtained preoperatively. Real-time access to this information has enabled surgeons to correct inadequate repairs before patients leave the operating room, has reduced the need for reoperation, and has facilitated the prevention and early treatment of perioperative complications.

Although other intraoperative monitoring devices can provide some of this information, TEE offers important advantages over other diagnostic monitoring techniques. For example, intraoperative echocardiograms can be obtained by transthoracic echocardiography (TTE) or, if the chest is open, by EE. However, the acoustic images of TTE are generally poorer than those of TEE, and monitoring must be discontinued if the chest is opened or if surgical equipment, drapes, or monitors block access to the chest. Epicardial echocardiographic images are equivalent and sometimes superior to TEE, but the probe must be placed in a sterile field, can disrupt surgical procedures, and must be removed once the chest is closed. In contrast, TEE can facilitate diagnosis, allow the institution of specific treatments, and monitor interventions throughout the operative course without disrupting surgical technique. Other devices, such as electrocardiography (ECG) and pulmonary artery catheters, can provide continuous monitoring of cardiac performance, but are often unable to provide important information (*e.g.*, wall motion abnormalities, perivalvular leakage) that can be provided readily and rapidly by TEE.

Anesthesiologists also have used TEE outside the operating room. Typical applications in this setting include the emergency assessment of patients preoperatively to determine whether surgery is indicated (*e.g.*, thoracic aortic disruption after blunt chest trauma), as well as the postoperative assessment and treatment of patients in the hours and days after surgery. Even in nonoperative settings, anesthesiologists engaged in critical care medicine increasingly use TEE to evaluate and treat unstable patients in the intensive care unit (ICU).

There are important limitations to TEE. Some regions of the heart and great vessels cannot be well visualized (although some of these limitations may be overcome by more advanced technology and new imaging planes). The procedure is generally safe, but insertion and manipulation of the TEE probe can produce pharyngeal and/or laryngeal trauma, dental injuries, esophageal trauma or bleeding, arrhythmias, respiratory distress, and hemodynamic effects. Case reports have attributed some perioperative deaths to TEE. The inaccurate interpretation of TEE images by inexperienced examiners can generate incorrect information, potentially resulting in improper clinical decisions by the anesthesiologist and surgeon and, hence, unnecessary perioperative complications. The performance of TEE can consume anesthesiologists' time and attention that they need to attend to other intraoperative responsibilities.

In recent years, the publication of practice guidelines has become a useful, and often necessary, means of establishing the scientific support for clinical procedures and for justifying their use in patient care. Although practice guidelines on TEE have been issued by the American College of Cardiology, American Society of Echocardiography, and Society of Pediatric Echocardiography, they include only brief comments on the use of TEE in the operating room. In 1993, the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists established the Ad Hoc Task Force on Practice Parameters for Transesophageal Echocardiography to develop evidence-based guidelines on the proper indications for performing TEE in the operative setting. The 12-member task force included 9 anesthesiologists (6 of whom hold academic appointments and 3 of whom are private practitioners), 2 cardiologists, and 1 methodologist.

Before developing its recommendations, the task force reviewed all evidence regarding the effectiveness of TEE in the perioperative setting. A computerized and manual literature search retrieved 1,844 studies, of which 558 were considered relevant to the perioperative setting. Evidence was considered relevant if it addressed the accuracy and reliability of perioperative TEE, its yield and predictive value, or the effect of perioperative TEE on therapeutic decisions or clinical outcomes. The role of TEE in the emergent preoperative assessment of potential surgical emergencies also was considered. Studies investigating TEE in nonoperative critical care patients were examined, but studies of TEE in the cardiac catheterization or echocardiography laboratory were not reviewed. Thus, a large body of indirect evidence of potential relevance to critical care and surgical patients is omitted from this report but is examined elsewhere.[1,2] Further details about the literature review process are available on request.

A detailed summary of the studies examined by the task force is published in a separate monograph. This Executive Summary provides an overview of the evidence for each of the topic categories examined by the task force. Each section includes a summary discussing the evidence obtained directly from studies of perioperative TEE, and an ``Expert Opinion'' section, in which the task force cites other relevant data and documents its opinions regarding the benefits and harms of perioperative TEE. The recommendations of the task force address *indications,* the clinical settings in which TEE should be considered, and *proficiency,* the cognitive and technical skills expected of anesthesiologists who perform perioperative TEE. Guidelines on how to perform TEE examinations were considered beyond the scope of this report.

Recommendations for performing TEE in this report are intended for those anesthesiologists who use TEE, rather than for all anesthesiologists. The recommendations are divided into three categories based on the strength of supporting evidence or expert opinion that the technology improves clinical outcomes (table 1). *Category I* indications are supported by the strongest evidence or expert opinion; TEE frequently is useful in improving clinical outcomes in these settings and often is indicated, depending on individual circumstances (*e.g.*, patient risk and practice setting; fig. 1). *Category II* indications are supported by weaker evidence and expert consensus; TEE may be useful in improving clinical outcomes in these settings, depending on individual circumstances, but appropriate indications are less certain. *Category III* indications have little current scientific or expert support; TEE infrequently is useful in improving clinical outcomes in these settings, and appropriate indications are uncertain. The lack of supporting evidence for category III indications is often owing to the absence of relevant studies rather than to existing evidence of ineffectiveness. Thus, many category III indications are currently investigational, and future research and technological developments may enhance their role in routine practice.

Recommendations in this report refer to clinical problems rather than to individual patients, who often have more than one potential reason for performing TEE. Thus, although patients may not necessarily require perioperative TEE because of a cardiomyopathy (category III), the same patients may need TEE because of coexisting hemodynamic problems (category I). Similarly, physicians must integrate multiple variables in assessing a patient's need for TEE. As illustrated in figure 1, factors associated with the patient, procedure, and clinical setting each contribute to the overall risk of perioperative complications and cumulatively alter the benefit-harm ratio of using TEE. Physicians should consider each of these variables when calculating the appropriateness of using TEE.

The recommendations in this report are intended as general guidelines. Guidelines differ from standards, which prohibit departure from recommended practices except under special circumstances.3 Guidelines are intended to provide practitioners with sufficient flexibility to alter their practices based on important clinical considerations or differing interpretations of the evidence. Accordingly, deviation from the guidelines in this report is expected and should not necessarily be viewed as inappropriate care. Recommendations to perform TEE are not applicable when the procedure cannot be performed properly or safely, neither do they apply when TEE equipment or skilled examiners are unavailable. The recommendations in this report are based on consideration of clinical benefits and harms. The economic implications of providing TEE, although important, were not explicitly examined by the task force because available data are inadequate to properly evaluate cost-effectiveness. The recommendations are intended for practitioners in the United States; elements of the recommendations and the principles on which they are based also may apply to practice settings in other countries. The recommendations are based on currently available evidence and should be updated as relevant new data become available.

Recommendations regarding training, certification, credentialing, and quality assurance were based on the aforementioned scientific evidence, as well as on legal, regulatory, and scientific literature and expert opinion. The task force refers to two levels of training in perioperative TEE, basic and advanced. Both basic and advanced TEE training refer to specialized training that extends beyond the minimum exposure to TEE that occurs during normal anesthesia residency training. Anesthesiologists with basic training are considered able to use TEE for indications that lie within the customary practice of anesthesiology. Anesthesiologists with advanced training are considered, in addition to the above, to be able to exploit the full diagnostic potential of perioperative TEE. Further details about requirements for each level of training are discussed later.

In this report, evidence of effectiveness, recommendations, and proficiency levels are discussed relative to the specific conditions that TEE can detect (*e.g.*, hemodynamic disturbances, congenital heart disease, emboli). This reductionist approach to examining the evidence often understates the important ability of TEE to detect multiple problems at once. For example, although the ability of TEE to evaluate myocardial ischemia, ventricular dysfunction, valvular insufficiency, thrombi, and air emboli is discussed in separate sections of this report, these problems often occur together during surgery and can be detected simultaneously by TEE. The capacity to study the physiologic and anatomic interrelationships of these problems and to monitor response to treatment is one of the unique advantages that TEE offers over other methods of intraoperative monitoring or diagnosis, as discussed later.

Wall Motion, Myocardial Ischemia, and Coronary Artery Disease

Hemodynamic and other physiologic stresses during the perioperative period increase the risk of perioperative myocardial ischemia, especially among patients with coronary artery disease, multiple risk factors for coronary artery disease, and peripheral vascular disease. Traditional methods for monitoring myocardial ischemia during surgery, such as continuous ECG, have limited sensitivity in the early detection of tissue injury. A growing body of evidence therefore has examined the role of TEE in detecting ischemia during both cardiac and noncardiac surgery.

Summary of the Evidence. There is good evidence that the development of regional ventricular dysfunction during surgery increases a patient's risk of developing perioperative myocardial infarction (MI) and sudden death. Transesophageal echocardiography can detect regional ventricular dysfunction, but there is little evidence about its accuracy, because neither a reliable reference standard is available, nor is it certain that the wall motion abnormalities reflect true myocardial ischemia. Most studies have examined the accuracy of TEE relative to intraoperative ECG tracings, an imperfect reference standard, and find weak concordance. Intraoperative

TEE evidence of regional ventricular dysfunction is reported to occur in 27--100% of cases in which there is ECG evidence of ischemia and in 56--85% of cases in which ECG evidence of ischemia is lacking. The reportedly high incidence of intraoperative regional ventricular dysfunction (21--30% of cardiac surgery cases, 10--52% of vascular cases, and 20--60% of noncardiovascular cases) and postoperative dysfunction (47--60% of cardiac surgery patients) raises important questions about the frequency of false-positive findings.

Moreover, there is little direct evidence that the detection of regional ventricular dysfunction or other TEE evidence of ischemia results in improved perioperative clinical outcomes or long-term survival. This lack of evidence is mainly due to the absence of studies examining these outcomes. Studies of cardiac surgery patients report that TEE findings were ``valuable or essential'' or resulted in a change in therapy (graft revision, hemodynamic support) in 2--12% of patients, but there is no direct evidence that patients experience better outcomes as a result of these changes. Intraoperative TEE also is capable of evaluating myocardial perfusion patterns, coronary artery anatomy, and graft patency, but few studies have examined whether this information improves clinical outcomes.

Expert Opinion. Evidence from animal experiments and angioplasty studies suggests that wall motion abnormalities generally precede ECG changes during myocardial ischemia.[4-7] The task force believes that TEE provides a more meaningful reference standard for ischemia than ECG. The limitations of TEE also are recognized, however. Interpretations of wall motion and thickening often are more subjective than quantifiable ECG changes (e.g., ST-segment depression). Transesophageal echocardiography interpretations can be influenced by translational motion of the heart, bundle branch block, and ventricular pacing. A marked worsening of segmental wall motion and thickening is required (in the absence of similar global changes) to strongly suggest the diagnosis of ischemia; less pronounced changes are interpreted inconsistently, even by experts. Moreover, all segmental wall motion abnormalities are not indicative of myocardial ischemia. Segmental wall motion abnormalities not caused by ischemia can occur because of preexisting disease (e.g., prior MI, myocarditis) or confounding intraoperative events (e.g., myocardial stunning after cardiopulmonary bypass <ob>CPB<cb>). Protocols have recently been suggested for distinguishing intraoperatively between stunned and infarcted myocardium, but they require further evaluation to be validated. Because an automated system for analyzing wall motion and thickness is currently unavailable for TEE, only qualitative wall motion assessment is available in real time. Moreover, real-time assessment of segmental wall motion may be less accurate than off-line (laboratory) assessment. When TEE is used to evaluate wall motion, the yield will increase with the use of multiple planes and methods that facilitate temporal comparisons (e.g., side-by-side cine loops).

Although there is little direct evidence that TEE detection of myocardial ischemia improves clinical outcome, the task force believes that indirect evidence can be extrapolated from non-TEE studies showing that early treatment of myocardial ischemia and MI improves survival. Intraoperative TEE detection of ischemia permits corrective interventions, including alterations in surgery, anesthetic management, and postoperative triage, which can prevent perioperative complications. For example, TEE detection of post-CPB myocardial ischemia during coronary artery bypass graft surgery permits, if indicated, immediate revascularization before the patient leaves the operating room, thereby reducing the risk of perioperative MI. Both indirect evidence and expert opinion suggest that these measures improve clinical outcomes.

Recommendations

Indications. An increased risk of myocardial ischemia or infarction during the perioperative period is a category II indication for perioperative TEE. An increased risk may occur when conditions associated with the *patient* (e.g., history of prior MI or coronary artery disease, left ventricular dysfunction, dysrhythmias), *procedure* (e.g., coronary artery bypass graft, operations on the great vessels or that involve aortic cross-clamping, noncardiac intrathoracic surgery, upper abdominal procedures), or *clinical setting* (e.g., anticipated duration of surgery, hospital-specific factors) predispose to myocardial ischemia or MI (fig. 1). Use of perioperative TEE to evaluate myocardial perfusion, coronary artery anatomy, or graft patency are category III indications. The argument for using TEE is strengthened when ECG monitoring cannot provide accurate information, such as in patients with conduction disorders or in procedures that interfere with ECG lead placement. The argument for using TEE is weakened when clinical factors (e.g., preexisting regional ventricular dysfunction) limit the accuracy of wall motion interpretations.

Proficiency. Anesthesiologists with basic TEE training should be able to use TEE to detect unequivocal changes in segmental wall thickening and motion (e.g., from normal wall motion to akinesis) and should be able to distinguish these changes from artifacts (e.g., translational motion of the heart, changing cross section, image dropout, abnormal ventricular activation). Subtle changes in segmental wall motion and thickening, however, are difficult to detect, even for experts. The ability to evaluate or quantify such changes in association with myocardial ischemia and MI requires advanced training.

Hemodynamic Function

Transesophageal echocardiography has been used extensively for the evaluation (monitoring of presence, followed by determination of etiology) of hemodynamic and global ventricular function. Some have used TEE to estimate standard hemodynamic variables (e.g., filling pressures, cardiac output) that are normally obtained by other invasive techniques, such as pulmonary artery catheterization, whereas others have used it to quantify cardiac dimensions, intracardiac flow rates, and overall cardiac performance. Such measurements were previously not readily obtainable in the operating room or ICU.

Summary of the Evidence. Current studies provide conflicting information about the correlation between TEE estimates of hemodynamic indexes (e.g., cardiac output, filling pressure) and measurements obtained by more conventional tests (e.g., thermodilution). Studies comparing TEE and thermodilution measurements of cardiac output report wide ranges in correlation coefficients (R <eq> 0.72--0.97), bias estimates (0.03--1.01 l/min), and limits of agreement. The frequency with which TEE detects hemodynamic disturbances has not been studied. Moreover, there is little evidence beyond case reports to confirm that hemodynamic monitoring by TEE results in improved clinical outcomes.

Expert Opinion. Quantitative analysis of TEE information may increase its sensitivity in detecting small changes in ventricular dimensions or ejection, a capacity that would dramatically enhance conventional hemodynamic monitoring, but it is time consuming and requires considerable skills. Until automated analysis systems overcome these limitations, intraoperative TEE will remain a largely qualitative tool for assessing hemodynamic function. Even with these limitations, however, the task force believes that TEE provides more accurate estimates of preload (end-diastolic volume) than the pulmonary artery catheter. Preload is physiologically determined by sarcomere length, a variable more accurately estimated by volume than by pressure measurements. When compared with the pulmonary artery catheter, TEE may be more expedient, because it can be inserted more quickly and without sterile technique; safer, because it does not enter the great vessels and heart; and more comprehensive, because it provides more global hemodynamic information about the performance and structure of the heart.

Although direct evidence is lacking, the task force believes that detecting acute hemodynamic disturbances during surgery improves clinical outcomes. These benefits are realized by using TEE to diagnose the hemodynamic problem (e.g., hypovolemia, myocardial depression) and to suggest appropriate therapy (e.g., volume expansion, inotropic therapy). The task force believes that failing to take action to correct or prevent hemodynamic disturbances increases the risk of end-organ damage and perioperative mortality.

Recommendations

Indications. An increased risk of hemodynamic disturbances during the perioperative period is a category II indication for perioperative TEE. Increased risk may occur when conditions associated with the *patient* (e.g., congestive heart failure, valvular heart disease, abdominal aortic aneurysm, preeclampsia, trauma, burn injuries), *procedure* (e.g., vascular surgery, CPB, extensive tumor resection, liver transplantation, total hip replacement), or *clinical setting* (e.g., difficulties in inserting central venous pressure catheters, inability to estimate blood loss, poor hospital-specific conditions, such as complication rates for a specific procedure) predispose to hemodynamic disturbances (fig. 1). The emergent use of perioperative TEE to determine the cause of acute, persistent, and life-threatening hemodynamic disturbances in which ventricular function and its determinants are uncertain and have not responded to treatment is a category I indication.

Proficiency. Anesthesiologists with basic TEE training should be able to make qualitative assessments of hemodynamic status and should have a cognitive understanding of more sophisticated TEE techniques for quantifying hemodynamic function.

Valvular Surgery

For patients requiring valve surgery, because of the potential for suboptimal results, it is preferable to recognize the need for further surgery in the operating room rather than waiting for postoperative complications to develop that necessitate a second operation. The unique ability of TEE to make these assessments during valve surgery accounts for its widespread application in this setting.

Summary of the Evidence. Perioperative TEE can characterize valvular insufficiency and morphology. Studies report a fair correlation between intraoperative TEE estimates of valvular insufficiency and preoperative angiographic data (R = 0.83--0.88). Access to this information before and after valve repair appears to be useful. Pre-CPB TEE provides new information or prompts changes in valve surgery in 9--13% of cases. Its ability to reveal unanticipated valvular disease (e.g., endocarditis, aortic valve tumor) is described in case reports. Post-CPB TEE identifies significant valve dysfunction in 6--11% of cases, prompting second pump runs in 3--10% of patients undergoing mitral valve repair. However, although there is evidence that post-CPB valve dysfunction is associated with increased postoperative complications and poorer survival, there is little evidence beyond case reports that perioperative interventions prompted by TEE improve clinical outcomes.

Expert Opinion. Although direct evidence of benefit is lacking, the task force believes that indirect evidence can be extrapolated to infer effectiveness. Observational data from patients undergoing surgery for ischemic heart disease suggest that mitral regurgitation on post-CPB TEE is the most important predictor of postoperative mortality. Based in part on these data and on expert opinion, the task force believes that patients who are not evaluated by TEE during valve surgery may have longer ICU stays and a higher incidence of congestive heart failure, reoperation, and mortality than patients monitored by TEE. Transesophageal echocardiography evaluation appears to decrease the need for valve replacement, and observational data suggest that the latter increases the risk of mechanical dysfunction, perivalvular leakage, thromboembolic events, and anticoagulation therapy. Although observational data cannot prove effectiveness conclusively, the findings are consistent with the expert opinion of the task force. While most available evidence comes from patients undergoing valve repair, the task force believes that similar benefits (lower incidence of reoperation, congestive heart failure, and mortality) are also realized for patients undergoing valve replacement, albeit less frequently than for valve repair. After valve replacement, significant periprosthetic leaks are uncommon but may require immediate correction. At centers experienced with valve replacement, the yield of intraoperative TEE is likely to be low.

The task force recognizes that the effectiveness of TEE during valve surgery may be limited by inaccurate interpretation: ``false-positive'' or ``false-negative'' findings. Moreover, TEE evaluation of post-CPB valvular regurgitation can be confounded by the presence of abnormal loading conditions or myocardial ischemia. These conditions must be normalized or resolved before valvular insufficiency can be confirmed. Hemodynamic changes associated with the induction of anesthesia can alter valvular function and render comparisons between pre-CPB TEE and preoperative echocardiography problematic. Patients with evidence of tricuspid regurgitation on preoperative echocardiography, for example, may have normal examinations on pre-CPB TEE, prompting inappropriate revision of the surgical plan. The absence of regurgitation on post-CPB TEE also can be falsely negative when the patient is volume underloaded.

The potential benefits of TEE evaluation during valve surgery are not limited to valve assessment. Hemodynamic disturbances are common (see Hemodynamic Function), and TEE may be especially helpful in weaning the patient from CPB. Transesophageal echocardiography can detect entrapped air and facilitate venting procedures (see Air Emboli). Other potential benefits are discussed in separate sections.

Recommendations

Indications. Valve repair is a category I indication, and valve replacement is a category II indication, for the use of intraoperative TEE.

Proficiency. When valve surgery will be dictated by TEE assessment of valve function, TEE should be performed by, or in timely consultation with, a physician with advanced TEE training. Anesthesiologists with basic TEE training should have an understanding of the anatomy and function of native and prosthetic valves, the hemodynamic changes that occur in valvular disease, and the echocardiographic tools (e.g., continuous-wave Doppler) that are available for valve assessment. They should be able to obtain multiple views of all valves, recognize gross valvular dysfunction on two-dimensional echocardiography, and appreciate the color patterns of antegrade and retrograde flow on color Doppler examinations. Quantitative echocardiographic measurements of valve function (e.g., jet area, flow-velocity pattern, effective valve orifice area) require advanced training. Utilization of TEE to detect and diagnose the causes of hemodynamic disturbances and to detect the presence of air emboli during valve surgery can be performed by anesthesiologists with basic TEE training.

Congenital Heart Surgery

Although the acoustic window provided by TEE gives access to a variety of congenital heart lesions, especially in the atria and atrioventricular junction, its use in children was limited for many years because available probes were too large. As recently as 1989, available probe sizes limited the use of TEE to children older than 7 yr. Smaller probes that are now available measure 5.9 mm in diameter and enable examination of children as small as 2,400 g. Transesophageal echocardiography has special application in evaluating the adequacy of surgical repair of congenital heart lesions. New technologies (e.g., biplane pediatric probes) and imaging techniques (e.g., longitudinal planes) have enhanced further the information obtainable from TEE examinations of children.

Summary of the Evidence. Intraoperative TEE has a reported sensitivity of 86--94% in detecting congenital heart lesions. Especially when performed with biplane probes, TEE can detect lesions not seen on preoperative TTE in as many as 30% of patients. The sensitivities of intraoperative TEE and EE are comparable, although each test may lack sensitivity in evaluating certain cardiac structures. In patients undergoing congenital heart surgery, pre-CPB findings prompt changes in treatment in 1--16% of patients, post-CPB TEE findings result in second pump runs or altered medical therapy in 3--45% of cases, and postoperative TEE detects information not available by TTE in 15--48% of patients. However, there is little direct evidence beyond case reports as to whether this information or the treatment changes that they prompt (e.g., returning to CPB to correct residual defects) improve clinical outcomes.

Expert Opinion. Most studies of TEE during congenital heart surgery, including those reporting poor visualization of the right ventricular outflow tract, pulmonary valve, and interventricular septum, lacked access to the enhanced imaging capabilities of recently introduced pediatric TEE technology (e.g., biplane probes, continuous-wave Doppler) and techniques (e.g., transgastric view of right ventricular outflow tract). When compared with EE, TEE offers the advantages of uninterrupted operation, decreased potential violation of the sterile field, and continuous hemodynamic evaluation. An important role of perioperative TEE during congenital heart surgery is the ability to detect previously unrecognized congenital anomalies.

The task force believes on the basis of indirect evidence [8] that the detection of residual defects improves outcomes by reducing the residual hemodynamic burden of these lesions and by decreasing the patient's risk of pulmonary hypertension and endocarditis. Despite these potential benefits, TEE may be inappropriate or infeasible in certain circumstances. Pre-CPB and post-CPB TEE examinations frequently are useful for patients undergoing repair of complex congenital heart lesions. In the repair of other defects (e.g., patent ductus arteriosus, patent foramen ovale) where TEE may be useful, the physician must be especially careful in weighing the potential benefits of TEE against its potential risks. In addition to the usual potential adverse effects of TEE, small children may face the added risks of hemodynamic or respiratory compromise, which is more common among patients weighing less than 3 kg or when an appropriately sized probe is unavailable. For patients in whom esophageal intubation is difficult, repeated attempts at probe insertion may result in more harm than good. When TEE is not appropriate or small probes are not available, EE can be used to assess the repair of congenital heart defects.

Practical constraints related to the recent introduction of pediatric TEE technology also may limit the feasibility of its routine use during congenital heart surgery. Because pediatric TEE probes of appropriate size and imaging quality (e.g., biplane) have become available only recently, practitioners currently face a temporary transition period during which some centers may lack access to appropriate equipment and expertise.

Recommendations

Indications. Congenital heart surgery for most lesions requiring CPB is a category I indication for intraoperative TEE, including pre-CPB and post-CPB imaging. Use of TEE is not recommended when available probes are too large for the child. Epicardial echocardiography can provide a useful alternative when TEE is inappropriate or small probes are unavailable.

Proficiency. When repair of congenital heart defects will be dictated by the results of intraoperative TEE assessment, TEE should be performed by, or in timely consultation with, a physician with advanced pediatric TEE training in complex congenital heart disease. Anesthesiologists with basic TEE training should have an understanding of how TEE is used during congenital heart surgery.

Cardiomyopathy

Hypertrophic, dilated, and restrictive cardiomyopathies are diagnosed accurately by echocardiography. The use of intraoperative TEE in patients with cardiomyopathy has centered on the detection and treatment of hypertrophic obstructive cardiomyopathy.

Summary of the Evidence. There is little evidence regarding the accuracy or yield of intraoperative TEE relative to cardiomyopathy. One study reported that the detection of persistent outflow tract gradients aided surgical revision in 20% of patients undergoing hypertrophic obstructive cardiomyopathy repair, but otherwise there is little evidence that TEE alters therapy or improves outcome.

Expert Opinion. Epicardial echocardiography may offer important advantages over TEE in evaluating hypertrophic cardiomyopathies. In addition to increased accuracy, EE can obtain outflow gradient measurements without the need for cardiac needle punctures. By either means, however, the task force believes that echocardiographic confirmation of the adequacy of hypertrophic obstructive cardiomyopathy repair improves clinical outcomes, based in part on natural history data suggesting poorer outcomes for patients with persistent hemodynamic compromise from hypertrophic obstructive cardiomyopathy.[9] Echocardiographic assessment also facilitates weaning from CPB, may offer improved myocardial protection during the procedure, and enables intraoperative detection of iatrogenic septal defects or systolic anterior motion resulting from the repair. The task force believes that these benefits improve clinical outcomes.

Recommendations

Indications. Hypertrophic obstructive cardiomyopathy repair is a category I indication for either EE or TEE assessments, but use of intraoperative TEE for other cardiomyopathies is a category III indication.

Proficiency. When hypertrophic obstructive cardiomyopathy repair will be dictated by intraoperative TEE assessment, TEE should be performed by, or in timely consultation with, a physician with advanced TEE training.

Cardiac Aneurysms

Summary of the Evidence. Beyond case reports, there is little evidence that intraoperative TEE is accurate in detecting cardiac aneurysms or results in improved outcomes for patients undergoing aneurysmectomy.

Expert Opinion. The task force believes that intraoperative TEE during aneurysmectomy can play an important role in evaluating the adequacy of repair and, occasionally, in detecting previously unsuspected abnormalities (e.g., pseudoaneurysms). Patients with cardiac aneurysms typically have advanced ischemic heart disease and associated hemodynamic complications, and TEE often is useful in evaluating these problems (see ``Wall Motion, Myocardial Ischemia, and Coronary Heart Disease'' and ``Hemodynamic Function''). Patients with cardiac aneurysms who undergo cardiac surgery often have difficulty weaning from CPB, and TEE monitoring of hemodynamic function often is helpful in withdrawing extracorporeal circulatory support.

Recommendations

Indications. Assessing surgical repair of cardiac aneurysms is a category II indication for intraoperative TEE.

Proficiency. When surgical repair of cardiac aneurysms will be dictated by the results of intraoperative TEE assessment, TEE should be performed by, or in timely consultation with, a physician with advanced TEE training.

Endocarditis

Summary of the Evidence. Although its accuracy in detecting endocarditis outside the operating room is well established, there is little evidence beyond case reports that the use of TEE during surgery is accurate in detecting endocarditis or achieves improved clinical outcomes.

Expert Opinion. Beyond the accepted applications of intraoperative TEE during valve surgery (see ``Valvular Heart Disease''), there is little role for TEE in evaluating endocarditis during surgery, unless preoperative testing was inadequate or the patient required urgent surgery. There are limitations to the sensitivity and specificity of TEE in detecting endocarditis. A negative TEE does not rule out endocarditis, and studies suggest that TEE evidence of vegetations may persist long after bacteriologic cure.

Recommendations

Indications. Noncardiac surgery involving patients with uncomplicated endocarditis is a category III indication for intraoperative TEE. A category I indication exists, however, when preoperative testing has been inadequate or extension of infection to perivalvular tissue is suspected.

Proficiency. When surgical exploration of endocarditic disease will be dictated by the results of intraoperative TEE assessment, TEE should be performed by, or in timely consultation with, a physician with advanced TEE training.

Cardiac Tumors

Summary of the Evidence. There is some evidence that intraoperative TEE may be more accurate than preoperative testing in characterizing the anatomy of some cardiac tumors and intracardiac extensions of pulmonary or renal tumors, but there is little evidence beyond case reports that this information or the use of TEE during resection results in improved clinical outcomes.

Expert Opinion. In many cases, the information that intraoperative TEE provides about the location and anatomy of intracardiac tumors to plan incision and excision techniques can be obtained before surgery by careful preoperative testing (including preoperative TEE). If preoperative testing is adequate, the most important role for intraoperative TEE is determining whether a mass has embolized and the new location of the mass, often preempting the need for further exploration or a change in surgical planning.

Recommendations

Indications. The removal of cardiac masses is a category II indication for intraoperative TEE.

Proficiency. Physicians with basic TEE training should be able to detect large, unequivocal cardiac masses. The use of TEE to accurately detect smaller or ill-defined masses, especially to distinguish potential masses from normal intracardiac structures, identify associated lesions, inspect the inferior vena cava, and rule out iatrogenic valve injury during resection of intracardiac masses, should be performed by, or in timely consultation with, a physician with advanced TEE training.

Foreign Bodies

Summary of the Evidence. The ability of intraoperative TEE to locate bullet fragments and medical devices (e.g., catheter fragments) is reported, but there is no evidence regarding its impact on clinical outcomes.

Expert Opinion. The yield of intraoperative TEE in detecting foreign bodies is likely to be low in most settings, but it may have greater utility at centers with a high incidence of gunshot injuries.

Recommendations

Indications. The detection of foreign bodies is a category II indication for intraoperative TEE.

Proficiency. To accurately detect foreign bodies, TEE should be performed by, or in timely consultation with, a physician with advanced TEE training.

Air Emboli

Summary of the Evidence. Intraoperative TEE can detect air bubbles in 8--60% of patients undergoing neurosurgery and 11--79% of patients undergoing cardiac surgery. Current evidence is inadequate, however, to determine whether these emboli increase the risk of neurologic complications or whether intraoperative TEE monitoring for air emboli improves clinical outcomes.

Expert Opinion. Transesophageal echocardiography is an extremely sensitive test for air (emboli as small as 2 micrometers usually can be detected) but the clinical significance of these bubbles is unclear. Animal studies suggest that air entrainment greater than 1 cc/kg increase the risk of neurologic complications, but the threshold value for safe air volumes in humans is uncertain. The task force believes that patients benefit when TEE detects air during cardiotomy and neurosurgical procedures. During cardiotomy, venting procedures before cessation of CPB can eliminate retained air, and the task force believes that such measures decrease the patient's risk of embolic neurologic events, right ventricular failure due to right coronary artery air embolism, and MI.[10] Transesophageal echocardiography offers similar benefits during sitting craniotomies, especially if the patient has not been screened preoperatively for patent foramen ovale. Patent foramen ovale appears to be a risk factor for stroke, and intraoperative maneuvers can induce intracardiac pressure changes that open probe-patent defects to permit paradoxical emboli. Transesophageal echocardiography is the only intraoperative tool for detecting these abnormalities; few other tests can detect air and sources of right-to-left shunts as accurately. The task force recognizes that the use of TEE during upright neurosurgical procedures may increase the risk of vocal cord injury, although these risks may be reduced by using proper technique and equipment.

Recommendations

Indications. The detection of air emboli during cardiotomy and heart transplant operations is a category II indication for using intraoperative TEE. It also should be considered on an individual basis for patients undergoing upright neurosurgical procedures (category II).

Proficiency. Anesthesiologists with basic TEE training should have an understanding of the physiologic effects of air emboli and should be technically capable of detecting air emboli intraoperatively, especially during upright neurosurgical procedures. The use of intraoperative TEE to accurately detect patent foramen ovale should be performed by, or in timely consultation with, a physician with advanced TEE training.

Intracardiac Thrombi

Summary of the Evidence. Intraoperative TEE can detect intracardiac thrombi in 2--10% of patients undergoing cardiac surgery, often exposing thrombi that were inapparent on preoperative TTE, but there is little evidence beyond case reports that the detection or evacuation of these clots results in improved clinical outcomes.

Expert Opinion. In patients undergoing thrombectomy, a preoperative echocardiographic examination can prevent an unnecessary operation if it determines that the thrombus has already embolized. If TTE was not performed in the immediate preoperative period, a pre-CPB TEE examination therefore is essential.

Recommendations

Indications. Intracardiac thrombectomy is a category II indication for pre-CPB TEE.

Proficiency. The use of intraoperative TEE to accurately detect intracardiac thrombi and to distinguish between true thrombi and artifacts should be performed by, or in timely consultation with, a physician with advanced TEE training.

Pulmonary Emboli

Summary of the Evidence. Case reports describe the use of perioperative TEE to detect and evaluate treatment of pulmonary emboli, but there is little evidence regarding its impact on clinical outcomes.

Expert Opinion. The task force believes that perioperative TEE is especially useful during pulmonary embolectomy to evaluate hemodynamic status and to detect residual emboli. The expert opinion of the task force, based on perioperative TEE monitoring, is that about 30% of embolectomy procedures fail to completely remove all emboli. The task force believes that these residual emboli are potentially harmful to the patient and that the use of TEE to detect them intraoperatively is therefore beneficial.

Recommendations

Indications. Transesophageal echocardiography may be useful to determine the cause of acute hemodynamic disturbances, such as those resulting from pulmonary emboli (see ``Hemodynamic Function''), but it is not necessary for all patients with known or suspected pulmonary emboli. Pulmonary embolectomy is a category II indication for using TEE.

Proficiency. The use of perioperative TEE to accurately diagnose pulmonary emboli or to monitor embolectomy or thrombolysis should be performed by, or in timely consultation with, a physician with advanced TEE training.

Emboli during Orthopedic Procedures

Summary of the Evidence. Intraoperative TEE can detect embolized air or medullary contents in as many as 30--62% of patients undergoing total hip replacement and, after tourniquet deflation, in 27--100% of patients undergoing knee arthroplasty. There is little evidence, however, that this information results in improved clinical outcomes.

Expert Opinion. In clinical practice, TEE detection of emboli during orthopedic procedures often prompts clinical interventions (e.g., replacing tourniquets) but the ultimate benefit to the patient of these maneuvers is uncertain.

Recommendations

Indications. Monitoring for emboli during orthopedic procedures is a category III indication for intraoperative TEE.

Traumatic Cardiac Injuries

Summary of the Evidence. Case reports describe the role of intraoperative TEE in detecting unrecognized traumatic injuries to the heart and of postoperative TEE in detecting injuries not seen on TTE, but there is otherwise little evidence that TEE improves the clinical outcome of cardiac trauma patients (see ``Traumatic Aortic Disruption'' and ``Nonoperative Critical Care Medicine'' later).

Expert Opinion. Routine use of TEE for evaluating cardiac trauma is predicated on the availability of TEE equipment and qualified staff at trauma units. Although there have been no studies beyond case reports to determine whether intraoperative TEE inspections during trauma surgery improve outcomes, cohort studies of postoperative trauma patients have shown that TEE in this setting often discloses injuries that went undetected during surgery. This evidence suggests that unsuspected injuries could be detected during surgery if TEE was performed intraoperatively. The need to return for further surgery and the risk of complications might thereby be reduced by intraoperative TEE, but this hypothesis needs to be confirmed through further research.

Recommendations

Indications. Suspected cardiac trauma is a category II indication for perioperative TEE.

Proficiency. The use of TEE to accurately detect traumatic cardiac injuries should be performed by, or in timely consultation with, a physician with advanced TEE training.

Thoracic Aortic Aneurysms and Dissections

The mortality rate in the first 48 h of aortic dissection is about 1% per hour, and prompt diagnosis and surgical intervention therefore are critical. Angiography and other imaging studies are often impractical because of the patient's rapidly worsening hemodynamic instability. The ability of TEE to detect aortic dissection was first described in 1986 and its ease of application has expanded its role in both the emergent evaluation of suspected dissection and in the recognition of dissections that occur during surgery.

Summary of the Evidence. With aortography, surgical findings, or necropsy as the reference standard, the use of TEE in the emergent preoperative assessment of aortic dissections has a reported sensitivity and specificity of 88--100% and 77--100%, respectively. Most of these studies, however, were unable to collect enough data to assess the true sensitivity and specificity of TEE. Transesophageal echocardiography in this setting appears to be more sensitive than TTE. However, beyond case reports and suggestive retrospective series, there is little direct evidence that the use of TEE for the emergent preoperative assessment of suspected aortic dissection results in improved clinical outcomes. In one series, its use during the repair of aortic dissections prompted a change in therapy in 14% of patients, but there is no direct evidence that the patients had better outcomes as a result of such interventions.

Expert Opinion. Although direct evidence of improved clinical outcomes is lacking, there is evidence that delayed detection of acute aortic dissection increases mortality. The task force therefore believes that any method that enhances prompt detection of acute dissections is potentially beneficial. The principal benefits of perioperative TEE during aortic reconstruction are to assess hemodynamic status (e.g., after cross-clamping), document entry and exit sites, confirm decompression of the false lumen, and determine whether valve surgery is needed.

Recommendations

Indications. The preoperative assessment of patients with suspected acute thoracic aortic dissections or aneurysms is a category II indication for TEE. Transesophageal echocardiography is among several accurate diagnostic tests, including angiography, computerized tomography, and magnetic resonance imaging. In unstable patients who should be evaluated quickly, there is a category I indication for TEE because it allows a more expedient examination than other preoperative imaging procedures.

The intraoperative use of TEE for assessing aortic valve function when patients undergo repair of aortic dissections with possible aortic valve involvement is a category I indication. The repair of other types of thoracic aortic dissections is a category II indication for intraoperative TEE.

Proficiency. The use of TEE to diagnose thoracic aortic dissection or aortic aneurysms should be performed by, or in timely consultation with, a physician with advanced TEE training. See ``Hemodynamic Function'' for proficiency recommendations in assessing intraoperative hemodynamic status.

Traumatic Thoracic Aortic Disruption

In trauma patients with suspected aortic injuries, hemodynamic shock often precludes the performance of diagnostic tests before the patient is taken to surgery. Preoperative or intraoperative TEE therefore can play an important role in the early detection of aortic injuries.

Summary of the Evidence. In most studies, the reported sensitivity and specificity of TEE in the emergent preoperative assessment of suspected aortic trauma is 100% and 94--100%, respectively, but limitations in study design make it difficult to determine the true sensitivity and specificity. There is little direct evidence that the use of TEE in this setting results in improved clinical outcomes.

Expert Opinion. Although scientific evidence may currently be lacking, the task force believes that early detection of undiagnosed traumatic aortic disruption improves clinical outcomes, because of the life-threatening nature of such injuries, and that TEE is an important method for diagnosing aortic trauma.

Recommendations

Indications. The preoperative assessment of suspected thoracic aortic trauma is a category II indication for TEE. It is among several accurate diagnostic tests, including angiography, computerized tomography, and magnetic resonance imaging. In unstable patients who need to be evaluated quickly, there is a category I indication for preoperative TEE because it allows a more expedient examination than other preoperative imaging procedures. Assessing the repair of thoracic aortic injuries is a category III indication for intraoperative TEE.

Proficiency. The use of TEE to accurately diagnose traumatic thoracic aortic disruption should be performed by, or in timely consultation with, a physician with advanced TEE training. See ``Hemodynamic Function'' for proficiency recommendations in diagnosing the cause of intraoperative hemodynamic dysfunction.

Sources of Aortic Emboli

About 1--5% of patients suffer strokes during CPB, and embolization of atheromatous ulcers on the aorta is considered a major risk factor. Palpation of the aorta, the standard method for detecting atherosclerotic aortic disease, is known to be insensitive. Transesophageal echocardiography, which has been shown outside the operating room to be capable of detecting aortic atheromas, has been used intraoperatively to complement palpation.

Summary of the Evidence. Intraoperative TEE may be less accurate than epivascular echocardiography in evaluating atheromatous disease in the ascending aorta. Atheromatous disease is noted on intraoperative TEE in 9% of elderly patients and result in a change in therapy in 8--17% of patients. However, although some studies suggest an association between TEE evidence of aortic atheroma and subsequent strokes, there is little direct evidence that the detection and treatment of such findings results in improved clinical outcomes.

Expert Opinion. Intraoperative TEE and epivascular echocardiography are capable of detecting aortic atheromatous disease, but it is currently unclear whether its detection improves clinical outcomes. Some studies suggest that the risk of embolism and stroke may be reduced by altering patient treatment.

Recommendations

Indications. The detection of aortic atheromatous disease or other sources of aortic emboli is a category II indication for intraoperative TEE. Transesophageal echocardiography infrequently is useful when compared with epivascular echocardiography.

Pericarditis

Summary of the Evidence. No studies have been performed to determine whether intraoperative TEE is accurate in detecting pericarditis or results in improved clinical outcomes.

Expert Opinion. In clinical practice, TEE may be helpful in evaluating constrictive pericarditis and pericardiectomy procedures.

Recommendations

Indications. Evaluating the effectiveness of pericardiectomy is a category II indication for intraoperative TEE. Uncomplicated pericarditis is a category III indication.

Proficiency. Use of TEE to guide diagnosis or surgical treatment of pericarditis should be performed by, or in timely consultation with, a physician with advanced TEE training.

Pericardial Effusions and Tamponade

Summary of the Evidence. There is some evidence suggesting that perioperative TEE is more sensitive than TTE in detecting pericardial effusions, but there is little evidence beyond case reports that such findings during or after surgery result in improved clinical outcomes.

Expert Opinion. Although supporting scientific evidence is limited, the task force believes that perioperative TEE is clinically beneficial if it detects pericardial tamponade and avoids serious hemodynamic sequelae. This application is especially important when effusions cannot be detected easily by other means. For example, clinical experience suggests that posterior or loculated pericardial effusions that are easily missed by the surgeon may develop in patients receiving pericardial windows.

Recommendations

Indications. The detection of pericardial effusions or evaluation of pericardial surgery is a category II indication for intraoperative TEE. In patients undergoing pericardial window procedures, there is a category I indication for using TEE to evaluate the adequacy of treatment.

Proficiency. Anesthesiologists with basic TEE training should be able to detect large, pericardial effusions. Physicians with advanced TEE training should be able to detect and assess the hemodynamic significance of effusions. Transesophageal echocardiography that is used to guide pericardial surgery should be performed by, or in timely consultation with, a physician with advanced TEE training.

Pleuropulmonary Diseases

Summary of the Evidence. There is no direct evidence that intraoperative TEE is accurate in detecting pleural or pulmonary parenchymal disease, or that such monitoring results in improved clinical outcomes.

Recommendations

Indications. The evaluation of pleuropulmonary diseases is a category III indication for perioperative TEE.

Transplant Surgery

Summary of the Evidence. Some studies suggest that TEE is more sensitive than TTE in screening cardiac donor patients and more accurate than pulmonary capillary wedge pressure measurements in detecting hemodynamic disturbances during transplant surgery. Postoperative studies have demonstrated its ability to evaluate cardiac allograft function and detect thrombotic obstruction and stenoses in patients with lung transplants. However, its effect on clinical outcomes has not been evaluated systematically.

Expert Opinion. Anastomotic integrity may be accurately assessed by TEE. The task force also believes that the hemodynamic benefits of TEE during major organ transplant surgery are especially important. In these patients, TEE is believed to be more accurate in diagnosing the cause of hemodynamic disturbances than is central venous pressure or pulmonary artery catheter monitoring.

Recommendations

Indications. Evaluating anastomotic sites during heart and/or lung transplantation is a category II indication for intraoperative TEE.

Proficiency. Perioperative TEE to evaluate the surgical results of transplant surgery, such as the integrity of anastomoses, should be performed by, or in timely consultation with, a physician with advanced TEE training. Anesthesiologists with basic training should be able to evaluate hemodynamic disturbances (see ``Hemodynamic Function'') and to detect entrapped air (see ``Air Emboli'') during transplant operations.

Mechanical Circulatory Support, Defibrillators, and Catheter Placement

Summary of the Evidence. Case reports and small series have described the use of intraoperative TEE to aid placement and monitor function of intraaortic balloon pumps, ventricular assist devices, automatic implantable cardiac defibrillators, pulmonary artery catheters, coronary sinus catheters, and ventriculoatrial shunts. There is little direct evidence, however, that TEE is necessary to insert and operate these devices safely or that its use results in improved clinical outcomes.

Expert Opinion. Although there is no direct evidence regarding the clinical effectiveness of TEE monitoring of mechanical circulatory assist devices, patients receiving such devices usually are experiencing hemodynamic disturbances for which TEE is considered beneficial (see ``Hemodynamic Function'' earlier). The task force also believes that its use to confirm placement of such devices reduces the need for intraoperative radiography, thereby decreasing radiation exposure and operating room time.

Recommendations

Indications. Monitoring placement and function of assist devices is a category II indication for TEE. Monitoring placement of intraaortic balloon pumps, automatic implantable cardiac defibrillators, or pulmonary artery catheters is a category III indication.

Proficiency. The specific use of TEE to monitor placement and function of mechanical circulatory assistance devices should be performed by, or in timely consultation with, a physician with advanced TEE training. Anesthesiologists with basic training should be capable of evaluating accurately the mechanism of hemodynamic disturbances in patients receiving mechanical circulatory assistance (see ``Hemodynamic Function'').

Cardioplegia

Summary of the Evidence. Studies have described the use of intraoperative TEE to evaluate the distribution of cardioplegia solution and to aid placement of cannulas for cardioplegia infusions, but there is little direct evidence that using TEE for this purpose results in improved clinical outcomes.

Expert Opinion. The use of TEE for achieving cardioplegia is an emerging technology, and future research findings may warrant a more routine role for aiding cannula placement and confirming adequate distribution of the solution.

Recommendations

Indications. Monitoring the administration of cardioplegia solution is a category III indication for intraoperative TEE.

Nonoperative Critical Care Medicine

The increasing availability of TEE, along with recent technological advances, has resulted in its increased use in nonsurgical ICU patients. Many anesthesiologists engaged in critical care medicine encounter potential applications of TEE when caring for unstable ICU patients, and supporting scientific evidence is briefly reviewed below. As noted earlier, the methodology of the task force required it to limit its literature review to studies of TEE conducted specifically in the critical care or perioperative setting. Thus, evidence from echocardiographic and cardiac catheterization laboratories regarding the accuracy and effectiveness of TEE in evaluating valvular heart disease, hemodynamic disturbances, embolic sources, and a variety of other common problems in the ICU could not be included. Although an examination of this large body of indirect evidence was beyond the scope of the task force project and is omitted from this report, information about these studies is available in other reviews.[1,2]

Summary of the Evidence. Some studies report that TEE detects information not detected by TTE in 44--59% of ICU patients, but the studies did not compare both tests systematically. Information provided by TEE examinations is reported to change therapy in 17--48% of critical care patients. There is little direct evidence of clinical benefit, however, beyond case reports of the use of TEE to detect the cause of hemodynamic disturbances; to diagnose endocarditis, aortic disease, valvular insufficiency, embolic sources; or to aid ventilator management, thrombolytic therapy, and resuscitation. These studies provide little direct evidence that the diagnoses could not be made by other means or that patients diagnosed or monitored by TEE experience better clinical outcomes than those without it.

Expert Opinion. Although there is little direct evidence that TEE affects clinical outcomes in the ICU, its effectiveness in correcting life-threatening problems can be inferred from its proven accuracy in detecting these problems and from evidence that early detection and treatment improves outcomes (e.g., see earlier sections on acute aortic dissection, myocardial ischemia, and hemodynamic function). For those conditions that can be evaluated accurately by TEE, the task force believes its use in the ICU is appropriate when TTE or other tests are unable to make the diagnosis or when patients are too unstable to consider other tests. Transesophageal echocardiography may be the first choice in diagnosing certain problems. Its superiority over other tests in detecting valve disease, hemodynamic disturbances, unsuspected traumatic cardiac injuries, embolic sources, and other problems has been reviewed already. The task force notes that, although the evidence reviewed in this section is limited to the nonoperative critical care patient, TEE has similar, if not greater, utility in the unstable postoperative patient being cared for in the postanesthesia care unit or ICU.

Recommendations

Indications. Unexplained hemodynamic disturbances, suspected valve disease, or thromboembolic problems in unstable ICU patients are category I indications for TEE if other tests or monitoring techniques have failed to confirm the diagnosis or if patients are too unstable to undergo other tests. Other reviews provide more detailed recommendations on the role of echocardiography and other diagnostic procedures in the critical care setting.

Proficiency. Transesophageal echocardiography examinations of nonoperative critical care patients for indications other than determining the cause of hemodynamic disturbances should be performed by, or in consultation with, a physician with advanced TEE training.

Adverse Effects

Summary of the Evidence. In most studies, serious complications (e.g., esophageal injury or bleeding, vocal cord paralysis, dysrhythmias, hypotension, seizures, cardiac arrest) occur in less than 3% of TEE examinations. Studies reporting a higher incidence of serious complications (8--13%) generally involve select study populations, outdated TEE techniques, or broader case definitions (e.g., including atrial ectopy among dysrhythmias). The reported mortality rate associated with TEE is 0.01--0.03%, but in most cases a causal link with TEE has not been established. Minor complications from TEE (and their reported incidence) include lip injuries (13%), hoarseness (12%), dysphagia (1.8%), endotracheal intubation (0.3%), bradycardia (0.2%), and dental injuries (0.1%). The reported incidence of bacteremia in most studies is 0--4%, but there is little direct evidence that patients experience clinical consequences. Respiratory complications occur more frequently in awake examinations (0.1--4%) or in small children (2%), whose membranous trachea is easily compressed by the probe. Hemodynamic compromise also may be more common in small children. There is no scientific evidence that anticoagulation increases significantly the risk of bleeding during TEE examinations.

Expert Opinion Reported complication rates for TEE, although low, may overestimate true complication rates in the operating room, for several reasons. First, operator skill is an important determinant of complication rates, and reported rates from TEE studies involving inexperienced examiners may not be applicable to rates observed by experienced practitioners. (Conversely, rates reported by seasoned TEE examiners may underestimate the risk of complications among other practitioners). Second, reported incidence rates for adverse effects often originate from examinations of awake patients, in whom some complications are more common than in anesthetized surgical patients. For example, the task force believes that dysrhythmias may be less common in anesthetized than in awake patients. Inadvertent endotracheal insertion of the TEE probe is uncommon in the operating room, in part because endotracheal intubation precedes placement of the TEE probe. Third, confounding variables may have a more direct effect on observed complications than TEE. For example, endotracheal intubation, rather than TEE, may account for the high reported incidence (12--13%) of hoarseness and lip injuries. Comorbidity (e.g., coronary artery disease, neoplasms), rather than TEE, may account for such observed outcomes as myocardial ischemia, dysrhythmias, and gastroesophageal bleeding.

Recommendations

Contraindications. The risk of esophageal injury can be minimized by avoiding TEE examination of patients with extensive esophageal or gastric disease. Relative contraindications include esophageal varices, Barrett's esophagus, Zenker's diverticulum, and postradiation therapy of the esophageal area. Attempts should be made to minimize the pressure exerted on the esophageal mucosa by the TEE probe, including avoiding the practice of keeping the probe in a locked, flexed position. An appropriate probe size should be selected for small children, and airway pressure monitoring should be emphasized during examinations. Most importantly, anesthesiologists performing TEE examinations should be careful that the procedure does not distract them from other intraoperative responsibilities.

Routine safety procedures also can reduce complication rates. Infectious complications can be reduced by adhering to proper probe sterilization practices. Universal precautions to reduce transmission of infectious diseases should be followed. In patients with valve disease or congenital heart malformations, preoperative antibiotic prophylaxis should be prescribed according to current guidelines. Manufacturers' recommendations for ensuring electrical safety should also be followed.

Proficiency. All anesthesiologists who perform TEE should be familiar with the full range of potential complications of the procedure and with methods for minimizing their risk.

Certification, Credentialing, Quality Assurance, and Training

The incorporation of TEE in the practice of anesthesia has led to a number of challenging issues related to certification, credentialing, quality assurance and training. Using the available legal, regulatory, and scientific literatures, the task force has attempted to address some of these issues. In many instances, however, the task force has needed to rely on expert opinion in its efforts to formulate recommendations.

Certification

Certification of proficiency is not currently available for practitioners of TEE. While the authority and responsibility for certification of consultants in anesthesiology lies with the American Board of Anesthesiology, it has no precedent for certifying proficiency in technical procedures. The task force recommends that certification of special qualification in perioperative TEE be pursued through multispecialty collaboration.

Credentialing

Credentialing of health-care professionals is a volatile arena for physician-hospital and physician-physician relations, because the stakes for practitioners and institutions are so high. Physicians are credentialed for two reasons: first, to ensure that, at a given hospital, an even standard of care is delivered to patients; and second, to fulfill the legal responsibility of the hospital for the patient. Although these reasons are similar, the difference is crucial. Hospitals usually are corporations, legal entities established under state law, with authority and responsibilities provided by those laws. The law recognizes a corporate duty on the part of a hospital's board of directors (or trustees) that is much more specific than is the case for their broader responsibility for the provision of quality medical care. In the fulfillment of these duties, hospital boards rely on state-specific directives from statutory law as well as common law and Joint Commission for the Accreditation of Health Care Organizations guidelines. Although the hospital board passes the responsibility on to the medical staff for the specifics of appointment, reappointment and granting of privileges, which the medical staff codifies in the medical staff bylaws, the final authority for credentialing rests with the hospital board.

The Joint Commission for the Accreditation of Health Care Organizations requires that the medical staff be responsible to the hospital board for the quality of care provided to patients. This quality of care responsibility begins with the granting of clinical privileges and is hospital-specific. Thus, the hospital must have adequate facilities and support staff to provide the services for which privileges are granted. Furthermore, ``Professional criteria specified in the medical staff bylaws and *uniformly* applied to all applicants for delineated clinical privileges constitute the basis for granting initial or continuing privileges.'' Each clinical department develops its own criteria for determining an applicant's ability to provide services within the scope of privileges requested. However, these department-specific criteria are in addition to the general medical staff criteria for clinical privileges.

These criteria must include evidence of relevant training and experience, and evidence of current competence. This evidence ideally includes at least proof of skill in performing invasive procedures and information on appropriateness and outcomes as well as the application of appropriate clinical judgment. Reappointment also must include information regarding the person's clinical and technical skills, as indicated in part by the results of quality assurance and improvement activities. The process should be most thorough when privileges are for complicated treatment or procedures.

Although many organizations, most notably the American College of Physicians, are attempting to develop guidelines to assist hospitals in the granting of clinical privileges, they are primarily based on the recommendations of postgraduate training programs with little supporting evidence. This problem is recognized by the Joint Commission for the Accreditation of Health Care Organizations, which requires that the granting of privileges take into account hospital-specific factors and, by inference, the local pool of specially trained professionals. In view of these considerations, the task force cannot justify the imposition of nationwide recommendations for the granting of initial clinical privileges in perioperative TEE. However, it strongly supports requirements of continuous assessment of an individual's clinical performance using objective evidence as the basis for the renewal of privileges.

Quality Assurance

Quality assurance programs employing total quality management concepts are used widely to improve medical services.11-17 Quality management employs three basic, closely related activities: quality planning, quality control, and quality improvement. Quality planning involves developing definitions of quality as applied to the customer, designing products and services to meet customer needs, and designing processes capable of producing these products and services. Quality control involves developing and applying methods for ensuring that processes work as they are designed. Quality improvement focuses on improving the level of performance of key processes. Continuous quality improvement maintains periodic reviews of the quality assurance program to meet changing customer needs and improve the organization's efficiency. When applying total quality management concepts to perioperative TEE, the terms ``products'' and ``customers'' need to be employed in their broadest meaning. The major product of perioperative TEE is information, which is provided to customers. These customers can include other anesthesiologists, surgeons, cardiologists, other physicians, the patient, or the manufacturers of echocardiographic equipment.

Which process of a TEE program is the current ``key process'' that may benefit from improvement will vary from program to program. The following outline of ``processes'' was developed to assist in focusing on possible key processes within echocardiography programs.

1. Indications for performing TEE

2. Technical aspects of performing and recording the examination

3. Application of examination findings to physiologic condition

4. Documentation

5. Equipment

6. Professional Communications

7. Education

8. Billing

The application of quality management to an echocardiographic service need not be restricted to the areas mentioned earlier. Periodic updating of the quality assurance program as the TEE service evolves will facilitate meeting the goals originally set forth and defining new goals to meet clinical needs.

Training

General Principles.

While several guidelines for the training of physicians who wish to practice TEE have been developed, few have focused on the specifics of a perioperative TEE practice.18-21 The task force recommends that two levels of training in perioperative TEE, basic and advanced, be recognized for the anesthesiologist. Advanced training should be pursued only after basic training has been completed.

Anesthesiologists with basic training in perioperative TEE should be able to use TEE for indications that lie within the customary practice of anesthesiology. Examples of such indications include: the perioperative diagnosis of myocardial ischemia, the perioperative assessment of hemodynamics and ventricular function, the perioperative management of cardiovascular collapse, and others. The task force realizes, however, that anesthesiologists with basic training occasionally will encounter unanticipated diagnostic issues that require the assistance of a physician with advanced TEE training. Anesthesiologists with basic training must be able to recognize their limitations in this setting and request assistance, in a timely manner, from a physician with advanced training. Anesthesiologists with advanced training in perioperative TEE should, in addition to the above, be able to exploit the full diagnostic potential of TEE in the perioperative period. The task force recognizes that, once basic training has been completed, advanced training may occur along a continuum and in a gradual manner. Learning curves will vary from person to person, but are likely to be substantial for some of the TEE applications requiring advanced training. Because it is essential for many intraoperative applications to obtain a definitive interpretation of the TEE examination at the time of surgery, the task force strongly recommends that anesthesiologists actively pursue collaboration with surgeons, cardiologists, or other physicians involved in a patient's care. Specific objectives for basic and advanced training are defined in table 2.

Training Pathways

Anesthesiologists. The anesthesiologist who wishes to attain basic or advanced training in perioperative TEE must undertake certain steps in the process. First, the anesthesiologist should begin to master the cognitive and some of the technical skills outlined in table 2 by studying standard texts and commercially available videotapes and by attending TEE workshops and training sessions. Second, the anesthesiologist should establish a collaborative relationship with a physician who is proficient in TEE to assist the anesthesiologist in acquiring additional technical skills in TEE. The nature of the collaborative relationship should be such that the anesthesiologist refers to the other physician in a timely manner when his/her expertise is exceeded. The collaboration should be an ongoing relationship rather than a brief period of assistance. Third, as with other clinical procedures, mastery of TEE requires time, practice, and repetition on the part of the anesthesiologist to achieve adequate proficiency. While training in perioperative echocardiography need not be restricted to a specific training pathway or protocol (e.g., specified duration of echocardiography laboratory rotations, mandatory TTE training, videotape reviews, required number of examinations to be performed), the task force recommends that anesthesiologist training in TEE be one of the essential processes that are assessed objectively in a quality assurance program for perioperative TEE. Recognizing the importance of maintaining proficiency, the task force recommends that another essential quality assurance process should evaluate an anesthesiologist's ability to maintain skills after training is complete.

Residents in Anesthesiology.

Introductory Knowledge. The task force recommends that all residents in anesthesiology acquire introductory knowledge in perioperative TEE. Every resident who completes the continuum of education in anesthesiology should understand how TEE can be safely and effectively used in essential perioperative applications. The training should include knowledge on the physical principles of echocardiographic imaging and blood flow measurements, two-dimensional echocardiographic anatomy of the heart and great vessels, and the perioperative indications, limitations, diagnostic capabilities, and risks of TEE.

Basic Proficiency. Residents in anesthesiology who wish to pursue basic training in perioperative TEE should acquire the cognitive and technical skills outlined in table 2 for basic training. The training program should have an active perioperative TEE program. Although basic TEE skills can be taught by a physician with basic proficiency, the training program should be under the guidance of, or in close collaboration with, a physician with advanced training in perioperative TEE.

Advanced Proficiency. Residents in anesthesiology who wish to attain an advanced level of training in perioperative TEE should acquire the cognitive and technical skills defined in table 2 for advanced training. The training should occur in cooperation with an established echocardiography service and under the direct guidance of a physician with advanced proficiency in perioperative TEE.

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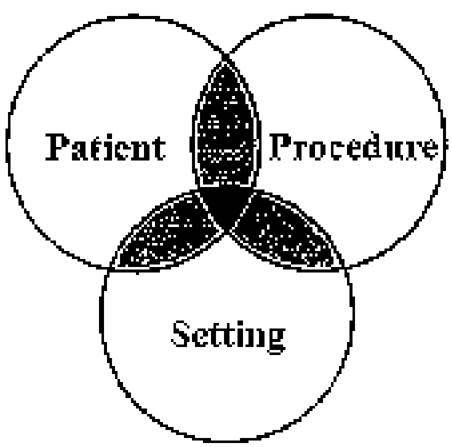

Fig. 1. The three domains of risk in assessing the appropriateness of transesophageal echocardiography (TEE). Risk factors for perioperative complications associated with the patient include age, sex, coexisting medical disorders, and past medical history, which influence the risk of perioperative complications. Factors associated with the procedure include characteristics of the operation that increase the likelihood of complications. Factors associated with the clinical setting include hospital-specific variables (e.g., complication rates, availability and skills of personnel, and access to equipment) and other special circumstances. A thoughtful examination of each of these variables is necessary to accurately assess a patient's risk of

perioperative complications and to gauge whether the potential benefits of TEE in reducing these risks outweigh potential harms associated with TEE itself. The complex interactions among these variables makes it inappropriate to specify surgical procedures or clinical problems that uniformly do or do not require TEE. For example, a healthy patient undergoing a simple procedure may require TEE if it occurs in a high-risk clinical setting; the overall risk of complications may exceed that of a high-risk patient undergoing surgery with skilled providers and excellent equipment. Only the overall magnitude of risk is useful in determining the potential utility and benefit-harm ratio of performing TEE.

Table 1. Quick Reference Guide: Indications for Perioperative Transesophageal Echocardiography

Category I indications: Supported by the strongest evidence or expert opinion; TEE is frequently useful in improving clinical outcomes in these settings and is often indicated, depending on individual circumstances (e.g., patient risk and practice setting; see fig. 1).

Intraoperative evaluation of acute, persistent, and life-threatening hemodynamic disturbances in which ventricular function and its determinants are uncertain and have not responded to treatment

Intraoperative use in valve repair

Intraoperative use in congenital heart surgery for most lesions requiring cardiopulmonary bypass

Intraoperative use in repair of hypertrophic obstructive cardiomyopathy

Intraoperative use for endocarditis when preoperative testing was inadequate or extension of infection to perivalvular tissue is suspected

Preoperative use in unstable patients with suspected thoracic aortic aneurysms, dissection, or disruption who need to be evaluated quickly

Intraoperative assessment of aortic valve function in repair of aortic dissections with possible aortic valve involvement

Intraoperative evaluation of pericardial window procedures

Use in intensive care unit for unstable patients with unexplained hemodynamic disturbances, suspected valve disease, or thromboembolic problems (if other tests or monitoring techniques have not confirmed the diagnosis or patients are too unstable to undergo other tests)

Category II indications: Supported by weaker evidence and expert consensus; TEE may be useful in improving clinical outcomes in these settings, depending on individual circumstances, but appropriate indications are less certain.

Perioperative use in patients with increased risk of myocardial ischemia or infarction

Perioperative use in patients with increased risk of hemodynamic disturbances

Intraoperative assessment of valve replacement

Intraoperative assessment of repair of cardiac aneurysms

Intraoperative evaluation of removal of cardiac tumors

Intraoperative detection of foreign bodies

Intraoperative detection of air emboli during cardiotomy, heart transplant operations, and upright neurosurgical procedures

Intraoperative use during intracardiac thrombectomy

Intraoperative use during pulmonary embolectomy

Intraoperative use for suspected cardiac trauma

Preoperative assessment of patients with suspected acute thoracic aortic dissections, aneurysms, or disruption

Intraoperative use during repair of thoracic aortic dissections without suspected aortic valve involvement

Intraoperative detection of aortic atheromatous disease or other sources of aortic emboli

Intraoperative evaluation of pericardiectomy, pericardial effusions or evaluation of pericardial surgery

Intraoperative evaluation of anastomotic sites during heart and/or lung transplantation

Monitoring placement and function of assist devices

Category III indications: Little current scientific or expert support; TEE is infrequently useful in improving clinical outcomes in these settings, and appropriate indications are uncertain.

Intraoperative evaluation of myocardial perfusion, coronary artery anatomy, or graft patency

Intraoperative use during repair of cardiomyopathies other than hypertrophic obstructive cardiomyopathy

Intraoperative use for uncomplicated endocarditis during noncardiac surgery

Intraoperative monitoring for emboli during orthopedic procedures

Intraoperative assessment of repair of thoracic aortic injuries

Intraoperative use for uncomplicated pericarditis

Intraoperative evaluation of pleuropulmonary diseases

Monitoring placement of intraaortic balloon pumps, automatic implantable cardiac defibrillators, or pulmonary artery catheters

Intraoperative monitoring of cardioplegia administration

TEE = transesophageal echocardiography.

Table 2. Specific Training Objectives

Basic training

Cognitive skills

1. Knowledge of the physical principles of echocardiographic image formation and blood flow velocity measurement

2. Understanding the operation of the ultrasonographic instrument, including the function of all controls affecting the quality of data displayed

3. Knowledge of the equipment handling, infection control, and electrical safety recommendations associated with the use of TEE

4. Knowledge of the indications and the absolute and relative contraindications to the use of TEE

5. General knowledge of appropriate alternative diagnostic modalities, especially transthoracic and epicardial echocardiography

6. Knowledge of the normal cardiovascular anatomy as visualized tomographically by TEE

7. Knowledge of commonly encountered blood flow velocity profiles as measured by Doppler echocardiography

8. Detailed knowledge of the echocardiographic presentations of myocardial ischemia and infarction

9. Detailed knowledge of the echocardiographic presentations of normal and abnormal ventricular function

10. Detailed knowledge of the physiology and TEE presentation of air embolization

11. Knowledge of native valvular anatomy and function as displayed by TEE; knowledge of the major TEE manifestations of valve lesions and dysfunction and of the TEE techniques available for valve assessment

12. Knowledge of the principal TEE manifestations of cardiac masses, thrombi, and emboli; cardiomyopathies; pericardial effusions; and lesions of the great vessels

Technical skills

1. Ability to operate the ultrasonograph, including controls affecting the quality of the displayed data

2. Ability to perform safely a TEE-probe insertion in the anesthetized, tracheally intubated patient

3. Ability to perform a basic TEE examination

4. Ability to recognize major echocardiographic changes associated with myocardial ischemia and infarction

5. Ability to detect qualitative changes in ventricular function and hemodynamic status

6. Ability to recognize echocardiographic manifestations of air embolization

7. Ability to visualize cardiac valves in multiple views, ability to recognize gross valvular lesions and dysfunction

8. Ability to recognize large intracardiac masses and thrombi

9. Ability to detect large pericardial effusions

10. Ability to recognize common artifacts and pitfalls in TEE examinations

11. Ability to communicate the results of a TEE examination to the patient and to other health care professionals and to summarize these results cogently in the medical record

Advanced training

Cognitive skills

1. All the cognitive skills defined under basic proficiency

2. Knowledge of the principles and methodology of quantitative echocardiography

3. Detailed knowledge of native valvular anatomy and function; knowledge of prosthetic valvular structure and function; detailed knowledge of the echocardiographic manifestations of valve lesions and dysfunction

4. Knowledge of the echocardiographic manifestations of congenital heart disease

5. Detailed knowledge of echocardiographic manifestations of pathologic conditions of the heart and great vessels (such as cardiac aneurysms, HOCM, endocarditis, intracardiac masses, cardioembolic sources, aortic aneurysms and dissections, pericardial disorders, and postsurgical changes)

6. Detailed knowledge of other cardiovascular diagnostic methods for correlation with TEE findings

Technical skills

1. All the technical skills defined under basic proficiency

2. Ability to perform a complete TEE examination

3. Ability to quantify subtle echocardiographic changes associated with myocardial ischemia and infarction

4. Ability to utilize TEE to quantify ventricular function and hemodynamics

5. Ability to utilize TEE to evaluate and quantify the function of all cardiac valves (e.g., measurement of gradient, regurgitant jet area, flow-velocity pattern, valve orifice area); ability to assess surgical intervention on cardiac valvular function

*6. Ability to utilize TEE to evaluate congenital heart lesions; ability to assess surgical intervention in congenital heart disease

*7. Ability to detect and assess the functional consequences of pathologic conditions of the heart and great vessels (such as cardiac aneurysms, HOCM, endocarditis, intracardiac masses, cardioembolic sources, aortic aneurysms and dissections, and pericardial disorders); ability to evaluate surgical intervention in these conditions if applicable

8. Ability to monitor placement and function of mechanical circulatory assistance devices

TEE = transesophageal echocardiography; HOCM = hypertrophic obstructive cardiomyopathy.

*Some of the technical skills may not apply, depending on practice setting.

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