Anesthesiology 2010; 112:1084–96

Practice Guidelines for Perioperative Transesophageal Echocardiography

*An Updated Report by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography**

PRACTICE Guidelines are systematically developed recommendations that assist the practitioner and the patient in making decisions about health care. These recommendations may be adopted, modified, or rejected according to clinical needs and constraints and are not intended to replace local institutional policies. In addition, Practice Guidelines developed by the American Society of Anesthesiologists (ASA) are not intended as standards or absolute requirements, and their use cannot guarantee any specific outcome. Practice Guidelines are subject to revision as warranted by the evolution of medical knowledge, technology, and practice. They provide basic recommendations that are supported by a synthesis and analysis of the current literature, expert and practitioner opinion, open forum commentary, and clinical feasibility data.

This update includes data published since the Practice Guidelines for Perioperative Transesophageal Echocardiography were adopted by the ASA and the Society of Cardiovascular Anesthesiologists in 1995 and published in 1996.[1]

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Received from American Society of Anesthesiologists, Park Ridge, Illinois. Submitted for publication October 22, 2009. Accepted for publication October 22, 2009. Supported by the American Society of Anesthesiologists and developed under the direction of the Committee on Standards and Practice Parameters, Jeffrey L. Apfelbaum, M.D. (Chair). Approved by the ASA House of Delegates on October 21, 2009, and the SCA Board of Directors on October 21, 2009. A complete bibliography used to develop these Guidelines, arranged alphabetically, is available as Supplemental Digital Content 1, http://links.lww.com/ALN/A567.

Address correspondence to The American Society of Anesthesiologists: 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573. This Practice Guideline, as well as all ASA Practice Parameters, may be obtained at no cost through the Journal Web site, www.anesthesiology.org.

Methodology

Definition of Perioperative Transesophageal Echocardiography

For these Guidelines, perioperative transesophageal echocardiography (TEE) refers to TEE performed on surgical patients before, during, or immediately after surgery, including the critical care setting. Evidence of effectiveness is discussed relative to specific settings where perioperative TEE is customarily used (*e.g.*, cardiac surgery, noncardiac surgery, and critical care).

Purposes of the Guidelines

The purposes of these Guidelines are (1) to assist the physician in determining the appropriate application of TEE and (2) to improve the outcomes of surgical patients by defining the utility of perioperative TEE based on the strength of supporting evidence.

Focus

These Guidelines focus on the application of TEE in surgical patients and potential surgical patients in the setting of cardiac surgery, noncardiac surgery, and postoperative critical care. The Guidelines do not apply to the assessment of nonsurgical patients or to postdischarge follow-up assessment of surgical patients.

The Task Force believes that physician proficiency in the use of perioperative TEE is of paramount importance due to the risk of adverse outcomes resulting from incorrect interpretation. The Guidelines do not address training, certification, credentialing, and quality assurance, which are addressed elsewhere.[2–5]

Application

These Guidelines are intended for anesthesiologists and other physicians (*e.g.*, cardiologists, surgeons, and intensivists) who use TEE in the perioperative setting. Recommendations to perform TEE are not applicable when the proce-

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dure cannot be performed properly or safely nor do they apply when TEE equipment or skilled examiners are unavailable. The recommendations in this report are based on consideration of the risk benefit ratio for individual patients.

Task Force Members and Consultants

The ASA and Society of Cardiovascular Anesthesiologists jointly appointed a task force of 13 members, including anesthesiologists in both private and academic practice from various geographic areas of the United States, two cardiologists (one representing the American College of Cardiology and the other representing the American Society of Echocardiography), and two consulting methodologists from the ASA Committee on Standards and Practice Parameters.

The Task Force developed the Guidelines by means of a seven-step process. First, they reached consensus on the criteria for evidence. Second, original published research studies from peer-reviewed journals relevant to TEE were reviewed and evaluated. Third, expert consultants were asked (1) to participate in opinion surveys on the effectiveness of TEE imaging and (2) to review and comment on a draft of the Guidelines developed by the Task Force. Fourth, opinions about the Guidelines recommendations were solicited from a sample of active members of the ASA who personally perform TEE as a part of their practice. Fifth, the Task Force held an open forum at a major international meeting† to solicit input on its draft recommendations. Sixth, the consultants were surveyed to assess their opinions on the feasibility of implementing the Guidelines. Seventh, all available information was used to build consensus within the Task Force to finalize the Guidelines (appendix 1).

Availability and Strength of Evidence

Preparation of these Guidelines followed a rigorous methodologic process (appendix 2). Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence.

Scientific Evidence

Study findings from scientific literature published after 1994 (not excluding sentinel articles published prior to 1994) were aggregated and reported in summary form by evidence category, as described later. All literature (*e.g.*, randomized controlled trials, observational studies, and case reports) relevant to each topic was considered when evaluating the findings. For reporting purposes in this document, only the highest level of evidence (*i.e.*, levels 1, 2, or 3 identified below) within each category (*i.e.*, A, B, or C) is included in the summary.

† Society of Cardiovascular Anesthesiologists, 30th Annual Meeting, Vancouver, British Columbia, Canada, June 20, 2008.

‡ All meta-analyses are conducted by the ASA methodology group. Meta-analyses from other sources are reviewed but not included as evidence in this document.

Category A: Supportive Literature

Randomized controlled trials report statistically significant ($P < 0.01$) differences between clinical interventions for a specified clinical outcome.

Level 1. The literature contains multiple randomized controlled trials, and the aggregated findings are supported by meta-analysis.‡

Level 2. The literature contains multiple randomized controlled trials, but there is an insufficient number of studies to conduct a viable meta-analysis for the purpose of these Guidelines.

Level 3. The literature contains a single randomized controlled trial.

Category B: Suggestive Literature

Information from observational studies permits inference of beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1. The literature contains observational comparisons (*e.g.*, cohort and case–control research designs) of two or more clinical interventions or conditions and indicates statistically significant differences between clinical interventions for a specified clinical outcome.

Level 2. The literature contains noncomparative observational studies with associative (*e.g.*, relative risk, correlation) or descriptive statistics.

Level 3. The literature contains case reports.

Category C: Equivocal Literature

The literature cannot determine whether there are beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1. Meta-analysis did not find significant differences among groups or conditions.

Level 2. There is an insufficient number of studies to conduct meta-analysis, and (1) randomized controlled trials have not found significant differences among groups or conditions, or (2) randomized controlled trials report inconsistent findings.

Level 3. Observational studies report inconsistent findings or do not permit inference of beneficial or harmful relationships.

Category D: Insufficient Evidence from Literature

The lack of scientific evidence in the literature is described by the following conditions.

(1) No identified studies address the specified relationships among interventions and outcomes.

(2) The available literature cannot be used to assess the relationships among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the "Focus" of the Guidelines or does not permit a clear interpretation of findings due to methodologic concerns (*e.g.*, confounding in study design or implementation).

Opinion-based Evidence

All opinion-based evidence relevant to each topic (*e.g.*, survey data, open-forum testimony, Internet-based comments, letters, and editorials) was considered in the development of these Guidelines. However, only the findings obtained from formal surveys are reported.

Opinion surveys were developed by the Task Force to address each clinical intervention identified in the document. Identical surveys were distributed to two groups of respondents: expert consultants and ASA members.

Category A: Expert Opinion

Survey responses from Task Force–appointed expert consultants are reported in summary form in the text. A complete listing of consultant survey responses is reported in a table in appendix 2.

Category B: Membership Opinion

Survey responses from a sample of members of the ASA are reported in summary form in the text. A complete listing of ASA member survey responses is reported in a table in appendix 2.

Expert consultant and ASA membership survey responses are recorded using a 5-point scale and summarized based on median values.§

Strongly agree: median score of 5 (at least 50% of the responses are 5).
Agree: median score of 4 (at least 50% of the responses are 4 or 4 and 5).
Equivocal: median score of 3 (at least 50% of the responses are 3, or no other response category or combination of similar categories contain at least 50% of the responses).
Disagree: median score of 2 (at least 50% of responses are 2 or 1 and 2).
Strongly disagree: median score of 1 (at least 50% of responses are 1).

Category C: Informal Opinion

Open-forum testimony, Internet-based comments, letters, and editorials are all informally evaluated and discussed during the development of Guidelines recommendations. When warranted, the Task Force may add educational information or cautionary notes based on this information.

Guidelines

Cardiac and Thoracic Aortic Procedures

Cardiac and thoracic aortic procedures consist of cardiac and thoracic aortic surgery, and catheter-based intracardiac procedures.

Cardiac and thoracic aortic surgery: For cardiac or thoracic aortic surgery patients, the literature reports variations in sensitivity, specificity, or positive and negative predictive values for the detection of abnormalities relating to valvular, coronary, aortic, congenital, and other cardiovascular disease (table 1 in appendix 2). Examples of these abnormalities include mitral valve abnormalities, valvular abscesses, myocardial ischemia, aortic dissection, and atrial septal defect (*Category B2 evidence*). The literature also reports a range of sensitivity, specificity, and positive and negative predictive values for the confirmation or refinement by TEE of the preoperative diagnosis (table 1 in appendix 2). Examples include aortic dissection, aortic intramural hemorrhage, and valvular or mural infective endocarditis lesions (*Category B2 evidence*). The ASA members agree and the consultants strongly agree that TEE should be used for all cardiac or thoracic aortic surgery patients.

Recommendations for cardiac and thoracic aortic surgery. For adult patients without contraindications, TEE should be used in all open heart (*e.g.*, valvular procedures) and thoracic aortic surgical procedures and should be considered in coronary artery bypass graft surgeries to: (1) confirm and refine the preoperative diagnosis, (2) detect new or unsuspected pathology, (3) adjust the anesthetic and surgical plan accordingly, and (4) assess the results of surgical intervention. In small children, the use of TEE should be considered on a case-by-case basis because of risks unique to these patients (*e.g.*, bronchial obstruction).

Catheter-based intracardiac procedures: Studies with observational findings confirm the utility of TEE or intracardiac echocardiography for guiding management of catheter-based intracardiac procedures (*e.g.*, occluder device placement, percutaneous valvular procedures, and intracardiac ablation procedures) (*Category B2 evidence*). In addition, studies with observational findings report the detection of unsuspected abnormalities by TEE, such as aortic root abscess, atrial thrombi, atrial septal aneurysm, shunting, mitral valve/annular calcification and regurgitation, wall motion abnormalities, and tamponade (*Category B2 evidence*). The detection of pericardial effusion is also reported (*Category B3 evidence*).

Both the consultants and ASA members agree that TEE should be used for patients undergoing transcatheter intracardiac procedures when general anesthesia is provided and intracardiac ultrasound is not used. The ASA members agree and the consultants strongly agree that TEE should be used for septal defect closure or atrial appendage obliteration. Both the consultants and ASA members strongly agree that TEE should be used during catheter-based valve replacement and repair. Finally, both the consultants and ASA members are equivocal regarding the use of TEE during dysrhythmia treatment.

Recommendations for catheter-based intracardiac procedures. For patients undergoing transcatheter intracardiac procedures, TEE may be used.

Noncardiac Surgery

For noncardiac surgery patients, studies with observational findings or case reports note the detection of the following abnormalities by TEE: (1) venous air embolism and patent foramen

§ When an equal number of responses are obtained, the median value is determined by calculating the arithmetic mean of the two middle values. Ties are determined by a predetermined formula.

ovale in neurosurgery (*Category B2 evidence*); (2) pericardial effusion and compression of the cardiac chambers in liver transplantation (*Category B3 evidence*); (3) intracardiac emboli and patent foramen ovale (*Category B2 evidence*), mitral regurgitation, left ventricular hypertrophy, and left ventricular outflow tract obstruction in orthopedic surgery (*Category B3 evidence*), (4) left ventricular segmental wall motion abnormalities (*Category B2 evidence*), aortic lesions and atrial tumors in vascular surgery (*Category B3 evidence*), and (5) atrial septal defect, myocardial ischemia, hypovolemia, pericardial tamponade, thromboembolic events (*Category B2 evidence*), pericardial effusion, tamponade, and intrapulmonary emboli in other major surgery (*i.e.*, lung, renal, abdominal, and head/neck/chest wall surgeries) (*Category B3 evidence*).

The consultants and ASA members agree that TEE should be used for noncardiac surgical patients when the patient has known or suspected cardiovascular pathology that might result in hemodynamic, pulmonary, or neurologic compromise. The consultants and ASA members both strongly agree that TEE should be used during unexplained persistent hypotension. Further, both the consultants and ASA members agree that TEE should be used when persistent unexplained hypoxemia occurs. The ASA members agree and the consultants strongly agree that TEE should be used when life-threatening hypotension is anticipated.

Both the consultants and ASA members agree that TEE should be used during either lung transplantation or major abdominal or thoracic trauma. The consultants agree although the ASA members are equivocal regarding the use of TEE during open abdominal aortic procedures and liver transplantation. Both the consultants and ASA members are equivocal regarding the use of TEE during: (1) endovascular aortic procedures, (2) neurosurgery in the sitting position, and (3) percutaneous cardiovascular interventions (*e.g.*, femoral artery stenting). Finally, the consultants and ASA members both disagree with the assertion that TEE should be used during orthopedic surgery.

Recommendations for noncardiac surgery. TEE may be used when the nature of the planned surgery or the patient's known or suspected cardiovascular pathology might result in severe hemodynamic, pulmonary, or neurologic compromise. If equipment and expertise are available, TEE should be used when unexplained life-threatening circulatory instability persists despite corrective therapy.

Critical Care

Studies with observational findings for critically ill patients with an unexplained adverse postoperative clinical course report TEE detection for the following abnormalities: regurgitant valvular lesions, aortic or mitral valve vegetation, aortic dissection, intracardiac mass, tamponade, ventricular failure, and hypovolemia (*Category B2 evidence*). Case reports of critically ill postoperative patients indicate that TEE detects abnormalities such as aortic root abscess, pericardial hematoma, atherosclerotic debris in the thoracic aorta, left ventricular hypertrophy, wall motion abnormalities, and ventricular masses (*Category B3 evidence*).

Both the consultants and ASA members strongly agree that TEE should be used for critical care patients when diagnostic information expected to alter management cannot be obtained by transthoracic echocardiography or other modalities in a timely manner. The ASA members agree and the consultants strongly agree that TEE should be used during unexplained persistent hypotension. They both agree that TEE should be used when persistent unexplained hypoxemia occurs.

Recommendations for critical care. For critical care patients, TEE should be used when diagnostic information that is expected to alter management cannot be obtained by transthoracic echocardiography or other modalities in a timely manner.

Contraindications for the Use of TEE

Studies with observational findings and case reports indicate that, although rare, potential complications associated with TEE may include esophageal perforation, esophageal injury, hematoma, laryngeal palsy, dysphagia, dental injury, or death (*Category B2 evidence*). However, there is insufficient literature to assess whether there are contraindications for the use of TEE (*Category D evidence*).

Both the consultants and ASA members are equivocal with regard to whether there are no absolute contraindications to TEE other than previous esophagectomy or esophagogastrectomy. Those consultants and ASA members who do not agree that there are no absolute contraindications other than previous esophagectomy or esophagogastrectomy do agree that the following four conditions should be absolute contraindications to TEE: esophageal stricture, tracheoesophageal fistula, postesophageal surgery, and esophageal trauma. Both the consultants and ASA members disagree that the following four conditions should be absolute contraindications to TEE: Barrett esophagus, hiatal hernia, large descending aortic aneurysm, and unilateral vocal cord paralysis. Finally, both the consultants and ASA members are equivocal with regard to whether the following three conditions should be absolute contraindications to TEE: esophageal varices, postradiation therapy, and previous bariatric surgery. The consultants agree but the ASA members are equivocal that Zenker diverticulum and colonic interposition are absolute contraindications. Finally, the ASA members disagree and the consultants are equivocal that dysphagia is an absolute contraindication to TEE.

Recommendations. TEE may be used for patients with oral, esophageal, or gastric disease, if the expected benefit outweighs the potential risk, provided the appropriate precautions are applied. These precautions may include the following: considering other imaging modalities (*e.g.*, epicardial echocardiography), obtaining a gastroenterology consultation using a smaller probe, limiting the examination, avoiding unnecessary probe manipulation, and using the most experienced operator.

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Appendix 1: Summary of Recommendations

Cardiac and Thoracic Aortic Procedures

- Cardiac and Thoracic Aortic Surgery
  - For adult patients without contraindications, TEE should be used in all open heart *(e.g.*, valvular procedures) and thoracic aortic surgical procedures and should be considered in CABG surgeries as well
    - to confirm and refine the preoperative diagnosis,
    - to detect new or unsuspected pathology,
    - to adjust the anesthetic and surgical plan accordingly, and
    - to assess the results of the surgical intervention.
  - In small children, the use of TEE should be considered on a case-by-case basis because of risks unique to these patients (*e.g.*, bronchial obstruction).
- Catheter-Based Intracardiac Procedures
  - For patients undergoing transcatheter intracardiac procedures, TEE may be used.

Noncardiac Surgery

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

Critical Care

- For critical care patients, TEE should be used when diagnostic information that is expected to alter management cannot be obtained by transthoracic echocardiography or other modalities in a timely manner.

Contraindications for the Use of TEE

- TEE may be used for patients with oral, esophageal, or gastric disease, if the expected benefit outweighs the potential risk, provided the appropriate precautions are applied. These precautions may include:
  - considering other imaging modalities *(e.g.*, epicardial echocardiography)
  - obtaining a gastroenterology consultation
  - using a smaller probe
  - limiting the examination
  - avoiding unnecessary probe manipulation
  - using the most experienced operator

Appendix 2: Methods and Analyses

State of the Literature

For these Guidelines, a literature review was used in combination with opinions obtained from expert consultants and other sources (*e.g.*, ASA members, open forums, Internet postings). Both the literature review and opinion data were based on evidence linkages or statements regarding potential relationships between clinical interventions and outcomes. The efficacy and outcomes from the use of TEE were examined for the following procedures:

1. cardiac and thoracic aortic surgery
2. transcatheter intracardiac procedures
3. pacemaker and implanted cardioverter defibrillator lead extraction
4. neurosurgery
5. liver transplantation
6. orthopedic surgery
7. vascular/endovascular surgery
8. other major surgery (*i.e.*, lung, renal, abdominal, and head/neck/chest wall)
9. postoperative critical care

The impact of the use of perioperative TEE was assessed on the basis of the following:

1. perioperative detection or diagnosis of new or unsuspected pathology
2. confirming or refinement of previous perioperative diagnoses
3. preoperative or intraoperative refinement of a surgical plan
4. detecting complications during surgery
5. assessing surgery outcomes
6. planning and confirming device placement
7. beneficial or adverse patient outcomes from the use of TEE

For the literature review, potentially relevant clinical studies published after 1994 were identified via electronic and manual searches of the literature. The electronic and manual searches covered a 16-yr period from 1994 through 2009. More than 8000 citations were initially identified, yielding a total of 861 nonoverlapping articles that addressed topics related to the evidence linkages. After review of the articles, 404 studies did not provide direct evidence and were subsequently eliminated. A total of 457 articles contained direct linkage-related evidence. A complete bibliography used to develop these Guidelines, organized by section, is available as Supplemental Digital Content 2, http://links.lww.com/ALN/A568.

Literature reporting the detection of new abnormalities by TEE was summarized, followed by a summary of literature reporting the confirmation of previously diagnosed abnormalities by TEE. The

sensitivity, specificity, and positive and negative predictive values for the efficacy of TEE in detecting new abnormalities and in confirming or redefining previous diagnoses were also obtained (table 1). Study findings reporting the misdiagnosis or limited effectiveness of TEE to detect pathology are also listed in table 1.

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a κ statistic for two-rater agreement pairs were as follows: (1) type of study design, $\kappa = 0.50–1.00$; (2) type of analysis, $\kappa = 0.50–0.83$; (3) evidence linkage assignment, $\kappa = 0.75–1.00$; and (4) literature inclusion for database, $\kappa = 0.78–1.00$. Three-rater chance-corrected agreement values were as follows: (1) study design, Sav = 0.66, Var (Sav) = 0.006; (2) type of analysis, Sav = 0.66, Var (Sav) = 0.007; (3) linkage assignment, Sav = 0.83, Var (Sav) = 0.005; and (4) literature database inclusion, Sav = 0.84, Var (Sav) = 0.046. These values represent moderate to high levels of agreement.

Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) survey opinion from consultants who were selected based on their knowledge or expertise in the perioperative use of TEE, (2) survey opinions solicited from active members of the ASA who personally perform TEE as part of their practice, (3) testimony from attendees of a publicly held open forum at an international anesthesia meeting, (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 53% ($n = 55$ of 103) for the consultants, and 818 surveys were received from active ASA members who indicated that they personally performed TEE as part of their practice. Results of the surveys are reported in tables 2 and 3 and summarized in the text of the Guidelines.

The consultants were asked to indicate which, if any, of the recommendations would change their clinical practices if the Guidelines were instituted. The rate of return was 14% ($n = 14$ of 103). The percent of responding consultants expecting a change in their practice associated with each linkage topic was as follows: (1) major cardiac and thoracic aortic surgery, 7%; (2) transcatheter intracardiac procedures, 0%; (3) pacemaker and implanted cardioverter defibrillator lead extraction, 7% (4); neurosurgery, 7% (5); liver transplantation, 0% (6); orthopedic surgery, 7% (7); vascular/endovascular surgery, 7%, (8) other major surgery (*i.e.*, lung, renal, abdominal, and head/neck/chest wall), 14%; and (9) postoperative critical care, 21%. Eighty-six percent indicated that their clinical practice will not need new equipment, supplies, or training to implement the Practice Guidelines. Eighty-six percent indicated that the Guidelines would not require ongoing changes in their practice which will affect costs. One hundred percent of the respondents indicated that the Guidelines would have no effect on the amount of time spent on a typical case.

Table 1. Sensitivity, Specificity, and Predictive Values for Perioperative TEE

Detection/Diagnosis of Pathology	Sensitivity (%)	Specificity (%)	PPV	NPV
Valvular disease:				
Aortic, mitral, or tricuspid valvular perforation (confirmed by surgery or autopsy)[6]	95	98	*	*
Abnormal bicuspid and tricuspid aortic valve morphology (confirmed by surgery)[7]				
Biplane TEE	66	56	*	*
Multiplane TEE	87	91	*	*
Chordal rupture (confirmed by surgery)[8]	79	96	*	*
Mitral valve annular dilatation (confirmed by surgery)[8]	78	50	*	*
Mitral valve leaflet degeneration (confirmed by surgery)[8]	41	87	*	*
Mitral valve prolapse/flail (confirmed by surgery)[9]				
Bileaflet involvement or combined lesion including the commissures	20	93	*	*
Single leaflet but multiscallop involvement	57	96	*	*
Commissure involvement	11	98	*	*
Mitral valve/flail leaflet scallop (confirmed by surgery)[10]	78	92	*	*
Mitral valve regurgitation (confirmed by surgery)[11]	87	100	100%	92%
Mitral vegetation (confirmed by surgery)[11]	90	100	100%	75%
Prosthetic valve endocarditis (pathoanatomic confirmation)[12]	92	97	*	*
Prosthetic valve fistula (confirmed by surgery or necropsy)[13]	100	100	*	*
Valvular abscess (confirmed by surgery or necropsy)[13]	90	100	*	*
Coronary disease:				
Myocadial infarction (confirmed by creatine kinase-MB level ≥100 ng/ml within 12 h after operation or new Q waves on arrival in ICU or on morning of postoperative day 1)[14]	45	73	27%	86%
Pseudonaneurysm (confirmed by surgery or necropsy)[13]	100	98	*	*
Aortic disease:				
Aortic dissection (confirmed by aortography, surgery, or necropsy)[15]	67	70	*	*
Aortic dissection (confirmed by double-blind readings of the images)[16]	86	67	*	*
Aortic dissection—type I or III (confirmed by CT/MRI, surgery, or autopsy)[17]	100	*	*	*
Aortic dissection—thoracic (confirmed by angiography, surgery, or autopsy)[18]	100	94	*	*
Atherosclerosis of the ascending aorta (confirmed by epiaortic scanning)[19]	100	60	34%	100%
Traumatic disruption of the aorta (confirmed by aortography, clinical findings, or both)[20]	57	91	*	*
Traumatic disruption of the aorta (confirmed by surgery)[21]	91	100	*	*
Other cardiovascular diseases:				
Left ventricular outflow tract lesions (confirmed by surgery, catheter findings)[22]	94	100	*	*
Pulmonary embolus (confirmed by surgery)[23]				
Anywhere within the pulmonary arterial circulation	46	*	*	*
At one of three specific localizations	26	95	93%	32%

False positives/negatives:

Preoperative TEE detected aneurysm and pericardial effusion; neither confirmed at surgery[24]
Preoperative TEE detected aortic dissection; surgery revealed Takayasu arteritis[25]
Preoperative TEE detected intramural hematoma; surgery revealed aortic dissection[26]
Preoperative TEE detected mass consistent with periannular abscess; surgery revealed coronary ostium[27]
Preoperative TEE detected type A aortic dissection; surgery revealed aortic valve commissural tear[28]
Preoperative TEE did not detect aortic outflow obstruction; surgery revealed occluded valve orifice[29]
Preoperative TEE did not detect ascending aortic dissection; revealed at surgery[30]
Preoperative TEE did not detect calcified fibrous tissue obstructing mechanical valve inflow; detected at surgery[31]
Preoperative TEE did not detect endocarditis, aortic root abscess; revealed at surgery[32]
Preoperative TEE did not detect endocarditis; detected by intracardiac echocardiography[33]
Preoperative TEE did not detect hematoma of ascending aorta; detected by CT[34]
Preoperative TEE did not detect torn ascending aorta, detected by aortography[35]

(*continued*)

Table 1. Continued

Detection/Diagnosis of Pathology	Sensitivity (%)	Specificity (%)	PPV	NPV
Confirming/refining diagnosis:				
Aortic intramural hemorrhage (confirmed by surgery or follow-up changes)[36]	100	91	*	*
False positives/negatives:				
Preoperative emergency TEE confirmed intramural hematoma; surgery revealed acute aortic intimal tear without a mobile flap[37]				
Preoperative emergency TEE confirmed pericardial cyst; surgery revealed coronary arterial aneurysm[38]				
Preoperative TEE confirmed ascending aorta dissection; surgery revealed chronic inflammatory aneurysm[39]				
Preoperative TEE confirmed tricuspid valve mass; surgery revealed thrombus[40]				
Preoperative TEE confirmed valvular tumor; surgery revealed organized thrombus when resected[41]				

* No available data.

CT = computed tomography; ICU = intensive care unit; MRI = magnetic resonance imaging; NPV = negative predictive value; PPV = positive predictive value; TEE = transesophageal echocardiography.

Table 2. Consultant Survey Responses

	n*	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Cardiac and thoracic aortic surgery						
TEE should be used for all cardiac and thoracic aortic surgical patients	55	61.8†	34.6	0.0	3.6	0.0
The following responses represent only those consultants who disagree that TEE should be used for all cardiac and thoracic aortic surgical patients.						
TEE should be used in patients undergoing						
Valve repair	3	100.0†	0.0	0.0	0.0	0.0
Aortic valve replacement	3	100.0†	0.0	0.0	0.0	0.0
Mitral valve replacement	3	100.0†	0.0	0.0	0.0	0.0
Other valve replacement	3	100.0†	0.0	0.0	0.0	0.0
CABG surgery with normal ventricular function	3	0.0	33.3	0.0	66.7†	0.0
CABG surgery with abnormal ventricular function	3	33.3	66.7†	0.0	0.0	0.0
Off-pump CABG	3	0.0	33.3	33.3†	33.3	0.0
Redo cardiac surgery	3	33.3	33.3†	0.0	33.3	0.0
Congenital heart surgery with cardiopulmonary bypass	3	100.0†	0.0	0.0	0.0	0.0
Congenital heart surgery without cardiopulmonary bypass	3	33.3	0.0	33.3†	33.3	0.0
Ascending thoracic aortic surgery	3	100.0†	0.0	0.0	0.0	0.0
Descending thoracic aortic surgery	3	33.3	0.0	0.0	66.7†	0.0
Hypertrophic cardiomyopathy surgery	3	100.0†	0.0	0.0	0.0	0.0
Resection of cardiac mass	3	100.0†	0.0	0.0	0.0	0.0
Ventricular remodeling surgery	3	100.0†	0.0	0.0	0.0	0.0
Open surgery for dysrhythmias	3	33.3	33.3†	0.0	33.3	0.0
Endocarditis surgery	3	66.7†	33.3	0.0	0.0	0.0
Heart transplant	3	33.3	66.7†	0.0	0.0	0.0
Pericardiectomy	3	33.3	66.7†	0.0	0.0	0.0
Open pericardial surgery	3	33.3	0.0	33.3†	33.3	0.0
Ventricular assist device	3	33.3	66.7†	0.0	0.0	0.0
Endoscopically assisted surgery	3	33.3	66.7†	0.0	0.0	0.0
Cannulae positioning	3	33.3	66.7†	0.0	0.0	0.0
Transcatheter intracardiac procedures						
For patients undergoing transcatheter intracardiac procedures, TEE should be used when general anesthesia is provided and intracardiac ultrasound is not used	54	48.2	37.0†	11.1	3.7	0.0
TEE should be used for the following transcatheter intracardiac procedures						
Septal defect closure	54	83.3†	14.8	1.9	0.0	0.0
Atrial appendage obliteration	53	64.2†	28.3	7.6	0.0	0.0
Valve replacement and repair	54	88.9†	11.1	0.0	0.0	0.0
Dysrhythmia treatment	54	14.8	29.6	37.0†	18.5	0.0
Noncardiac surgery						
For noncardiac surgical patients, TEE should be used						
When the patient has known or suspected cardiovascular pathology that might result in hemodynamic, pulmonary or neurologic compromise	55	30.1	43.6†	12.7	10.9	1.8
During unexplained persistent hypotension	54	87.0†	13.0	0.0	0.0	0.0
When persistent unexplained hypoxemia occurs	55	34.6	38.2†	18.2	7.3	1.8
When life-threatening hypotension is anticipated	55	54.6†	29.1	9.1	7.3	0.0
TEE should be used in noncardiac surgical patients undergoing						
Open abdominal aortic procedures	55	18.2	41.8†	23.6	14.6	1.8
Endovascular aortic procedures	52	17.3	25.0	38.5†	15.4	3.9
Orthopedic surgery	55	5.5	14.6	20.0	50.9†	9.1
Liver transplantation	54	25.9	27.8†	33.3	11.1	1.9
Neurosurgery in the sitting position	55	9.1	30.9	25.5†	30.9	3.6
Percutaneous cardiovascular interventions	55	16.4	27.3	30.9†	16.4	9.1
Lung transplantation	54	40.7	24.1†	29.6	5.6	0.0
Major abdominal or thoracic trauma	53	37.7	35.9†	20.8	5.7	0.0

(*continued*)

Table 2. Continued

	n*	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Critical care						
For critical care patients, TEE should be used						
When diagnostic information expected to alter management cannot be obtained by TTE or other modalities in a timely manner	53	83.0†	15.1	1.9	0.0	0.0
During unexplained persistent hypotension	53	67.9†	32.1	0.0	0.0	0.0
When persistent unexplained hypoxemia occurs	54	33.3	38.9†	22.2	5.6	0.0
Contraindications						
There are no absolute contraindications to TEE other than prior esophagectomy or esophagogastrectomy	54	22.2	25.9	1.9†	40.7	9.3
The following conditions should be absolute contraindications to TEE						
Esophageal varices	29	10.3	37.9	13.8†	34.5	3.5
Esophageal stricture	29	20.7	55.2†	6.9	17.2	0.0
Barrett esophagus	29	3.5	24.1	17.2	44.8†	10.3
Zenker diverticulum	29	20.7	31.0†	17.2	31.0	0.0
Postradiation therapy	29	3.5	13.8	44.8†	37.9	0.0
Hiatal hernia	29	0.0	3.5	13.8	62.1†	20.7
Previous bariatric surgery	29	0.0	20.7	31.0†	41.4	6.9
Large descending aortic aneurysm	29	6.9	3.5	10.3	65.5†	13.8
Dysphagia	29	6.9	17.2	37.9†	31.0	6.9
Tracheoesophageal fistula	29	20.7	58.6†	17.2	3.5	0.0
Postesophageal surgery	29	13.8	69.0†	13.8	3.5	0.0
Esophageal trauma	29	48.3	34.5†	13.8	3.5	0.0
Unilateral vocal cord paralysis	29	0.0	0.0	20.7	75.9†	3.5
Colonic interposition	29	13.8	48.3†	20.7	13.8	3.5

* n is the number of consultants who responded to each item. All other numbers in the table represent the percentage of consultants who selected the designated response category. † Median response falls within the designated response category.

CABG = coronary artery bypass graft; TEE = transesophageal echocardiography.

Table 3. ASA Members Survey Responses

	n*	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Cardiac and thoracic aortic surgery						
TEE should be used for all cardiac and thoracic aortic surgical patients	818	45.2	30.7†	6.5	15.8	1.8
The following responses represent only those ASA members who are uncertain or disagree that TEE should be used for all cardiac and thoracic aortic surgical patients.						
TEE should be used in patients undergoing						
Valve repair	194	77.3†	22.2	0.5	0.0	0.0
Aortic valve replacement	194	64.9†	32.0	2.6	0.5	0.0
Mitral valve replacement	193	74.1†	24.9	1.0	0.0	0.0
Other valve replacement	186	61.8†	31.7	5.9	0.5	0.0
CABG surgery with normal ventricular function	191	1.6	10.5	23.0	56.5†	8.4
CABG surgery with abnormal ventricular function	193	14.5	54.4†	22.8	7.8	0.5
Off-pump CABG	193	8.8	27.5	35.8†	24.9	3.1
Redo cardiac surgery	192	15.6	37.0†	33.9	13.0	0.5
Congenital heart surgery with cardiopulmonary bypass	181	43.6	33.2†	23.2	0.0	0.0
Congenital heart surgery without cardiopulmonary bypass	182	26.4	29.1†	37.9	6.6	0.0
Ascending thoracic aortic surgery	191	51.3†	36.7	7.3	4.2	0.5
Descending thoracic aortic surgery	192	18.2	34.4†	31.8	15.6	0.0
Hypertrophic cardiomyopathy surgery	192	50.0†	35.9	13.0	0.5	0.5
Resection of cardiac mass	193	56.5†	35.8	5.2	2.1	0.5
Ventricular remodeling surgery	192	50.0†	40.6	8.3	0.5	0.5
Open surgery for dysrhythmias	192	9.4	22.4	43.2†	24.5	0.5
Endocarditis surgery	189	39.7	36.5†	19.6	4.2	0.0
Heart transplant	190	33.7	31.1†	31.6	3.7	0.0
Pericardiectomy	192	12.5	31.3	30.7†	24.0	1.6
Open pericardial surgery	193	8.3	29.0	35.8†	25.9	1.0
Ventricular assist device	189	39.7	33.9†	20.1	5.8	0.5
Endoscopically assisted surgery	185	28.1	26.0†	39.5	6.0	0.6
Cannulae positioning	193	14.5	28.0	39.4†	17.6	0.5
Transcatheter intracardiac procedures						
For patients undergoing transcatheter intracardiac procedures, TEE should be used when general anesthesia is provided and intracardiac ultrasound is not used	777	22.3	35.1†	37.5	5.0	0.1
TEE should be used for the following transcatheter intracardiac procedures						
Septal defect closure	776	49.5	34.3†	14.8	1.4	0.0
Atrial appendage obliteration	776	36.7	39.4†	21.8	2.1	0.0
Valve replacement and repair	776	68.8†	23.1	8.1	0.0	0.0
Dysrhythmia treatment	776	7.7	18.8	49.7†	21.1	2.6
Noncardiac surgery						
For noncardiac surgical patients, TEE should be used						
When the patient has known or suspected cardiovascular pathology that might result in hemodynamic, pulmonary or neurologic compromise	789	22.2	47.0†	20.7	9.8	0.4
During unexplained persistent hypotension	789	50.1†	43.7	4.9	1.1	0.1
When persistent unexplained hypoxemia occurs	786	21.3	42.4†	28.1	8.1	0.1
When life-threatening hypotension is anticipated	791	30.7	37.2†	23.1	8.6	0.4
TEE should be used in noncardiac surgical patients undergoing						
Open abdominal aortic procedures	786	12.2	29.1	31.0†	25.2	2.4
Endovascular aortic procedures	785	5.4	14.1	32.0†	41.0	7.6
Orthopedic surgery	786	0.1	6.2	26.7	55.5†	11.5
Liver transplantation	779	15.5	30.6	40.8†	11.6	1.5
Neurosurgery in the sitting position	783	9.8	32.4	33.1†	22.0	2.7
Percutaneous cardiovascular interventions	784	5.0	13.4	32.9†	40.4	8.3
Lung transplantation	780	23.1	34.6†	36.0	6.0	0.3
Major abdominal or thoracic trauma	785	20.5	37.1†	28.7	12.4	1.4

(*continued*)

Table 3. Continued

	n*	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Critical care						
For critical care patients, TEE should be used						
When diagnostic information expected to alter management cannot be obtained by TTE or other modalities in a timely manner	782	52.7†	43.9	3.3	0.0	0.1
During unexplained persistent hypotension	780	41.5	49.2†	6.9	2.2	0.1
When persistent unexplained hypoxemia occurs	781	21.5	42.9†	28.0	7.4	0.1
Contraindications						
There are no absolute contraindications to TEE other than previous esophagectomy or esophagogastrectomy	788	11.7	33.0	12.6†	32.9	9.9
The following conditions should be absolute contraindications to TEE						
Esophageal varices	428	12.4	35.5	18.0†	33.2	0.9
Esophageal stricture	427	16.6	49.7†	15.7	17.3	0.7
Barrett esophagus	428	4.2	18.5	25.7	45.3†	6.3
Zenker diverticulum	429	9.3	33.6	30.5†	25.6	0.9
Postradiation therapy	427	5.2	27.9	42.2†	23.7	1.2
Hiatal hernia	425	0.5	3.8	12.0	67.5†	16.2
Previous bariatric surgery	427	5.6	21.1	33.7†	36.5	3.0
Large descending aortic aneurysm	426	1.4	4.5	25.8	60.6†	7.8
Dysphagia	423	1.4	12.5	31.2	50.4†	4.5
Tracheoesophageal fistula	417	18.0	47.0†	25.7	8.6	0.7
Postesophageal surgery	423	20.8	47.0†	24.6	7.6	0.0
Esophageal trauma	423	35.0	53.7†	10.2	1.2	0.0
Unilateral vocal cord paralysis	425	2.1	5.2	31.5	57.2†	4.0
Colonic interposition	428	11.0	29.7	41.4†	17.1	0.9

* n is the number of American Society of Anesthesiologists (ASA) members who personally perform transesophageal echocardiography (TEE) and responded to each item. All other numbers in the table represent the percentage of ASA members who selected the designated response category. † Median response falls within the designated response category.

CABG = coronary artery bypass graft.