Indications and Guidelines for Performance of Transesophageal Echocardiography in the Patient with Pediatric Acquired or Congenital Heart Disease

A Report from the Task Force of the Pediatric Council of the American Society of Echocardiography

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Over the past 15 years transesophageal echocardiography (TEE) has assumed an integral role in the diagnosis and management of patients with acquired pediatric cardiovascular disorders and congenital heart disease (CHD). It is particularly suited to define complex anatomical structures, functional abnormalities, and flow disturbances that may not always be obtainable from transthoracic echocardiography (TTE) alone. TEE has become a standard imaging technology for patients with CHD undergoing intervention in the catheterization laboratory or in the operating room.[1-9] As miniaturized probes, novel technologies, and new methodologies develop, the applications of TEE in the patient with CHD continue to expand.[10-13] The American Society of Echocardiography (ASE) and the Society of Cardiovascular Anesthesiologists have established guidelines and standards for performing a comprehensive TEE in the adult with heart disease.[14] Recognizing the unique aspects and growing applications of TEE in the pediatric patient with acquired or congenital cardiovascular disease (henceforth referred to as "the patient with CHD"), the Pediatric Council of the American Society of Echocardiography selected a task force to create a position statement specifically for the performance of TEE in this select category of patient. This statement serves as an update of a previous statement published in 1992[15] and reviews current indications, contraindications, safety issues, and training guidelines for TEE in the pediatric patient with CHD.

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I. INDICATIONS FOR TEE IN THE PATIENT WITH CHD

Intraoperative TEE

The most common indication for TEE in patients with CHD is for assessment during cardiac surgery. Intraoperative TEE requires considerable preoperative preparation. The task force recommends that a preoperative TTE be performed in every patient undergoing TEE during congenital heart surgery and that the findings be reviewed by the echocardiographer before the intraoperative TEE is performed. The intraoperative TEE should not stand alone as the sole diagnostic study since there are inherent limitations in imaging certain important structures that are otherwise identified best by TTE (ie, transverse aortic arch, aortic isthmus, distal left pulmonary artery, and collateral pulmonary vessels). Additional constraints specific to intraoperative TEE include limited potential for optimal Doppler alignment, limited time to perform a complete study, and suboptimal ambient lighting. While the preoperative TTE provides information unobtainable by intraoperative TEE, the intraoperative TEE performed just

before surgical intervention can provide additional information and may be of benefit. It may confirm or exclude preoperative TTE findings and assess the immediate preoperative hemodynamics and ventricular function of the patient. In addition, the findings can be directly demonstrated to the surgeon and anesthesiologist for immediate review just prior to commencement of the operation. Preoperative TEE may also facilitate the placement of central venous catheters, selection of anesthetic agents, and use of preoperative inotropic support by demonstrating ventricular systolic function and size.[16,17]

Previous authors have addressed the utility and importance of intraoperative TEE in patients with congenital cardiac abnormalities.[1-9,18,19] Performance of TEE in the patient with CHD immediately *after* surgery, but before chest closure, has been a contributor to the overall excellence in outcome for congenital heart surgery achieved in the past decade. Based upon the TEE and clinical findings, the surgeon, in conjunction with the TEE echocardiographer and anesthesiologist, determines whether the surgical repair is acceptable. TEE provides the opportunity to detect significant and potentially treatable disease before disconnection of bypass cannulae, sternal closure, and return to the ICU. In addition, it assesses cardiac function, presence of intracardiac air, and may aid in the diagnosis of cardiac rhythm abnormalities. TEE has been used to monitor ventricular function and loading conditions following cardiac transplantation.[20] TEE assists in evaluating the intracardiac results of minimally invasive cardiac surgical procedures, in which there is limited direct visualization of the heart. In the critically ill postoperative patient with limited transthoracic views, TEE permits assessment of ventricular function and assists in determining appropriate timing and hemodynamic effect of sternal closure or discontinuation of ventricular assist device or extracorporeal membrane oxygenation. When postoperative TTE is not feasible, TEE may be used to monitor hemodynamic changes as inotropic drugs or ventilator settings are adjusted.[21]

Intraoperative TEE in high risk CHD patients undergoing *noncardiac* procedures enhances monitoring of myocardial function and intravascular volume status. High risk patients who would benefit from intraoperative TEE monitoring may include those with complex CHD and significant residual anatomic defects, as well as patients with myocardial dysfunction, cardiomyopathies, or pulmonary hypertension.

TEE in the Cardiac Catheterization Laboratory

TEE is instrumental during many interventional congenital cardiac catheterization procedures and it has been shown to reduce fluoroscopy time and contrast load. In addition, it allows for continuous assessment of results and detection of potential complications.[22-25] TEE has become a standard imaging modality during atrial septal defect (ASD) closure in the catheterization laboratory. TEE provides precise identification of the location, geometry, and number of atrial septal defects as well as the extent of surrounding atrial septal tissue and location of adjacent structures, information that aids the interventionist's strategy for device closure. Newer imaging modalities, multiplane and 3-dimensional TEE have been found to further enhance visualization of the atrial septum and positioning of the ASD device.[26-31] TEE has also been used to guide catheter-directed ventricular septal defect closure.[32] It may also facilitate manipulation of catheters used for radiofrequency ablation, balloon valvuloplasty, or laser perforation of valvar atresia, since immediate effects of treatment may be demonstrated.[22]

TEE Outside of the Operating Room or Catheterization Laboratory

TEE in the pediatric patient may be performed outside of the operating room in the intensive care unit, a specialized monitored procedure room, endoscopy suite, or in the echocardiographic laboratory with appropriate monitoring and support personnel.[33] Table 1 lists common indications for performance of TEE in the pediatric patient outside of the setting of an intervention. Patients with suspected CHD, but who have a nondiagnostic TTE, may benefit from a TEE.[33] The patient with intracardiac or extracardiac baffles or conduits (ie, Fontan, Senning, Mustard, or Rastelli operation) may have pathways that are particularly difficult to image with TTE.[34-38] In patients after Fontan operation, TEE is very useful in assessing baffle leak or dehiscence, thrombus, or obstruction.[39] Patients with atrial baffles are often at risk for atrial tachycardia and intracardiac thrombi. TEE is helpful in excluding the presence of thrombus prior to cardioversion in these patients.[40,41]

When endocarditis is suspected, TEE may not always be necessary in infants and younger children who have clear TTE windows; however it should be considered for diagnostic evaluation when the TTE is suboptimal. Conversely, when endocarditis has been diagnosed, TEE can be more helpful than TTE in clearly identifying the site of infection and the hemodynamic consequences thereof. Patients with suspected prosthetic valve dysfunction and suboptimal TTE should have TEE to exclude valvar dysfunction. TEE can be helpful in identifying patency of the foramen ovale in the young patient (with or without CHD) and a stroke of unknown etiology, when the TTE examination is inconclusive.

Table 1 Some current indications for TEE in the patient with CHD

Diagnostic indications
Patient with suspected CHD and nondiagnostic TTE
Presence of PFO and direction of shunting as possible etiology for stroke
PFO evaluation with agitated saline contrast to determine possible right-to-left shunt, prior to transvenous pacemaker insertion
Evaluation of intra or extracardiac baffles following the Fontan, Senning, or Mustard procedure
Aortic dissection (Marfan syndrome)
Intracardiac evaluation for vegetation or suspected abscess
Pericardial effusion or cardiac function evaluation and monitoring postoperative patient with open sternum or poor acoustic windows
Evaluation for intracardiac thrombus prior to cardioversion for atrial flutter/fibrillation
Evaluating status of prosthetic valve
Perioperative indications
Immediate preoperative definition of cardiac anatomy and function
Postoperative surgical results and function
TEE guided interventions
Guidance for placement of ASD or VSD occlusion device
Guidance for blade or balloon atrial septostomy
Catheter tip placement for valve perforation and dilation in catheterization laboratory
Guidance during radiofrequency ablation procedure
Results of minimally invasive surgical incision or video assisted cardiac procedure

ASD, Atrial septal defect; *CHD,* congenital heart disease; *PFO,* patent foramen ovale; *TTE,* transthoracic echocardiography; *VSD,* ventricular septal defect.

II. SAFETY ISSUES

Patient Safety

When conducted properly, TEE is considered a safe procedure in the pediatric patient. Several large series have reported a 1% to 3% incidence of complications during performance of TEE in the pediatric population.[4,42] Patients as small as 1.4 kg have successfully and safely undergone intraoperative TEE,[43] however additional caution is to be exercised when inserting a probe in a neonate weighing ≤3 kg.

Although complications are rare, those most frequently encountered relate to oropharyngeal and esophageal traumas including hoarseness and dysphagia after the procedure. Rare cases demonstrating serious or fatal complications associated with TEE have been reported in the adult population.[44] Esophageal perforation has been reported in a neonate.[45] Studies have evaluated the integrity of esophageal mucosa by either direct endoscopy in pediatric patients, or pathologic inspection in small animals following a prolonged intraoperative TEE.[46,47] These studies demonstrate that TEE can be safely performed in pediatric patients and in anticoagulated small animals with minimal or no mucosal injury. Probe related injuries include thermal pressure trauma, mechanical problems resulting in laceration and/or perforation of the oropharynx, hypopharynx, esophagus, and stomach.[48-51] Complications can also include arrhythmias, pulmonary complications (bronchospasm, hypoxemia, laryngospasm), and circulatory derangement.

Ventilatory compromise in the pediatric patient undergoing operative TEE has been reported.[52,53] A study of intraoperative TEE and postoperative esophagoscopy in 50 children (weights of 3.0 to 39.8 kg) demonstrated hypotension and airway obstruction with probe insertion in two patients, a 2.6 kg infant with tetralogy of Fallot and a 3.0 kg infant with totally anomalous pulmonary venous return.[46] Another study evaluated changes in hemodynamic and ventilatory status of small infants undergoing intraoperative TEE for cardiac surgery and found no significant hemodynamic change attributable to the TEE. In this series, compromised ventilation occurred in only one patient with massively dilated pulmonary arteries in whom the TEE probe was withdrawn due to concern for possible airway compression.[54,55] To avoid airway compression, positioning the probe in the hypopharynx while not actively imaging has been recommended in small infants who display compromised ventilation.[56] Hemodynamic compromise has also been reported during TEE in a small neonate with totally anomalous pulmonary venous drainage where the direct pressure of the TEE probe compressed the posterior venous confluence.[57] TEE risks also include compression of structures adjacent to the esophagus, such as the trachea, bronchus, descending aorta or atrium. In cases of anomalous origin of the subclavian artery from the descending aorta, compression of the anomalous subclavian artery by the TEE probe can occur.[58,59]

Probe Safety

In order to ensure patient safety during TEE, it is important that the integrity of the insulating layers of the transducer be intact. Before each use, the probe should be inspected visually and then manually with a gloved hand to detect defects in the probe encasement with close attention to the regions of mechanical deflection. Small cracks or breaks may occur at the deflection region of the TEE probe. Thus, careful inspection of the deflection region is recommended with the distal tip maneuvered in all rotational positions. After a TEE study has been performed, reinspection of the probe integrity is recommended to exclude probe damage during the procedure. Probe cleaning technique and specific brands of disinfectants are recommended by the probe manufacturers. Standards for inspection, cleansing, and disinfection of TEE probes is recommended for each echocardiographic laboratory. Manufacturers' specifications for disinfection soaking time should be followed. Damage to the probe

encasement can also occur with use of a wrong disinfectant or excessive immersion time in the recommended disinfectant. It is recommended by each manufacturer that the probe be intermittently tested for electrical safety. The probe is placed in a saline bath and connected to a leakage current analyzer that measures leakage, with guidelines established by the various manufacturers.

Endocarditis Prophylaxis During the Procedure

The risk of endocarditis with a direct endoscopic procedure is small. Transient bacteremia may occur during or immediately following endoscopy; however infective endocarditis attributable to endoscopy has been noted in only rare cases.[60] There is a 2% to 5% risk of bacteremia during most gastrointestinal endoscopic procedures, and the organisms identified are unlikely to result in endocarditis.[61-63] However, positive blood cultures have been documented in the first 10 minutes following transesophageal intubation in 7% to 17% of adult patients tested.[63,64] We agree with the AHA recommendations that endocarditis antibiotic prophylaxis is not recommended for standard TEE, but may be considered optional in high risk patients with prosthetic or homograft valves, previous history of endocarditis, cyanotic CHD or surgically placed systemic to pulmonary shunts or conduits.[65]

Contraindications to TEE in the Patient with CHD

Table 2 lists the absolute and relative contraindications for performing a TEE examination in the patient with CHD. The risk of the TEE procedure and benefits must be carefully weighed in patients with cervical and thoracic spinal abnormalities that may distort the normal orientation of the esophagus. Patients with Down syndrome have intrinsic narrowing of the hypopharyngeal region in addition to having increased incidence of cervical spine anomalies that may result in difficult, or failed, probe insertion.[2] Previous esophageal surgery, history of dysphagia, or significant coagulopathy are associated with higher risk and are considered relative contraindications to TEE.[66]

Table 2 Contraindications for transesophageal echocardiography

Absolute contraindications	Relative contraindications
Unrepaired tracheoesophageal fistula	History prior esophageal surgery
Esophageal obstruction or stricture	Esophageal varices or diverticulum
Perforated hollow viscus	Gastric or esophageal bleeding
Poor airway control	Vascular ring, aortic arch anomaly with or without airway compromise
Severe respiratory depression	Oropharyngeal pathology
Uncooperative, unsedated patient	Severe coagulopathy
	Cervical spine injury or anomaly

III. KNOWLEDGE BASE, SKILLS, AND TRAINING NECESSARY TO PERFORM A TEE EXAMINATION IN THE PATIENT WITH CHD

Performance of the TEE examination in the pediatric patient requires skills, knowledge, and training, which differ from those needed to perform TEE in the adult. Specific requirements include a thorough knowledge and understanding of congenital heart defects, skill in manipulation of the TEE probe in younger patients, the ability to perform the study efficiently with the time constraints that are often related to intraoperative studies, and the skill in imparting information clearly and accurately to surgeons or interventionists during therapeutic procedures. The following skills, experience, and training are recommended in order to achieve and maintain competency in performing TEE in the patient with CHD.

Cognitive Skills, Technical Skills, and Training Guidelines

One should have a thorough knowledge of the spectrum of congenital heart defects and a rich experience in 2-dimensional, pulsed, continuous wave, and color Doppler echocardiography of CHD. Experience can only be obtained by performing and interpreting many TTE studies on patients with a wide variety of cardiac abnormalities. The physician should be able to diagnose a variety of structural defects by TTE before attempting to perform supervised TEE with its associated potential risks and time constraints. For these reasons, general pediatric echocardiography skills at Level 2 are recommended for physicians who wish to perform TEE independently on pediatric patients with CHD (Table 3).[67]

In order to perform TEE on pediatric patients with CHD, the echocardiographer should understand oropharyngeal anatomy, the technique of endoscopy, potential risks of TEE, and contraindications for the procedure. Prior recommendations regarding training for esophageal intubation have been published.[14,14,68] Patients with CHD may have associated congenital abnormalities of the esophagus—repaired or unrepaired—that may make esophageal intubation difficult or impossible. In these cases the

Table 3 Guidelines for training and maintenance of competence

Component	Objective	Duration	No. cases
Echocardiography (Level 2)*	Prior experience in perform/interpreting TTE	6 mo or equivalent	400: ≥ 200 < 1 y
Esophageal intubation	TEE probe insertion	Variable	25 cases (12 < 2 y)
TEE exam	Perform and interpret with supervision	Variable	50 cases
Ongoing TEE experience (Level 3)*	Maintenance of competency	Annual	50 cases; or achievement of laboratory-established outcomes variables

TEE, Transesophageal echocardiography; *TTE*, transthoracic echocardiography.
*From references 15, 67, and 68.

risks and benefits of TEE should be assessed before the procedure is attempted. Significant supervised experience in esophageal intubation in small children is necessary in order to select proper probe size and intubate the esophagus safely and correctly.[52] In the patient weighing ≤3 kg, esophageal intubation may be particularly challenging. We therefore recommend that probe placement be performed on at least 25 patients with CHD under the direct supervision of an experienced pediatric echocardiographer, gastrointestinal endoscopist, or anesthesiologist before the TEE probe is placed unsupervised. At least half of the patients should be less than 2 years of age with special emphasis placed on the practical aspects of esophageal intubation in the neonate.

Technical skills necessary for TEE of CHD not only include competence in esophageal intubation, but also probe manipulation in order to achieve standard views and optimize image and Doppler profiles. During interventions the echocardiographer must communicate findings to the surgeon or interventionist quickly, lucidly, and accurately. Optimally, these skills are obtained through training in an active, accredited echocardiography laboratory under the supervision of echocardiographers experienced in TEE in the pediatric patient. Experience is necessary in a variety of clinical settings where the indications for study and patient hemodynamics differ. These sites include the operating room, intensive care unit, outpatient setting, and cardiac catheterization laboratory. It is recommended that supervised performance and interpretation of TEE examination be performed in a minimum of 50 patients before TEE studies of CHD are performed independently.

Recommendations for Physicians Not Formally Trained in TEE Performance in Patients with CHD

The aforementioned skills are best achieved by completing a formal fellowship training program in pediatric cardiology with emphasized training in TEE. Physicians who have not trained in pediatric cardiology or those who trained without emphasis in TEE must acquire similar knowledge of congenital heart disease, general echocardiography, and skills in TEE in order to perform TEE independently. The intent of the task force is not to exclude physicians from performing TEE in pediatric patients, but to clarify the necessary components, skills, and extent of supervised training and experience necessary. The goal is to promote patient safety and quality of care since TEE evaluation of the patient with CHD is more complex, and procedures on the young may be more risky than in the adult without CHD.[1,42,69-71]

The physician without formal pediatric cardiology training must undertake an intensive training period in an accredited pediatric/congenital echocardiography laboratory. The task force recommends that physicians acquire knowledge in cardiac anatomy, congenital cardiac pathology, pathophysiology, differential diagnosis, and alternative diagnostic modalities as they would during a pediatric cardiology fellowship. Physicians must achieve the equivalent experience of a Level 2 pediatric echocardiographer with a strong knowledge base in congenital heart disease before they begin to learn how to perform and interpret TEE in pediatric patients.[67] For this, a training program to learn esophageal intubation, probe manipulation, and image interpretation under the supervision of an experienced Level 3 pediatric echocardiographer is recommended.

Many pediatric cardiovascular anesthesiologists have received appropriate training and experience in TEE in the pediatric patient and provide interpretation in the operating room. Often the intraoperative TEE is used to monitor cardiac function and intravascular volume status by observation of LV systolic function and cardiac chamber dimension. In these cases, we recommend that a second trained person in TEE or congenital cardiovascular anesthesiology be available in order to ensure that undivided attention is paid to the postoperative/interventional findings on TEE, as well as the anesthetic care and hemodynamics of the patient.

Maintenance of Skills

Once the skills and knowledge base are achieved, it is recommended that 50 TEE examinations in pediatric patients be performed annually to maintain

proficiency. In a large program in which duties may be shared among many TEE competent physicians, it is conceivable that fewer than 50 studies per TEE competent physician per year may be performed. In these cases, maintenance of proficiency can be alternatively achieved based on outcomes variables, as established by the individual laboratory director. In such cases, laboratory guidelines and outcomes variables should be established with annual review of the physician's TEE performance and interpretative accuracy by identification of complications as well as correlation with other imaging modalities, operative findings, and patient clinical outcome.

IV. PERFORMANCE OF THE TEE EXAMINATION IN A PEDIATRIC PATIENT

A systematic and complete approach to TEE in the pediatric patient ensures that unexpected and clinically significant findings are recognized. Comprehensive studies enable one to readily recognize normal anatomy and normal variants from pathologic states. The methods used for performance of the TEE examination have been extensively described elsewhere. Standardized imaging planes have been established for the comprehensive adult TEE examination, and were published in a position paper by the ASE/SCA in 1999.[14] These views and planes may be applied to the pediatric patient as well. Currently, there is no uniform consensus on standardized views and planes to be used for the TEE examination in the pediatric patient. A number of centers have established excellent algorithms for performance of TEE examination for a variety of types of CHD. It is currently not the intention of this task force to endorse any particular form of imaging algorithm or method of image display for the pediatric patient, but rather to encourage the use of a careful, detailed, and consistent systematic approach to each and every TEE examination performed. Review of techniques used and methods applied is encouraged on a regular basis in order to provide for continual quality improvement.

SUMMARY

TEE in the pediatric patient is a unique procedure that requires a special fund of knowledge and skills base that differs from that which is necessary for the performance of TEE in the adult. We have outlined the indications, safety issues, and training and proficiency guidelines for performance of TEE in the pediatric patient. TEE has had a substantial positive impact on the care and management of the patient with CHD in all age groups, from the infant to the adult. In the future, high quality TEE in CHD will continue to be in great demand as the need for imaging of complex cardiovascular structures, both before and after intervention, continues to expand. It is hoped that these guidelines will act as a benchmark of quality for the performance of this important procedure.

REFERENCES

1. Russell IA, Miller-Hance WA, Silverman NH. Intraoperative transesophageal echocardiography for pediatric patients with congenital heart disease. Anesth Analg 1998;87:1058-87.
2. Bezold LI, Pignatelli R, Altman CA, Feltes TF, Garajski RJ, Vick GW 3rd, et al. Intraoperative transesophageal echocardiography in congenital heart surgery. The Texas Children's Hospital experience. Tex Heart Inst J 1996;23:108-15.
3. O'Leary PW, Hagler DJ, Seward JB, Tajik AJ, Schaff HV, Puga FJ, et al. Biplane intraoperative transesophageal echocardiography in congenital heart disease. Mayo Clin Proc 1995; 70:317-26.
4. Randolph GR, Hagler DJ, Connolly HM, Dearani JA, Puga FJ, Danielson GK, et al. Intraoperative transesophageal echocardiography during surgery for congenital heart defects. J Thorac Cardiovasc Surg 2002;124:1176-82.
5. Bengur AR, Li JS, Herlong JR, Jaggers J, Sanders SP, Ungerleider RM. Intraoperative transesophageal echocardiography in congenital heart disease. Semin Thorac Cardiovasc Surg 1998;10:255-64.
6. Smallhorn JF. Intraoperative transesophageal echocardiography in congenital heart disease. Echocardiography 2002;19: 709-23.
7. Cyran SE, Kimball TR, Meyer RA, Bailey WW, Lowe E, Balisteri WJ, et al. Efficacy of intraoperative transesophageal echocardiography in children with congenital heart disease. Am J Cardiol 1989;63:594-8.
8. Stevenson JG, Sorensen G, Gartman DM, Hall DG, Rittenhouse EA. Transesophageal echocardiography during repair of congenital cardiac defects: identification of residual problems necessitating reoperation. J Am Soc Echocardiogr 1993;6: 356-65.
9. Ungerleider RM. Biplane and multiplane transesophageal echocardiography. Am Heart J 1999;138:612-3.
10. Rice MJ, McDonald RW, Li X, Shen I, Ungerleider RM, Sahn DJ. New technology and methodologies for intraoperative, perioperative, and intraprocedural monitoring of surgical and catheter interventions for congenital heart disease. Echocardiography 2002;19:725-34.
11. Shiota T, Lewandowski R, Piel JE, Smith LS, Lancee C, Djoa K, et al. Micromultiplane transesophageal echocardiographic probe for intraoperative study of congenital heart disease repair in neonates, infants, children and adults. Am J Cardiol 1999;83:292-5.
12. Bruce CJ, O'Leary P, Hagler DJ, Seward JB, Cabalka AK. Miniaturized transesophageal echocardiography in newborn infants. J Am Soc Echocardiogr 2002;15:791-7.
13. Douglas DE, Fyfe DA. Use of miniature biplane transesophageal echocardiography during pediatric atrial catheter interventional procedures. Am Heart J 1996;132:179-86.
14. Shanewise JS, Cheung AT, Aronson S, Stewart WJ, Weiss RL, Mark JB, et al. ASE/SCA guidelines for performing a comprehensive intraoperative multiplane transesophageal echocardiography examination: recommendations of the American Society of Echocardiography Council for Intraoperative

Echocardiography and the Society of Cardiovascular Anesthesiologists task force for certification in perioperative transesophageal echocardiography. J Am Soc Echocardiography 1999;12:884-900.
15. Fyfe DA, Ritter SB, Snider AR, Silverman NH, Stevenson JG, Sorensen G, et al. Guidelines for transesophageal echocardiography in children. J Am Soc Echocardiography 1992;5: 640-4.
16. Andropoulos DB. Transesophageal echocardiography as a guide to central venous catheter placement in pediatric patients undergoing cardiac surgery. J Cardio Vasc Anesth 1999; 13:320-1
17. Andropoulos DB, Stayer SA, Bent ST, Campos CJ, Bezold LI, Alvarez M, et al. A controlled study of transesophageal echocardiography to guide central venous catheter placement in congenital heart surgery patients. Anesth Analg 1999;89:65-70.
18. Ninomiya J, Yamauchi H, Hosaka H, Ishii Y, Terada K, Sugimoto T, et al. Continuous transesophageal echocardiography monitoring during weaning from cardiopulmonary bypass in children. Cardiovasc Surg 1997;5:129-33.
19. Rosenfeld HM, Gentles TL, Wernovsky G, et al. Utility of transesophageal echocardiography in the assessment of residual cardiac defects. Pediatr Cardiol 1998;19:346-51.
20. Wolfe LT, Rossi A, Ritter SB. Transesophageal echocardiography in infants and children: use and importance in the cardiac intensive care unit. J Am Soc Echocardiography 1993; 6:286-9.
21. Marcus B, Wong PC, Wells WJ, Lindesmith GG, Starnes VA. Transesophageal echocardiography in the postoperative child with an open sternum. Ann Thorac Surg 1994;58:235-6.
22. Tumbarello R, Sanna A, Cardu G, Bande A, Napoleone A, Bini Rm. Usefulness of transesophageal echocardiography in the pediatric catheterization laboratory. Am J Cardiol 1993; 71:1321-5.
23. van der Velde ME, Perry SB, Sanders SP. Transesophageal echocardiography with color Doppler during interventional catheterization. Echocardiography 1991;8:721-30.
24. Rigby ML. Transesophageal echocardiography during interventional cardiac catheterization in congenital heart disease. Heart 2001;86:1123-9.
25. van der Velde ME, Perry SB. Transesophageal echocardiography during interventional catheterization in congenital heart disease. Echocardiography 1997;14:513-28.
26. Minich L, Snider AR. Echocardiographic guidance during placement of the buttoned double-disk device for atrial septal defect closure. Echocardiography 1993;10:567-72.
27. Elzenga NJ. The role of echocardiography in transcatheter closure of atrial septal defects. Cardiol Young 2000;10:474-83.
28. Zhu W, Cao QL, Rhodes J, Hijazi ZM. Measurement of atrial septal defect size: a comparative study between three-dimensional transesophageal echocardiography and the standard balloon sizing methods. Pediatr Cardiol 2000;21:465-9.
29. Maeno YV, Benson LN, Boutin C. Impact of dynamic 3D transesophageal echocardiography in the assessment of atrial septal defects and occlusion by the double-umbrella device (CardioSEAL). Cardiol Young 1998;8:368-78.
30. Cae Q, Radtke W, Berger F, Zhu W, Hijazi ZM. Transcatheter closure of multiple atrial septal defects. Initial results and value of two- and three-dimensional transesophageal echocardiography. Eur Heart 2000;21:941-7.
31. Marx GR, Sherwood MC, Fleishman C, Van Praagh R. Theedimensional echocardiography of the atrial septum. Echocardiography 2001;18:433-43.
32. van der Velde ME, Sanders SP, Keane JF, Perry SB, Lock JE. Transesophageal echocardiographic guidance of transcatheter ventricular septal defect closure. J Am Coll Cardiol 1994;23: 1660-5.
33. Marcus B, Steward DJ, Khan NR, Scott EB, Scott GM, Gardner AJ, et al. Outpatient transesophageal echocardiography with intravenous propofol anesthesia in children and adolescents. J Am Soc Echocardiography 1993;6:205-9.
34. Marelli AJ, Child JS, Perloff JK. Transesophageal echocardiography in congenital heart disease in the adult. Cardiol Clin 1993;11:505-20.
35. Masani ND. Transesophageal echocardiography in adult congenital heart disease. Heart 2001;86:1130-40.
36. Miller-Hance WA, Silverman NH. Transesophageal echocardiography (TEE) in congenital heart disease with focus on the adult. Cardiol Clin 2000;18:861-92.
37. Seward JB. Biplane and multiplane transesophageal echocardiography: evaluation of congenital heart disease. Am J Card Imaging 1995;9:129-36.
38. Fyfe D, Kline CH, Sade RM, Greene CA, Gillette PC. The utility of transesophageal echocardiography during and after Fontan operations in small children. Am Heart J 1991;122: 1403-15.
39. Marcus B, Wong PC. Transesophageal echocardiographic diagnosis of right atrioventricular valve patch dehiscence causing intracardiac right-to-left shunting after Fontan operation. Am Heart J 1993;126:1482-4.
40. Feltes TF, Friedman RA. Transesophageal echocardiographic detection of atrial thrombi in patients with nonfibrillation atrial tachyarrhythmias and congenital heart disease. J Am Coll Cardiol 1994;24:1365-70.
41. Fyfe D, Kline CH, Sade RM, et al. Transesophageal echocardiography detects thrombus formation not identified by transthoracic echocardiography after the Fontan operation. J Am Coll Cardiol 1991;18:1733-7.
42. Stevenson JG. Incidence of complications in pediatric transesophageal echocardiography: experience in 1650 cases. J Am Soc Echocardiogr 1999;12:527-32.
43. Mart CR, Fehr DM, Myers JL, Rosen KL. Intraoperative transesophageal echocardiography in a 1.4-kg infant with complex congenital heart disease. Pediatr Cardiol 2003;24: 84-5.
44. De Vries AJ, van der Maaten JM, Laurens RR. Mallory-Weiss tear following cardiac surgery: transesophageal echoprobe or nasogastric tube? Br J Anaesth 2000;84:646-9.
45. Muhiudeen-Russell IA, Miller-Hance WC, Silverman N. Unrecognized esophageal perforation in a neonate during transesophageal echocardiography. J Am Soc Echocardiogr 2001; 14:747-9.
46. Greene MA, Alexander JA, Knauf DG, Talbert J, Langham M, Kays D, et al. Endoscopic evaluation of the esophagus in infants and children immediately following intraoperative use of transesophageal echocardiography. Chest 1999;116:1247-50
47. O'Shea JP, Southern JF, Ambra MN, Magro C, Guerrero JL, Marshall JE, et al. Effects of prolonged transesophageal echocardiographic imaging and probe manipulation on the esophagus—an echocardiographic-pathologic study. J Am Coll Cardiol 1991;17:1426-9.
48. Kharasch ED, Sivarajan M. Gastroesophageal perforation after intraoperative transesophageal echocardiography. Anesthesiology 2000;85:426-8.
49. Spahn DR, Schmid S, Carrel T, Pasch T, Schmid ER. Hypopharynx perforation by a transesophageal echocardiography probe. Anesthesiology 1995;82:581-3.

50. Chow MS, Taylor MA, Hanson CW III. Splenic laceration associated with transesophageal echocardiography. J of Cardio and Vas Anesth 1998;12:314-5.
51. Savino JS, Hanson CW III, Bigelow DC, Cheung AT, Weiss SJ. Oropharyngeal injury after transesophageal echocardiography. J of Cardio and Vas Anesth 1994;8:76-8.
52. Stevenson JG, Sorensen GK. Proper probe size for pediatric transesophageal echocardiography. Am J Cardiol 1993;72: 491-2.
53. Muhiudeen I, Silverman N. Intraoperative transesophageal echocardiography using high resolution imaging in infants and children with congenital heart disease. Echocardiography 1993;10:599-608.
54. Andropoulos DB, Ayres NA, Stayer SA, Bent ST, Campos CJ, Fraser CD. The effect of transesophageal echocardiography on ventilation in small infants undergoing cardiac surgery. Anesth Analg 2000;90:47-9.
55. Andropoulos DB, Stayer SA, Bent ST, Campos CJ, Fraser CD. The effects of transesophageal echocardiography on hemodynamic variables in small infants undergoing cardiac surgery. J Cardio Vasc Anesth 2000;14:133-5.
56. Stayer SA, Bent ST, Andropoulos DA. Proper probe positioning for infants with compromised ventilation from transesophageal echocardiography. Anesth Analg 2001;92:1073-7.
57. Frommelt PC, Stuth EA. Transesophageal echocardiographic in total anomalous pulmonary venous drainage: hypotension caused by compression of the pulmonary venous confluence during probe passage. J Am Soc Echocardiogr 1994;7:652-4.
58. Bensky AS, O'Brien JJ, Hammon JW. Transesophageal echo probe compression of an aberrant right subclavian artery. J Am Soc Echocardiogr 1995;8:964-6.
59. Janelle G, Lobato EB, Tang Y. An unusual complication of transesophageal echocardiography. J Cardio Vasc Anesth 1999;13:223-34.
60. Foster E, Kusumoto F, Sobol S, Schiller N. Streptococcal endocarditis temporally related to transesophageal echocardiography. J Am Soc Echocardiogr 1990;3:424-7.
61. Botoman V, Surawicz C. Bacteremia with gastrointestinal endoscopic procedures. Gastrointest Endosc 1986;32:342-6.
62. Bryne W, Euler A. Bacteremia in children following upper gastrointestinal endoscopy or colonoscopy. J Pediatr Gastroenterol Nutr 1982;1:551-3.
63. Dennig K, Seldmayer V, Selig B, Rudolph W. Bacteremia with transesophageal echocardiography. Circulation 1989;80:II473.
64. Gorge G, Erbel R, Henrichs J, Wenchel H, Werner H, Meyer J. Positive blood cultures during transesophageal echocardiography. Am J Cardiol 1990;65:1404-504.
65. Dajani AS, Taubert KA, Wilson W, Bolger AF, Bayer A, Ferrieri P, et al. Prevention of bacterial endocarditis: recommendations by the American Heart Association. JAMA 1997; 227:1794-1801.
66. Fleischer DE, Goldstein SA. Transesophageal echocardiography; what the gastroenterologist thinks the cardiologist should know about endoscopy. J Am Soc Echocardiogr 1990; 3:428-34.
67. Quinones MA, Douglas PS, Foster E, Gorcsan J, Lewis JF, Pearlman AS, et al. Competence statement in echocardiography: a report of the ACC/AHA/ACP-ASIM task force on clinical competence. J Am Coll Cardiol 2003;41:687-708
68. Pearlman AS, Gardin JM, Martin RP, Parisi AF, Popp RL, Quinones MA, et al. Guidelines for physician training in transesophageal echocardiography; recommendations of the American Society of Echocardiography Committee for Physician Training in Echocardiography. J Am Soc Echocardiogr 1992;5:187-94.
69. Fyfe D. Intraoperative transesophageal echocardiography in children with congenital heart disease: how, not who! J Am Soc Echocardiogr 1999;12:1011-3.
70. Aronson S. Adherence to physician training guidelines for pediatric transesophageal echocardiography affects the outcome of patients undergoing repair of congenital cardiac defects. J Am Soc Echocardiogr 1999;12:1008.
71. Fyfe D. Transesophageal echocardiography guidelines: return to bypass or to bypass the guildelines? J Am Soc Echocardiogr 1999;2:343-4.