Transesophageal Echocardiography
Clinical Indications and Applications
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Case: A 36-year-old woman without significant past medical history was admitted with left-sided hemiparesis. Imaging studies confirmed a right middle cerebral artery (MCA) stroke with normal carotid arteries. Transesophageal echocardiogram (TEE) showed right heart enlargement and a large secundum atrial septal defect (ASD) (Figure 1). Using TEE guidance, an ASD occluder device was placed without complication (Figure 2).

General Applications
The use and indications for transesophageal echocardiography have expanded since its introduction over a decade ago. The suggested approach for a TEE examination is given in Table 1. As illustrated in the case above, TEE is used not only as a diagnostic tool but also as a monitoring adjunct for operative and percutaneous cardiac procedures (Table 2). The short distance between the transducer and the heart allows for the use of increased frequency transducers, yielding better spatial resolution and superior performance. Although major complications of TEE are rare (<0.02%), insertion and manipulation of the TEE probe can result in oral, esophageal, or pharyngeal trauma and arrhythmias, along with complications of conscious sedation. Because inaccurate acquisition and interpretation of images can lead to improper clinical decisions, experienced operators are essential to the success of TEE.

TEE as a Diagnostic Tool
Stroke
In many centers, the most common indication for TEE is stroke, for which the diagnostic yield may exceed 50%.
Findings associated with recurrent cerebral ischemia include spontaneous echocardiographic contrast (the most common TEE finding in stroke patients), aortic atheroma >4 mm thick, and patent foramen ovale (PFO). Other findings linked to cardiac embolization are left atrial thrombus, atrial septal aneurysm, and valvular abnormalities. Left atrial appendage (LAA) thrombi are most closely associated with atrial fibrillation or mitral stenosis, but have been reported without an obvious underlying etiology (Figure 3). Unlike LAA thrombi, left ventricular thrombi may be visualized better from an apical transthoracic window because of the close position between thrombi and the transducer.

TEE may be a valuable tool even in those stroke patients without a clinical suspicion for cardiac embolization. In one small series, 24 of 40 subjects without a clinical suspicion for a cardiac source had TEE findings associated with increased thromboembolic risk.

The impact of TEE findings on management of stroke patients is not clearly defined. In the case of intracardiac thrombus, anticoagulation is clearly indicated. Identification of aortic atheroma may prompt therapy with aspirin, statins, and anticoagulation. Using statins in such patients decreases the likelihood of subsequent stroke.

Atrial Fibrillation
Atrial fibrillation is associated with a 2-fold increase in cardiovascular mortality and a 4- to 6-fold increase in thromboembolism, presumably from LAA thrombi, which are detected in 7% to 14% of patients with the disorder. LAA Doppler flow patterns are available as an online-only Data Supplement at http://www.circulationaha.org.
demonstrate decreased flow velocities in patients at risk for stroke and correlate with decreased success in maintaining sinus rhythm.\textsuperscript{11}

Short-term anticoagulation, combined with TEE before cardioversion to exclude thrombi, has been investigated as an alternative to 3 to 4 weeks of empiric anticoagulation before cardioversion. In most cases, patients receive systemic anticoagulation for at least 1 month after cardioversion. Potential advantages to the TEE-guided approach include shortened duration of atrial fibrillation, reduced risk of hemorrhage, and decreased embolic events by avoiding cardioversion in patients with confirmed thrombus. Successful execution of the TEE approach requires operators who are experienced in distinguishing thrombi from pectinate muscles, artifacts, and dense SEC while acknowledging that TEE may be inadequate to visualize extremely small thrombi.

Comparing the TEE-guided and conventional approaches in 1222 patients, the Assessment of Cardioversion Utilizing Transesophageal Echocardiography (ACUTE) trial results support TEE-guided cardioversion as an acceptable management approach.\textsuperscript{10} Although there was no difference in the rate of embolic events (0.5% in the conventional arm versus 0.8% in the TEE arm), the TEE-guided approach was associated with significantly lower bleeding risk (2.9% vs 5.5%) and a greater rate of successful restoration of sinus rhythm 30 days after study enrollment.

Management of patients with LAA thrombus on TEE generally involves intensification of anticoagulation. Thrombus resolution varies widely, but was noted in 83% of 164 patients.\textsuperscript{12} Most clinicians advocate repeat TEE before future cardioversion attempts to evaluate thrombus resolution.

**Prosthetic Valve Dysfunction**

When used in conjunction with trans-thoracic imaging (TTE), TEE provides excellent anatomic and hemodynamic evaluation of prosthetic heart valves. In most patients, TTE provides adequate assessment of transvalvular gradients and aortic and pulmonary regurgitation. In contrast, prosthetic mitral and tricuspid regurgitation may not be visualized because of reverberation artifacts and inadequate ultrasound penetration beyond a mechanical valve. The posterior position of the TEE transducer allows excellent visualization of paraprosthetic mitral and tricuspid anatomy and differentiation of valvular from paravalvular regurgitation.

Assessment of a prosthetic aortic valve by TEE may be more challenging. Both esophageal and transgastric views are necessary for full evaluation of prosthetic aortic regurgitation. A deep transgastric view mimicking an apical “5-chamber” view allows assessment of the gradient across the prosthesis and better evaluation of prosthetic aortic regurgitation and leaflet motion.
Thrombus, vegetation, and pannus are visualized better using TEE than other imaging techniques. Although clinical data are essential to differentiate these abnormalities, thrombi are generally larger, with softer echo densities and reduced video intensity when compared with pannus.\footnote{The location of thrombi and their effect on valve function should be determined. In addition to its diagnostic utility, TEE can be used to monitor the effectiveness of thrombolytic therapy when treating valve thrombosis.}

### Infective Endocarditis

Echocardiography has contributed to improved diagnostic criteria for infective endocarditis (IE). TEE offers improved detection of small vegetations and identification of paravalvular pathology. The sensitivity of TEE for detecting vegetations is 82% to 100% for native valves and 77% to 94% for prosthetic valves, with specificities of 88% to 100%. If a clinical suspicion for IE persists after a negative TEE, a repeat TEE should be performed in 7 to 10 days. False-negative studies are usually caused by vegetations that are smaller than the resolution limits, vegetations that have embolized, or artifacts from prosthetic acoustic shadowing.

TEE is preferred over TTE as the initial imaging tool in patients with difficult images, patients with possible prosthetic valve infection, or those who are at high risk for developing complications (including those with Staphylococcus aureus bacteremia, fungemia, systemic-to-pulmonary shunts, cyanotic congenital heart disease, and prior IE). TEE-guided therapy has been recommended to determine duration of antibiotic therapy in patients with catheter-associated Staphylococcus aureus.\footnote{TEE may guide management of patients with IE. Vegetation size $>1$ cm, particularly on the mitral valve, predicts embolic rates in many studies, and an increase in vegetation size over time predicts complications.\footnote{For patients not responding to antibiotic therapy, and those developing heart block or new heart failure, TEE can rapidly identify complications, such as abscess formation or valve perforation, that require prompt surgical therapy.}

### Aortic Dissection

TEE is a rapid and reliable tool for the diagnosis of aortic dissection, allowing differentiation of dissection from intramural hematoma and penetrating aortic ulcers. Evaluation of the aorta by TEE is comparable to MRI and computed tomography; however, the aortic arch may be poorly visualized by TEE.

### TEE as a Procedural Adjunct

Intraoperative use of TEE is essential in monitoring valve and congenital heart disease repairs and in evaluating life-threatening and unexpected hemodynamic disturbances that are associated with cardiac and noncardiac surgery (Table 3). Many centers use TEE to monitor left ventricular function during CABG. TEE findings can confirm a suspected diagnosis, alter medical therapy or surgical management, identify ischemia, and assist in positioning of intravascular devices. Intraoperative TEE may be performed by anesthesiologists or cardiologists with the appropriate level of training. TEE alters therapy more often in patients with category I indications (28%) (Table 3) than in those with category II indications (14%).\footnote{One of the strongest indications for intraoperative TEE is evaluation of the mitral valve during repair. When a systematic approach is used to assess mitral valve morphology, there is excellent agreement between TEE and surgical findings, with a 92% agreement on

<table>
<thead>
<tr>
<th>View</th>
<th>Structures Evaluated</th>
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<tr>
<td>Transgastric</td>
<td>LV and RV function, papillary muscles</td>
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<tr>
<td>Mid-esophageal</td>
<td>MV, TV</td>
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<tr>
<td>Deep transgastric</td>
<td>LV, MV and subvalvular structures, LA, CS</td>
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<tr>
<td>LVOT and AV, MV</td>
<td>TV and subvalvular structures, RV, RA</td>
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<tr>
<td>LVOT, AV, ascending aorta, MV</td>
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<td>LV indicates left ventricle; RV, right ventricle; MV, mitral valve; TV, tricuspid valve; LA, left atrium; CS, coronary sinus; LVOT, left ventricular outflow tract; AV, aortic valve; RA, right atrium; LAA, left atrial appendage; PA, pulmonary artery; SVC, superior vena cava; RVOT, right ventricular outflow tract; PV, pulmonary valve; and IVC, inferior vena cava; Adapted from Shanewise et al.\textsuperscript{13}</td>
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mechanism and precise location of pathology compared with a 60% agreement in patients not systematically studied. The routine use of TEE during all valve replacements and repairs impacts surgical management and provides baseline data for postoperative care.

TEE plays an important role in the selection and surgical management of patients undergoing left ventricular assist device (LVAD) implantation. An intact aortic valve is essential for proper LVAD function because significant retrograde flow can result from an incompetent aortic valve. Activation of the LVAD can produce right-to-left shunting across an ASD or PFO. Therefore, significant aortic regurgitation and PFO or other intracardiac shunts should be corrected before LVAD implantation. TEE helps to identify left ventricular thrombus and significant atheroma before device placement and assists in de-airing the pump. TEE can detect mechanisms of LVAD dysfunction, including cannula obstruction or inlet or outlet valve regurgitation, and can help to optimize assist device performance and guide weaning.

Up to 40% of congenital heart malformations can be treated with catheter-based approaches, and TEE improves the safety and success of many of these procedures (for further information, see the Clinician Update by B. Meier and J.E. Lock. Contemporary management of patent foramen ovale. Circulation. 2003;107:5-9). TEE assists in the appropriate selection of patients for percutaneous ASD and PFO closure by assessing the morphology and diameter of the defect, determining the relation of the septal defect to valves and adjacent veins, and quantifying the tissue available for device anchoring. During the procedure, TEE helps to guide device positioning and deployment. After closure, the presence and degree of residual defects, obstruction to systemic or pulmonary venous pathways, and interference with valve function can be recognized. TEE may be used to monitor fenestration of Fontan conduits, closure of ventricular septal defects and baffle leaks after an atrial switch procedure, and placement of novel percutaneous LAA occlusion devices.

Percutaneous mitral balloon valvuloplasty (PMBV) is the preferred interventional therapy for pure rheumatic mitral stenosis. Left atrial thrombus and significant mitral regurgitation are contraindications to the procedure. Preprocedural use of TEE to exclude these findings has been credited with a reduction in the occurrence of complications. Although TEE is not used routinely in most labs during the procedure, it can assist with catheter position during septal puncture, assess mitral gradients and regurgitation after each balloon inflation, and detect procedural complications such as ASD, mitral regurgitation, and hemo-pericardium. TEE during valvuloplasty has been successfully employed using only mild sedation and results in shorter procedure and fluoroscopic times. Using TEE as the sole imaging technique during PMBV has also been described, with particular advantages in pregnant patients.

**Conclusion**
TEE provides diagnostic and prognostic information and is increasingly important in guiding a variety of surgical and percutaneous cardiac procedures. Advances in technology continue to develop, expanding the role for TEE. Intravenous ultrasound contrast agents have been successfully used by some investigators to improve endocardial border determination, better detect thrombi, and assess myocardial perfusion. The use of contrast agents in combination with TEE imaging for online assessment of myocardial perfusion will be particularly useful during minimally invasive coronary bypass surgery. Three-dimensional TEE will aid in the analysis of myocardial chamber volume and shape, improve quantification of ventricular mass, and better define regurgitant color-flow jet.
### TABLE 3. Indications for Operative TEE

<table>
<thead>
<tr>
<th>Category I (Supported by the Strongest Evidence or Expert Opinion)</th>
<th>Category II (Supported by Weaker Evidence and Expert Consensus)</th>
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<tbody>
<tr>
<td>Heart valve repair</td>
<td>Heart valve replacement</td>
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<tr>
<td>Most congenital heart surgery requiring cardiopulmonary bypass</td>
<td>Removal of cardiac tumors</td>
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<tr>
<td>Endocarditis, particularly with extensive disease or inadequate preoperative evaluation of disease extent</td>
<td>Increased risk of myocardial ischemia or hemodynamic disturbances</td>
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<tr>
<td>Ascending aortic dissection repair when aortic valve involvement unknown</td>
<td>Intracardiac thrombectomy or pulmonary embolectomy</td>
</tr>
<tr>
<td>Evaluation of life-threatening hemodynamic disturbances when ventricular function is unknown</td>
<td>Suspected cardiac trauma or for detection of foreign bodies</td>
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<tr>
<td>Pericardial window procedures</td>
<td>Cardiac aneurysm repair</td>
</tr>
<tr>
<td>Hypertrophic obstructive cardiomyopathy repair</td>
<td>Thoracic aortic dissection repair without suspected aortic valve involvement</td>
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<td>Evaluation of anastomotic sites during heart and/or lung transplantation</td>
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<td>Monitoring placement and function of assist devices</td>
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volume. In the near-future, real-time 3-dimensional TEE imaging will likely play an important role defining valvular and congenital abnormalities in detail and aiding in operative and percutaneous repair.

### References
