Transesophageal echocardiography is a relatively new ultrasonic imaging technique that has been recently introduced, and despite its infancy, it has already become an established technique. The recent development of a transesophageal transducer with the capabilities of color flow Doppler is a major advance in the assessment of many patients in whom standard transthoracic two-dimensional or Doppler echocardiography has significant limitations.

What Is Transesophageal Echocardiography?

Transesophageal echocardiography uses a 5.0-MHz transducer fixed to the tip of a modified flexible gastroscope without fiberscopes. To obtain the required imaging planes, the gastroscope is passed into the esophagus and manipulated in a manner similar to that in upper gastrointestinal endoscopy. Transesophageal echocardiography provides ultrasonic access to the heart and thoracic aorta from the esophagus without being restricted by lung tissue or ribs, and the vicinity of both structures allows the use of high-frequency, near-focused transducers, which results in increased image quality. Transesophageal echocardiography is performed in the outpatient setting in ambulatory patients, intraoperatively in patients undergoing either cardiac or noncardiac surgery, or at the bedside in intensive care units. For outpatient or bedside studies, mild intravenous sedation is usually given. Many published reports show the usefulness of transesophageal echocardiography in assessing mitral prosthetic dysfunction, mitral valve disease, and left and right atrial heart disease, in monitoring intraoperatively cardiac function, and in assessing the adequacy of mitral valve repair.

Historical Perspective

Initial consideration of using the esophagus as a site of echocardiographic imaging was made in the mid 1970s by Frazin et al, who described the use of an M-mode ultrasonic crystal. Hanrath et al were the first to modify a gastroscope and mount a two-dimensional transducer to obtain the first twodimensional echocardiographic imaging from the esophagus. After these initial developments, progress was slow because of the reluctance of "noninvasive" cardiologists to become "invasive" and of the lack of further technologic advances in image quality. Interestingly, the pathway of further development differed significantly between investigators in Europe and the United States. In Europe, cardiologists were the first to embrace the technique, and they found the improved imaging of transesophageal echocardiography invaluable in imaging patients with aortic dissection, atrial masses and thrombi, mitral valve disease, and infective endocarditis. In the United States, however, transesophageal echocardiography was initially used in the operating room by anesthesiologists and was used predominantly for the intraoperative monitoring of left ventricular function in high-risk noncardiac surgical patients.

After these developments, the next important event was the introduction of intraoperative epicardial echocardiography to assess the integrity of the mitral valve after valve repair. However, the biggest breakthrough was in 1987 with the introduction of higher resolution transesophageal probes with color flow Doppler capability. This led to an explosive and worldwide application of transesophageal echocardiography that broke down previous perceptions of echocardiography being only a noninvasive technique and established the era of "invasive echocardiography."

Why Is Transesophageal Echocardiography Developing So Rapidly?

To understand why transesophageal echocardiography is developing so rapidly, one initially needs to consider the advantages of transesophageal over standard transthoracic echocardiography. In many patients, image quality with transthoracic echocardiography is significantly limited by ultrasonic interference from the chest wall and lung, especially in obese, elderly patients and in patients with chronic obstructive pulmonary disease. This limitation is overcome with transesophageal echocardiography,

See p 24

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for consistent high-quality imaging is obtainable in all patients. In addition, in patients with prosthetic heart valves, the ultrasonic shielding and artifact in the left atrium produced by the prosthesis is overcome. In the transthoracic approach, color flow Doppler imaging has decreased sensitivity at increasing depth, which is especially seen in patients with mitral regurgitation.

Although transthoracic echocardiography has been useful in diagnosing many cardiac diseases, its major limitation has been its inability to obtain consistently high-quality imaging of the heart and aorta in all patients. Transesophageal echocardiography overcomes this limitation and opens up "a new window to the heart." The value of the additional data obtained by transesophageal echocardiography in clinical decision making has lead echocardiographers who by nature are noninvasive to become "semi-invasive" and quickly take up this valuable technique. The advantages of transesophageal echocardiography in image quality and improved sensitivity of color flow Doppler significantly outweigh its relative disadvantages of mild patient discomfort, need for mild sedation, and the need for it to be performed by the physician.

**Ambulatory Transesophageal Echocardiography in Aortic Dissection**

Acute aortic dissection is a medical emergency requiring prompt diagnosis and maybe emergency surgery especially if the ascending aorta is involved. Angiography has been considered the reference standard for the diagnosis, but for screening, computed tomographic scanning, magnetic resonance imaging, and echocardiography have been widely used. Standard surface echocardiography has significant limitations due to inconsistent quality of imaging of the ascending aorta and the aortic arch. In addition, imaging of the descending aorta is generally suboptimal despite special transducer positions. In patients with acute aortic dissection, transesophageal echocardiography has been used very successfully because of the high-quality imaging of the thoracic aorta. Erbel and the European Cooperative Study Group For Echocardiography recently published a multicenter study showing the diagnostic accuracy in 164 consecutive patients with suspected aortic dissection. The sensitivity and specificity were 99% and 98%, respectively, for transesophageal echocardiography compared with 83% and 100%, respectively, for computed tomographic scanning, and 88% and 94%, respectively, for aortic angiography. Transesophageal echocardiography provides a dynamic assessment of the intimal flap and of the presence and extent of luminal thrombus and an assessment of sites of communications. The major advantage of transesophageal echocardiography as the optimal screening test is its ease of application at the bedside, which allows immediate and accurate diagnosis for emergency surgical intervention. This is compared with cardiac catheterization and computed tomographic scanning that take several hours to organize and perform, hours that may be life threatening. Aortography and coronary arteriography can then be performed if there is need to delineate the blood supply of vital organs or the coronary arteries.

Transesophageal echocardiography also has an important role in the follow-up of patients with aortic dissection. Mohr-Kahaly et al in this issue of *Circulation* followed up 18 patients with aortic dissection by serial transesophageal echocardiographic studies performed in the outpatient setting. The study showed the structure of the dissection, the surgical repair, and blood flow dynamics in the true and false lumen. It showed the evolution of the dissection in many patients, 25% having complications of either extension of the dissection (5%), dilatation of the aorta (11%), or aortic regurgitation (17%). In addition, in two patients, transesophageal echocardiography documented healing of the dissection and obliteration of the false lumen with time. This study shows the potential application of transesophageal echocardiography to follow up these patients for disease progression, healing, or the need for surgical intervention. Assessment of the prognostic value of the transesophageal echocardiographic data cannot be made by this study because of the small number of patients and relatively short follow-up period. A large multicenter study is needed to answer this important question.

The limitations in evaluating the aorta by transesophageal echocardiography need to be discussed. With single-plane transesophageal echocardiography, optimal imaging of the ascending aorta in the short axis can be obtained from the aortic valve to the pulmonary artery bifurcation. The upper ascending aorta cannot be visualized because of the interposition of the left main stem bronchus between the ascending aorta and the esophagus. The aortic arch is only suboptimally visualized, and the arch vessels are not seen. The descending thoracic aorta is visualized in the short axis from the arch to just below the diaphragm. There is a varying relation of the esophagus to the descending aorta in the chest, and the only reference landmark for transesophageal echocardiography is the depth of the probe from the incisors. There is a relative disadvantage of transesophageal echocardiography compared with the other imaging modalities of computed tomographic scanning, magnetic resonance imaging, and angiography: In patients with an ectatic, tortuous, or aneurysmal aorta, the image planes may be oblique, and therefore, accurate cross-sectional measurement of luminal diameter is difficult.

**Future Directions With Transesophageal Echocardiography**

Although the introduction of single-plane transesophageal echocardiography has represented an important advance permitting consistently high-quality two-dimensional and color flow Doppler
imaging, a significant drawback has been the inability of obtaining enough orthogonal tomographic views in any single patient. Extensive probe manipulation with an associated increase in study duration is needed to maximize imaging planes with the single-plane transesophageal probe. The advent of the biplane transesophageal echocardiographic probe is an important advance with the probe having transverse and longitudinal imaging transducers. Although transesophageal echocardiography has been referred to as the new window to the heart, the introduction of biplane transesophageal echocardiography has more than doubled the size of this window. The level of confidence in imaging certain conditions and structures has increased. Some of the most important of these are as follows. 1) The assessment of the severity of aortic regurgitation by the single-plane probe has been inconsistent in optimally visualizing the aortic regurgitant jet in the left ventricular outflow tract in short and long axes. 2) The visualization of the descending thoracic aorta is good with the single-plane probe, but the addition of a longitudinal plane provides data to better conceptualize aortic disease. The aortic arch is suboptimally visualized with the single-plane probe; the addition of orthogonal viewing planes with the biplane probe increase the diagnostic power of the technique. Although, the proximal ascending aorta is optimally visualized with the single-plane probe, the left main stem bronchus prevents imaging of the distal half of the ascending aorta. The biplane probe (i.e., longitudinal transducer) permits direct imaging of this structure. 3) Determination of the site of periprosthetic mitral regurgitation may be difficult with a single plane. Switching from a four-chamber view with the transverse transducer to a two-chamber left ventricular view with the longitudinal transducer provides excellent interrogation of the medial and lateral mitral annulus and the mitral prosthesis. 4) Transesophageal echocardiography has been useful in assessing left ventricular function because of the consistently high-quality imaging of the left ventricle. An important limitation, however, occurs in patients with regional left ventricular wall motion abnormalities to which optimal assessment requires orthogonal image planes that are obtainable only with biplane imaging.

Another important advance is the addition of continuous wave Doppler to the probe. Currently, most probes have only pulsed wave or high PRF Doppler capabilities, which are suboptimal in assessing high-velocity flow disturbances such as mitral stenosis, mitral prosthetic stenosis, or left ventricular outflow tract obstruction. Although continuous wave Doppler can be adequately performed in ambulatory patients from the transthoracic approach, the addition of continuous wave Doppler as an intraoperative technique would be important.

References
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