TRANSESOPHAGEAL ECHOCARDIOGRAPHY FOR CLINICAL DECISION MAKING

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Taams, Meine Aldert

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TRANSESOPHAGEAL ECHOCARDIOGRAPHY FOR CLINICAL DECISION MAKING

De toepassing van transoesofagale echocardiografie voor het maken van klinische beslissingen

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Promotor	Prof. Dr. J.R.T.C. Roelandt
Co-promotor	Dr. W.J. Gussenhoven
Overige leden	Prof. Dr. N. Bom
	Prof. Dr. E. Bos
	Prof. P.G. Hugenholtz

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CHAPTER 1

General Introduction

Aim of this study

Transesophageal echocardiography was initially developed to supplement an inadequate precordial echocardiographic examination. With high frequency transducers providing high resolution and detailed imaging, the technique has gained importance as a diagnostic tool in a considerable number of patients with cardiovascular disease, by providing unique information. In this study, the diagnostic utility and benefits of the application of transesophageal echocardiography in the clinical practice of cardiology are investigated.

The first part of the study (Chapter 1) provides a review of the technological developments in transesophageal echocardiography. This is followed by a description of the comparative diagnostic value and limitations of precordial and transesophageal echocardiography. Subsequently, the transesophageal cross-sectional echocardiographic anatomy; the execution of the transesophageal procedure; the indications; the contraindications; the limitations; the technical perspectives and recommendations for training are described. Finally, a survey of the Thoraxcenter experience is presented.

An overview of the diagnostic value of transesophageal echocardiography in solving diverse clinical problems is discussed in Chapter 2. In Chapters 3 to 7 the unique advantages of transesophageal echocardiography are described for the diagnosis of thoracic aorta pathology, the assessment of native and Björk Shiley mitral valve regurgitation by color Doppler flow imaging, for diagnosis of infective endocarditis, the detection of intracardiac thrombus, and visualization of the left coronary artery.

Technological developments of transesophageal echocardiography in a historical perspective

Since the introduction of echocardiography in 1954 by Edler and Hertz [1] it soon became apparent that scanning of the heart can be hindered by inadequate

penetration of ultrasound through the thoracic wall and lungs. This stimulated investigators to search for alternative approaches using cavities within the thorax.

There are two types of cavities leading to the heart or its direct vicinity: the blood vessels and the esophagus. Historically, the intravascular approach became the first to be examined, since the presence of blood around the transducer facilitates the direct coupling of ultrasonic energy.

The intravascular approach

As early as 1960 Cieszynski [2] introduced a single element mounted on a catheter in the jugular vein of dogs, to observe echoes in an A-mode from cardiac structures on an oscilloscope screen. The transducer remained in a stationary position. In 1963 Omoto [3] described a similar, slowly rotating device which was also introduced in the jugular or femoral vein. Using ECG triggering, this technique provided a static cross-sectional image on the screen of a storage oscilloscope. A device introduced into the left ventricle to monitor the dynamic behaviour of intracardiac dimensions was reported in 1968 by Carleton and Clark [4] using an omnidirectional single element at the tip of a catheter. The dimensions had to be reconstructed from minimal and maximal echo arrival times.

Eggleton [5] constructed in 1970 a catheter with four elements at the tip. Using slow rotation and ECG triggering, a cross-sectional image of intracardiac structures was reconstructed by computer. Two years later, in 1972, Bom and coworkers [6] at the Thoraxcenter of the Erasmus University Rotterdam reported on a real-time intracardiac scanner using an electronically phased circular array of 32 elements at the tip of a 9 French catheter.

To conclude this survey of intravascular scanning devices another monitoring device, reported by Stegall in 1974 [7], should be mentioned. A catheter with two elements was manoeuvered in the left ventricle such that the elements were opposite to one another. Following motion of opposing walls and by measuring the transmission of ultrasound, a dynamic registration of the ventricular short axis could be obtained. In general the image quality was below a clinically acceptable level.

The transesophageal approach

The first interest in the application of ultrasound via the esophagus was to obtain CW Doppler registrations of cardiac flow. In 1971 Side and Gosling reported the use of a dual element construction mounted on a standard gastroscope [8]. The Doppler applications through the esophagus were further expanded by Daigle in 1975 [9] who applied pulsed Doppler with a single element. The first approach for imaging through the esophagus was M-mode echocardiography which was reported by Frazin in 1976 [10].

Two-dimensional imaging through the esophagus began in 1977 when Hisanaga reported on a real-time scanning system [11]. The scanning device consisted of a rotating single element in a liquid-filled balloon mounted at the tip of a gastroscope. One year later the same group also described a mechanical linear scanning device for transesophageal applications [12].

Mainly as a result of interest by anesthesiologists, research was continued and the next and most important stage in the development of transesophageal transducers was the introduction of electronic scanners. In 1980 DiMagno [13] described a high frequency (10 MHz) linear array for small parts scanning - mainly of organs in the gastrointestinal tract. The electronic phased array transducer reported by Souquet [14] was particular for cardiac application. The frequency of this transducer was 2.25 MHz. From this moment on, phased array scanning via the esophagus rapidly evolved.

In our institution the first transesophageal phased array transducer was constructed in 1982 by Lancée [15]. The design featured a tilted 24 element 3.1 MHz array with a crystal interelement space (pitch) of 400 μm (Fig. 1). Clinical studies, however, showed no need for the 20 inclination of the scanning plane and subsequent designs left the array in line with the gastroscope long axis. Improvements in micro-miniature cutting and bonding technology resulted in a series of transducers with progressively better image quality.

In 1983 a 32 element 3.5 MHz array with a pitch of 300 μm was constructed (Fig. 2A) and its successor - a 52 element 4.7 MHz array with a pitch of 210 m - were introduced for clinical use in 1984 and reported by de Jong [16]. The carrier was a gastroscope of 9 mm diameter while the scanhead incorporated an active area of 10 x 10 mm2. The final design was realized in 1985 [17] featuring a 64 element 5.6 MHz array with a pitch of only 160 μm (scanhead width/height 16/8.5 mm).

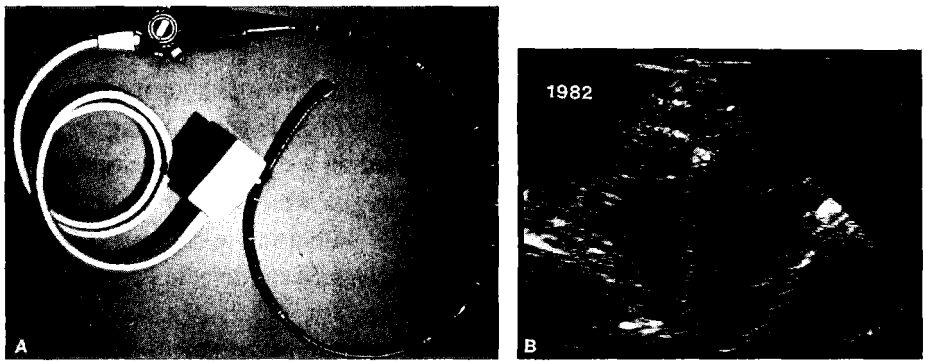


Fig. 1 A, Prototype transesophageal phased array transducer (24 x 13 x 10 mm) with 24 elements 3.1MHz, mounted on the tip of an Olympus XP gastroscope with a diameter of 7.9 mm. B, Transesophageal two-dimensional echocardiogram showing a cardiac four-chamber view obtained with this transducer in an anesthetized pig in 1982.

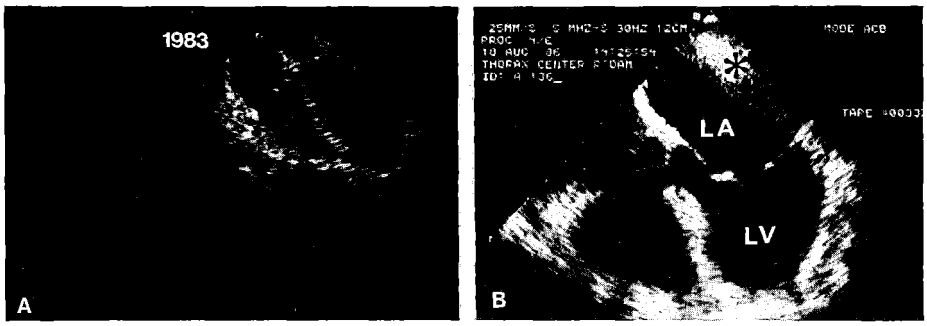


Fig. 2 A, Transesophageal two-dimensional echocardiogram showing a cardiac four-chamber view obtained in a healthy volunteer in 1983, obtained with the 32 elements 3.5 MHz prototype transducer. B, A cardiac four-chamber view obtained in 1985 in a patient with mitral stenosis and extensive thrombus formation (asterisk) in the left atrium, obtained with the 64 elements 5.6 MHz prototype transducer. Note the difference in image quality between Figs. 1B, 2A and 2B. LA = left atrium; LV = left ventricle.

This design exhibited an extremely low artifact level (grating lobes) combined with superior lateral and axial resolution (Fig. 2B); Gussenhoven [18] and Lancée [19]. Experience with these transducers provided the clinical material presented in this thesis.

Precordial echocardiography

Precordial echocardiography is a unique method for the non-invasive study of cardiac morphology and function. The two-dimensional technique is ideally suited to visualize cardiac geometry whereas accurate measurements of, for example, left ventricular wall thickness are best obtained from M-mode recordings guided by cross-sectional echo [20]. With the introduction of pulsed, continuous wave and color Doppler, study of the velocity and other characteristics of blood flow became possible.

The advantage of two-dimensional imaging is that the transducer can be applied from different positions on the chestwall using several acoustic windows (parasternal, apical, suprasternal, subxyphoid) which give a high degree of spatial orientation of the interrogating plane or cross-section. Thus an "imaginary three-dimensional reconstruction" of cardiac morphology and function is possible.

In daily practice, integrated precordial cardiac ultrasound including M-mode, two-dimensional and Doppler techniques has become the "diagnostic work-horse" of the cardiologist in the in- and outpatient clinic and the intensive care environment. In most patients adequate image quality is obtained and important diagnoses are made with a high degree of reproducibility. However, the diagnostic information of precordial echocardiography can be hampered by physical limitations such as obesity, chestwall abnormalities, changes due to age and lung diseases. In addition, intracardiac artificial material may give rise to attenuation, distortion and reflection of the ultrasound energy resulting in ambiguous images. Moreover, imaging of cardiovascular structures in the far-field (>7.5 cm) of the precordial transducer suffers from impaired resolution, irrespective of which frequency transducer is used.

In certain clinical conditions the execution of precordial echocardiography may be impractical and/or precluded. This applies especially for patients on a ventilator or in the early post-cardiac surgery period when entrapped air and drains are present in the precordial space.

Transesophageal echocardiography

The rationale for transesophageal echocardiography lies in the fact that this technique overcomes many of the disadvantages experienced with precordial ultrasound. No signal attenuation occurs from the esophagus; the close relationship between esophagus and cardiovascular structures allows the use of higher frequency transducers. Thus, higher resolution and detailed images can be achieved. Structures in the far-field of a precordial transducer are now anatomically close to the transesophageal transducer. The transesophageal approach provides detailed visualization of cardiovascular structures and lesions (e.g. masses) which are poorly imaged, or not even seen (or are inaccessible) from the precordium; these include:

Structures:
- Thoracic aorta
- Distal part and orifices of the caval veins
- Pulmonary veins
- Atrial cavities and atrial appendages
- Interatrial septum
- Coronary arteries

Lesions:
- Thoracic aorta dissection and/or aneurysm
- Abnormalities of native and prosthetic valve, anulus and cardiac skeleton
- Higher yield in detection of vegetations in infective endocarditis and its complications
- Adherence of intracardiac mass lesions

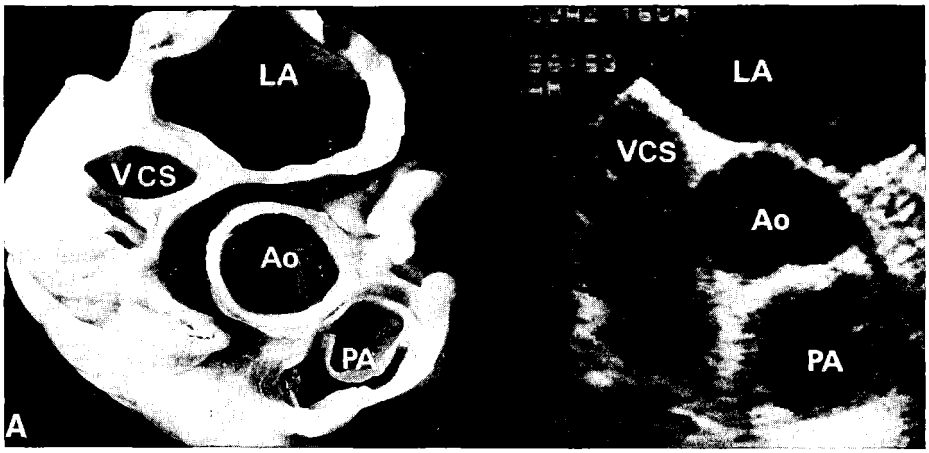
Transesophageal echocardiographic anatomy

The intimate relationship between the esophagus, the heart and great vessels offers the unique possibility to visualize these structures with transesophageal echocardiography. Unlike in precordial echocardiography, specific windows are not required as the ultrasound beam travels through the esophagus unhampered (Figs. 3,4).

With the transducer at a distance of approximately 35 cm from the teeth the left atrium, which is situated directly anterior to the esophagus, is visualized.

Fig. 3 Schematic drawings of images obtained with transesophageal echocardiography via the left atrium (LA). Images are obtained by tilting the transducer with the scope in a stationary position from a superior (1) to intermediate (2,3) to inferior (4) tilt. From the stomach, short axis cross-sections of both ventricles are obtained (5). The descending aorta is seen when the probe is rotated in the esophagus (6). LAA = left atrial appendage; Ao = aorta; PA = pulmonary artery; RVOT = right ventricular outflow tract; RV = right ventricle; LV = left ventricle; SCV = superior caval vein; RA = right atrium.

Fig. 4 Anatomic specimen showing the heart and its relation to the esophagus. Note that the long-axis of the heart is oblique to the axis of the esophagus. LA = left atrium; LV = left ventricle; LPA = left pulmonary artery; LB = left bronchus; Ao = aorta.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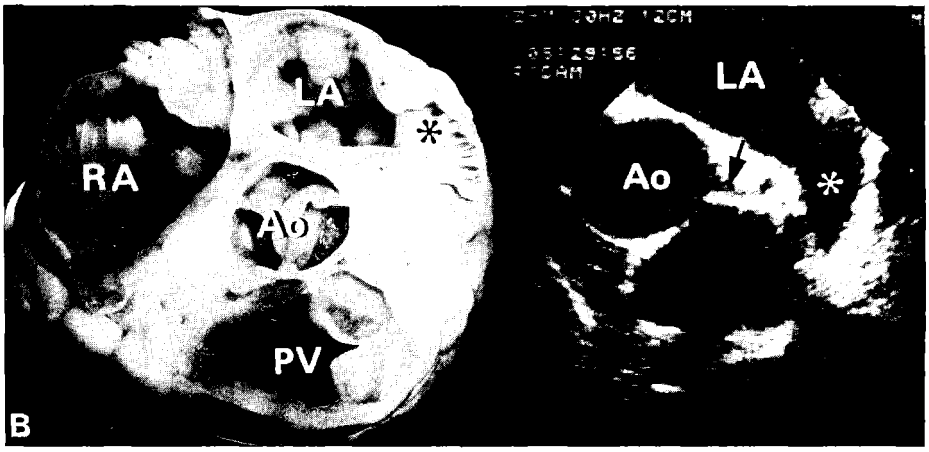
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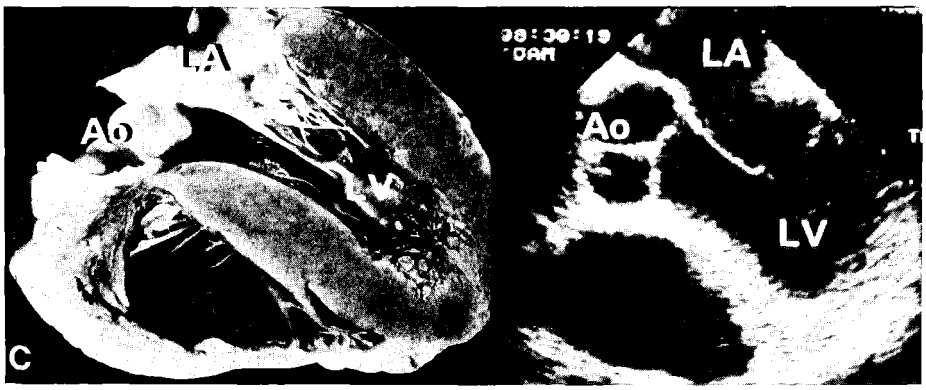
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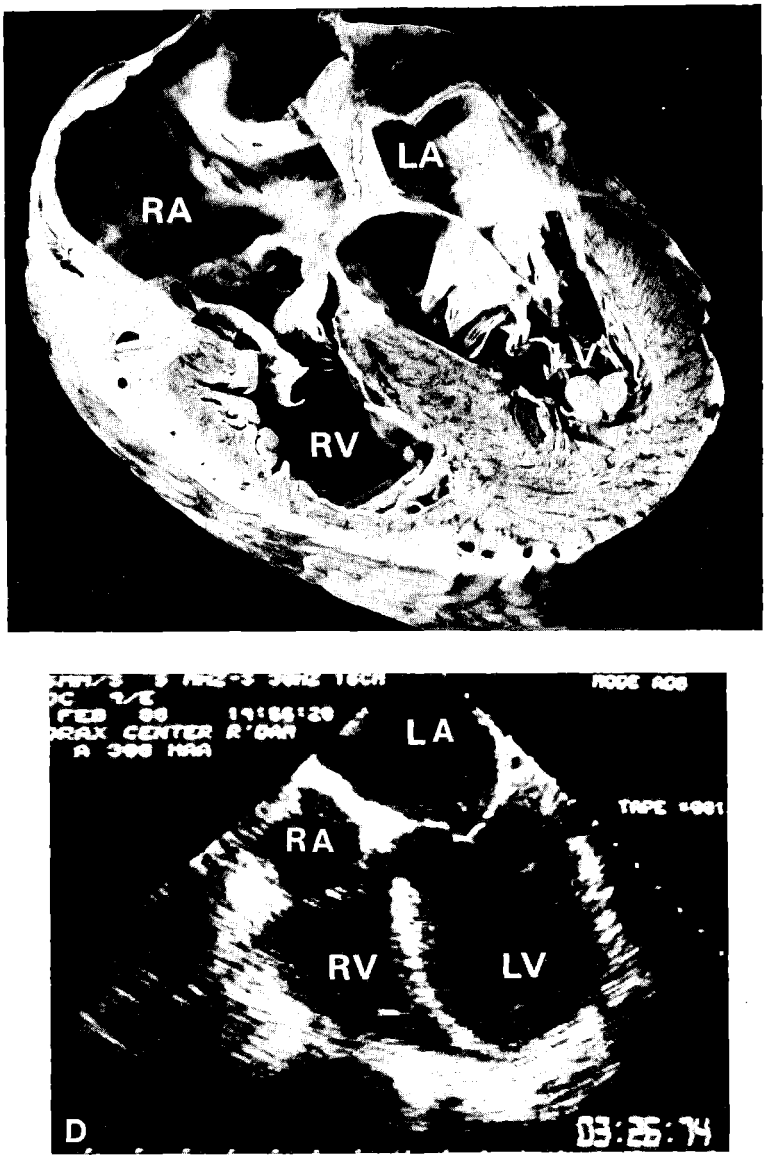

Fig. 5 Anatomic cross-sections through the heart and corresponding transesophageal two-dimensional echocardiograms. The transducer is positioned at the level of the left atrium (LA). A, Shows cross-sections obtained with a superior tilt of the transducer. This view typically shows the short axis of the superior caval vein (SCV), aorta (Ao) and pulmonary artery (PA);
B, A slightly inferior tilt of the transducer allows identification of the left atrial appendage (asterisk), the left coronary artery (arrow), the aorta, the right atrium (RA) and the pulmonary valves (PV); C, More inferiorly the left ventricular outflow tract and mitral valve can be studied; D, Characteristically, the cardiac four-chamber view is observed with the transducer tilted even more inferiorly. LA = left atrium; RA = right atrium; LV = left ventricle; RV = right ventricle.

From this position, four basic horizontal and oblique echocardiographic cross-sections of the heart and proximal great vessels are obtained by tilting the transducer superior and inferior using the remote control (Fig. 5 A-D).

Cross-section 1 is just superior to the aortic valve leaflets and the following structures are depicted:

left atrium with its appendage, orifices of the right and left upper pulmonary veins; the proximal coronary arteries; the superior vena cava; and the pulmonary artery.

Cross-section 2 is at the level of the aortic valve leaflets delineated in a short-axis plane. The right ventricular outflow tract is outlined anterior to the aorta and part of the right atrium is imaged, to the viewer's left, lateral to the aortic root. In the roof of the left atrium the entry of right and left lower pulmonary veins is visualized.

Cross-section 3 is at the level of the mitral valve leaflets in an oblique left ventricular long-axis view, imaging the left atrium, left ventricle with outflow tract, interventricular septum and part of the right ventricle. In this plane mitral leaflet apposition and commissures are best studied by inferior and superior tilt of the transducer.

Cross-section 4 outlines the four cardiac chambers, the interatrial septum with the fossa ovalis and both atrioventricular valves. Deeper introduction of the probe reveals the inferior vena cava, the floor of the right atrium and the coronary sinus entering the right atrium in the atrioventricular groove.

Cross-section 5 In order to study left ventricular function and myocardial wall thickness the probe is advanced into the stomach. Usually, slight resistance is felt due to the passage of the cardiac sphincter. After superior tilting of the transducer, short-axis views at the papillary muscle level of the left ventricle or cardiac apex are obtained. The posterior wall lies closest to the transducer. The interventricular septum divides the right and left ventricle (Fig. 6).

Cross-section 6 Rotation of the transducer shows the descending aorta and withdrawal of the probe from the level of the diaphragm visualizes the entire thoracic aorta, including the aortic arch. In the presence of thoracic aortic pathology simultaneous notation of the depth of the transducer within the esophagus is imperative, allowing an imaginary three-dimensional schematic reconstruction. Interference of the right main bronchus may prevent a complete image of the mid portion of the ascending aorta (Fig. 7).

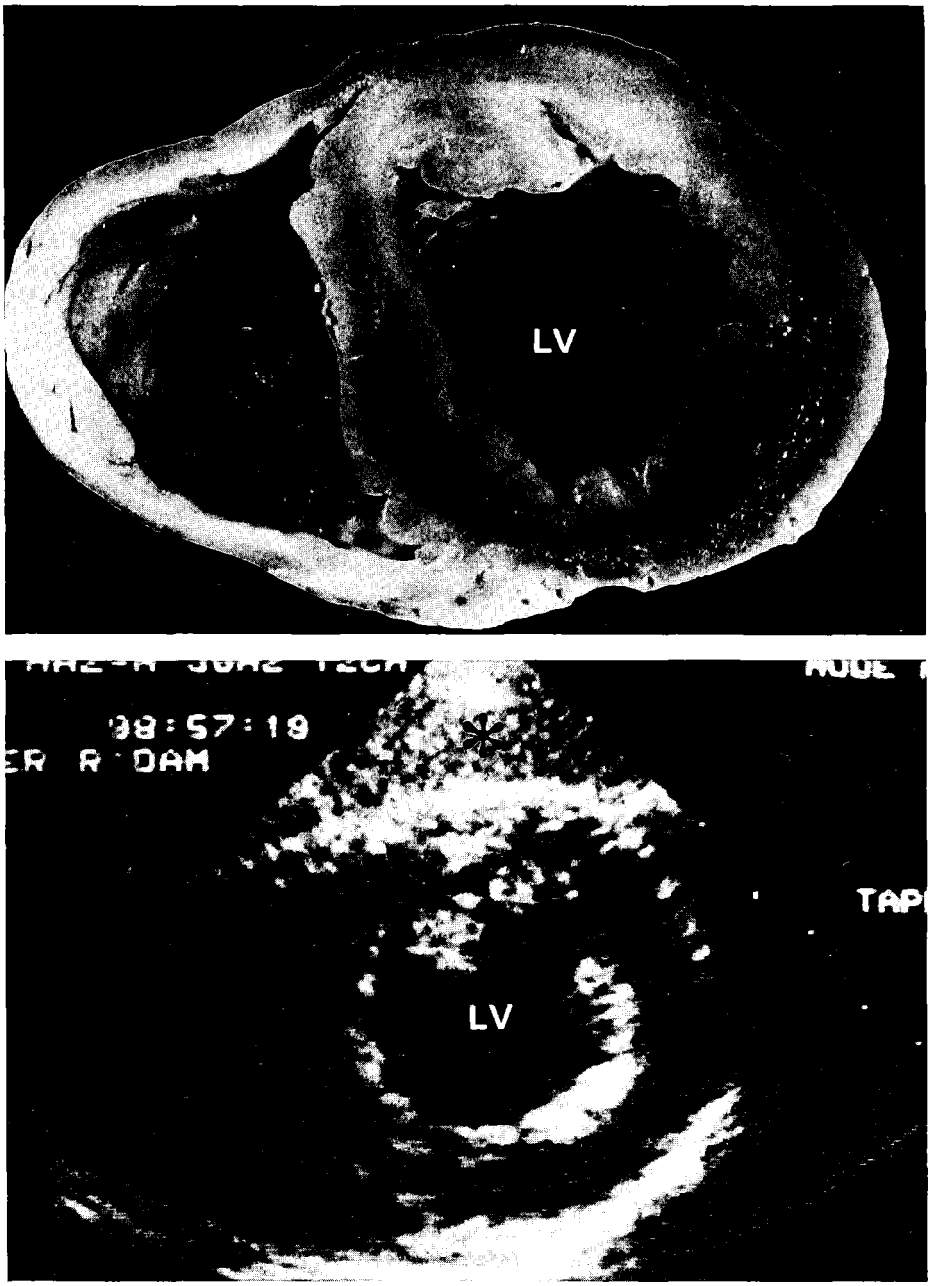

Fig. 6 Anatomic ventricular cross-sections through the heart and corresponding transesophageal two-dimensional echocardiogram. The transducer is positioned in the stomach at the level of the left ventricle (LV). Note that the liver tissue is interposed between transducer and the heart (asterisk).

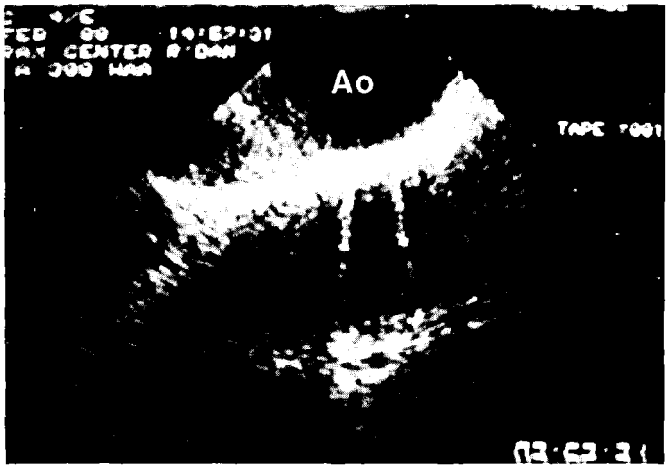

Fig.7 Transesophageal two-dimensional echocardiographic cross-section through the descending thoracic aorta (Ao) at the level of the aortic arch.

Procedure

Transesophageal echocardiography is a semi-invasive procedure and before application of this technique a clear objective should be defined. Both the rationale for, and procedural methods of the study should be adequately explained to the patient in written form. In addition, prior to the examination, the physician performing the study should discuss necessary details with the patient.

As in a gastroscopic study, a minimum fasting time of 4 hours prior to the examination is ideal; otherwise, the study is postponed. This prerequisite is waived, however, when transesophageal echocardiography is crucial in patients in a critical clinical condition.

Topical anesthesia with 10% lidocaine spray to the patient's hypopharynx is applied. In younger patients, or children, midazolam 37.5 µg/kg intravenously is used for premedication. Patients with suspected thoracic aortic dissection are investigated under intra-arterial pressure monitoring and, if necessary, an intravenous line for immediate nitro-prusside therapy is placed. With critically ill patients an anesthesiologist is always present.

Routine prophylaxis for endocarditis is not necessary as the procedure causes no traumatic or thermal injury to the esophagus mucosa. However, the American Heart Association and the British Society for Antimicrobial Chemotherapy recommend prophylaxis for endoscopy in high-risk patients with a

prosthetic valve [21, 22]. Although the question arises as to whether, in patients with suspected infective carditis, prophylaxis might obscure the bacteriological diagnosis.

Prior to insertion of the probe, any dentures are to be removed, and a bite guard is placed. Gel is smeared on the sheath wrapping the probe and the scope unlocked.

Continuous monitoring of the electrocardiogram, directly visible on the monitor, is compulsory. The standard position for the examination is, similar to gastroscopy, with the patient in the left lateral decubitus position.

Introduction of the probe is according to standard practice in awake patients. Important is to move the deflexed probe forward, watching the patient swallow. Extra flexion of the patient's head forward is helpful to swallow the probe. In intubated patients, introduction of the probe is facilitated under direct vision with a laryngoscope.

In addition an experienced technologist in echocardiography operates the controls of the ultrasound equipment and videorecording system. A prerequisite for a room in which the examination is conducted is the immediate availability of oxygen support, nasogastric and/or endotracheal suction. The presence of a watertap and sink is a convenient accessory for washing and cleaning the probe after termination of the investigation.

In awake patients the diagnostic examination takes less than 10 minutes and during this period suction is not usually necessary. During longer sessions a drying agent (atropine 0.5 mg i.m.) might be indicated. In a full examination all standard imaging planes should be obtained with visualization of all intracardiac structures, the great arteries and veins, including the thoracic aorta. Sometimes it is advisable to enter the stomach first, to acquire a left ventricular function view, as some patients during the examination may not tolerate the discomfort caused by further introduction of the probe into the stomach, due to esophageal spasm.

Display of the two-dimensional real-time images on the monitor are in accordance with the human anatomy and comparable with angiographic or computer-tomographic imaging. Thus, the left side of the heart appears to the viewer's right side on the television screen.

On completion of the study the probe is withdrawn.

The first food allowed should be water. Other foods should be delayed until it is established that there are no difficulties with swallowing. Sedated patients are advised to wait one hour before allowed to leave.

Indications

When non-diagnostic data are obtained by precordial ultrasound imaging a decision should be made for each patient as to whether transesophageal echocardiography is clearly clinically indicated, since the procedure is not entirely non-invasive.

Transesophageal echocardiographic studies have been found to provide unique diagnostic information in the following cardiac conditions:

- Suspected thoracic aorta pathology
- Suspected infective endocarditis of native valves
- Presence of intracardiac prosthetic material (especially mitral prostheses and suspected dysfunction or endocarditis)
- Suspected intracardiac mass lesion (i.e. in pulmonary or systemic emboli)
- Detailed morphology of native valve pathology i.e. calcifications, flail, prolapsing or billowing leaflets or cusps
- Direct pre- and postoperative evaluation of cardiac valvular surgery.
- Monitoring ventricular function during surgery
- Perioperative assessment of complex congenital heart disease

Contraindications

Some conditions are associated with risk for the transesophageal examination and should be discussed with the gastroenterologist, such conditions include:

- Dysphagia (e.g. following a stroke)
- Upper gastrointestinal bleeding
- History of esophageal varices, diverticulum, tumor, stenosis, severe lesions or post-thoracic high-voltage radiation therapy. A barium swallow may be necessary in patients with a history suggesting esophageal pathology
- Any bleeding disorder; full anticoagulation, however, is no contraindication
- Infective conditions (AIDS, hepatitis-B), where sheaths are not available

Limitations

Limitations of transesophageal echocardiography include:

- The size of the transesophageal transducer (width/height 14/11 mm) and diameter of the gastroscope (10 mm) currently available prohibits their use in children.
- Scanning planes with the current transesophageal transducer are reduced to transverse scans or a view around the short axis. This is a particular handicap for study of the right ventricular outflow tract.
- Poor visualization of structures in the far-field of the transesophageal transducer; i.e. anterior and distal interventricular septum.

In general, the left ventricular outflow tract and cardiac structures proximal to the atrioventricular valves are superiorly visualized, while structures to the atrioventricular level are less accessible."Blind-zones" in visualization of the thoracic aorta are the mid-portion of the ascending aorta, where the right main bronchus crosses the aorta, and the cephalic arteries. In this respect, a DeBakey type II dissection can be problematic.

Technical perspectives

Our experience indicates that the following technical developments are likely to prove highly advantageous:

- Miniaturization to a pediatric transesophageal transducer and tube. However, in order to keep the thickness of the tube within acceptable limits only a limited number of elements and cables can be installed resulting in a diminished resolution
- Higher frequency transducers (7.5 MHz) for pediatric or coronary imaging
- Combination with continuous wave Doppler application from the esophageal approach in order to quantify flow velocities
- On-line automatic contour detection systems for monitoring of cardiac ventricular function
- Pacing ring electrodes built into the tube for direct contact atrial pacing in order to induce ischemia and to detect resulting ventricular wall motion abnormalities

- To overcome limitations of one transverse view a bi-plane transesophageal probe with a larger number of elements and higher frequency to obtain good spatial resolution.

Although imaging in the short-axis or a view around the short-axis is popular in transesophageal echocardiography, possible advantages of the bi-plane probe include the possibility to execute more scanning planes i.e. simultaneous longitudinal imaging in the long-axis without having to change probes. As some diagnoses are more obvious in a longitudinal view, the transesophageal bi-plane transducer can assist in the evaluation of ventricular outflow tracts, thoracic aortic aneurysm, the entry of aortic dissection, antero-trabecular septum, or in intraoperative monitoring of cardiac function. Initial clinical evaluation, however, of the current bi-plane prototype probes revealed contact problems with the esophagus of the two separate arrays mounted in succession, necessitating repositioning of the transducer. The resolution of bi-plane prototypes is currently below a clinically acceptable level due to insufficient number of elements, although more views are obtained from bi-plane formation.

Prototype matrix phased-array scanheads are currently under investigation. The advantage of this type of transducer is one entry point of the ultrasound beam resulting in less contact problems. However, in the matrix transducer the configuration of the acoustic beam may be distorted due to its typical shape and interference between the two orthogonal arrays.

Maintenance of the probe

Disinfection of the probe has initially been executed with an enzyme-containing detergent (Biotex®), 90% denaturated alcohol and a 20-min soak in 10% povidone iodine solution in H2O (Betadine®). Since disposable latex sheaths (International Medical®) became available in 1987 these replaced the earlier, more complex, disinfection procedure and provided an extra layer of protection for patient safety with regard to contagious diseases such as HIV and hepatitis B virus. These sheaths do not affect the quality of the images nor do they influence the manoeuverability of the scope.

Apparatus should fulfill regular safety criteria for medical equipment with respect to safety and temperature. Periodic check-up for electrical safety (i.e. insulation) and, before each study, routine inspection of the probe for any visible cracks or fractures are mandatory.

Recommendations for training

Successful and correct examination relies upon the physician's expertise in recognition and interpretation of transesophageal imaging patterns. Any physician intending to learn transesophageal echocardiography should fulfill the following recommendations :

- Should be a cardiologist with good structural insight into the precordial ultrasound techniques for normal and pathologic anatomy of the heart and great vessels.
- The cardiologist-in-training should analyze transesophageal echocardiographic videotapes recorded in patients
- Be acquainted with the relevant scientific literature on transesophageal-echocardiography
- Be acquainted with the standard gastroscopic procedures
- Following these initial steps, attendance of live transesophageal echocardiographic examinations is beneficial. The training of a physician, usually a cardiologist, to perform the introduction of the transesophageal probe should be under the supervision of a cardiologist experienced with this technique.

Thoraxcenter experience

On indication, transesophageal echocardiography has been employed in the department of cardiology of the Thoraxcenter, University Hospital Rotterdam, since 1984. Approximately 750 studies have been performed in conscious patients in the outpatient clinic or coronary care unit. These studies were additional to precordial examinations (approximately 14,000) during a 5-year period. Barium swallows for the detection of esophageal disease were never indicated.

The youngest patient was aged 11 years; the oldest 83 years. Two patients suffered from anxiety and premedication was necessary; otherwise, premedication was not routinely given unless specifically requested. Insertion of the probe was unsuccessful in 3 patients due to lack of cooperation. In 2 patients paroxysmal atrial fibrillation occurred due to irritation of the left atrium by the transesophageal transducer; irritation subsided after repositioning of the probe. Established reasons in the literature for cessation of the examination procedure, such as intolerance, third-degree atrioventricular block, ventricular tachycardia,

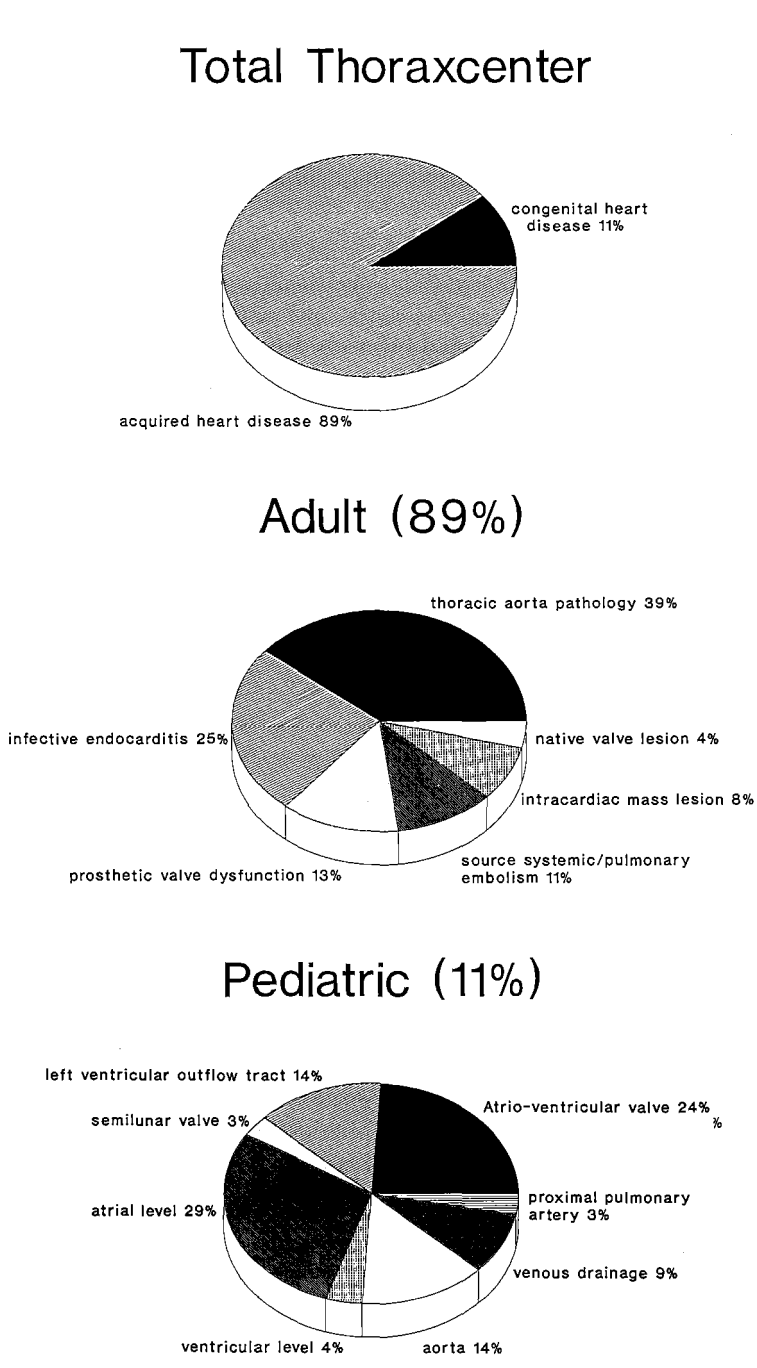

Fig. 8 Indications for referral (750 patients).

bronchospasm or severe angina pectoris did not occur during these studies. Full anticoagulation has not been a problem in our experience. Late complications, such as esophagus perforation, infections or sore throat were not encountered. In general, transesophageal echocardiography is well tolerated and a safe diagnostic procedure.
Indications for referral are summarized in Figure 8.

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CHAPTER 2

2.1 Transesophageal two-dimensional echocardiography: its role in solving clinical problems

E.J. Gussenhoven[1,2], M.A. Taams[1], J.R.T.C. Roelandt[1], C.M. Ligtvoet[1], J. McGhie[1], L.A. van Herwerden[1], M.K. Cahalan[3]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam;
[2]the Interuniversity Cardiology Institute of The Netherlands;
[3]Dept. of Anesthesiology, University of California, San Francisco, USA.

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Abstract

The diagnostic value of transesophageal two-dimensional echocardiography is described in 32 patients in whom precordial echocardiography or angiography, or both, failed to establish a definitive diagnosis. All attempted transesophageal studies were completed without complication and the referral question was definitively answered. Nineteen patients were subsequently submitted to surgery. In 18 of them, the transesophageal echocardiographic diagnoses were proven correct; in 1 patient the diagnosis was proven partially incorrect. In the 13 unoperated patients the transesophageal echocardiographic diagnoses were not independently confirmed but were assumed correct because incontrovertible images were obtained. These results indicate that transesophageal echocardiography significantly extends the diagnostic capabilities of echocardiography.

Introduction

Transesophageal echocardiography was developed to supplement inadequate precordial echocardiographic examinations [1]. However, when the technique became available most investigators used it as a monitoring tool in unconscious patients during surgery [2-9]. Thus, experience with this technique for diagnostic purposes is limited [10-12]. In this report we describe the indications and diagnostic benefits of transesophageal echocardiography.

Methods

Study patients
During 1 year, we studied 32 patients (17-80 years old; 16 women and 16 men) referred for transesophageal two-dimensional echocardiography because precordial echocardiography was inadequate or because cardiac catheterization was inadequate or unjustified, or both. Informed consent was obtained from each patient before the examination. None of the patients had a history of swallowing problems or esophageal disease. In five patients, a precise anatomic evaluation of aortic valvular and subvalvular disease was requested; and in another five patients, confirmation of an abnormality in the aortic root was desired. Eleven patients were referred for documentation of valve vegetations because of suspected infective endocarditis, while another 11 patients had a suspected intracardiac mass lesion.

Echocardiography
We used a 3 or 5 MHz transducer mounted at the tip of a commercially available adult gastroscope and interfaced with a Hewlett-Packard ultrasonograph (HP 77020 AC). The patients fasted for 8 hours and no premedication was given. As a local anesthetic, 50 to 100 mg of 10% topical lidocaine was administered to the patient's hypopharynx.

Results

Transesophageal echocardiography was performed 38 times: once in 27 patients, twice in 4 patients and 3 times in 1 patient. The repeat examinations were necessary to monitor therapy. No examination lasted longer than 15 minutes.

Patients were able to swallow the transducer without vomiting or other complications. All attempted studies were completed and the clinical question was answered. In 18 of 19 patient subsequently submitted to surgery, the transesophageal echocardiographic diagnoses were proven to be correct; in 1 patient the diagnosis was proven partially incorrect and this case is discussed later. In the other 13 patients studied, the correct diagnosis was not independently confirmed but was probably correct because incontrovertible images were obtained.

Suspected aortic valvular or subvalvular disease

In four of the five patients referred for evaluation of aortic valvular or subvalvular disease, transesophageal echocardiography revealed new information that facilitated subsequent surgical management: visualization of severe mitral valve disease in one; demonstration of the supra-annular origin of an aortic mycotic aneurysm associated with dehiscence of a Hancock valve prosthesis in one; and precise knowledge of the subaortic obstruction in two. In one patient transesophageal echocardiography suggested aortic insufficiency because images of the aortic root were interpreted to show exaggerated motion and redundancy of the aortic leaflets. Because the patient was hemodynamically unstable, angiography was not attempted. Direct surgical inspection confirmed aortic insufficiency, but the cause was a transverse dissection of the aortic root (whose intimal flap was the abnormality seen on the transesophageal echocardiogram) and the valve leaflets were normal.

Suspected aortic root or arch disease

In the five patients referred for evaluation of aortic root disease, transesophageal echocardiography correctly excluded dissection in one patient and diagnosed it and its site or origin in another. A residual coarctation was diagnosed once and in one patient a large thrombus was seen around a valved aortic conduit. In one patient, the existence of a saccular aneurysm of the aortic arch and the site of its connection through a fistula to the left pulmonary artery was demonstrated (Fig. 1). Additional preoperative studies already scheduled (angiography and computed tomography) were then deemed unnecessary. Surgery was promptly performed and confirmed the transesophageal echocardiographic findings.

Suspected endocarditis

Among the 11 patients referred with suspected endocarditis, transesophageal echocardiography discovered no evidence for the diagnosis in 6, but revealed lesions in 5. In two patients, vegetations of the mitral valve consistent with

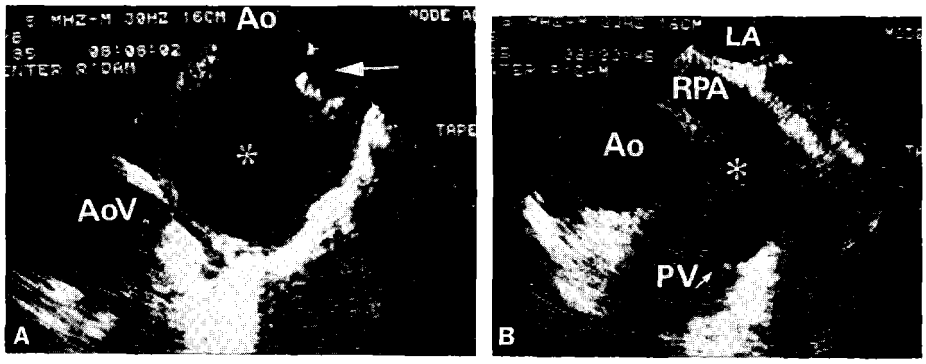

Fig. 1 Transesophageal two-dimensional echocardiograms (5 MHz transducer) obtained in a patient with a suspected saccular aneurysm of the aorta. A, The transducer at the level of the aortic arch (Ao) reveals a large saccular aneurysm (asterisk) which gives access to the left pulmonary artery (arrow). B, The cross-sectional view with the transducer advanced somewhat deeper into the esophagus reveals an obstruction of the main pulmonary artery caused by the aneurysm (asterisk). AoV = aortic valve; PV = pulmonary valve; RPA = right pulmonary artery.

infective endocarditis were seen. In another patient, a disruption of the fibrous continuity between the aortic and mitral valve leaflets was noted which gave access to a large mycotic aneurysm between the left atrium and aortic root (Fig. 2). In two patients, lesions were noted in the aorta: a mycotic aortic sinus aneurysm in one and a mass lesion within the dilated aorta in the other (Fig. 3).

Suspected mass lesions

In the 11 patients referred with a suspected mass lesion, transesophageal echocardiography confirmed the presence and size of a mass in 3 patients: a mitral valve mass in 2 and multiple left atrial clots in 1 (Fig. 4). In the other eight patients, no mass was seen despite multiple images of excellent resolution in the suspected area.

Discussion

We believe that diagnostic transesophageal echocardiography has had slow acceptance because of concern about discomfort and risk to conscious patients. Although the initial pharyngeal passage may be unpleasant, once the probe advances into the esophagus, the procedure is well tolerated. None of our patients prevented us from completing the transesophageal study or refused restudy. The only published complication of transesophageal echocardiography is unilateral, transient vocal cord paralysis in two neurosurgical patients after

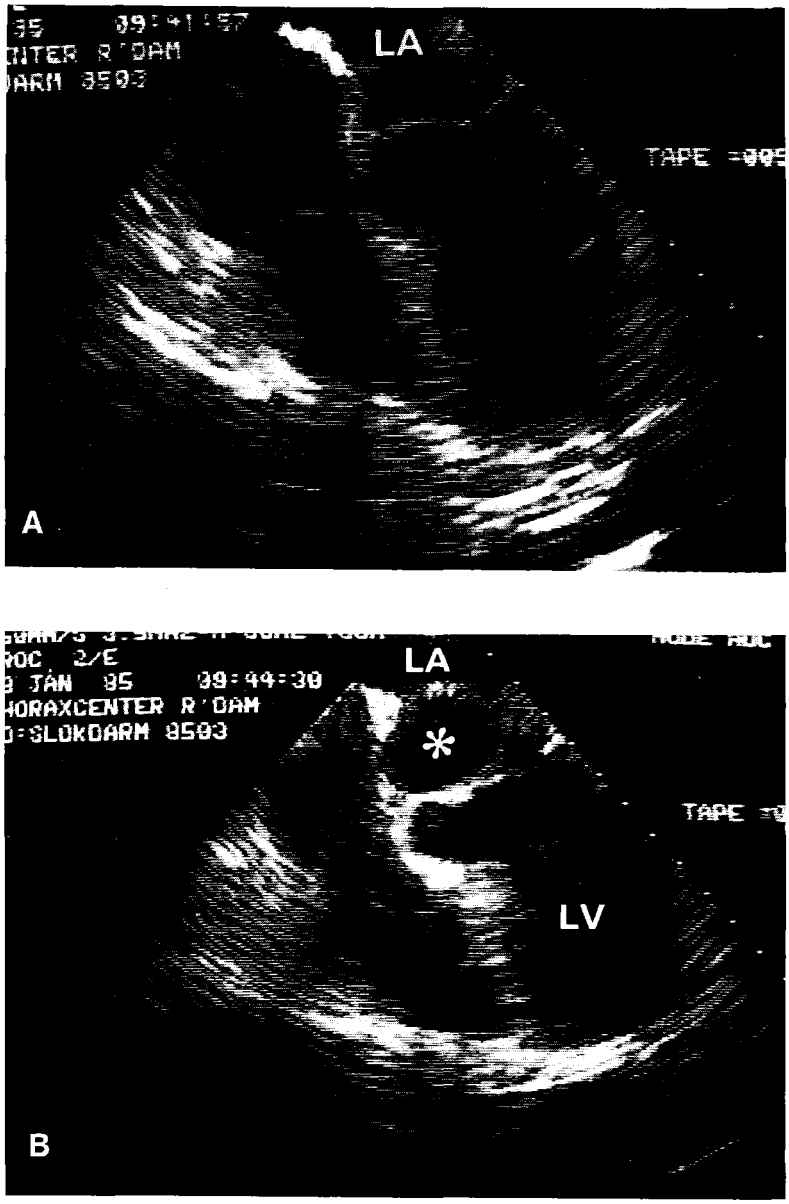

Fig. 2 Transesophageal two-dimensional echocardiograms (3 MHz transducer) obtained in a patient with an aortic valve prosthesis and a history of infective endocarditis. A, The four chamber image is normal. B, When the transducer tip is tilted slightly upward a mycotic aneurysm (asterisk) is noted between the left atrium (LA) and left ventricular (LV) outflow tract adjacent to the anterior mitral valve leaflet.

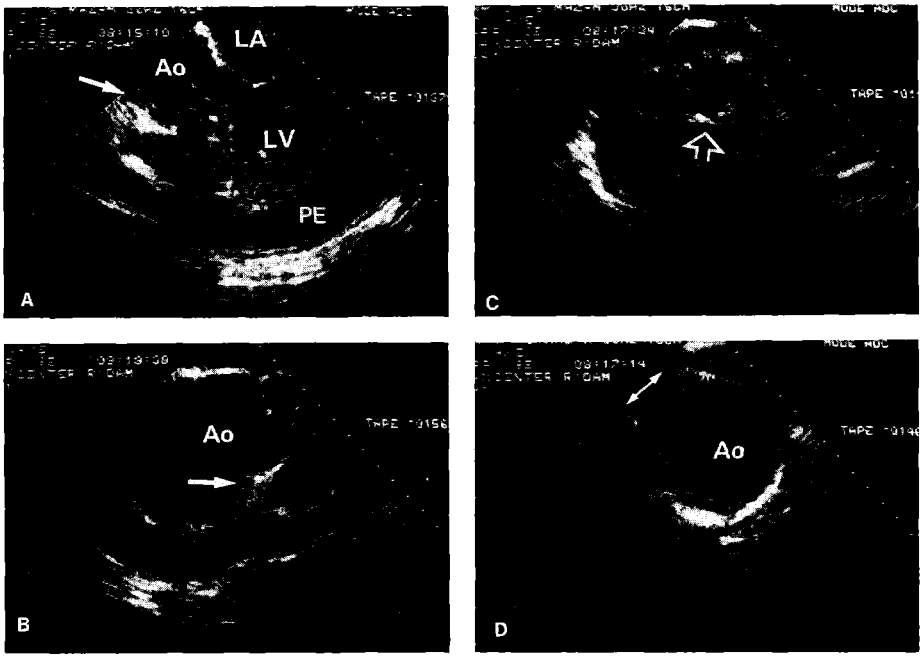

Fig. 3 Transesophageal two-dimensional echocardiograms (5 MHz transducer) obtained in a patient with a history of infective endocarditis. A, The long-axis view shows an apparently normal intracardiac geometry surrounded by a large amount of pericardial effusion (PE). B, Directing the beam to the aortic (Ao) root, a huge ascending aorta is visualized. Serial cross sections in this region revealed highly reflective echo structures (A and B, arrow) in the area of the right sinus of Valsalva. C, A mass lesion is seen within the dilated aorta which has "soft" echo characteristics (open arrow). D, A further superior tilt of the transducer shows a normal caliber of the ascending aorta distal to the dilated part (arrow). Abbreviations as in Figures 1 and 2.

hours of transesophageal echocardiographic monitoring. These patients were receiving general anesthesia and were positioned with extreme neck flexion [13].

Indications

All of our patients were referred because of inadequacy of precordial echocardiographic investigations or other conventional diagnostic procedures, or both. Well known reasons for inadequate precordial echocardiographic images are obesity, emphysema and chest wall changes common in old age [14]. Another important indication for transesophageal echocardiography is limitation of the precordial echocardiographic investigation by interposition of a prosthetic valve (Fig. 2). Transesophageal echocardiography consistently overcomes all these difficulties by avoiding intervening structures and providing unique cross sections. It also may occasionally eliminate the need for preoperative angiography. Identification of a residual coarctation in one patient explained high blood pressures in the arms. In two other patients, unequivocal demonstration of an aortic root dissection and a saccular aneurysm permitted immediate surgery (Fig. 1). Similarly, documentation of the presence and extent of destructive lesions due to infective endocarditis may spare some patients angiography. In this category of patients the conventional preoperative investigation procedures may be particularly prone to failure in assessing the exact nature of the destruction [15].

Conclusions

Our experience with two-dimensional transesophageal echocardiography indicates that it can be of unequivocal importance in establishing a definitive diagnosis of cardiothoracic disease, when other diagnostic methods prove inadequate. In certain patients, transesophageal echocardiography will facilitate timely surgical intervention without the potential hazard of cardiac catheterization. Transesophageal echocardiography is a well tolerated technique that significantly extends the diagnostic capabilities of echocardiography and should be considered whenever precordial echocardiography or other cardiac studies are deemed inadequate.

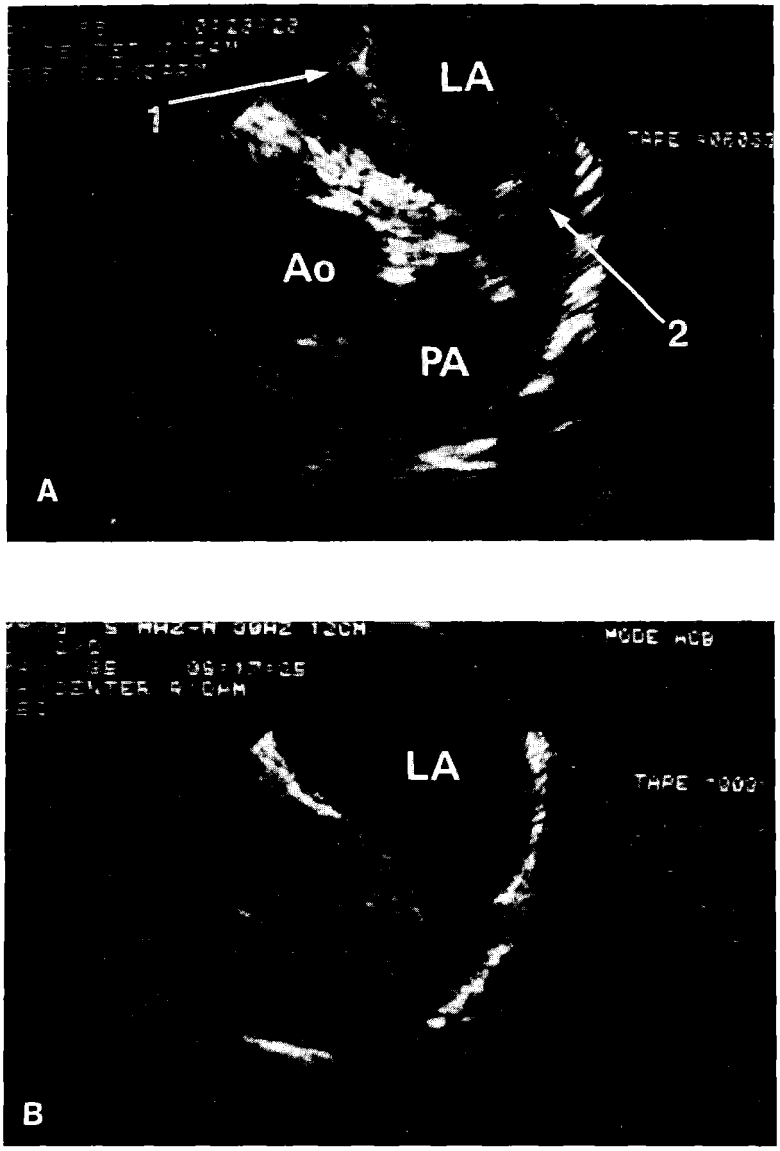

Fig. 4 Transesophageal two-dimensional echocardiograms (3 and 5 MHz transducers, respectively) obtained in a patient with mitral valve stenosis and a history of peripheral embolism. A, Two mass lesions are identified in the left atrium (LA): one superiorly near the entrance of the right pulmonary veins (arrow 1) and one at the junction of the left atrial appendage (arrow 2). B, The cross sections obtained after 3 months of anticoagulant therapy reveal the resolution of both mass lesions. Abbreviations as in Figure 1.

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2.2 Esophageal Echocardiography

E.J. Gussenhoven[1,2], M.A. Taams[1], J.R.T.C. Roelandt[1], N. Bom[1], J. Honkoop[1], N. de Jong[1] and C.M. Ligtvoet[1]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam; [2]the Interuniversity Cardiology Institute of The Netherlands.

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Abstract

The diagnostic value of esophageal echocardiography is most striking in patients in whom precordial studies are of inadequate quality or fail to establish a definitive diagnosis. Esophageal studies have excellent image quality, can be completed within 10 minutes without complications and, in most instances, enables the clinical question to be answered. In 50 patients referred for suspected thoracic aorta pathology, esophageal echocardiography correctly excluded or diagnosed the type of aortic dissection, aortic aneurysm or the site of coarctation. Of 35 patients referred with suspected infective endocarditis, esophageal echocardiography revealed complications in 18 patients, including vegetation, mycotic aneurysm, abscess or chordal rupture. Esophageal echocardiography is extremely helpful to visualize intracardiac mass lesions. In 27 patients with a history of systemic or pulmonary embolism, the technique confirmed the presence, size and position of a mass lesion in 11 patients. Esophageal color Doppler flow imaging further expands the diagnostic capabilities, particularly in patients with mitral valve prostheses. Our experience indicates that esophageal echocardiography significantly extends the diagnostic potential of echocardiography. Detailed knowledge of cardiothoracic anatomy and its pathologic sequelae is, however, a prerequisite for the efficient and safe application of this method.

Introduction

Esophageal two-dimensional echocardiography provides detailed imaging of the cardiac anatomy [1-3]. The superior image quality results from the avoidance of chest wall problems, lung tissue or intracardiac obstruction to ultrasound penetration. Specific structures, impossible to image from the precordium, can now be visualized. Furthermore, the distance between transducer and areas of interest is reduced, yielding minimal signal attenuation. Color Doppler flow imaging using the esophageal approach further increases the diagnostic information. Thus, compared to precordial studies, esophageal echocardiography expands the diagnostic capabilities of cardiac ultrasound.

Although the esophageal technique was already introduced in 1976 acceptance of its use in conscious patient has been slow, mainly due to concern about discomfort and risk to these patients. American investigators used the technique mainly for intraoperative monitoring of wall motion and overall left ventricular function [4-7]. European investigators, however, have employed it for diagnostic purposes in the conscious patient in the outpatient clinic [8-10]. Another reason why the technique was not widely applied was the fact that the early devices provided low quality images. Many technical refinements have since been achieved and, currently, a 5.6 MHz 64-element phased array transducer is used at our center.

This paper will review the diagnostic possibilities and advantages of esophageal echocardiography for clinical decision making in the outpatient clinic.

Technique

For studying morphology we employ a 5.6 MHz phased array transducer mounted at the tip of a gastroscope and interfaced with a Hewlett-Packard ultrasonograph (HP 77020 AC). Color Doppler flow imaging is performed with a 3.7 MHz phased array transducer, interfaced with a Toshiba ultrasonograph (SSH-65A). Patients are fasted for 8 hours. As a local anesthetic, a 10% lidocaine spray is administered in the hypopharynx. The transducer is introduced to a depth of 35 cm, with the patient lying in a left supine position. The heart is identified by slightly rotating the transducer. Via the left atrium, serial tomographic views are obtained by tilting and rotating the transducer tip using the remote controls of the gastroscope (Fig. 1). In order to obtain left ventricular cross-sections, the transducer is introduced slightly deeper. The thoracic aorta

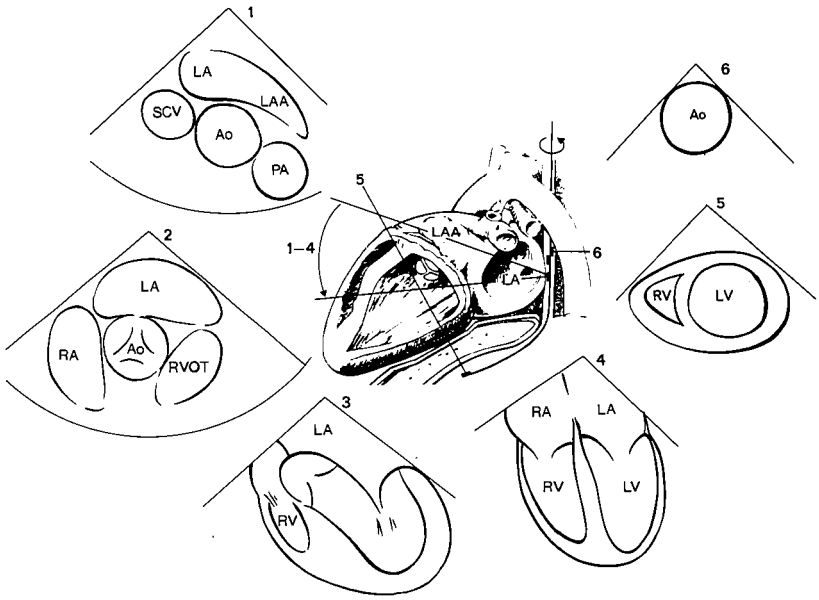


Fig. 1 Schematic drawings of images obtained with esophageal echocardiography via the left atrium (LA). Images are obtained by tilting the transducer from a superior (1), to intermediate (2,3), to inferior (4) tilt. From the stomach, cross-sections of both ventricles are obtained (5). The descending aorta is seen when the probe is rotated (6). LAA = left atrial appendage; Ao = aorta; PA = pulmonary artery; RVOT right ventricular outflow tract; RV = right ventricle; LV = left ventricle; SCV = superior caval vein; RA = right atrium.

is visualized after rotation of the transducer and serial scans are made. The total investigation takes approximately 10 minutes.

Results

Pathology of the thoracic aorta

Visualization of pathology of the thoracic aorta by precordial echocardiography is limited by interposition of structures between transducer and aorta, and limited ultrasonic windows on the chest [11]. Come and coworkers [12] studied 50 consecutive patients with pathology of the descending thoracic aorta and achieved a 92% correct diagnosis with precordial echocardiography. But it should be noted that such a success rate is not routinely achieved. The unique

position of a transducer within the esophagus allows almost unrestricted scanning of the entire thoracic aorta (Fig. 1).

Aortic aneurysm, dissection and coarctation are readily detected [13-15]. Our experience covers 50 patients suspected of having thoracic aorta pathology; of these, 22 patients underwent surgery of the thoracic aorta. With esophageal echocardiography, an aneurysm of the aorta was diagnosed in the 11 patients in whom this was found at surgery, and the nature of the aneurysm was correctly specified as saccular or fusiform. In one patient a combined saccular and fusiform aneurysm was present in the descending thoracic aorta and this diagnosis was missed by both angiographic and computed tomographic methods which suggested a dissection. Ten patients were operated for aortic dissection and, in all cases, the type of dissection proved to be correct by esophageal echocardiography (Fig. 2). In one operated patient, a tumor partially embracing the descending thoracic aorta was diagnosed by esophageal echocardiography. Histologic examination showed it to be a leiomyosarcoma.

Infective endocarditis

Precordial two-dimensional echocardiography is presently being considered as the best non-invasive method for the evaluation and follow-up of patients with

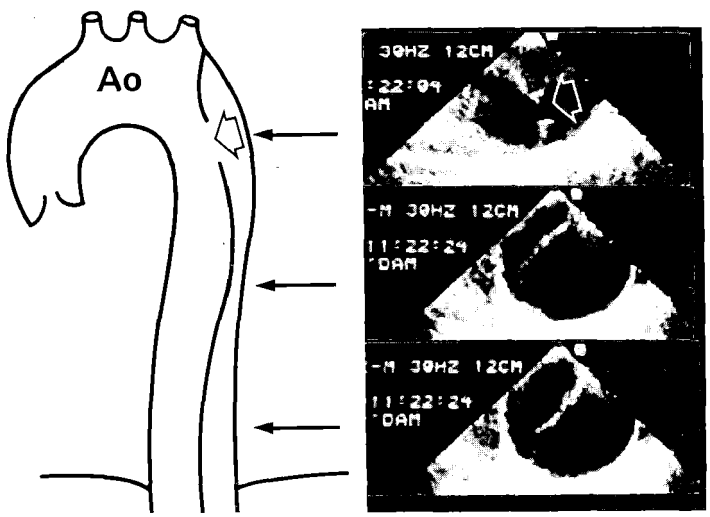


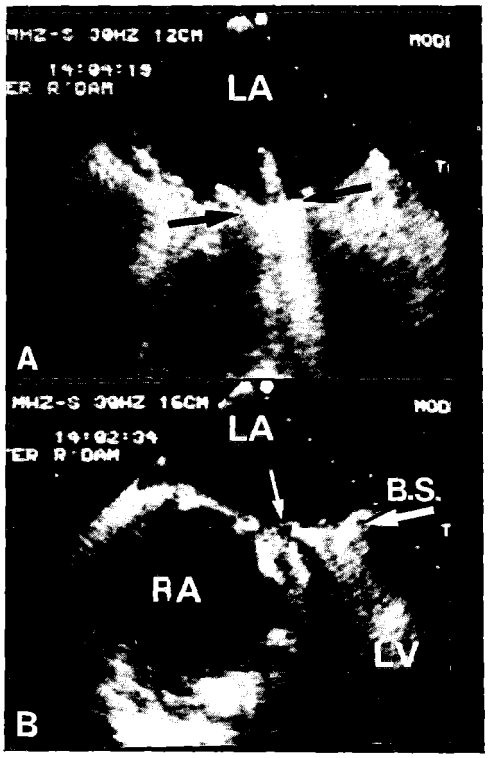
Fig. 2 Esophageal echocardiograms and corresponding diagram obtained in a patient with a DeBakey type III aortic dissection. The dissection was only seen in the descending aorta (Ao). Proximal in the descending aorta the entry tear was seen (open arrow).

infective endocarditis. Unfortunately some limitations exist. These include patient suitability and interference of additional echoes from surrounding structures. Diagnosis of vegetations is often equivocal in patients with redundant valves or echo-dense, heavily calcified and prosthetic valves [16]. Recently, Van Herwerden and coworkers [17] have reported on the use of intraoperative echocardiography in patients with complicated infective endocarditis, facilitating the complete visualization and correct diagnosis of all pathology found during surgery in 4 of the 6 patients studied. The limitations of precordial echocardiography and angiography are overcome by esophageal echocardiography. A high accuracy in the detection of abscesses has been reported by Daniel et al. [18] and Erbel et al. [19] which was mainly attributed to the improved image quality.

Our experience with 35 patients with suspected infective endocarditis is in accordance with this observation. Esophageal echocardiography revealed lesions in 18 patients and excluded lesions in 17. In 3 patients the condition was related to a pacemaker electrode and numerous vegetations were present on the atrial electrode. In the other 15 patients, lesions were found at the left side of the heart. These included vegetations, mycotic aneurysms, chordal rupture and a large intramural abscess. In this group, the findings of precordial echocardiography were diagnostic in only 3 and suggestive of vegetations in 7 patients. The size and position of the mycotic aneurysm in patients with a valve prosthesis was precisely determined. In one patient, with a Björk Shiley mitral valve, vegetations were attached to the atrial surface of the prosthesis and a para-valvular small mycotic aneurysm with systolic pulsation was demonstrated (Fig. 3). This aneurysm subsequently ruptured and surgery was performed after an esophageal color Doppler study showing the rupture and para-valvular regurgitation (Fig. 3).

Systemic and pulmonary embolism

For most clinicians precordial echocardiography is the method of choice for the assessment of an intra-atrial mass lesion. The method has limitations, however, as the atrial appendages are not readily visualized. Conversely, esophageal echocardiography provides optimal imaging of this particular structure. Daniel and coworkers [20], reporting on 29 patients with episodes of systemic embolism, visualized a thrombosis in the left atrium in 14 patients. Precordial echocardiography had failed to identify thrombosis in all these patients. Our experience is similar. In 3 of 7 patients with a history of pulmonary embolism, esophageal echocardiography showed mass lesions in the right atrium which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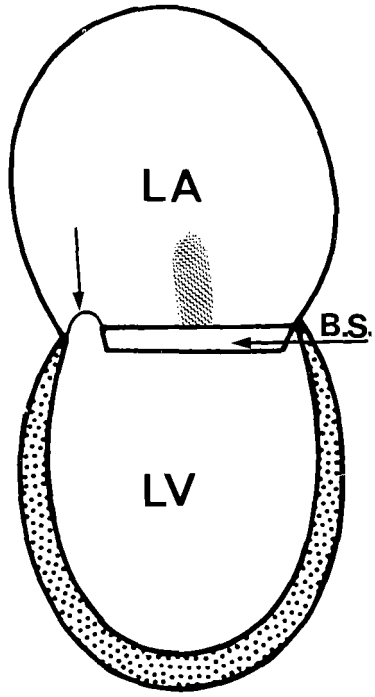
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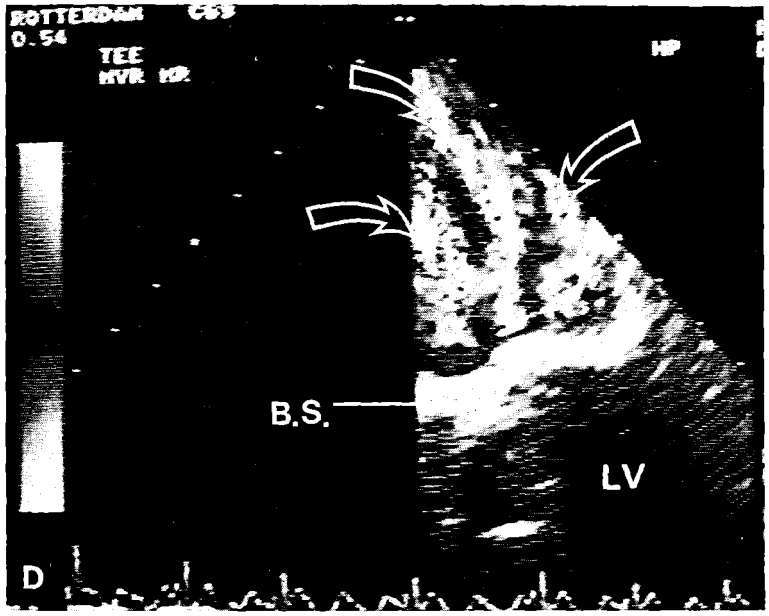
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were not recognized by precordial echocardiography. A mass was attached to the Eustachian valve of the inferior vena cava in one of these patients (Fig. 4). While precordial echocardiography was suggestive of a right atrial mass lesion, it was not possible to precisely determine its origin. In 2 patients a mass was not only present in the right atrium but extended through a patent foramen ovale into the left atrium where it was seen as a mobile structure (Fig. 5).

Esophageal echocardiography proved an intracardiac embolic source in 8 of 20 patients with a history of systemic emboli. The mass lesions were found in the left atrial appendage, the left atrium, or were attached to the atrial side of the mitral valve (Fig. 6). In one patient the source of embolism was an unsuspected saccular aneurysm in the aortic arch. Esophageal echocardiography may reveal left atrium thrombosis in patients without embolic events. Aschenberg and coworkers [21] identified in 6 of 21 patients with documented mitral valve stenosis a left atrial thrombosis, despite adequate anticoagulation. We encountered a similar situation. In a patient with a Björk Shiley mitral valve, in association with an aneurysmatic left atrium, we found a large thrombosis [22].

Mass lesions

In the presence of massive pericardial fluid, a calcified native valve, a mechanical prosthetic valve, or an intracardiac patch, precordial echocardiography may identify intracardiac echoes mimicking a mass lesion, the nature of which is not clearly understood. For this reason, 17 patients were referred for esophageal echocardiography. This investigation excluded any abnormality in 14 patients. In one of these patients, operated for a secundum-type atrial septal defect, precordial echocardiographic findings were suggestive for left atrial tumor. Esophageal echocardiography, however, did not reveal a mass lesion. It was assumed that multiple reverberations from the intra-atrial patch resulted in a false, positive precordial study. In another patient, esophageal echocardiography revealed a large Eustachian valve which had imitated a tumor on the precordial echocardiogram. Three patients had a mass lesion. In 2, a left atrial

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Fig. 3 Esophageal echocardiograms (A,B) and corresponding diagram (C) obtained in a patient with a Björk Shiley (B.S.: arrow) mitral valve and history of infective endocarditis. A, Attached to the valve prosthesis (black arrows) vegetations were seen within the left atrium (LA). B, Inferior tilting of the transducer tip visualized the right atrium (RA) and left ventricle (LV). A small mycotic aneurysm (whire arrow) was noted between the valve ring and the interatrial septum. Esophageal color Doppler investigation (D) indicated 3 paravalvular regurgitation jets (arrows). LV = left ventricle.

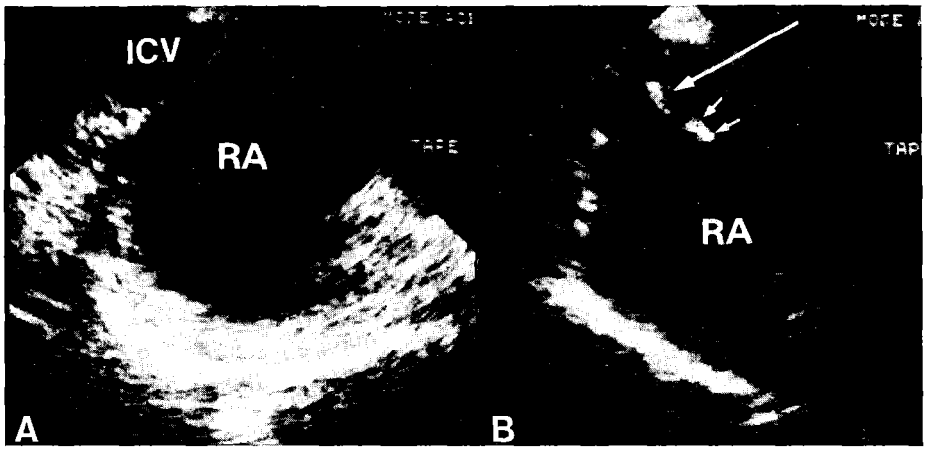

Fig. 4 Esophageal echocardiograms obtained in a normal individual (A) and a patient (B) with a mass lesion (arrows) attached to the inferior caval vein (ICV). RA = right atrium.

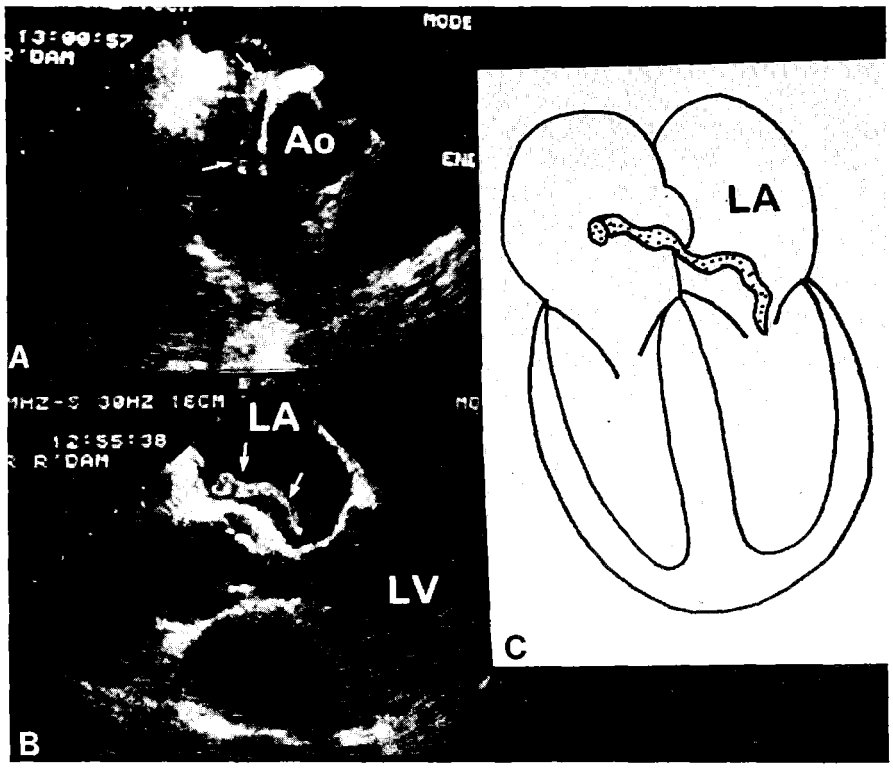

Fig. 5 Esophageal echocardiograms (A, B) and corresponding diagram (C) obtained in a patient with a history of pulmonary emboli. Note a pendulating lesion (arrows) migrating from the right atrium to the left atrium (LA). Ao = aorta; LV = left ventricle.

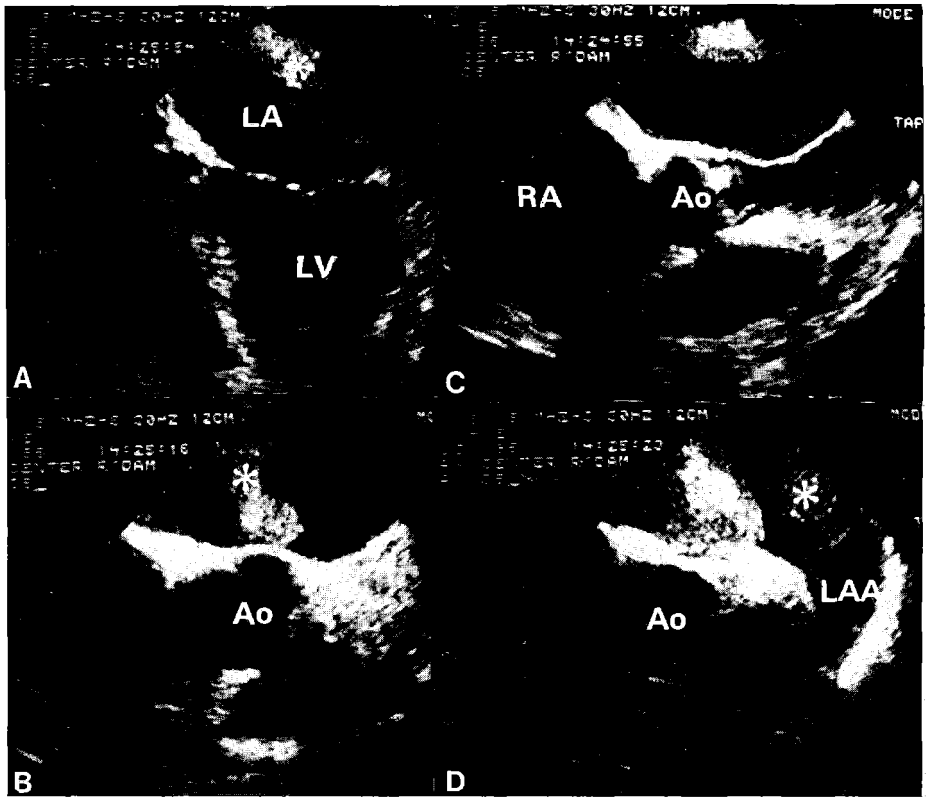

Fig. 6 Esophageal echocardiograms (A-D) obtained in a patient with mitral valve stenosis and a history of transient ischemic attacks. A large mass lesion (asterisk) was attached to the left atrium (LA) posterior and superior wall. Note the extension of this mass in different cross-sections. The left atrial appendage (LAA) remained free from the mass. Ao = aorta; RA = right atrium; LV = left ventricle.

myxoma attached to the interatrial septum was found and one patient showed a mass lesion, superior to the right atrium, enfolding the superior vena cava.

Color coded Doppler imaging

Doppler techniques have evolved from pulsed to continuous wave velocity measurements to color Doppler flow imaging [23]. Since ultrasound signals reflected by red blood cells are extremely weak, Doppler applications suffer from poor signal: noise ratio. Esophageal echocardiography improves the potential of the Doppler methods as it avoids signal attenuation in the chest wall.

This technique has been used for intraoperative cardiac evaluation in patients with valve regurgitation or intracardiac shunt [24,25]. We performed esopha-

geal color Doppler studies in over 75 awake patients [26]. This technique provides a unique possibility to study the function of a mitral valve prosthesis. A normal functioning Björk Shiley mitral valve, with a spherical disc, exhibits a holosystolic regurgitant jet [27,28]. Minimal or mild degrees of aortic or mitral regurgitation have been found by precordial Doppler echocardiography in patients with a normal functioning Björk Shiley valve [29]. Incidences varied according to valve position: 42% for aortic and 11% for mitral valve prosthesis. This underlines the limitation of precordial echocardiography in the detection of blood flow velocities posterior to a mechanical mitral valve. Esophageal color Doppler revealed physiologic or pathologic mitral regurgitation in all 25 patients with a Björk Shiley mitral valve. In 10 patients with an uneventful operative course, only physiologic jets were seen characterized by 2 separate, identical, red, holosystolic jets. They originated from inside the prosthetic valve ring. In these patients neither precordial continuous wave nor precordial color Doppler studies enabled diagnosis of these regurgitant jets. From 15 patients with a complicated clinical course, 12 had both physiologic and pathologic regurgitant jets. Pathologic jets were characterized as long, broad, mosaic-colored, holosytolic jets. Esophageal echocardiography excluded the presence of pathologic mitral regurgitation in 3 of the 15 patients with a complicated course. Precordial continuous wave and color Doppler studies in this group were less sensitive.

Conclusions

The versatility offered by esophageal echocardiography as a diagnostic tool has been presented, with special reference to the imaging of anatomy, its pathologic sequelae and flow characteristics. General advantages of this technique include, high resolution of the images (due to the absence of intervening structures), bedside application, low costs and speed of completion. A possible disadvantage is that the procedure may be unpleasant for the patient. It should be emphasized that for optimal, safe and efficient application the procedure should be performed only by a physician familiar with both echocardiography and the spectrum of cardiac pathology.

Indications for the clinical application of esophageal echocardiography include:

- clinical suspicion of serious cardiac pathology following an inadequate precordial study;

- to obtain additional and/or detailed information in patients with complicated cardiac pathology;
- suspicion of prosthetic mitral valve dysfunction;
- pathology of the thoracic aorta;
- suspicion of infective endocarditis or intracardiac mass lesion.

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CHAPTER 3

3.1 Echocardiografisch onderzoek van de aorta thoracalis via de slokdarm

E.J. Gussenhoven[1,2], M.A. Taams[1], O.A. Schippers[1], L.A. van Herwerden[1], J.R.T.C. Roelandt[1], N. Bom[1]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam; [2]the Interuniversity Cardiology Institute of The Netherlands.

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Abstract

Transesophageal echocardiography for the diagnosis of pathology of the thoracic aorta.

The role of transesophageal echocardiography in the diagnosis of thoracic aorta pathology was evaluated in 18 patients. All patients subsequently underwent surgery of the thoracic aorta. An aortic dissection was present in 8 patients, an aortic aneurysm in 9 and in one patient an aortic tumor was involved. Transesophageal echocardiography correctly diagnosed the type of aortic dissection in 7 of 8 patients. In all patients correct distinction was made between fusiform and saccular aortic aneurysm. The presence of organized thrombus covering the inner wall of the thoracic aorta could adequately be assessed. In one patient a tumor was noted embracing the descending aorta. We conclude that transesophageal echocardiography is a sensitive method for the diagnosis of thoracic aorta pathology. The technique offers practical advantages. It is quick and can be performed at the bedside. In our opinion, it is the method of choice in the detection of thoracic aorta pathology.

Samenvatting

De mogelijkheden van echocardiografie via de slokdarm voor diagnostiek van de thoracale aorta afwijkingen werden beoordeeld bij 18 patiënten. Allen ondergingen nadien thoraxchirurgie. Bij 8 patiënten bestond een aortadissectie, bij 9 een aorta-aneurysma en bij 1 patiënt een tumor van de aortawand. Het type aortadissectie werd bij 7 van de 8 patiënten correct vastgesteld. Eenmaal werden prolaberende aortakleppen waargenomen, maar er bleek echter aorta-dissectie type II volgens DeBakey te bestaan.

Bij alle patiënten met een aneurysma kon onderscheid gemaakt worden tussen een aneurysma fusiforme en een aneurysma sacciforme. De aanwezigheid van trombus of atheromateuze massa gehecht aan de binnenwand van de aorta kon adequaat in beeld gebracht worden, terwijl een tumor van de aortawand werd herkend als een gelobde structuur, grenzend aan de buitenwand van de aorta.

Gezien onze ervaringen, verdient oesophagus-echocardiografie de voorkeur in de diagnostiek van afwijkingen van de thoracale aorta. Het onderzoek is veilig en snel en kan aan het bed van de patiënt worden verricht, waardoor tijdrovende onderzoekmethoden, zoals computertomografie en angiografie, bij de diagnostiek van levensbedreigende dissecties in eerste instantie overbodig zijn geworden.

Inleiding

Voor de vastelling van de afwijkingen van de thoracale aorta staat de clinicus een aantal methoden ter beschikking. Gezien de betrouwbaarheid verdient aortografie de voorkeur boven precordiale echocardiografie en computertomografie. Er zijn echter beperkingen bekend die inherent zijn aan deze methoden. Zo kan trombosering van het valse lumen van een dissectie tot een fout-negatieve diagnose leiden [1-6], terwijl de aanwezigheid van een wandstandige trombus in een aneurysmatisch verwijde aorta een fout-positieve diagnose aortadissectie kan opleveren [6-8]. Indien er gelijktijdig meer dan één afwijking bestaat, blijkt dat zowel computertomografie als angiografie niet altijd leidt tot een geheel juiste diagnose [9-11]. Door de anatomische ligging van de slokdarm ten opzichte van de aorta biedt echocardiografie via de slokdarm voordelen voor de beoordeling van afwijkingen van de thoracale aorta [12-15].

In dit artikel wordt nader ingegaan op de resultaten die met deze nieuwe techniek worden verkregen bij 18 patiënten die allen nadien thoraxchirurgie ondergingen.

Patienten en methoden

Er werden 18 patiënten, verdacht van afwijkingen van de thoracale aorta, onderzocht met echocardiografie via de slokdarm. Het betrof 8 vrouwen en 10 mannen die gemiddeld 56 jaren oud waren. Allen ondergingen nadien thoraxchirurgie. Na het opnemen van de anamnese, het lichamelijk onderzoek en röntgenologisch onderzoek van de thorax werd precordiale echocardiografie verricht bij 12 patiënten, computertomografie bij 9 en angiografie bij 15 patiënten. De gegevens verkregen met oesophagus-echocardiografie werden getoetst aan de chirurgische bevindingen.

Het echocardiografische onderzoek via de slokdarm werd verricht met een 64-elements 5,6 MHz phased array transducer ingebouwd in een endoscoop met een diameter van 8,9 mm. De transducer werd aangesloten op een Hewlett-Packard-echocardiograaf (HP 77020 AC). Het onderzoek werd bij voorkeur verricht als de patiënt nuchter was. De hypopharynx werd plaatselijk verdoofd met 10% lidocaine (spray). Zo nodig werd nitroprusside intraveneus gegeven aan patiënten met hypertensie op de afdeling hartbewaking. De transducer werd ingebracht, terwijl de patiënt op de linkerzij lag, zoals bij een gastroscopisch onderzoek. De anatomie van de aortakleppen en aorta ascendens werd in beeld gebracht. Vervolgens werd de aorta descendens zichtbaar gemaakt door de transducer te draaien. De transducer werd daarna langzaam vanaf het diafragma naar proximaal tot het niveau van de aortaboog bewogen. De aldus verkregen informatie werd tot een schematische voorstelling geconstrueerd (figuur 1).

Resultaten

Het echocardiografisch onderzoek via de oesophagus gaf geen complicaties. De duur van een onderzoek was ten hoogste 10 minuten.

Bij 8 patiënten werd bij operatie een aortadissectie vastgesteld: bij 2 patiënten betrof het een DeBakey type I-dissectie, bij 3 patiënten een type II-dissectie en bij de drie overigen een type III-dissectie. Bij 7 van de 8 patiënten kon met oesophagus-echocardiografie het type van de aortadissectie worden vastge-

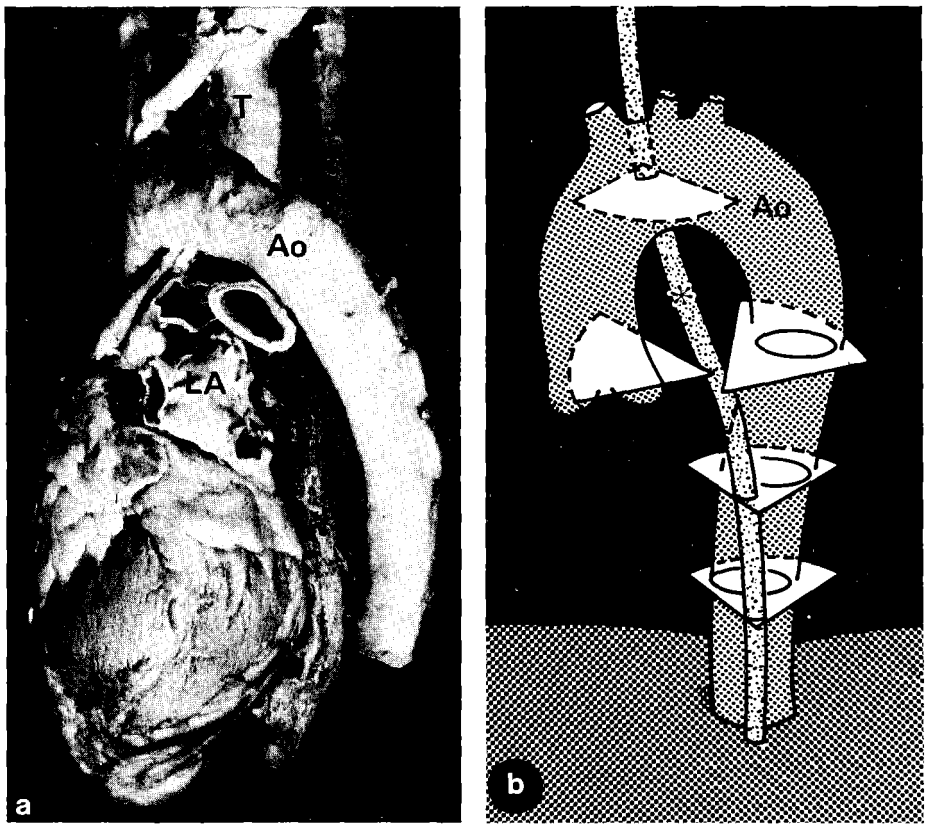
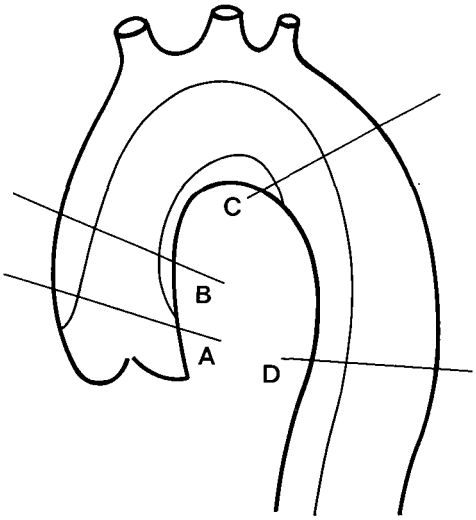


Fig. 1 Anatomische (a) en schematische (b) voorstelling van het verloop van de slokdarm (*) en de aorta thoracalis (Ao). Met de transducer kan vanuit de slokdarm de gehele thoracale aorta systematisch in beeld gebracht worden. T = trachea; LA = linker atrium.

steld: kenmerkend voor type I-dissectie was dat intimaweefsel in de gehele thoracale aorta werd gezien (figuur 2); bij een type II-dissectie alleen in de aorta asendens (figuur 3), en bij type III-dissectie alleen in de aorta descendens. Trombusformatie in het valse lumen werd bij 1 patiënt waargenomen.

Bij 3 patiënten met een aortadissectie bleek het echocardiografische onderzoek via de slokdarm niet volledig te zijn geweest: éénmaal kon de plaats van de intimascheur niet worden vastgesteld, bij de tweede patiënt met een type III-dissectie kon dit niet ten aanzien van de proximale uitbreiding van de dissectie in relatie tot de halsvaten en bij de derde patiënt werden prolaberende aortakleppen gezien, aanleiding gevend tot een acute, ernstige aortaklepinsufficiëntie. Bij operatie bleek een dissectie type II aanwezig te zijn waarbij een



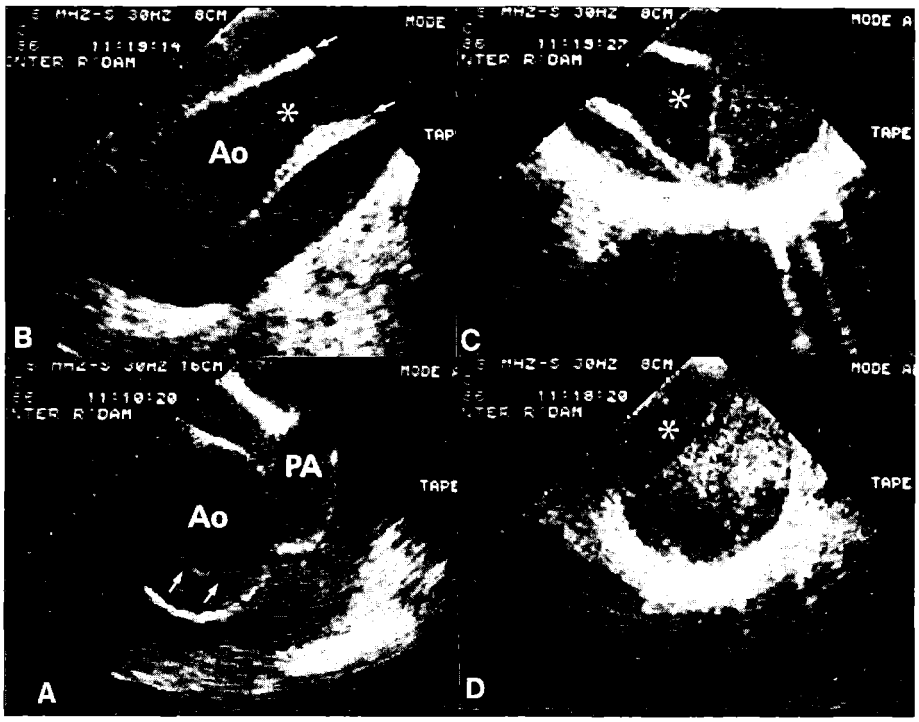


Fig. 2 Via de oesophagus vervaardigde tweedimensionale echocardiogrammen (A-D) met een corresponderend schema verkregen bij een patiënt met een dissectie type I volgens DeBakey. A, Het proximale begin was te zien even boven de aortaklep (Ao, pijlen) ter hoogte van de bifurcatie van de pulmonale arterie (PA). De dissectie kon tevens in de aortaboog (B,C) en in de aorta descendens (D) worden waargenomen. Het ware lumen van de aorta is met een sterretje aangeven.

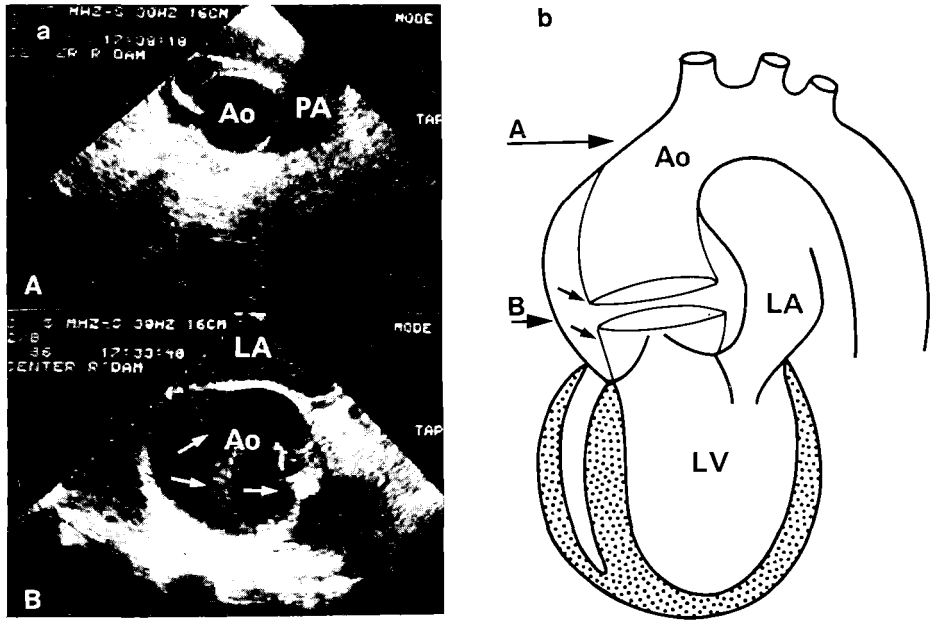


Fig. 3(a) Vanuit de oesophagus vervaardigde tweedimensionale echocardiogrammen (A,B) met (b) een corresponderend schema verkregen bij een patiënt met een dissectie type II volgens DeBakey. De verwijding van de aorta (Ao) met daarin de intima (pijlen) werd alleen waargenomen in de eerste 10 cm van de aorta ascendens. LA = linker ventrikel; PA = pulmomale arterie.

circulaire dissectiescheur boven de aortakleppen was gelokaliseerd, waardoor intimaweefsel door de aortakleppen prolabeerde.

Bij 9 patiënten werd een aneurysma van de aorta vastgesteld. Slokdarm-echocardiografie bleek bij allen geheel correct onderscheid gemaakt te hebben wat betreft plaats en aard van het aneurysma. Een aneurysma fusiforme werd bij 4 patiënten in de aorta ascendens vastgesteld en bij 2 in de aorta descendens. Bij 2 anderen was er sprake van een aneurysma sacciforme ter hoogte van de arcus aortae. Bij 1 patiënt werd een gecombineerd fusiform en sacciform aneurysma gezien in de aorta descendens (figuur 4). Tevens kon met deze vorm van echocardiografie de uitbreiding van trombusformatie binnen de verwijde aorta en in het sacciforme aneurysma aangetoond worden.

Tenslottte werd met slokdarm-echocardiografie bij een patiënt een groot ruimte-innemend proces gezien naast de aorta descendens, grenzend aan de aortawand. De buitencontour van deze tumor was gelobd, terwijl de begrenzing met de aortawand gladwandig was. De bij operatie verwijderde tumor bleek een maligne leiomyosarcoom van de aortawand te zijn.

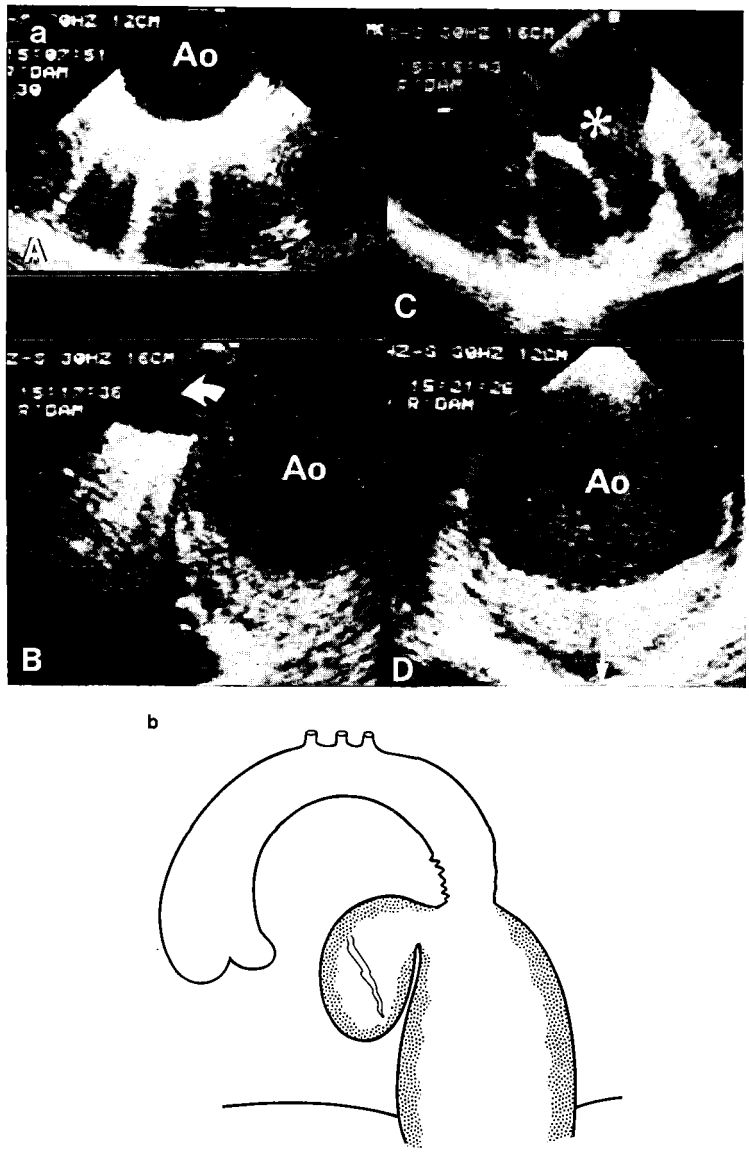


Fig. 4(a) Via de oesophagus vervaardigde tweedimensionale echocardiogrammen (A-D) met (b) een corresponderend schema verkregen bij een patiënt met een gecombineerd vitium van de aorta descendens (Ao). A, Het proximale deel van de aorta descendens toont geen afwijkingen. Halverwege de thoracale aorta descendens wordt naast een aneurysma sacciforme (B,C sterretje) ook een aneurysma fusiforme vastgesteld (D). De ingang van het aneurysma sacciforme (B: dikke pijl) is ter hoogte van het proximale begin van het aneurysma fusiforme (zie schema). In beide aneurysmata wordt trombusformatie gezien (gestippelde zone; D = pijl). Merk op dat door de trage bloedstroom in het aneurysma fusiforme het bloed echografisch zichtbaar wordt (D).

Beschouwing

De meest voorkomende afwijkingen van de thoracale aorta bij volwassenen zijn aneurysma en aortadissectie. Ondanks hun beperkingen zijn onderzoek methoden zoals computer-tomografie en angiografie belangrijk in de diagnostiek van afwijkingen van de thoracale aorta [2-7]. De anatomische positie van de slokdarm en de aorta biedt met echocardiografie via de slokdarm de mogelijkheid opnames van de thoracale aorta met een hoge resolutie te verkrijgen [12-15]. In ons onderzoek is het behalen van 83% volledig correcte diagnostiek met oesophagus-echocardiografie hoog te noemen. Dit is op zichzelf niet verwonderlijk, gezien het zeer hoge ruimtelijk oplossend vermogen van deze techniek dank zij het ontbreken van ultrageluid verstorende elementen zoals longen en vetweefsel.

Dissectie

Met betrekking tot de diagnostiek van de aortadissectie werd bij geen van de onderzochte patiënten een fout-positieve diagnose gesteld. Dit geschiedde echter eenmaal met zowel computertomografie als met angiografie bij een patiënt met een gecombineerd sacciform en fusiform aneurysma van de aorta descendens. Deze afwijking werd met oesophagus-echocardiografie geheel correct gediagnostiseerd (zie figuur 4).

Bij oesophagus-echocardiografie werd daarentegen de diagnose aortadisectie gemist bij een patiënt met een niet verwijde aorta ascendens. De circulaire dissectiescheur, gelegen vlak boven de aortakleppen, werd geinterpreteerd als prolaberende aortakleppen die aanleiding gaven tot ernstige aorta-insufficientie. Het dient vermeld te worden dat deze patiënt de eerste was in de reeks patiënten met een aorta-thoracalisafwijking die met oesophagus-echocardiografie onderzocht werd; er was op dat moment nog geen ervaring opgedaan. De mogelijkheid van fout-negatieve diagnostiek met precordiale echocardiografie van soortgelijke afwijkingen waarbij intimaweefsel de aortakleppen imiteert, is onlangs beschreven [16-18]. Met echocardiografie is routinematig gezocht naar de plaats van de intimascheur. Deze bleek met een uitzondering bij alle patiënten te kunnen worden gelokaliseerd. Deze uitslag is gunstiger dan het door Earnest et al. beschreven succespercentage van 56 met angiografie [19]. Hoewel wordt gesuggereerd dat het gebruik van kleuren-Doppler-echocardiografie het bepalen van de plaats van de intimascheur gunstig kan beinvloeden [20-22], betwijfelen wij dat in geval van echocardiografie via de oesophagus. Immers, de echografische doorsneden van de thoracale aorta, die doorgaans

loodrecht op het echosignaal staan, zijn intrinsiek niet geschikt voor het verkrijgen van informatie met behulp van Doppler, tenzij er een turbulente bloedstroom is.

In tegenstelling tot angiografie blijkt oesophagus-echocardiografie niet in staat de halsvaten in beeld te brengen. Derhalve is het in het algemeen niet mogelijk in het geval van een DeBakey type III de juiste plaats van de proximale uitbreiding van de dissectie in relatie tot de halsvaten aan te geven. Dit ondervonden wij bij een patiënt.

Aneurysma

Echocardiografie via de slokdarm is een uitermate geschikte techniek gebleken om de aard en de uitbreiding van een aneurysma van de thoracale aorta vast te stellen. Fout-positieve, noch fout-negatieve diagnosen kwamen voor, dit in tegenstelling tot de bevindingen bij computertomografie en angiografie. Bij een patiënt werd met de combinatie van oesophagus-echocardiografie en pulsed Doppler-onderzoek een aneurysmatische divertikel van de ductus arteriosus waargenomen met een fistel tussen het aneurysma en de linker A. pulmonalis. Met computertomografie was de diagnose aneurysma van de A. pulmonalis gesteld, terwijl met angiografie de fistel niet gediagnostiseerd werd.

Tevens is het mogelijk gebleken de aanwezigheid en uitbreiding van atheromateuze aandoeningen of trombusformatie binnen de thoracale aorta vast te stellen met oesophagus-echocardiografie. Zo kan een aneurysma sacciforme in het geheel niet, ten dele of geheel met trombus gevuld zijn (zie figuur 4 en 5). Bovendien kan onderscheid gemaakt worden tussen een aneurysma fusiforme met wandstandige trombusformatie en aortadissectie met een getromboseerd vals lumen. In het eerste geval is er een onregelmatige scheiding tussen trombus en stromend bloed waar te nemen, terwijl in het laatste geval het intimaweefsel een scherp begrensde scheiding veroorzaakt. Het is bekend dat juist dit onderscheid moeilijk te maken is met computertomografie [23].

Tenslotte kan echocardiografie via de slokdarm een rol spelen in een gericht radiologisch onderzoek. Bij 1 patiënt bij wie met oesophagus-echocardiografie een ruimte-innemend proces was gezien in een aneurymatisch verwijde aorta, werd alleen veneuze digitale subtractie-angiografie verricht. Bekend is dat arteriële angiografie dislocatie van een dergelijk proces kan veroorzaken [24,25].

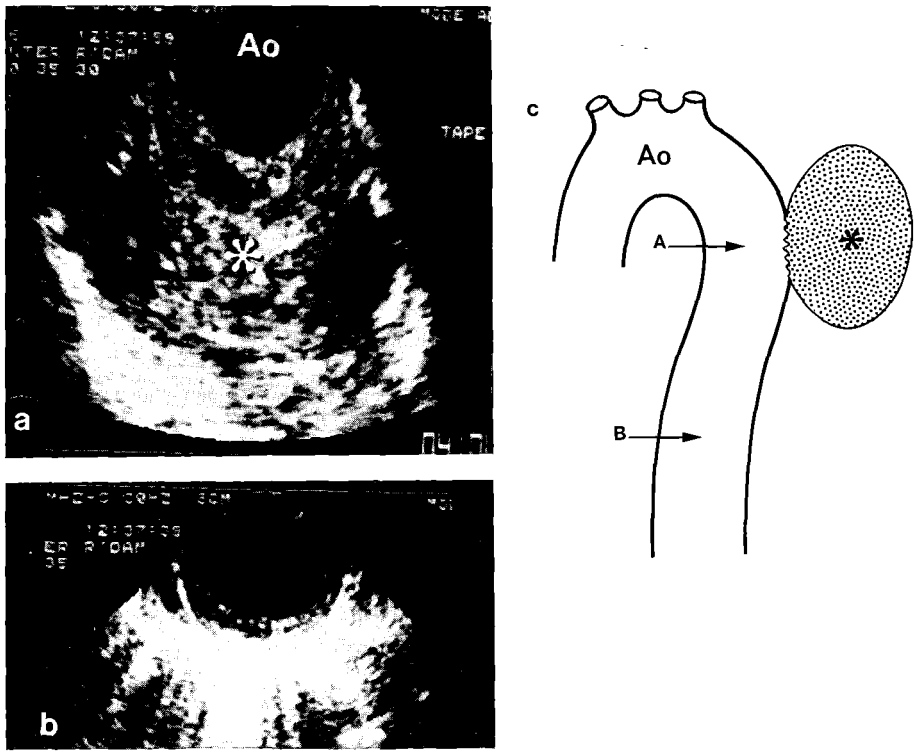


Fig. 5(a,b) Tweedimensionale echocardiogrammen vervaardigd via de oesophagus en (c) een corresponderend schema verkregen bij een patiënt met een aneurysma sacciforme (sterretje) geheel met trombusmassa gevuld. Ao = aorta.

Conclusie

Dit onderzoek heeft aangetoond dat echocardiografie via de slokdarm een waardevolle en betrouwbare methode is voor de diagnostiek van de afwijkingen van de thoracale aorta. Het resultaat van 83% volledig correcte diagnostiek met deze nieuwe werkwijze is hoog te noemen, zeker in het licht van de leercurve die de onderzoekers onvermijdelijk hebben moeten doorlopen. Bovendien is ons gebleken dat zowel computertomografie als angiografie lager scoorde, repectievelijk 33 en 60%.

De echocardiografie via de slokdarm kent, in tegenstelling tot computertomografie en angiografie, praktische voordelen, zoals een korte onderzoeksduur en de mogelijkheid dit onderzoek aan het bed van de patiënt te verrichten. Dit zal vooral van levensbelang zijn bij patiënten die in een kritische klinische

toestand verkeren, waarbij dissectie niet uitgesloten is, of bij hen die verwezen worden wegens een stomp thoraxtrauma. Het snel en correct uitsluiten dan wel vaststellen van afwijkingen is cruciaal voor het te voeren beleid. Het vertrouwen van chirurgen in deze nog jonge methode mag blijken uit het feit dat nu reeds 4 patiënten met een dissectie op basis van het echocardiografische onderzoek via de slokdarm peracuut zijn geopereerd. Computertomografisch en angiografisch onderzoek werd wegens de kritische klinische toestand van deze patiënten in alle gevallen gecontra-indiceerd geacht.

Onze ervaringen wijzen erop dat oesophagus-echocardiografie als eerste keuze in aanmerking komt voor de diagnostiek van afwijkingen van de thoracale aorta.

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3.2 The value of transesophageal echocardiography for the diagnosis of thoracic aorta pathology

M.A. Taams[1], E.J. Gussenhoven[1,2], L.A. Schippers[1], J.R.T.C. Roelandt[1], L.A. van Herwerden[1], E. Bos[1], N. de Jong[1], N. Bom[1]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam ; [2]the Interuniversity Cardiology Institute of The Netherlands.

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Abstract

The potential of transesophageal echocardiography for preoperative diagnosis of thoracic aorta pathology was evaluated in 15 patients with aortic dissection and 15 patients with aortic aneurysm. The transesophageal echocardiographic findings were compared with 14 computed tomograms and 21 angiograms. Six patients underwent only transesophageal echocardiography. All patients were operated upon and the surgical findings were used as a reference for these diagnostic methods. Transesophageal echocardiography established a complete and correct diagnosis in 27 patients. The diagnosis was partially correct in three patients, all having an aortic dissection. A complete and correct diagnosis was obtained by computed tomography and angiography in 8 and 17 patients, respectively. The results indicated that transesophageal echocardiography is a sensitive and convenient method for the definitive diagnosis of pathology of the thoracic aorta. It could become the technique of choice in patients suspected of having acute aorta pathology as it enables a rapid and definitive diagnosis at the bedside.

Introduction

Angiography is a routine diagnostic procedure in the evaluation of thoracic aorta pathology. Precordial cross-sectional echocardiography and, more particularly, computed tomography are alternative techniques. These methods, however,

have their limitations and false positive, as well as false negative diagnoses, have been reported [1-10]. In cases involving complicated thoracic aorta pathology, computed tomography and angiography may not provide the exact morphology of the underlying pathology [11]. Transesophageal echocardiography provides an alternative approach for studying patients with thoracic aorta pathology [12-15].

The aim of this study was to evaluate the preoperative diagnostic value of transesophageal echocardiography to determine thoracic aorta pathology. The results were compared with the surgical findings and with those acquired from computed tomography and angiography, when performed.

Patients and methods

Since the introduction of transesophageal echocardiography in our unit, 30 consecutive patients (18 males, 12 females: aged 24-71 years; mean 56 years) who underwent thoracic aorta surgery were studied preoperatively with transesophageal echocardiography. For all patients a clinical history, physical examination and chest x-ray were obtained; computed tomography was performed in 14 patients and angiography in 21. Six patients underwent emergency surgery solely on the basis of the transesophageal study. The results of transesophageal echocardiography, computed tomography and angiography were judged against the definitive surgical findings. The data from each type of diagnostic test were assessed as being correct, partially correct or incorrect. The diagnosis was designated as correct when the precise nature, position and extent of the pathology visualized corresponded with the surgical findings. A partially correct diagnosis was ascribed to cases in which thoracic aorta pathology was established but the exact underlying disorder was only ascertained at surgery.

Transesophageal echocardiography

A 5.6 MHz ultrasound transducer, built into an Olympus gastroscope (diameter 8.9 mm), was connected to a Hewlett-Packard ultrasonograph (HP 77020AC). Six of the 30 patients were critically ill and thus examined in the coronary care unit and controlled with intravenous nitroprusside under hemodynamic monitoring. The minimal interval between the last meal and transesophageal study was 4 h. The examination was performed following local anesthesia of the hypopharynx with 10% lidocaine spray. The aortic valve was used as an anatomic landmark and the ascending aorta visualized first. After rotation of

the transducer, the descending aorta was systematically visualized by withdrawal from the diaphragm to the aortic arch so that a composite image of the thoracic aorta could be constructed.

Results

Surgical findings (30 patients)
Aortic dissection was present in 15 patients: a DeBakey type I dissection in six patients; type II dissection in four patients; type III dissection in 4 patients; and a type II and type III dissection in one patient.

Fifteen patients underwent surgery for aneurysm of the thoracic aorta: fusiform aneurysm of the ascending aorta in four patients; in the aortic arch in two patients; in the descending aorta in five patients; three patients presented with saccular aneurysm; and in one patient a combined saccular and fusiform aneurysm was present in the descending thoracic aorta. The results of the three diagnostic techniques are summarized in Tables I and II.

Computed tomography (14 patients)
A correct diagnosis was made in eight patients. The diagnosis was partially correct in three: the aortic arch was not adequately visualized in the presence of a type II and type III aortic dissection in one; infective vegetations in a fusiform aneurysm of the ascending aorta were not diagnosed in another, while a combined fusiform and saccular aneurysm of the descending aorta was misinterpreted as a DeBakey type III dissection in the third patient.

In three patients the diagnosis was incorrect: in two patients computed tomography showed no apparent thoracic pathology, whereas in one patient a DeBakey type I dissection and in the second patient a fusiform aneurysm of the ascending aorta were found at surgery; in the third patient a saccular aneurysm of the aortic arch was misinterpreted as an aneurysm of the pulmonary artery.

Angiography (21 patients)
Angiography provided a correct diagnosis in 17 patients. A partially correct diagnosis was obtained in four patients. The estimation of the proximal extension of a type I dissection was incorrect in one patient due to thrombus formation in the false lumen. A false positive diagnosis of aortic dissection was made in another, while an aorto-pulmonary fistula was missed in the third patient.

Table I Surgical data and diagnostic results in 15 patients with aortic dissection

Patient no.	Type of dissection	CT	Angio	TEE	Limitations in preop. diagnoses
1	I, thrombus	++	++	++	
2	I, thrombus	0	+	++	Angio: proximal extension of dissection uncertain
3	I	-	++	++	CT: not diagnostic
4	I, recurrence	0	++	+	TEE: aortic arch not adequately visualized
5*	I	0	0	++	
6*	I	0	0	++	
7*	II	0	0	+	TEE: AR, 'floppy' aortic valves
8*	II	0	0	++	
9*	II	0	0	++	
10*	II	0	0	++	
11	III	0	++	+	TEE: proximal extension of dissection uncertain
12	III	++	++	++	
13	III, thrombus	++	++	++	
14	III, thrombus	0	++	++	
15	II, III	+	0	++	CT: aortic arch not adequately visualized

*: emergency surgery; preop.: preoperative; Angio: angiography; CT: computed tomography; TEE: transesophageal echocardiography; AR: aortic regurgitation; ++: correct diagnosis; +: parttially correct diagnosis; -: incorrect diagnosis; 0: not performed.

Table II Surgical data and diagnostic results in 15 patients with thoracic aortic aneurysm

Patient no.	Type of aortic aneurysm	CT	Angio	TEE	Limitations in preop. diagnoses
	Fusiform				
1	ascending Ao	0	++	++	
2	ascending Ao	-	++	++	CT: not diagnostic
3	ascending Ao	0	++	++	
4	ascending Ao vegetations	+	+	++	DVA + CT: vegetations not visible
5	ascending Ao + arch	0	++	++	
6	aortic arch + hematoma	0	++	++	
7	descending Ao + thrombus	++	0	++	
8	descending Ao + thrombus	0	++	++	
9	descending Ao + thrombus	++	++	++	
10	descending Ao + thrombus	++	0	++	
11	descending Ao + thrombus	++	++	++	
	Saccular				
12	aortic arch; diverticle ductus arteriosus with fistula	-	+	++	CT: 'pulmonary artery aneurysm' Angio: fistula Ao-LPA missed
13	descending Ao + thrombus	++	++	++	
14	descending Ao + thrombus	0	++	++	
	Saccular & Fusiform				
15	descending Ao + thrombus	+	+	++	CT + Angio: dissection suspected

preop.: preoperative; Angio: angiography; CT: computed tomography; TEE: transesophageal echocardiography; DVA: digital venous angiography; Ao: aorta; LPA: left pulmonary artery; ++: correct diagnosis; +: partially correct diagnosis; -: incorrect diagnosis; 0: not performed.

In the fourth patient only a venous digital substraction angiogram was made, which failed to visualize vegetations associated with endocarditis in a fusiform aneurysm of the ascending aorta.

Transesophageal echocardiography (30 patients)
In 27 patients results of transesophageal echocardiography were in agreement with the surgical findings. A partially correct diagnosis was made in three patients with aortic dissection. In one patient the proximal extension of a DeBakey type III dissection in relation to the brachiocephalic vessels could not be determined. In the second patient, with a recurrent type I dissection, the aortic arch was not adequately visualized. The third patient was admitted in acute pulmonary edema. The transesophageal echocardiographic findings were interpreted as rupture of redundant aortic valve leaflets with a non-dilated ascending aorta resulting in acute aortic regurgitation. At surgery, however, a DeBakey type II dissection with a circular tear just above the level of the aortic valve was detected. Subsequently, Ehlers-Danlos syndrome was diagnosed.

Discussion

In adults, aortic aneurysm and dissection are the most frequent pathological changes of the thoracic aorta. Although angiography and, more recently, computed tomography are the accepted diagnostic methods they do not always allow a detailed analysis of the complicated pathology involved [6,11,16]. Due to the close anatomical relationship between the esophagus and the thoracic aorta, transesophageal echocardiography allows visualization of the entire thoracic aorta including the aortic arch [12-15]. Although visualization of the mid-portion of the ascending aorta can be concealed by the right main bronchus, lack of information concerning this structure did not impede the pathologic evaluation in our study. Close proximity to the aorta and avoidance of chest wall structures permits visualization of multiple cross-sections of high resolution to provide detailed images in patients with aortic dissection or aortic aneurysm.

Aortic dissection
Aortic dissection is a life-threatening disease and survival is influenced by prompt diagnosis [17]. Identification of a detached intima either in the ascending aorta, aortic arch and/or the descending aorta is the hallmark of the type

of dissection involved. As scanning with computed tomography is perpendicular to the intimal flap, the flap is more easily observed than with angiography - which necessitates a tangential projection [8].

In this study computed tomography, however, failed to diagnose an aortic dissection in one patient. Conversely, angiography correctly established aortic dissection in all instances, but in one patient the proximal extension of a type I dissection was not accurately assessed due to thrombus formation in the false lumen.

Lack of experience in the interpretation of the transesophageal echocardiographic images might explain the partially correct diagnosis in the first patient of this study. While this method had indicated redundancy of the aortic valve leaflets creating severe aortic regurgitation, surgery demonstrated a DeBakey type II dissection. Similar pathology, in which intimal tissue mimics the aortic valve leaflets, has been reported [18-20].

Determination of the actual site of entry of the intimal tear is of major significance for the surgical approach. Computed tomography is inferior to angiography in detecting the entry site of a dissection [6]. In this study, angiography correctly disclosed the entry site in one-third of the patients. Transesophageal echocardiography, however, detected the entry site in 11 patients (77%); this success rate exceeds that of angiography which is reported to be about 50% [21]. Assessment of the entry site by transesophageal echocardiography was either by direct visualization of an interruption (Fig. 1) or, indirectly, by detecting thrombus formation proximally whilst spontaneous blood flow was noted more distally (Fig. 2).

The major advantage of transesophageal echocardiography is that critically ill patients with aortic dissection can be studied with this technique. In six such patients, using only transesophageal echocardiography, the findings were sufficiently detailed and definitive to justify emergency surgery. In these high-risk patients with 2% mortality per hour [17] and associated poor hemodynamic status or diminished renal function, implementation of time-consuming computed tomography or angiography can be especially hazardous.

One restriction to transesophageal echocardiography is that it does not allow visualization of the brachiocephalic arteries. Supplementary information concerning the arch vessels can be obtained with angiography.

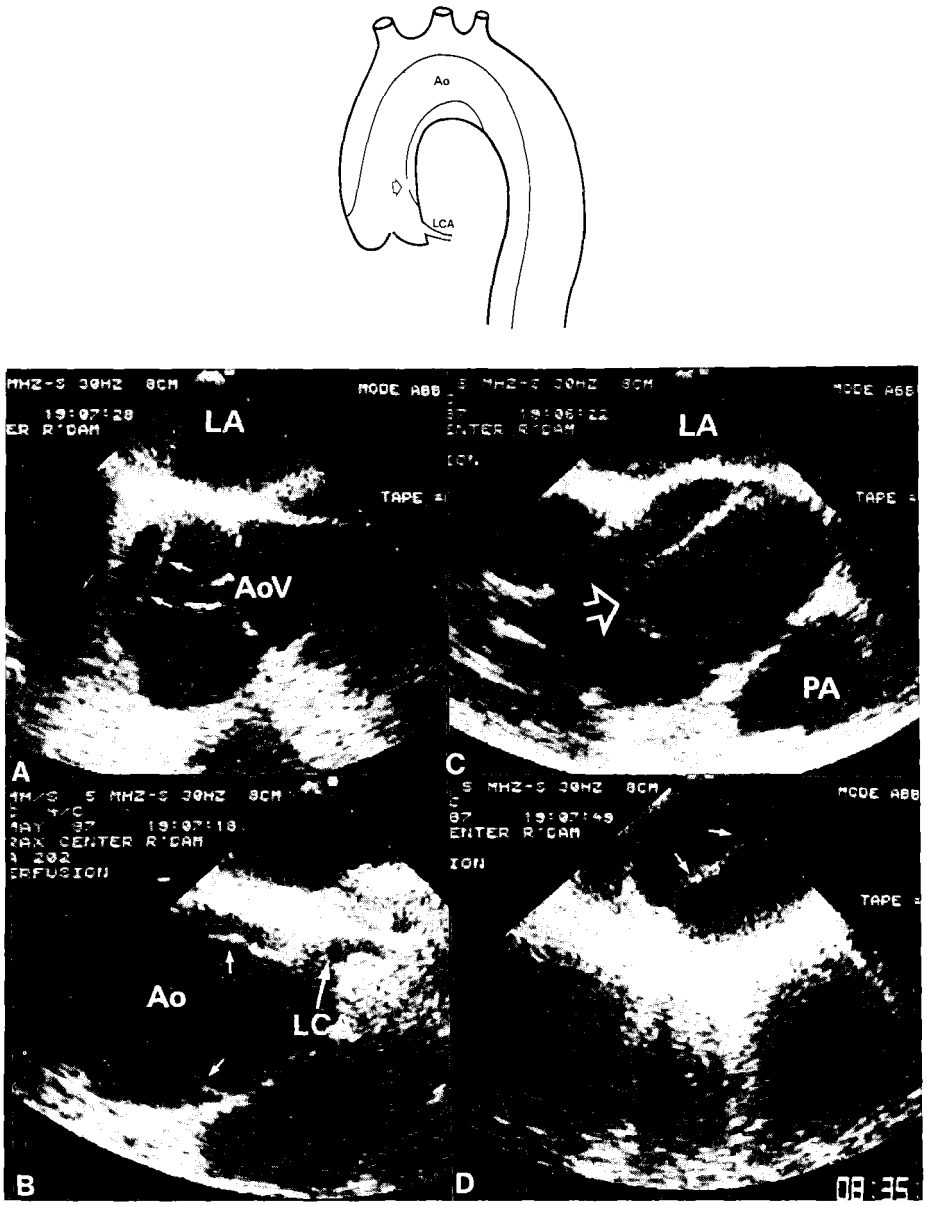

Fig. 1 Transesophageal echocardiographic images of the ascending (A-C) and descending (D) aorta (Ao) and corresponding diagram which offered complete visualization of an aortic dissection DeBakey type I. The detached intima (B-D; arrows) was seen distal to the aortic valves (AoV) and the left main coronary artery (LCA). The intimal tear (open arrow) was seen in the proximal part of the ascending aorta (C). Multiple reverberations of echoes noted behind the aortic wall extending into the aorta (A; arrows) should be distinguished from the true intima seen in B, C and D. LA = left atrium; PA = pulmonary artery.

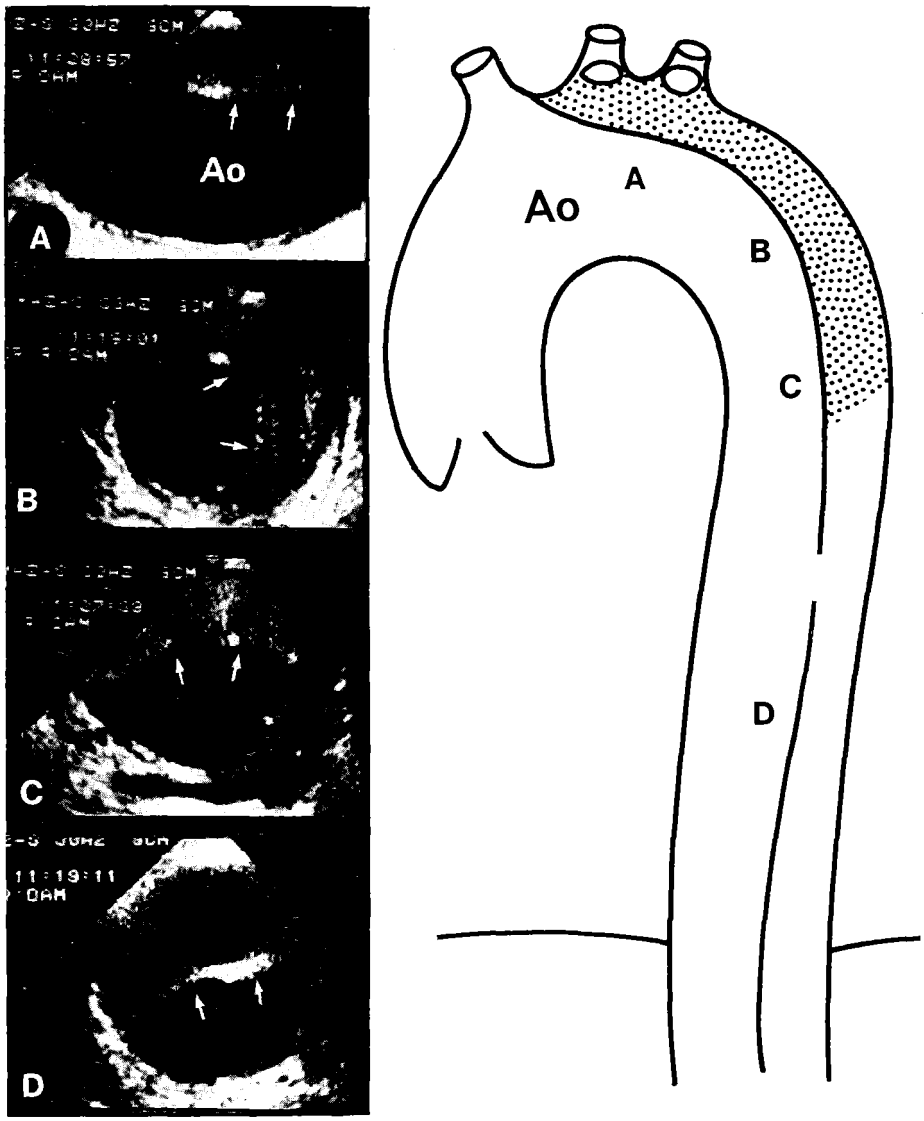

Fig. 2 Transesophageal echocardiographic images and corresponding diagram of the aortic arch (A) and descending aorta (B-D) of an aortic dissection DeBakey type III. A discrete intimal flap (arrows) was detected. A, Thrombus formation (shaded area) was noted proximally. More distally, the blood flow was echogenic. These findings indirectly indicated that the entry tear was in the lower part of the descending thoracic aorta. This observation was confirmed at surgery. Ao = aorta.

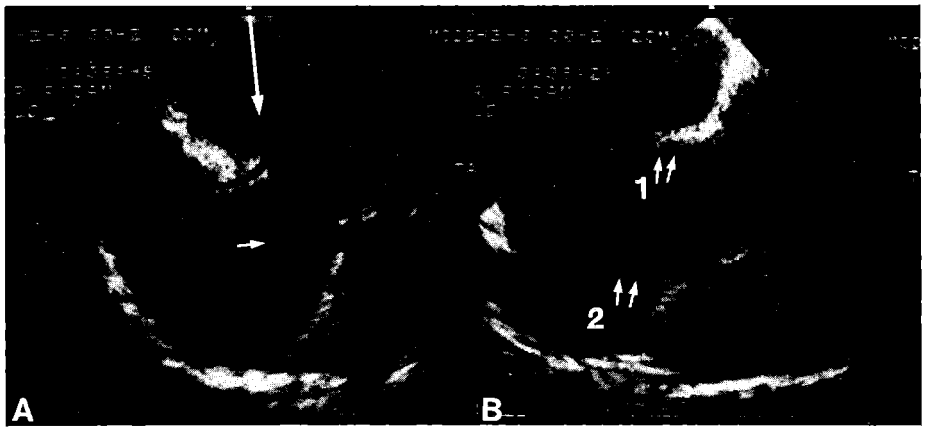

Fig. 3 Transesophageal two-dimensional echocardiograms demonstrating 2 examples of artefacts which may mimic aortic dissection. A, Multiple reverberations of echoes behind the aortic wall (small arrow) extending in the aorta imitating an intimal flap (compare with Fig. 1A). B, Reverberations between the aortic wall (arrows 1) and the transducer resulted in an echo simulating an intimal flap (arrows 2). Note that both artefacts can be extrapolated originating from the transducer.

Artefacts in the diagnosis of aortic dissection

In most instances, echoes of the intimal flap of the aortic dissection are recognized as a free-floating mobile structure (Figs. 1, 2). These structures must be distinguished from reverberation artefacts of the aortic wall. These artefacts are either characterized as straight lines starting from the aortic wall into the aortic root, or as a duplicate of the aortic wall (Fig. 3). These echoes can always be extrapolated to the starting point of the transducer. Knowledge of the physics of ultrasound will avoid false positive diagnosis of aortic dissection.

Aortic aneurysm

Aneurysms of the thoracic aorta may be fusiform or saccular and may be present in the ascending aorta, aortic arch and/or descending aorta. The high potential of transesophageal echocardiography in the diagnosis of this type of pathology has been demonstrated in this study; in all 15 patients a correct diagnosis was made. With computed tomography, a false negative diagnosis of aortic aneurysm was made in three patients. In one patient, angiography failed to establish a fistulous connection between a saccular aneurysm and the left pulmonary artery. This pathology was correctly identified by additional information provided by transesophageal pulsed Doppler echocardiography [11].

Transesophageal echocardiography did not give any false positive diagnoses of aortic dissection. Both computed tomography and angiography incorrectly diagnosed aortic dissection in a patient who subsequently proved to have a combined saccular and fusiform aneurysm with thrombus in the enlarged lumen; this was correctly identified preoperatively with transesophageal echocardiography (Fig. 4). Thrombotic material in an enlarged aortic lumen is a common observation in transesophageal studies and its extension is always restricted to the dilated area of the diseased aorta. It is noteworthy that thrombus formation was never observed in ascending aortic aneurysms. Increased echogenicity of slow blood flow was seen in most patients with a dilated descending thoracic aorta. Visualization of spontaneous echo contrast is greatly facilitated by use of a high frequency transducer (5.6 MHz). Slow blood flow is readily differentiated from a true thrombosis by its slow circular motion without well-defined borders (Fig. 5).

More importantly, due to the high resolution images, a distinction could be made between intimal calcifications in an atherosclerotic aorta (Fig. 5), calcification on the surface of a thrombus in a fusiform aneurysm, and a thrombosed false lumen of a dissection (Fig. 2). In cross-section, calcifications show echo-dense deposits on the intimal surface, while a luminal thrombus shows an irregular border, with soft and/or echodense echoes (Figs. 4, 5). In the presence of a dissection, a discrete echo-dense separation, caused by the intima, is observed (Fig. 2). This distinction is difficult to achieve with either computed tomography or angiography [6, 16].

An important consideration in patients with thoracic aorta aneurysm is that the disease can be associated with a separate distal aneurysm. Consequently, supplementary abdominal echography, computed tomography or angiography may still be necessary.

Conclusion

The data of this study in 30 preoperative patients indicate that computed tomography has a limited role in diagnosing pathology of the thoracic aorta and that transesophageal echocardiography has equal diagnostic potential when compared with angiography. Transesophageal echocardiography is an attractive alternative as radiodiagnostic procedures are time-consuming and the patients' condition may contraindicate their use. Our unit has adopted transesophageal echocardiography as the investigational technique of choice,

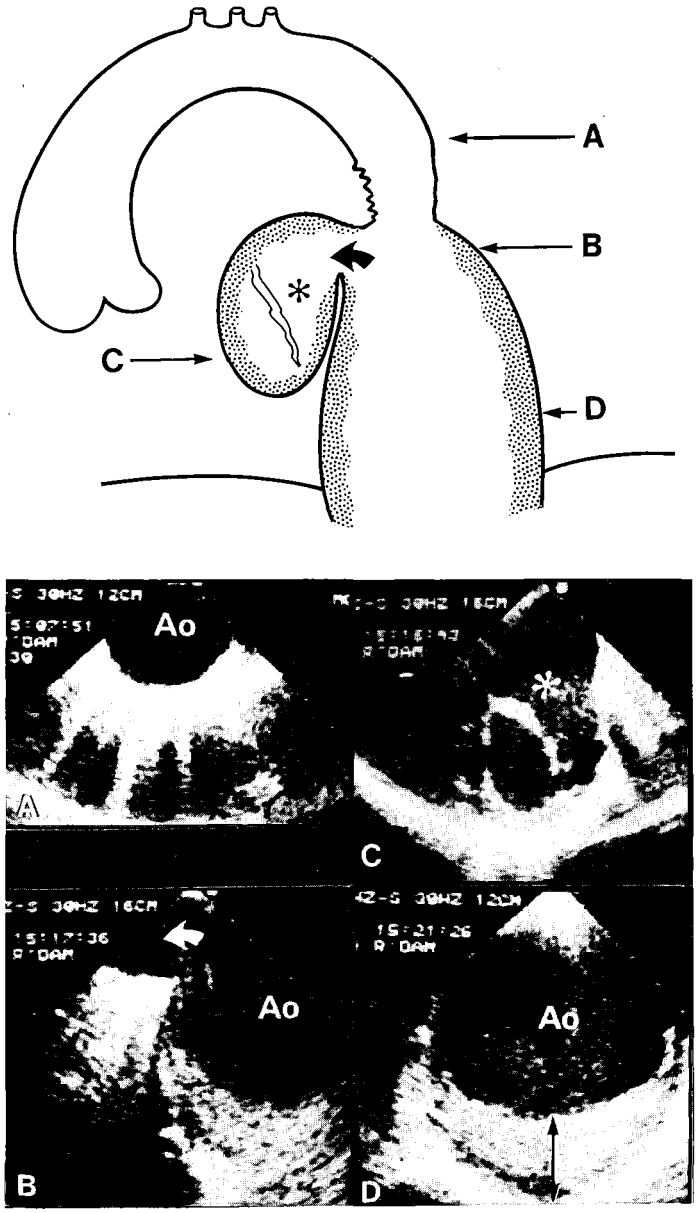

Fig. 4 Transesophageal echocardiographic images of the descending thoracic aorta and corresponding diagram obtained in a patient with a combined saccular and fusiform thoraco-abdominal aneurysm. The proximal part of the descending aorta (Ao) showed a normal caliber (A). The entry of the saccular aneurysm (asterisk) was identified at the proximal region of the fusiform aneurysm (B; bold arrow). Both the saccular (C) and fusiform aneurysms (D) presented with clot formation (arrow) characterized by an irregular border (shaded area).

particularly in patients suspected of aortic dissection. Any risk associated with hypertension can be controlled by intravenous drugs under close hemodynamic monitoring. The investigation can be performed safely and rapidly (within 10 min), is inexpensive and suitable for short and long term follow-up. The technique can be undertaken in critically ill patients at the bedside, in intensive care units or emergency departments. Interpretation of transesophageal echocardiographic images, however, requires substantial experience and theoretical background of both physics and anatomy.

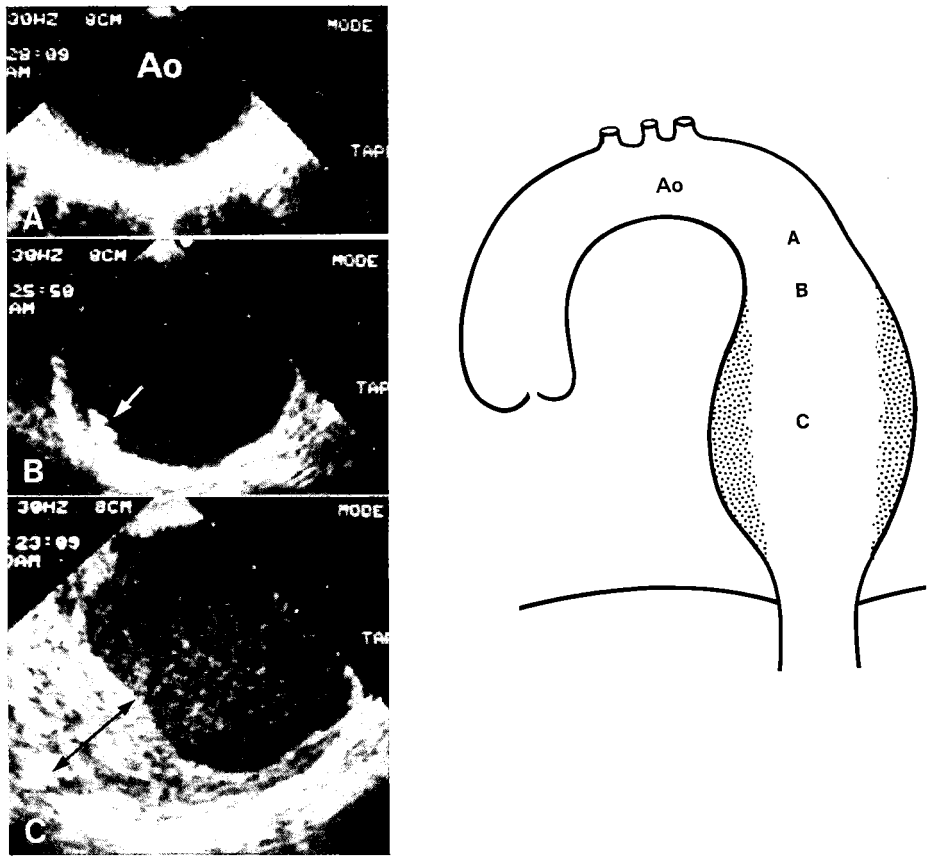

Fig.5 Transesophageal echocardiographic images (A-C) and corresponding diagram of a fusiform aortic aneurysm with thrombotic stratification (shaded area in diagram; black arrow in C) involving the descending thoracic aorta (Ao). Note the atherosclerotic lesion indicated by the white arrow (B).

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3.3 Saccular aneurysm of the transverse thoracic aorta detected by transesophageal echocardiography

M.A. Taams[1], E.J. Gussenhoven[1,2], E. Bos[1], J.R.T.C. Roelandt[1]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam;
[2]the Interuniversity Cardiology Institute of The Netherlands.

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Abstract

A patient with a saccular aneurysm of the thoracic aortic arch presented with severe right ventricular failure due to pulmonary artery compression. Contradictory data were derived from computed tomography, pulmonary isotope perfusion scan and cardiac catheterization. Transesophageal echocardiography revealed a saccular aneurysm which compressed the main pulmonary artery and gave access to a fistulous connection to the left pulmonary artery. Surgery confirmed these findings.

Introduction

The incidence of aneurysmal involvement of the transverse thoracic aorta equals that of the ascending aorta. Life-threatening complications of aneurysm of the thoracic aorta include compression of adjacent vascular structures, rupture and fistula formation [1]. Angiography and computed tomography are established diagnostic methods [2]. We present a patient in whom transesophageal echocardiography correctly established a complicated saccular aneurysm of the aortic arch.

Case Report

A 60-year-old patient developed hoarseness and a 10-kg increase in weight in two weeks and was admitted to a community hospital with intractable right heart failure. He had been treated for 15 years for systemic hypertension, but his medical history was otherwise uneventful. On admission, he was orthopneic and had upper right abdominal pain. There was edema of the legs, scrotum, ascites and a 5 cm enlarged, painful liver. Blood pressure and pulse rate were normal. The jugular venous pressure was extremely elevated. The left vocal cord and hemidiaphragm were paralyzed. A grade 3/6 systolic murmur existed, radiating to the carotid arteries and back. On the electrocardiogram, signs of right ventricular overload and a right axis were present. Chest x-ray film showed right-sided pleural effusion and a mediastinal mass underneath the aortic arch suggestive of an aortic aneurysm or a tumor. No diagnostic information from the aortic arch could be obtained from precordial echocardiography.

The CT-scan of the thorax showed a main pulmonary artery aneurysm. A pulmonary isotope perfusion scan showed no apparent abnormality. Aortography revealed a saccular aneurysm with its origin proximal to the left subclavian artery compressing the pulmonary artery. Right heart catheterization showed pulmonary hypertension (60/20 mm Hg) and an elevated right atrial pressure (10 mm Hg).

The patient was transferred to our unit for surgery. As the above findings were conflicting, the surgeon demanded further investigation. Transesophageal echocardiography was scheduled. A 3.7 MHz phased-array transducer was used mounted at the tip of a gastroscope and interfaced with a Hewlett-Packard ultrasonograph (HP 77020 AC). A pulsed Doppler study was concurrently performed using the same transducer switched to a Toshiba ultrasonograph (SSH 60A). The patient fasted for 8 hours and antihypertensive drugs as premedication were given. As a local anesthetic, topical lidocaine was administered to the patient's hypopharynx. A large saccular aneurysm was visualized underneath the aortic arch. Neither dissection nor thrombus formation was present. Pulsed Doppler tracings showed bloodflow from the aneurysm into the left pulmonary artery indicating a fistula (Fig 1). The main pulmonary artery was compressed by the aneurysm. Numerous atherosclerotic lesions were noted in the thoracic aorta. Planned selective left cardiac catheterization was no longer felt mandatory.

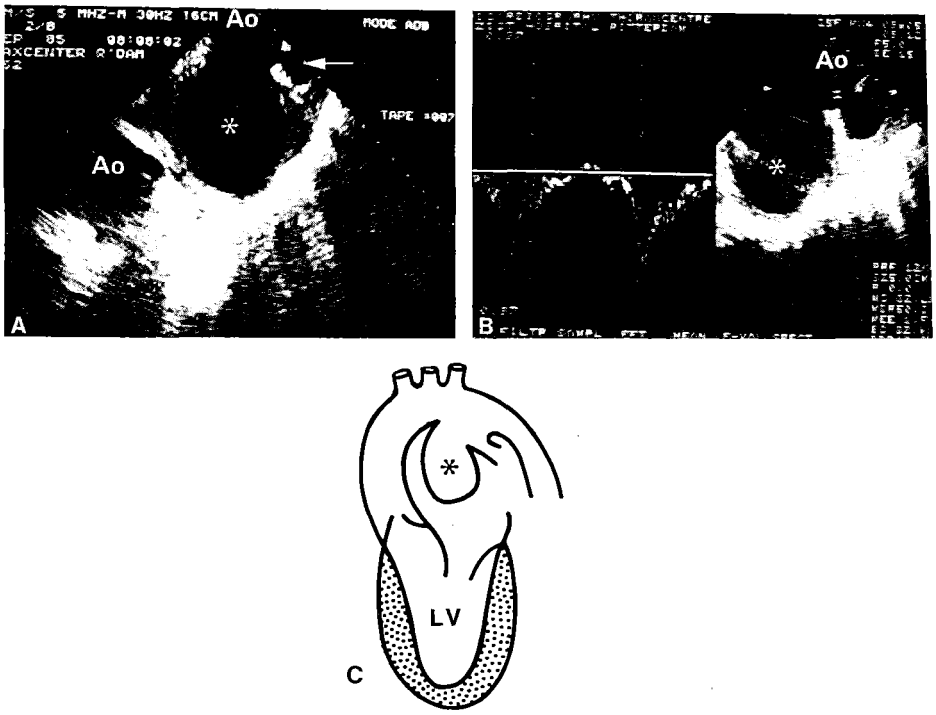

Fig. 1 Transesophageal echocardiographic still-frames (A, B) and schematic diagram(C) showing the saccular aneurysm (asterisk). A, The aneurysm is seen at the concave side of the aortic arch (Ao). A fistula connecting the aneurysm with the left pulmonary artery was noted (arrow). B, Pulsed Doppler tracings show bloodflow from the aneurysm into the left pulmonary artery. LV = left ventricle.

Within 24 hours after transesophageal echocardiography, the patient underwent surgery. Epicardial echocardiography after sternotomy confirmed the transesophageal findings. Deep hypothermia, cardioplegia and 64 minutes of circulatory arrest without occlusion of the aorta were performed. The ascending aorta was incised to the innominate artery. The orifice of the saccular aneurysm was situated in the inner curve of the arch and closed with a Hemashield patch and fibrin glue.

The postoperative course was uneventful. The right axis deviation seen on the electrocardiogram normalized within 24 hours. Transesophageal echocardiography performed two months postoperation showed the aneurysm sealed off by the patch. Its size had significantly decreased. There was thrombus formation, and bloodflow between aneurysm and left pulmonary artery was no longer detectable with pulsed Doppler. The patient is doing well one year postoperation.

Discussion

Saccular types of aneurysms of the thoracic aorta are mostly situated at the inner curve of the thoracic arch or descending thoracic aorta. Less often the ascending aorta is involved [1]. The aneurysm, by definition, has an orifice with the aorta and is often filled with thrombus material. Atherosclerosis is the most frequent etiology of this form of aneurysm [3]. Less commonly, the aneurysm results from a diverticulum of the ductus arteriosus. The latter type clearly shows a distinct pathologic entity fulfilling several diagnostic criteria. These include communication with the aorta at the site of the ductus, closure of the pulmonary orifice, and the presence of a portion of the lower end of the ligamentum arteriosum [4]. Associated atherosclerosis occurs in one third [5]. In our opinion, the patient herein reported falls in the latter category, as it fulfills the criteria of this pathologic entity.

Visualization of aortic aneurysms by means of precordial echocardiography has been disappointing because of the inability to obtain diagnostic images [6,7]. On the other hand, an aortogram can easily miss a saccular thoracic aneurysm either due to a contrast medium dilution in the aneurysm or due to the absence of opacification in the presence of thrombus [8,9]. Computed tomography avoids the vascular catheterization needed for aortography, but is limited by low spatial resolution. Occlusion of major vessels or a fistulous connection will stay undetected with this technique [2].

Transesophageal echocardiography overcomes the limitations of precordial echocardiography, computed tomography and angiography [10,11]. The investigation can be performed at the patient's bedside, is not time-consuming, and is inexpensive. The transducer is in close proximity to the thoracic aorta and allows high quality images. Moreover, the short distance between transducer and the area of interest yields the unique possibility for diagnostic pulsed Doppler studies. Surgery was carried out without delay on the basis of the crucial morphologic information obtained with transesophageal echocardiography.

This report illustrates one of the superior aspects of transesophageal cardiography: the ability to image the thoracic aorta in comprehensive detail.

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3.4 Evaluation of transesophageal echocardiography in suspected thoracic aorta pathology (Thoraxcenter January 1988 - July 1989)

The experience described in Chapter 3 showed an excellent correlation between transesophageal imaging and surgically proven dissection or aneurysm of the thoracic aorta. The data represent 30 patients studied in the period 1984 to 1988. It was concluded that transesophageal echocardiography could become the technique of first choice for the recognition or exclusion of suspected pathology of the thoracic aorta.

This Chapter represents an update of 101 consecutive patients referred to the Thoraxcenter for transesophageal echocardiographic examination in the period January 1988 to July 1989 with the clinical question "suspected for thoracic aorta pathology". The value of transesophageal echocardiography is evaluated from a clinical viewpoint. Transesophageal examinations were carried out by cardiologists with experience in transesophageal echocardiography, as well as by colleagues in the phase of their training.

The majority of the 101 patients were referred from the Thoraxcenter (82), whereas 19 patients were referred from other departments of the University Hospital Rotterdam. Table I summarizes the various departments from which the patients were referred. Transesophageal investigations were conducted either at the bedside in intensive care units and the trauma ward; or in the department of Echocardiology of the Thoraxcenter when patients were mobile and not in need of hemodynamic monitoring.

Table I Departments from which patients were referred

THORAXCENTER	NO. OF PATIENTS	OTHER UNITS	NO. OF PATIENTS
Cardiac outpatien department	43	General surgery	9
Coronary care	36	Trauma ward	5
Cardiac clinic	2	Pulmonology	3
Cardiothoracic intensive care	1	Internal Medicine	1
		Neurology	1
TOTAL	82	TOTAL	19

Table II Indications of referral for transesophageal echocardiography in suspected thoracic aorta pathology

INDICATIONS	NO. OF PATIENTS
Thoracic pain of non-cardiac origin	49
Chest X-ray abnormalities (widened mediastinum and/or thoracic aorta)	24
Known abdominal aneurysm with query involvement of the thorax	9
Follow-up Marfan's syndrome	5
Thoracic trauma	4
Questionable intimal flap in the ascending aorta on precordial echocardiography	4
Cerebral vascular accident or TIA	3
Miscellaneous (including sudden deafness and blood pressure difference R/L arm, mesenteric arterial thrombosis, anterior mediastinal mass in thymoma)	3

The indications of referral for transesophageal echocardiography for clinical signs and/or symptoms indicating possible involvement of the thoracic aorta, are summarized in Table II.

Results

From the 101 patients transesophageal echocardiography revealed no thoracic aorta abnormalities in 33 patients; in 68 patients pathology of the thoracic aorta i.e. dissection or aortic aneurysm, was detected.

Normal thoracic aorta (33 patients)
Transesophageal echocardiography detected no thoracic aorta pathology in 33 patients referred with suspected thoracic aorta pathology (Table III). In 27 patients no further diagnostic examinations were performed. One patient in this group with dissection clinically, abstained from further investigation and died.Autopsy was performed and the clinical diagnosis was confirmed.

Table III Results of transesophageal echocardiography (TEE) performed in 101 patients with suspected thoracic aorta pathology

DIAGNOSIS ESTABLISHED BY TEE			CONFIRMATION BY SURGERY OR AUTOPSY
Normal thoracic aorta	33 patients	**false negative in 3 patients** 2 patients-type II dissection (1-autopsy; 1-CT) 1 patient-saccular aneurysm (angio) **pathology of neck vessels in 3 patients** (angio; MRI)	
Aortic dissection	24 patients	**false positive in 1 patient:** "type II dissection" (surgery)	63% (15 patients)
Aortic aneurysm	44 patients		34% (15 patients)

At follow-up 6-12 months later (mean 8.2 months) no clinical symptoms of thoracic aorta pathology nor death occurred. Five patients underwent additional studies. Two patients because of clinical signs and symptoms indicating unequivocal thoracic vascular pathology (CT - 1 patient; angiography - 1 patient) and 3 patients due to chest X-ray abnormality i.e. widened mediastinum or widened thoracic aorta (angiography - 2 patients; MRI - 1 patient).

A false negative transesophageal echocardiographic study for thoracic aorta pathology occurred in 3 patients. In 2 patients a DeBakey type II dissection was not visualized. Both patients had pericardial effusion and typical clinical signs and symptoms of aortic dissection. In the third patient a saccular aneurysm of the descending aorta was overlooked.

In the first patient computed tomography was performed three days later and revealed a type II dissection. Repeat transesophageal echocardiography on the fourth day confirmed a type II dissection and subsequent surgery was performed. The reason for this initial false negative study is probably due to the dynamic evolution of the dissecting process in the previous period. It is therefore

recommended to repeat the transesophageal study when clinical signs and symptoms indicate dissection and transesophageal imaging is negative. Otherwise a complementary radiodiagnostic study is indicated.

The second patient, in a critical clinical condition, refused further management and died. At autopsy the diagnosis type II dissection was established. The reason for this false negative study can be twofold: either insufficient tilting of the transducer at the level of the ascending thoracic aorta; or the anatomical relationship between the esophagus, right main bronchus and ascending aorta, whereby the midportion of the ascending aorta can be concealed by the right main bronchus crossing the esophagus. Thus information on pathology restricted to this area of the aorta is limited by using a transesophageal transducer with horizontal scanning planes. This problem might be solved by a transducer with optional sagittal scanning planes.

In the third patient transesophageal echocardiography failed to visualize a thrombosed saccular aneurysm of the descending aorta, which was subsequently diagnosed by angiography. In retrospect this false negative result is most likely due to insufficient rotation of the endoscope tube in a pull-back from the level of the diaphragm to the aortic arch. We consider that failure to perform the proper examination procedure accounted for this false negative result.

In 3 patients the thoracic aorta was indeed normal but the pathology was found to be restricted to the carotid artery in 2 patients presenting with a hemiparalysis and chest trauma, respectively; or to the left subclavian artery in 1 patient with a widened upper mediastinum revealed on chest x-ray.

Aortic dissection (24 patients)

Transesophageal echocardiography had accurately established a dissection in 23 patients: type I in 6 patients; type II in 4 patients; and type III in 13 patients (Table III). Confirmation at surgery or autopsy was obtained in 15 patients (63%).

In one patient with pericardial effusion, transesophageal echocardiography revealed an atypical structure in the ascending aorta. Computed tomography showed fluid around the aortic root and possible dissection. Emergency surgery, however, revealed no signs of dissection, besides hemorrhagic pericardial effusion due to malignancy. The false positive diagnosis with transesophageal echocardiography, in retrospect, was due to inexperience of the investigator in recognizing artefacts.

Five out of 8 patients (60%) with a dissection involving the ascending aorta were operated solely on the basis of transesophageal echocardiography.

Initial computed tomography performed in other units showed evidence for aortic dissection in 6 patients before being transferred to our unit. Twelve patients underwent additional studies in our unit (CT - 2 patients; angiography - 7 patients; CT and angiography - 3 patients).

Indications for additional radiodiagnostic investigations were:

- Distal extension of a DeBakey type II dissection in the aortic arch when surgeons were not convinced by the transesophageal echocardiographic images.
- Specific information on any involvement of the cephalic vessels of the proximal extension of a DeBakey type III dissection when transesophageal echocardiography was inconclusive about the extent of an intimal flap relative to the left subclavian artery. This information is of crucial importance in planning the appropriate surgical approach i.e. a median sternotomy or lateral thoracotomy.
- Involvement of abdominal or renal vessels in an aneurysmatic DeBakey type III dissection with subdiaphragmatic extension.

Contributions of radiodiagnostic techniques were:
In one patient with type II dissection computed tomography combined with angiography remained inconclusive about extension into the aortic arch; surgery revealed dissection restricted to the ascending aorta and confirmed the transesophageal echocardiographic findings.

Uncertainty about a non-thrombosed DeBakey type III dissection into the aortic arch, relative to the left subclavian artery, occurred in 2 patients. Complementary angiography was advised, which provided conclusive evidence.

In contrast, we cite a patient with a DeBakey type III dissection in whom transesophageal echocardiography had shown a thrombosed false lumen in the aortic arch and a distal false lumen with spontaneous blood flow. Cineangiography failed to show the extent of this type III dissection into the aortic arch, as the thrombus formation prevented filling with contrast.

In 3 patients with a type III abdominal dissection angiography provided essential information in planning the procedure in combined thoraco-abdominal surgery.

Aortic aneurysm (44 patients)

Transesophageal echocardiography had correctly diagnosed an aortic aneurysm in 44 patients suspected to have thoracic aorta pathology: fusiform aneurysm in 37 patients and saccular aneurysm in 7 patients (Table III). Confirmation at surgery was obtained in 15 patients (34%).

Before being referred for a transesophageal echocardiographic study 12 patients underwent radiodiagnostic procedures (CT - 7 patients; angiography - 5 patients). Additional radiodiagnostic investigation was performed following transesophageal echocardiography examination in 22 patients [CT - 3 patients; angiography - 12 patients (including 5 patients with previous CT); CT and angiography - 7 patients].

Indications for additional radiodiagnostic investigations were:

- Possible involvement of cephalic vessels, in particular the left subclavian artery in cases with an aneurysm of the proximal descending aorta.
- Visualization of the aortic arch, when the surgeon felt uncertain about distention of a fusiform aneurysm of the ascending aorta into the arch.
- Sub-diaphragmatic extension of a thoracic aneurysm with visualization of the visceral and renal vessels, in case transesophageal echocardiography had shown a dilated descending aorta at the level of the diaphragm.

Contributions of radiodiagnostic techniques were:

Computed tomography confirmed the transesophageal echocardiography diagnosis in all instances and contributed no essential new information. Angiography provided additional information in one patient where transesophageal echocardiography failed to establish the exact proximal extent of an aneurysmatic descending aorta in the area of the left subclavian artery. Arch angiography, however, supplied conclusive evidence about the expansion of the aneurysm.

In contrast, one patient presented with an abdominal aneurysm and a thrombosed saccular aneurysm of the descending thoracic aorta on transesophageal echo; aortography did not detect this pathology. The reason is that angiography basically visualizes vessel lumen and will not identify intraluminal thrombus. Similarly, in a second patient routine cineangiography diagnosed a fusiform aneurysm of the ascending aorta but failed to assess the entirely aneurysmatic dilated aortic arch and descending thoracic aorta filled with thrombus.

Conclusion

Sixty percent (5 out of 8) of patients with a **DeBakey type I or type II** dissection were operated solely on the basis of transesophageal echocardiography in this follow-up study - this percentage has not changed since our initial study of 1984-1987 (Chapter 3). Not only does this emphasize that transesophageal echocardiography provides sufficiently detailed anatomical information and accuracy of diagnoses of thoracic aorta pathology, but also reflects the confidence surgeons have placed in transesophageal echocardiography to diagnose this life-threatening disease since the technique was introduced in our center in 1984. The remaining 3 patients had additional computed tomography, which contributed important diagnostic information only in the patient with an initial false negative transesophageal echocardiographic study and type II dissection

After rapid diagnosis of acute aortic dissection at the bedside, immediate operation can be scheduled without further delay needed for radiological imaging. In cases with clinically certain dissection and a negative transesophageal echocardiographic examination, complementary radiodiagnostic imaging is indicated.

Inexperience with the transesophageal technique is an explanation for false positive diagnoses of dissection, which occurred in 1 out of 24 patients. Knowledge of the physics of ultrasound and the recognition of reverberation artefacts are mandatory.

DeBakey type III dissection is less life-threatening and complementary X-ray procedures are recommended, especially in establishing the exact retrograde extension of the dissection into the aortic arch and/or subdiaphragmatic extension in case a dilated dissection is detected at the level of the diaphragm.

Transesophageal echocardiography accurately establishes **thoracic aorta aneurysm.** Appropriate execution of the examination procedures will avoid a false negative diagnosis of a localized saccular aneurysm of the descending aorta.

In planning thoracic surgery, radiodiagnostic techniques are required when uncertainty exists about the extension of the aneurysm into the aortic arch in relation to the cephalic vessels.

Angiography of the visceral and renal vessels is indicated in planning combined abdominal surgery once transesophageal echocardiography shows a dilated aorta at the level of the diaphragm.

CHAPTER 4

4.1 PROLOGUE: Transesophageal echocardiography of the prosthetic mitral valve

Initially transesophageal echocardiography was performed as an alternative approach in patients with non-diagnostic precordial echocardiograms. Transesophageal echocardiography has, however, evolved as an ultimate diagnostic technique in several clinical conditions. These include dysfunction and endocarditis of a mitral prosthesis, increasing the yield of evaluation by the application of transesophageal echocardiography. This technique produces high quality images of the atrial side of the prosthesis and is not hampered by flow masking, nor cluttering of the left atrial cavity by ultrasound artefacts created by non-tissue elements. Transesophageal echocardiography is therefore particularly suited in depicting thrombi, vegetations and complications of infective endocarditis in patients with a mitral prosthesis.

Recognition of the characteristics of normal trans-valvular mitral prosthetic backflow is essential to avoid misdiagnosing of "physiologic" regurgitation, inherent to the design of the prosthesis, as a sign of pathology.

In this regard, transesophageal Doppler color flow imaging is an extremely sensitive technique for the detection of valvular and/or paravalvular regurgitation in mitral prostheses. In the Björk Shiley mitral valve, two normal regurgitant color flow jets arise from sites of known apertures in its closure mechanism. The jets are consistent in nature and are displayed as non-turbulent, narrow, short, low-velocity jets (type I). These jets should be distinguished from pathologic prosthetic mitral regurgitation, which appear as turbulent, broad, long, higher velocity jets (type II). However, assessment of the severity of pathologic mitral regurgitation is contended as the exact relationship between regurgitant Doppler color velocity mapping and regurgitation volume remains controversial.

4.2 Transesophageal Doppler color flow imaging in the detection of native and Björk-Shiley mitral valve regurgitation

M.A. Taams[1], E.J. Gussenhoven[1,2], M.K. Cahalan[3], J.R.T.C. Roelandt[1], L.A. van Herwerden[1], S.H.K. The[1], N. Bom[1], N. de Jong[1]

[1]Thoraxcenter, Erasmus University and Univerity Hospital Rotterdam;
[2]the Interuniversity Cardiology Institute of The Netherlands;
[3]Dept. of Anesthesiology, University of California, San Francisco, USA.

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Abstract

Regurgitant blood flow of mitral valves was studied by transesophageal Doppler color flow imaging in 11 healthy volunteers (Group I), 25 cardiac patients with a native mitral valve (Group II), 10 patients with a normal functioning Björk-Shiley mitral prosthesis without clinical evidence of mitral regurgitation (Group III) and 10 patients with angiographic or surgical evidence of Björk-Shiley mitral valve regurgitation (Group IV). Holosystolic regurgitant color jets were classified as type I or type II. The data were compared with results obtained with precordial techniques, i.e., continuous wave and Doppler color flow echocardiographic imaging (Groups I-IV) and left ventricular angiography or surgery (Groups II and IV). In Group I transesophageal Doppler color flow imaging revealed no mitral regurgitant flow in 7 of the 11 volunteers and a type I jet in 4 volunteers that was detected in only 1 volunteer by precordial techniques. In Group II, angiography showed no mitral regurgitation in 20 patients and documented mitral regurgitation in five. Transesophageal Doppler color flow imaging detected in 4 of the 20 patients a type I jet that was not visualized with precordial techniques in 2 patients. Type II jets were detected by the transesophageal technique in all 5 patients with proven mitral regurgitation and were also visualized with precordial echocardiography. All patients in Group III showed two identical type I jets that were not detected with precordial echocardiography. In Group IV, transesophageal Doppler color flow imaging

revealed a type II jet in all 10 patients and, in addition, a type I jet in 7; the precordial continuous wave and Doppler color flow techniques detected mitral regurgitation in 6 and 3 patients, respectively. From this study it is concluded that transesophageal Doppler color flow imaging is an extremely sensitive method for the detection of mitral regurgitation. The unique position of the transesophageal transducer behind the Björk-Shiley mitral prosthesis makes it the technique of choice for the evaluation of prosthetic mitral valve regurgitation.

Introduction

Precordial Doppler color flow imaging provides vivid images of intracardiac blood flow and aids the rapid recognition of aberrant intracardiac flow patterns [1]. This technique, however, may not reveal mitral valve regurgitation, because of attenuation of the ultrasound signal due to the distance involved, the interposition of calcified tissue or the presence of a valve prosthesis [2,3]. Transesophageal Doppler color flow imaging theoretically facilitates detection of mitral valve regurgitation as the transducer is closer to the mitral valve and provides an unobstructed view. This study was designed to determine the systolic mitral valve flow characteristics imaged by transesophageal Doppler color echocardiography in healthy volunteers, patients with valvular or coronary artery disease, or both, and patients with a Björk-Shiley mitral valve prosthesis. The results were compared with those obtained with precordial continuous wave and Doppler color flow echocardiography, and left ventricular angiography or surgery, when performed.

Methods

Study groups

Approval from our Committee on Human Research was granted and informed consent was obtained from each subject.

Group I comprised 11 healthy volunteers (8 men and 3 women aged 20 to 37 years [mean 31]) with no history of cardiac disease or cardiac symptoms. One subject was studied three times.

Group II included 25 cardiac patients (15 men and 10 women aged 22-71 years [mean 55]) with valvular or coronary artery disease, or both, and a native

mitral valve. All patients had undergone left ventricular angiography within 10 days to 4 months of the transesophageal study.

Group III comprised 10 patients with a Björk-Shiley mitral prosthesis (7 men and 3 women aged 31-72 years [mean 59]). These patients clinically had no signs of mitral regurgitation after implantation of the prosthesis, and presented with an uneventful postoperative course.

Group IV included 10 patients with Björk-Shiley mitral valve prostheses (6 males, 4 females) aged 36-76 years (mean 63 years). Nine patients had signs and symptoms necessitating left ventricular angiography within 2 months of the transesophageal study. All of these nine patients had mitral valve regurgitation, and seven had concomitant tricuspid regurgitation. Four patients required reoperation for paravalvular mitral regurgitation. One critically ill patient (Table I, Case 6) with three mechanical valves and suspected dehiscence of the mitral valve prosthesis underwent cardiac surgery for mitral valve regurgitation within two days after the transesophageal study.

All patients (Groups I - IV) had a precordial continuous wave and Doppler color flow echocardiographic study in the week before the transesophageal study.

Equipment and performance

Precordial studies were performed with use of a real-time two-dimensional Doppler flow imaging system and a 3.7 MHz transducer (Toshiba SSH-65A). For transesophageal studies a 3.7 MHz phased-array transducer mounted at the tip of a gastroscope tube was employed. The procedure of transesophageal echocardiography in this study was performed as previously described [4]. Blood flow toward the transducer was encoded in red and flow away from the transducer was encoded in blue. In proportion to the extent of turbulence the color hue varied from red to yellow and from blue to cyan. Images were stored on 0.75 inch (1.905 cm) videotape.

Evaluation of regurgitant flow

Mitral valve flow characteristics were analyzed by an observer unaware of the subjects' clinical history or results of the other techniques. After frame by frame off- line analysis, mitral regurgitant flow was diagnosed if color flow imaging indicated blood flow into the left atrium through the mitral valve during systole. Onset of the regurgitant flow and duration, length, width and color characteristics of the flow were evaluated. The following types of color jets were observed:

type I - a holosystolic, short (< 30 mm), narrow (< 10 mm) and predominantly red jet; type II- a holosystolic, long (> 30 mm) or broad (> 10 mm), or both, and multicolored jet (Fig. 1). Type I jets were directed toward the center of the left atrium whereas type II jets were either directed toward the center of the left atrium or eccentrically directed.

Results

Transesophageal Doppler color echocardiography was completed, without complication and within 15 min in all subjects.

Group I. Precordial continuous wave and Doppler color flow imaging revealed no mitral regurgitation in 10 of the 11 volunteers and none of these participants showed signs of mitral valve prolapse. In one subject, precordial continuous wave and Doppler color studies revealed a small amount of mitral valve regurgitation (Table I, Case 11). The transesophageal Doppler color study revealed no mitral regurgitant flow in seven and a type I jet in four of the volunteers (Fig. 2). In one of these four subjects (Case 11) mitral regurgitation had also been noted with the precordial Doppler color flow study.

In one volunteer with a type I jet, the transesophageal examination was repeated twice during an interval of 4 months and the color jet was identical in all three studies. In this subject precordial Doppler color flow study revealed no mitral regurgitation, whereas the jet was clearly evident from the simultaneously conducted transesophageal examination.

Fig. 1 Mitral valve regurgitation. Diagram showing features of holosystolic mitral valve regurgitant flow observed with transesophageal color Doppler echocardiography in the native mitral valve and Björk-Shiley mitral valve. LA = left atrium; I = type I regurgitant jet; II = type II regurgitant jet.

Fig.2 Transesophageal Doppler color flow images obtained in a healthy volunteer (group I, Case 8). A, the two-dimensional image shows a type I jet in the left atrium (LA) predominantly encoded in red. B, M-mode registration through this jet displays holosystolic regurgitant flow (between arrows). LV = left ventricle.

Fig. 3 A systolic transesophageal Doppler color flow still-frame showing 2 type I jets in a patient with a normal functioning Björk-Shiley mitral valve (Group 3). Abbreviations as in Figure 2.

Fig. 4 A systolic transesophageal Doppler color flow still-frame from a patient with a Björk-Shiley mitral valve (Group IV, Case 7). Both a type I (arrow 1) and a type II (arrow 2) holosystolic regurgitant color jet are identified. In addition, tricuspid valve regurgitation is seen (arrow 3). Abbreviations as in Figure 2.

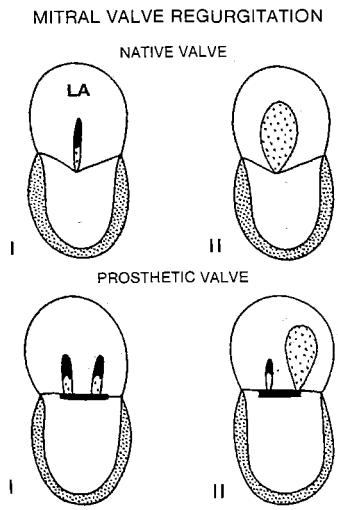

Figure 1

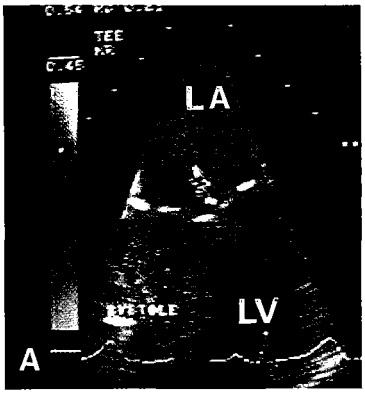

Figure 2 A

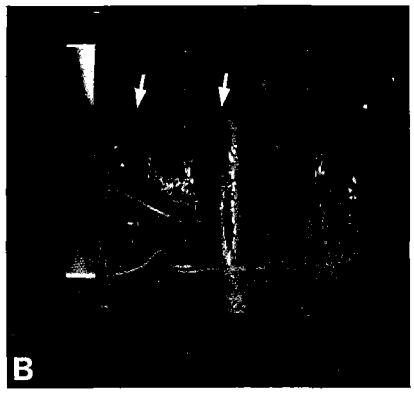

Figure 2 B

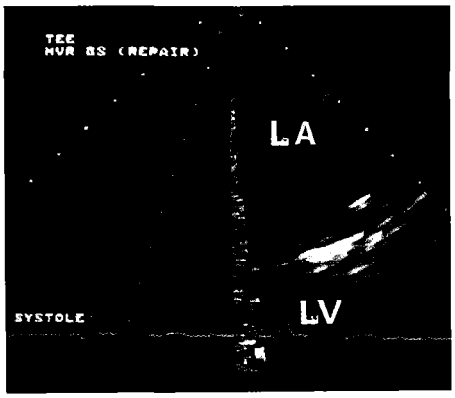

Figure 3

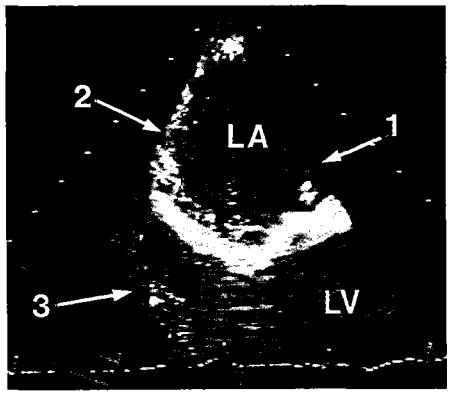

Figure 4

Group II. Left ventricular angiograms of 20 of the 25 patients with a native mitral valve showed no mitral regurgitation. In 4 of these 20 patients, a type I jet was noted on transesophageal Doppler color flow imaging and its features were similar to those of the jet observed in the volunteers (Table I). Results of precordial continuous wave and Doppler color flow imaging were positive for mitral regurgitation in two of these four patients. Reanalysis of the 20 angiograms confirmed the apparent competence of the mitral valve.

Five of the 25 angiograms demonstrated mitral regurgitation that was mild in one patient and severe in four patients. Transesophageal Doppler color flow imaging revealed a type II jet in all. Precordial continuous wave and Doppler color flow imaging detected holosystolic mitral valve regurgitation in all five patients.

Group III. Precordial continuous wave and Doppler color flow studies had not indicated mitral regurgitation in any of the 10 patients with a Björk-Shiley mitral valve. Transesophageal Doppler color flow study detected two identical type I jets in all 10 patients (Figs. 1 and 3, Table I).

Group IV. Transesophageal Doppler color flow imaging revealed type II jets in all 10 patients and an additional type I jet in 7 patients (Figs. 1 and 4). Precordial continuous wave Doppler and color flow imaging disclosed holo-systolic mitral regurgitation in only six and three patients, respectively (Table I).

Discussion

Transesophageal Doppler color flow imaging revealed a specific color pattern of holosystolic mitral regurgitation (type I) to be designated as physiologic backflow that must be distinguished from pathologic mitral regurgitation (type II).

Table I Detection of mitral regurgitation in healthy volunteers (Group I), cardiac patients with a native mitral valve (Group II) and patients with a Björk-Shiley mitral valve without (Group III) and with evidence of mitral valve regurgitation(GroupIV).

Case No.	Angio MR	TEDC MR	Precordial CW Doppler MR	Precordial Doppler Color MR
Group I (n=11)				
1-7	NP	-	-	-
8	NP	I	-	-
9	NP	I	-	-
10	NP	I	-	-
11	NP	I	+	+
Group II (n=25)				
1-16	-	-	-	-
17	-	I	-	-
18	-	I	+	+
19	-	I	+	+
20	-	I	-	-
21	1+	II	+	+
22*	3+	II	+	+
23*	4+	II	+	+
24*	4+	II	+	+
25*	4+	II	+	+
Group III (n=10)				
1-10	NP	I	-	-
Group IV (n=10)				
1	1+	I,II	-	-
2	1+	I,II	-	-
3	2+	I,II	-	-
4	2+	I,II	+	-
5	2+	II	+	+
6*	NP	II	-	-
7*	3+	I,II	+	-
8*	3+	I,II	+	-
9*	3+	I,II	+	+
10*	3+	II	+	+

*: required surgery for mitral valve regurgitation; Angio: left ventricular angiography; TEDC: transesophageal Doppler color imaging; CW: continious wave; MR: mitral regurgitation; NP: not performed; 1+, 4+: angiographic degree of mitral regurgitation; -: absent; +: present; I: type I jet; II: type II jet.

Patients with a native mitral valve

A type I jet was observed in 36% of the healthy volunteers and in 20% of the cardiac patients with a native mitral valve who had shown no previous evidence of regurgitation. A simultaneous transesophageal M-mode and pulsed Doppler recording of this jet showed holosystolic mitral regurgitation (Fig. 2), further validating the suspicion that this type of jet represented regurgitant flow. A type II jet was detected in all patients with a native mitral valve in whom a similar jet had been revealed with precordial continuous wave Doppler and color flow imaging and angiography. Thus, transesophageal Doppler color flow imaging offered no substantial advantage in the detection of pathologic mitral regurgitation of the native mitral valve.

Regurgitant flow patterns have been documented with precordial Doppler flow imaging in healthy persons, but with a predominance of right-sided valve regurgitation [5-7]. The incidence of this physiologic backflow in apparently normal mitral valves varies widely from 0-40% [5]. In our study the results of precordial and transesophageal Doppler color flow imaging substantiate in Group I (healthy volunteers) a four-fold and in Group II (coronary or valvular disease) a two-fold higher sensitivity of the transesophageal technique in the detection of regurgitant flow over the mitral valve. On the other hand, false negative precordial Doppler flow studies have been reported, especially in the presence of angiographically documented mild mitral valve regurgitation, in patients with a native [2,7] or a mechanical mitral valve [8].

This gives rise to the question as to why mitral regurgitation can be missed with conventional diagnostic techniques. With precordial echocardiographic methods the regurgitant jet is observed from a greater distance than with transesophageal methods and an interfering, calcified or prosthetic valves may be interposed [3]. Angiography could overcome these problems. However, there are fundamental differences between what is detected by these various methods. Angiography maps the position of an indicator carried by blood flow, whereas Doppler color flow imaging maps velocity of blood flow. Therefore, a small volume of regurgitant flow at high velocity may produce a vivid Doppler color signal but carry an insignificant amount of indicator for detection on the angiogram.

Since the introduction of transesophageal two-dimensional echocardiography there has been concern about the possible dangers of this technique. More than 500 studies have been performed in our unit; all were well tolerated. Only two periods of paroxysmal atrial fibrillation occurred, which were terminated by repositioning the scope.

The possibility that the transesophageal examination itself may induce mitral regurgitation has been excluded by a simultaneously conducted study. Although we could clearly localize the origin and extent of the regurgitant jet with the transesophageal approach, we were unable to find the jet from the precordium using the same ultrasonograph at the same time (Fig. 2).

Patients with a Björk-Shiley mitral valve

In the presence of a normally functioning Björk-Shiley mitral valve prosthesis, transesophageal Doppler color flow imaging revealed two identical type I jets in all patients, but these jets were not detected with precordial Doppler studies. The type I regurgitant color jets are inherent to the design of the prosthesis [9,10]; they represent 1) dynamic regurgitation (i.e. blood volume necessary to close the disc), and 2) static regurgitation (i.e. blood volume passing the disc and housing during systole)[11].

Among the patients with a Björk-Shiley mitral prosthesis and angiographically or surgically documented mitral regurgitation, a type II jet was always recorded. Thus it appears that the presence of a type II jet on transesophageal Doppler color flow studies is 100% sensitive and specific for detection of angiographically or surgically documentable pathologic prosthetic mitral valve regurgitation. This is not surprising because the regurgitant jet in the left atrium is unobstructively observed, behind the prosthesis, by the esophageal transducer. Because of interposition of the mitral prosthesis, precordial continuous wave and Doppler color flow imaging failed to identify pathologic prosthetic mitral regurgitation, respectively, in 4 and 7 of the 10 patients in Group IV.

Conclusions

This study describes the different systolic flow patterns observed with transesophageal Doppler color flow imaging in the native mitral valve and Björk-Shiley mitral prosthesis. Whereas Miyatake et al. [2] documented four grades of mitral regurgitation using precordial Doppler color flow imaging, we were able with the transesophageal approach to distinguish two types of regurgitation. The distinction between type I and type II jets was clear. Type I jets were not pathologic, but type II jets were always associated with pathologic mitral regurgitation. Having detected the pathologic regurgitant jet with transesophageal Doppler color flow imaging it was, however, not possible to make further estimations concerning the significance of the regurgitation. Analysis of type

II jets with respect to size and relative ratio of the jet to left atrial size allowed no subclassification in our study groups. In case of doubt about the type of jet, a close clinical follow-up is recommended.

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CHAPTER 5

Enhanced morphological diagnosis in infectious endocarditis by transesophageal echocardiography

M.A. Taams[1], E.J. Gussenhoven[1,2], E.Bos[1], P. de Jaegere[1], J.R.T.C Roelandt[1], G.R. Sutherland[1], N. Bom[1]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam; [2]the Interuniversity Cardiology Institute of the Netherlands.

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Abstract

Thirty three consecutive patients with clinically suspected endocarditis were studied by both precordial cross-sectional echocardiography and transesophageal echocardiography. The diagnostic value of both techniques was assessed. The data were compared with findings at operation in 25 patients. In 21 patients with native valve endocarditis precordial echocardiography showed evidence of vegetations in six patients and suggested their presence in nine. Transesophageal echocardiography identified vegetations in 18 patients. Complications were seen in four patients at precordial echocardiography and in nine patients at transesophageal echocardiography. Precordial echocardiography did not show vegetations in any of the 12 patients with prosthetic valve endocarditis whereas transesophageal echocardiography showed vegetations in four. Complications were seen in four patients at precordial echocardiography and in 10 with transesophageal echocardiography. Echocardiographic findings were confirmed at operation in all 25 operated patients. In three patients one or both echocardiographic techniques had missed the perforation of the cusps of the aortic valve that was seen at operation, but this had no effect on patient management. Transesophageal echocardiography is the best diagnostic approach when infective endocarditis is suspected in patients with either native or prosthetic valves.

Introduction

Before the introduction of transesophageal echocardiography, high resolution precordial cross-sectional echocardiography was widely accepted as a valuable method of diagnosing infective endocarditis. But this method has limitations, and false positive [1-3] as well as false negative diagnoses have been reported in patients who eventually required operation [4-6]. In patients with a prosthetic valve precordial echocardiography is hampered because the prosthesis interferes with the ultrasound beam [7-9]. Cardiac catheterization is of limited value in such patients [6, 10]. The introduction of transesophageal echocardiography provided an alternative diagnostic approach [11-13]. We assessed the diagnostic value of transesophageal echocardiography in identifying abnormalities caused by infective endocarditis. The results were compared with the findings at precordial echocardiography and at surgery.

Patients and methods

Study Group

Over a four year period (1984-1988) 33 consecutive patients (24 men and nine women; mean age 45, range 18-81 years) with clinically suspected infective endocarditis were investigated by precordial echocardiography and subsequently by transesophageal echocardiography (the interval between studies was <3 days).

The clinical diagnosis of infective endocarditis was supported by bacteriological findings (32 patients had positive blood cultures) and surgical description (25 patients). Indications for cardiac surgery were: congestive cardiac failure (15 patients); persistent fever (five patients); multiple embolism (one patient); and endocarditis during the waiting period for elective cardiac surgery in our unit (four patients).

Twenty one patients had endocarditis of a native valve (12 mitral; nine aortic). The underlying valve disease was mitral stenosis in two, mitral valve myxomatous degeneration in three and bicuspid aortic valve in four patients (Tables I and II). Operation was performed within 16 days at the transesophageal echocardiographic study in 15 patients (range 1-16 days). The six unoperated patients were successfully treated with antibiotics.

Twelve patients were referred with prosthetic valve endocarditis. The prostheses implanted included two mitral; six aortic; mitral and aortic in one; and mitral, aortic and tricuspid in three (Table III). Operation was performed in 10

Table I Detection of vegetations or complications or both in patients with mitral valve endocarditis.

NATIVE MITRAL VALVE	PRECORDIAL ECHOCARDIOGRAPHY		TRANSESOPHAGEAL ECHOCARDIOGRAPHY		SURGERY
Patient No.	Vegetations	Complications	Vegetations	Complications	
1	-	-	+	-	NP
2	-	-	-	MV cordal rupture	P
3	?	-	-	MV cordal rupture	P
4 MD	?	-	+	-	P
5	?	-	+	MV cordal rupture	P
6	?	-	+	MV cordal rupture	P
7 MS	?	-	+	-	NP
8 MS	?	-	+	-	P
9	+	-	+	-	NP
10 MD	+	-	+	-	NP
11 MD	+	-	+	-	NP
12 (Fig. 3)	-	Abnormal MV	-	Mycotic aneurysm MV & fistula	P

MD = myxomateus degeneration
MV = mitral valve
MS = mitral stenosis
P = performed
NP = not performed

Table II Detection of vegetations or complications or both in patients with aortic valve endocarditis

NATIVE AORTIC VALVE	PRECORDIAL ECHOCARDIOGRAPHY		TRANSESOPHAGEAL ECHOCARDIOGRAPHY		SURGERY
Patient No.	Vegetations	Complications	Vegetations	Complications	
1	-	-	+	-	P
2	-	-	+	-	P
3 bicuspid	-	-	+	-	P
4	?	*	+	*	P
5 bicuspid (fig. 2)	?	*	+	Aortic cusp perforation	P
6 bicuspid	?	-	+	Mycotic aneurysm posterior and subannular to aorta	NP
7	+	Abnormal MV	+	MV cordal rupture	P
8	+	Mycotic aneurysm anterior and supra-annular to aorta	+	Mycotic aneurysm anterior and supra-annular to aorta	P
9 bicuspid	+	Aortic cusp perforation	+	*	P

MV = mitral valve
* = aortic cusp perforation missed
P = performed
NP = not performed

Table III Detection of vegetations or complications or both in patients with prosthetic valve endocarditis

PROSTHETIC VALVE Patient No.	PRECORDIAL ECHOCARDIOGRAPHY Vegetations	PRECORDIAL ECHOCARDIOGRAPHY Complications	TRANSESOPHAGEAL ECHOCARDIOGRAPHY Vegetations	TRANSESOPHAGEAL ECHOCARDIOGRAPHY Complications	SURGERY
1 M	-	-	+	-	P
2 M	-	-	+	-	NP
3 A	-	-	-	Valve dehiscence	P
4 A	-	-	-	Valve dehiscence	P
5 A	-	-	-	Valve dehiscence	P
6 A	-	-	+	Valve dehiscence & mycotic aneurysm posterior and subannular to aorta	P
7 A	-	Abnormal echo structure in LA?	-	Mycotic aneurysm posterior and subannular to aorta	P
8 A	-	Mycotic aneurysm posterior to aorta	-	Mycotic aneurysm posterior and subannular to aorta & intramural abscess	#
9 MA	-	Mycotic aneurysm anterior to aorta	-	Valve dehiscence (A)	P
10 MAT (fig. 1)	-	-	+	Mycotic aneurysm of M annulus	P
11 MAT	-	-	-	Valve dehiscence (M)	P
12 MAT (fig. 4)	-	Mycotic aneurysm anterior to aorta	-	Mycotic aneurysm at the posterior aortic annulus & flail Hancock (M)	P

M = mitral prosthesis
A = aortic prosthesis
T = tricuspid prosthesis
LA = left atrium
# = died, no necropsy

P = performed
NP = not performed

patients within seven days of the transesophageal echocardiographic study (range 1-7 days). One patient died and necropsy was not performed. One patient was treated successfully with antibiotics.

Equipment and techniques

We performed precordial cross-sectional echocardiographic studies with a Toshiba SSH-65A, Toshiba SH 160 or Hewlett-Packard HP 77020 AC imaging system. The frequency of the transducers used was 3.5, 3.75 or 5 MHz respectively.

The transesophageal study was performed with a 5.6 MHz phased array transducer mounted at the tip of a gastroscope tube. The transducer was interfaced with a Hewlett-Packard imaging system (HP 77020 AC). All patients fasted for at least 4 hours. Premedication was not given and local anesthetic (10% lignocaine) was sprayed into the patient's hypopharynx [14]. In the last 23 patients the tube was wrapped in a disposable sheath (International Medical) before the procedure. This did not cause any problems or image deterioration. An imaginary three dimensional outline of the defect was obtained from cross sections taken in different planes after careful tilting and repositioning of the transducer.

Definition of lesion

A vegetation was defined as a localized mobile mass of echoes contiguous with a valve leaflet or prosthetic valve (Figs. 1 and 2).

Cordal rupture was defined as a systolic whipping motion of an affected mitral leaflet tip within the left atrial cavity with loss of normal leaflet apposition.

Cusp perforation was recognized as an interruption of echoes in an aortic cusp (Fig. 2) or Hancock valve (Fig. 4).

Abscess was defined as an abnormal echolucent area within the perivalvar tissue without communication with the circulation.

Mycotic aneurysm presented as an abnormal pulsatile echo-free protrusion that was annular, supra-annular, or subannular (Figs. 1, 3 and 4).

Valve dehiscence presented as an echolucent area seen around the prosthetic valve ring resulting in open communication between two adjacent cavities (Fig. 1).

Results

Tables I-III summarize precordial and transesophageal echocardiography findings and at operation.

Native mitral valve (12 patients, Table I)
Precordial echocardiography did not show a defect related to infective endocarditis in two patients. In six patients the images suggested the possibility of vegetations.
Vegetations were positively identified in three patients. In one patient (case 12) the mitral valve was abnormal.
Transesophageal echocardiography revealed pathology in all 12 patients: vegetations in nine and complications in five. These data were confirmed at surgery in seven patients. Five patients were successfully treated with antibiotics.

Native aortic valve (9 patients, Table II)
Precordial echocardiographic studies did not reveal pathology in three patients. Vegetations were questionable in three patients and were definitely seen in three other patients. Signs for more complex pathology was noticed in three patients (patients 7-9).
Transesophageal echocardiography identified pathology in all nine patients. Vegetations were seen in all, and additional complications were identified in four (patients 5-8). In eight patients the data were confirmed at surgical inspection. The remaining patient (case 6) was successfully treated with antibiotics. The additional feature of aortic cusp perforation was missed in three patients with one or both techniques (patients 4, 5, and 9).

Prosthetic valve (12 patients, Table III)
Precordial echocardiography did not reveal any pathology in 8 patients. In one patient (case 7) an abnormal echo structure was noticed in the left atrium; the cause was not identified. In three patients (cases 8, 9 and 12) a mycotic aneurysm was found anterior to the aortic prosthesis.
Transesophageal echocardiography disclosed vegetations in four patients: in three patients these were attached to the left atrial site of the mitral prosthesis and in one patient at the aortic valve ring. Complications were found in 10 patients: dehiscence of the posterior site of an aortic prosthesis in six; mycotic aneurysm in five; left ventricular free wall abscess in one patient; and a flail

findings were confirmed at operation in 10 patients. One patient died, necropsy was not performed, and one patient was successfully treated with antibiotics.

Discussion

Infective endocarditis is potentially a life-threatening disease. The need for surgery in these patients usually indicates that the diagnosis and onset of treatment have been delayed [15].

The incidence of detectable mycotic aneurysms or abscess formation during life is not known [16], but these complications were often found in necropsy series [17-19]. Because perivalvar infective endocarditis is usually associated with a higher incidence of serious complications, a more complicated surgical procedure or death [10, 20, 21], early diagnosis is essential [22]. But angiography proved to be of limited value [6, 10, 23]. Despite increasing experience in precordial echocardiography and the availability of more sophisticated equipment, false negative studies in native valve endocarditis have been reported [4-6].

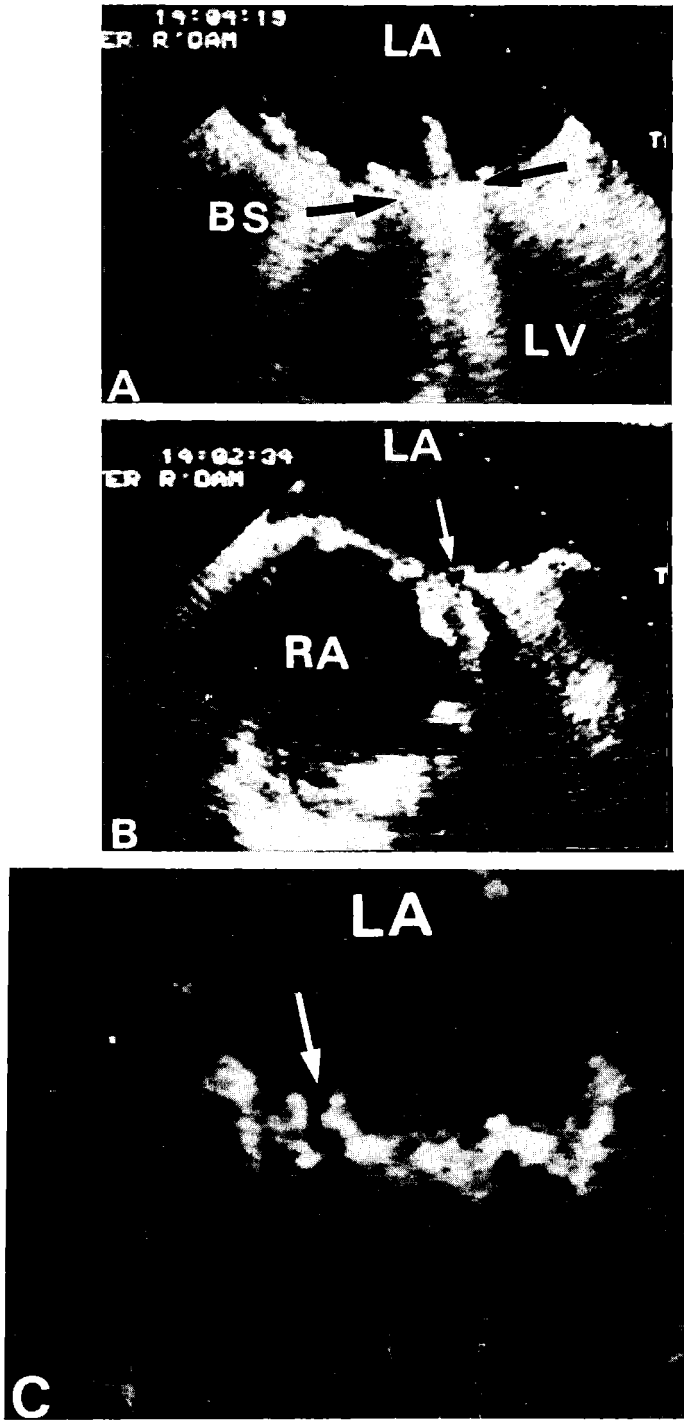
In the presence of prosthetic valve endocarditis, the prosthesis can interfere with the ultrasound beam and ultrasound artefacts can hamper an adequate precordial study [6, 12].

Limited resolution from the precordium also produced false positive images when there was pre-existing valve disease, which interferes with the precise visualization of the underlying infectious process and any associated complications [1-3].

The proximity of the transducer to the heart and avoidance of chest wall interference during transesophageal echocardiography allows the use of a high frequency beam and this gives images of high resolution [24-26] showing a precise morphologic delineation of the destructive cardiac pathology.

In all 33 patients in this study with clinically suspected endocarditis transesophageal echocardiography detected vegetations or complications, or both.

Fig. 1 Transesophageal echocardiographic systolic still frames (A, B, C) from a patient with endocarditis of the mitral Björk-Shiley prosthesis (Table III, case 10). A, As well as a vegetation attached to the left atrial site of the prosthesis (BS, black arrows); B, A small and pulsatile mycotic aneurysm was noticed at the mitral annulus (arrow). C, Follow-up examination after a period of pulmonary edema showed a perforation (arrow) of the aneurysm resulting in partial valve dehiscence. This pathology was not detected by precordial echocardiography. LA = left atrium; LV = left ventricle; RA = right atrium.


LA
BS
LV
A
LA
RA
B
LA
C

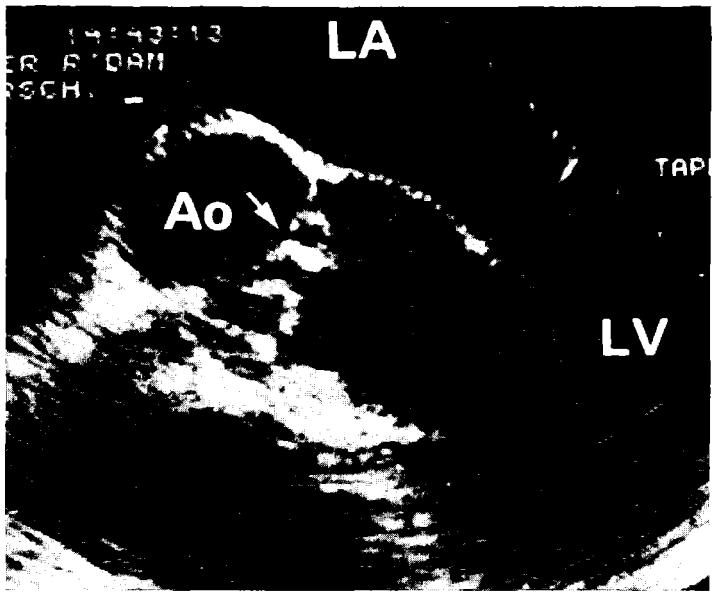


Fig. 2 Transesophageal echocardiographic diastolic still frame from a patient with native aortic valve endocarditis (Table II, case 5) showing a perforation in the aortic cusp (arrow) with a vegetation. This was not detected by the precordial approach. Ao = aorta; LA = left atrium; LV = left ventricle.

In all 33 patients in this study with clinically suspected endocarditis transesophageal echocardiography detected vegetations or complications, or both.

Using a 3.5 MHz transesophageal transducer Daniel and co-workers achieved a detection rate of 85% [13]. With precordial echocardiography we detected valve defects in 30% of patients. Twenty-five eventually underwent surgery because transesophageal echocardiography established the diagnosis without preoperative angiography.

The surgical findings revealed that false positive diagnoses did not occur with transesophageal echocardiography. The technique failed to demonstrate aortic cusp perforation in two patients. The explanation for this may be the combination of the size and position of the perforation within the aortic cusp. Neither medical management nor surgery was influenced by the absence of this specific information. Though the information obtained with transesophageal echocardiography in the eight unoperated patients could not be independently confirmed, the quality of the images meant that an unequivocal diagnosis was possible.

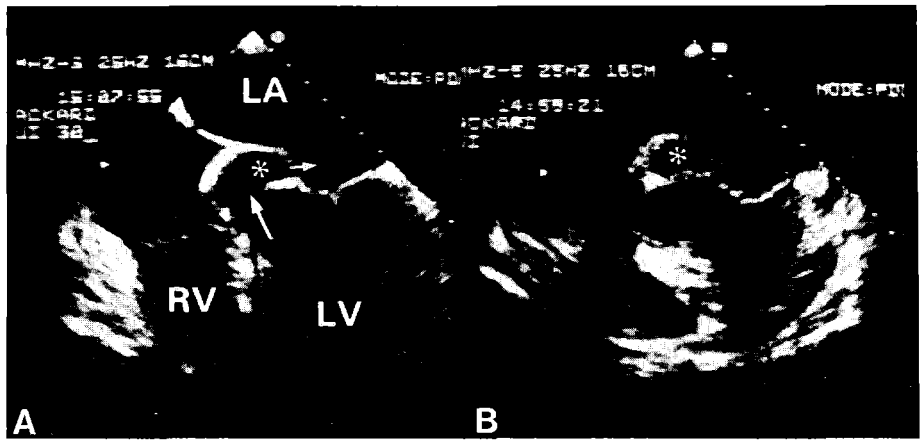


Fig. 3 Transesophageal echocardiographic systolic still frame (A, B) from a patient with native mitral valve endocarditis (Table I, case 12). A, A subannular (to the aortic junction) mycotic aneurysm (asterisk) with a fistulous connection of the left ventricular outflow tract (large arrow) via the aneurysm into the left atrium (LA, small arrow). B, Slight superior tilting of the transducer showed there was communication between the aneurysm and left ventricle or left atrium. LV = left ventricle; RV = right ventricle.

Native valve endocarditis

Transesophageal echocardiography detected many more vegetations in patients with native valve endocarditis (86%) than precordial echocardiography (28%). Complications too were more often detected with transesophageal echocardiography (48%) than precordial echocardiography (20%).

Five distinct pathologic features in native mitral valve endocarditis were seen only with transesophageal echo-cardiography only. These were a) mitral stenosis with vegetations; b) myxomatous degeneration of leaflets with vegetations; c) cordal rupture with vegetations and d) without vegetations; and e) mycotic aneurysm with fistulous connection (Fig. 3).

Similarly, in patients with aortic valve endocarditis high resolution images depicted vegetations on a bicuspid aortic valve. The precise origin and outline of mycotic aneurysms were clearly visualized.

Prosthetic valve endocarditis

Transesophageal imaging visualized the pathology of the infective process in all patients whereas precordial echocardiography was successful in only a third. This is not surprising because in the presence of a prosthetic valve the transesophageal approach avoids ultrasonic shadowing by the prosthesis. In four

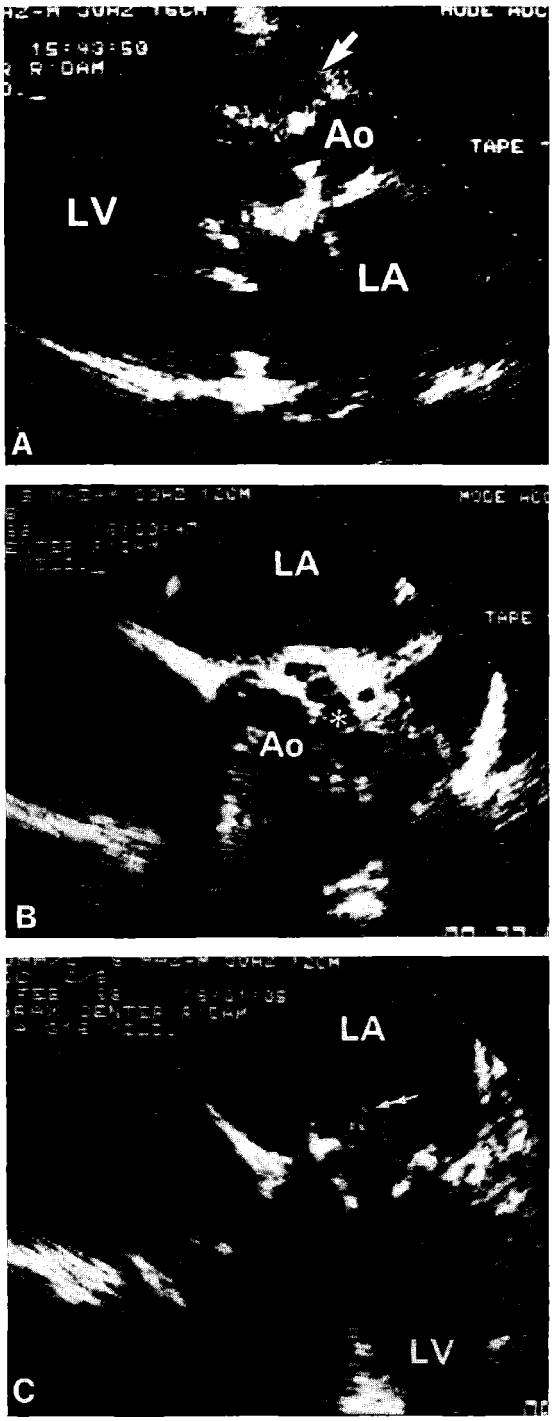

Ao
LV
LA
A
LA
Ao
B
LA
LV
C

Fig. 4 Precordial (A) and transesophageal (B, C) systolic still frames from a patient with triple valve replacement and infective endocarditis (Table 3, case 12). A, A mycotic aneurysm (arrow) anterior to the aortic Björk-Shiley prosthesis was characterized by an echolucent area. B, Posterior to the aortic prosthesis a mycotic aneurysm was observed (asterisk). C, There were additional flail leaflets (arrow) of the Hancock mitral prosthesis. Ao = aorta; LA = left atrium; LV = left ventricle.

patients with prosthetic valve endocarditis transesophageal echocardiography detected vegetations that were not depicted by the precordial approach.

Complications at the valve ring of a mitral prosthesis (Fig. 1) or posterior portion of the aortic prosthesis (Fig. 4) are well displayed by transesophageal echocardiography.

But in patients with an aortic valve prosthesis the anterior aortic root is best visualized by the precordial approach. This observation is highlighted in two patients (Table III, patients 9 and 12) in whom precordial echocardiography showed evidence of a mycotic aneurysm anteriorly situated to an aortic prosthesis (Fig. 4). Transesophageal echocardiography did not identify this pathology, though a mycotic aneurysm in the posterior valve ring was diagnosed only by this technique (Fig. 4).

Conclusion

Transesophageal echocardiographic images were diagnostic and allowed appropriate clinical management in all patients. The technique was often very useful where clinical features suggested endocarditis and precordial echocardiographic imaging was either equivocal or negative.

We think that transesophageal echocardiography is the best diagnostic approach in patients with suspected endocarditis of either a native or prosthetic valve.

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CHAPTER 6

Left atrial vascularized thrombus diagnosed by transesophageal cross sectional echocardiography

M.A. Taams[1], E.J. Gussenhoven[1,2], C.T. Lancée[1]

[1]Thoraxcenter, Erasmus University and University Hospital Rotterdam;
[2]the Interuniversity Cardiology Institute of The Netherlands.

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Abstract

This report describes a patient with a Björk-Shiley mitral valve prosthesis in whom transesophageal cross sectional echocardiography revealed a large vascularized mass within the left atrial appendage with smoke-like opacification of blood flow in the left atrium. Transesophageal cross sectional echocardiography gave a detailed image of the lesion which was unobtainable with precordial cross sectional echocardiography.

Introduction

Left atrial thrombi are common in patients with low cardiac output and are predominantly situated in the left atrial appendage [1]. Precordial cross sectional echocardiography is the technique of choice for the identification of intracardiac mass lesions. However, the left atrial appendage is difficult to visualize and morphological details are rarely obtained [2]. Transesophageal echocardiography offers the potential of imaging this cardiac area in detail [3,4].

We describe the role of transesophageal cross sectional echocardiography in the detailed analysis of a left atrial vascularized thrombus.

Case Report

A 66-year-old woman was admitted with congestive cardiac failure and central cyanosis. In 1976 the mitral valve had been replaced with a spherical 25 Björk-Shiley prosthetic valve because of severe mitral valve stenosis and moderate regurgitation. She had had atrial fibrillation for many years. Five months before admission a VVI pacemaker was implanted because long periods of asystole and rapid paroxysmal atrial fibrillation were causing symptoms. Three weeks before admission she had noticed increasing fatigue and general malaise. On admission she was in New York Heart Association functional class IV and was taking digoxin, diuretics, and oral anticoagulants.

On physical examination she had orthopnea and was afebrile. The blood pressure was 170/60 mm Hg and the pulse rate 90 beats/minute. Jugular venous pressure was elevated. A strong right ventricular lift was palpated at the left sternal border. A loud pulmonary closure sound was heard. The prosthesis produced crisp metallic opening and closing clicks. There was no mitral incompetence but there was a grade III/VI tricuspid murmur. The liver was enlarged 5 cm below the costal margin. There was no peripheral edema. There were no physical signs of endocarditis or of peripheral embolization. The electrocardiogram showed atrial fibrillation and right ventricular hypertrophy. The cardiothoracic ratio on the chest x-ray was 0.66 and there were signs of pulmonary congestion.

While she was on oxygen support arterial blood gas analysis showed severe hypercapnea, hypoxemia, and low oxygen and carbon dioxide saturations. Routine laboratory investigations were within normal limits. There were no signs of hemolysis. Emergency right heart catheterization showed pulmonary hypertension (64/24 mm Hg), a raised pulmonary capillary wedge pressure (27 mm Hg) and mean right atrial pressure (12 mm Hg), and a low cardiac index (2.6 $1/min/m^2$).

Precordial cross-sectional echocardiography with a 3.5 MHz transducer showed left atrial dilatation with a left atrial dimension of 100 mm; the left ventricle was of normal size with good contractility. Continuous wave Doppler investigation showed an early diastolic velocity of 2.3 m/s over the prosthesis and a mean velocity of 1.8 m/s. She improved dramatically on intravenous vasodilators, diuretics, and oxygen. Repeat catheterization after two weeks showed that right and left cardiac pressures had dropped to normal. The cardiac index was 1.8 $1/min/m^2$. There was no mitral valve incompetence. No gradient was found over the mitral prosthesis and at screening disc motion seemed

unimpaired. There was grade 2 aortic incompetence. The coronary arteries appeared normal. Cineangiography showed that the atrial branch of the left coronary artery supplied a mass lesion within the left atrium (Fig. 1) but gave no specific details about the mass. A repeat continuous wave Doppler study showed that the mean velocity over the valve prosthesis had dropped to 1.1 m/s.

Because precordial echocardiography gave an image of unsatisfactory quality, we decided to use transesophageal echocardiography to obtain more details about the nature, extent, and location of the mass. We used a 5.6 MHz transducer (64 elements) mounted on an Olympic gastroscope and interfaced with a commercially available ultrasonograph [4]. The inter-element spacing of the individual elements is 210 μm, so that the active area of the transducer resembles the active area of precordial 5 MHz phased array transducers. The housing of the esophageal transducer is much smaller than that of the precordial transducer.

The Björk-Shiley prosthesis and disc showed no apparent abnormalities and its motion was undisturbed. The enlarged left atrial cavity was completely filled with echoes swirling in phase with the inflow of blood from the pulmonary veins (Fig. 2). From the dilated left atrial appendage a mass emerged into the left atrial cavity along the lateral wall, reaching the orifices of the left pulmonary veins. In cross-section the lesion measured approximately 20 x 80 mm. Within this lesion there were several echo-free spaces (Fig. 2). The image of the mass suggested a thrombus. The favorable clinical course and improvement of the non-invasive and invasive data suggested tat the patient's condition was the result of intermittent valve obstruction produced by dislodged thrombus. We therefore decided to operate. We found a large organized thrombotic mass attached to the left atrial lateral wall and partially obstructing the entrance of the left pulmonary veins. The patient's postoperative course was uneventful. Microscopy showed typical thrombus material with fibrin layers and scar tissue containing small and medium-sized vessels. The left atrial endocardium consisted of elastic fibers mixed with scar tissue, and the myocardium was collagenous with scattered elastic tissue.

Discussion

Echocardiographic imaging of circulating blood in the left atrium has been described in obstructive mitral valve disease [5,6]. The low shear rates associated with low blood flow favour rouleaux formation [7,8] and predispose to

thrombus formation [6]. Our patient had scattered echoes from the atrial blood pool and an abnormal mass in the left atrium. Doppler, cardiac catheterization studies, and surgical inspection showed no evidence of mitral valve obstruction. The possible presence of concomitant aortic regurgitation was obscured by the diastolic inflow Doppler signal over the mitral valve prosthesis. We assume that the echogenicity of the atrial blood was caused by the low blood flow created by the aneurysmal left atrial dilatation that in turn was the result of longstanding mitral valve disease before valve replacement and by low cardiac output. This might have been the result of the partial loss of atrial muscular fibers that was confirmed at postoperative microscopic investigation. This resulted in progressive left atrial enlargement and impaired atrial function. In 1955 Bailey described a similar condition of the right atrium.

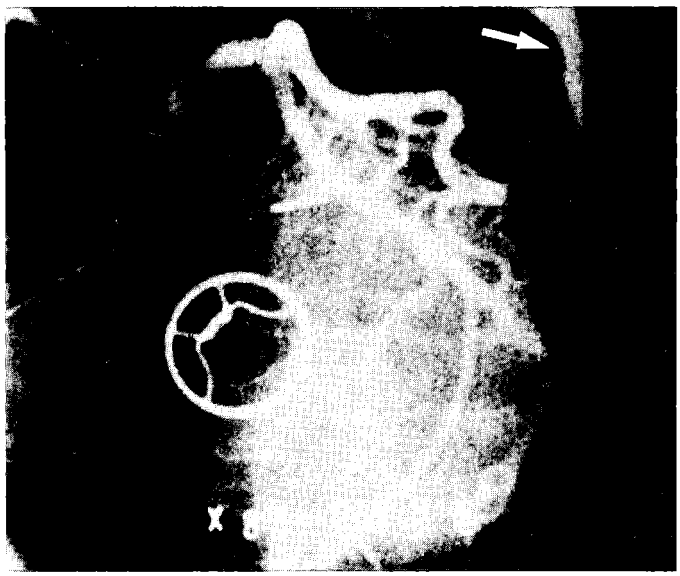
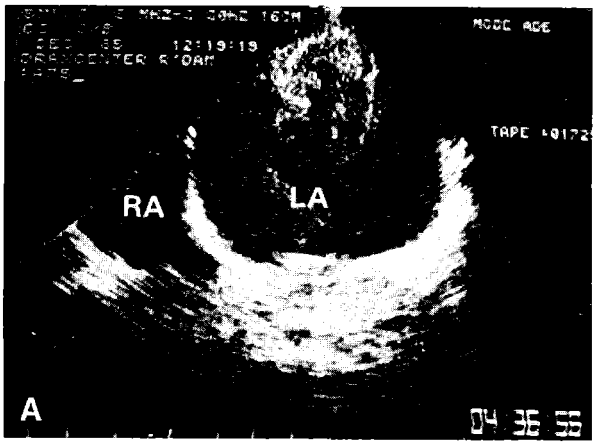


Fig. 1 Left coronary artery angiogram showing a vascularized structure in the left atrium (arrow).

Fig. 2 Transesophageal cross sectional echocardiograms taken at the level of the left atrium (LA) showing numerous micro-echoes in the dilated left atrium (A). Blood flow coming from the pulmonary veins had immediate effect on the microbubble movement. A slight tilt of the transducer revealed a mass attached to the left atrium lateral wall (B; open arrow) which emerged into the left atrial appendage (C; arrows). Oblong echo-free spaces were visible within this mass (arrow 1; 2). Ao = aorta; RA = right atrium; MV = mitral valve prosthesis.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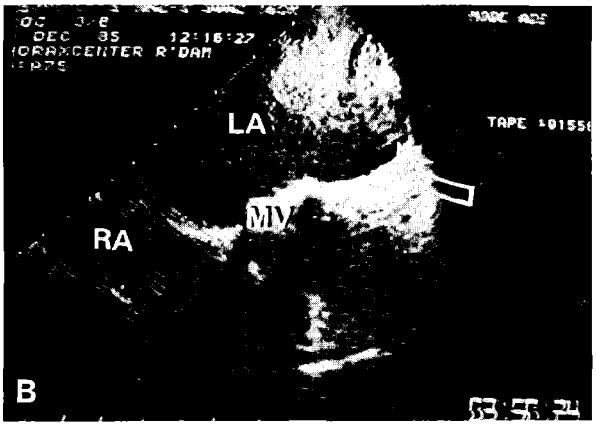
LA
A


LA
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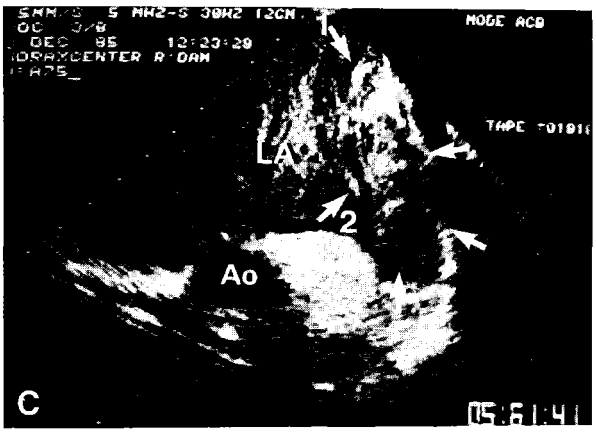
1
LA
2
Ao
C

Because attenuation along the ultrasound propagation path is much reduced by transesophageal echocardiography a high frequency transducer can be used. High frequency improves resolution and also increases the sensitivity for back-scattering. In particular small particles will produce a back-scattering signal with an intensity (I) which shows a strong non-linear relation with frequency (f), where $I \div f^4$ [10]. Thus the sensitivity for objects producing back-scattering will increase with frequency.

Under normal conditions increased back-scattering in blood at diagnostic frequencies (2-5 MHz) can only be explained by an increase in the ratio of blood particle size to wavelength. The mechanism for this increase in particle size must be an aggregation of blood cells associated with low blood flow. A high frequency transesophageal transducer will therefore detect stagnant blood flow more effectively than precordial examinations at lower frequencies [11]. There are two possible explanations why precordial echocardiography failed to image the lesion. Firstly the position of the esophageal transducer results in a much better signal to noise ratio than the precordial position. Also the position of the thrombus in relation to the precordial acoustic window may hamper adequate imaging. The high resolution images also showed oblong echolucent areas within the lesion that indicate vascularization of this lesion, which was also noted on the angiograms.

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CHAPTER 7

Detection of left coronary artery stenosis by transesophageal echocardiography

M.A. Taams[1], E.J. Gussenhoven[1,2], J.H. Cornel[1], S.H.K. The[1], J.R.T.C. Roelandt[1], C.T. Lancée[1], M. v.d. Brand[1].

[1]Thoraxcenter, Erasmus Univerity and University Hospital Rotterdam; [2]the Interuniversity Cardiology Institute of The Netherlands.

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Abstract

The ability of transesophageal echocardiography to visualize the left coronary artery was retrospectively analyzed in 60 consecutive patients without clinical evidence of coronary artery disease. The left main coronary artery was visualized in 56 patients, the proximal circumflex in 34 patients and the proximal anterior descending artery in nine patients. Patency of these arteries was established in all these patients. Subsequently, a prospective study was undertaken in 23 patients with angiographically proven left coronary artery disease. Both the left main coronary artery and the circumflex artery were adequately visualized with transesophageal echocardiography in all 23 patients, whereas the anterior descending artery was identified in three patients. The extent of stenosis in the left main coronary artery and the circumflex artery was correctly diagnosed in 18 patients. In five patients the degree of stenosis was overestimated. These findings indicate the potential of transesophageal echocardiography to detect or exclude stenosis of both the left main coronary artery and circumflex artery.

Introduction

Non-invasive methods to diagnose proximal left coronary artery disease would have major clinical advantages [1-4]. Several investigators have advocated the use of precordial cross-sectional echocardiography for visualization of the left main coronary artery (LMCA) and to assess its patency [5-8], but the success rate of imaging this artery is limited, ranging from 57 to 86% [3-6,9,10]. Moreover, the image quality is generally sub-optimal, particularly in the presence of chronic pulmonary disease, obesity, prosthetic valves or chest-wall changes due to old age. Therefore, diagnostic conclusions are rarely possible. To evaluate the efficacy of transesophageal echocardiography (TEE) in the detection of proximal left coronary artery disease the recordings of 60 consecutive patients without coronary artery disease were analyzed retrospectively; subsequently 23 patients with angiographically proven left coronary artery disease were studied prospectively.

Methods

Approval from our Committee on Human Research was granted and informed consent was obtained from each patient.

The first study group included 60 consecutive patients, studied retrospectively, without clinical evidence of coronary heart disease (28 females and 32 males; aged 13-86 years; mean 52 years). These patients were referred for TEE because their precordial echocardiographic study was inadequate and/or because cardiac catheterization was inconclusive or was not considered necessary. In eight patients coronary angiograms obtained not more than eight months previously (mean three months) were available.

The second group comprised 23 prospectively studied patients with angiographically proven left coronary artery disease (five females and 18 males; aged 40-74 years; mean 64 years). The patients were studied with TEE following coronary artery bypass grafting (mean interval 15 days).

A 5.6 MHz 64-element phased array transducer mounted on the tip of an Olympus gastroscope (GIF P3, diameter 9 mm) was used. The transducer was interfaced with a Hewlett-Packard ultrasonograph (HP 77020AC) [11].

Premedication (2.5 mg midazolam hydrochloride i.m.) was given only to patients in the second group. The patients were investigated lying in the left supine position. With the transducer facing the left atrium, tomographic cross-

sections of the left coronary artery were obtained by carefully tilting the transducer using the controls of the gastroscope.

Data Analysis and Scoring
The transesophageal echocardiograms and coronary angiograms were interpreted with consensus of opinion by two independent observers without knowledge of the patients's identity or clinical course. The echocardiographic and angiographic data were compared.

Echocardiographic Analysis
The LMCA was identified at the base of the aorta, originating from the aorta lumen (Fig. 1). The left circumflex (CX) and left anterior descending coronary artery (LAD) were considered adequately visualized when at least 20 mm of these arteries distal to the bifurcation could be seen (Fig. 1).

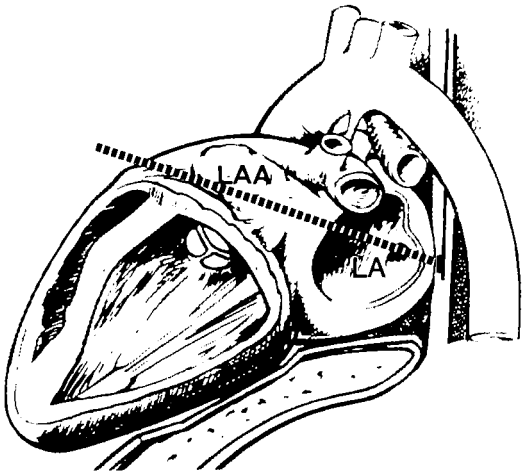
In the absence of bifurcation, visualization of the first 10 mm of the left coronary artery was classified as the LMCA. The degree of coronary artery stenosis was expressed as a percentage of the original lumen as seen proximal or distal to the lesion. Scores were designated as normal, <50% stenosis, 50-90% stenosis, or > 90% stenosis.

Angiographic Analysis
The degree of the LMCA, CX and LAD stenosis was expressed as a percentage of the unobstructed lumen. Scores were designated as normal, <50% stenosis, 50-90% stenosis, or >90% stenosis.

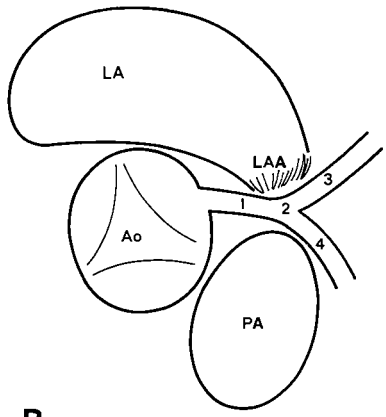
Results

The TEE investigation was completed, without complaints or electrocardiographic changes, in all patients within 10 min. During the examination, the patency of the coronary artery can be established: off-line analysis, however, is necessary to determine the degree of stenosis precisely.

Group 1 (60 patients)
Adequate images of the LMCA were obtained in 56 patients, of the CX in 34 patients and of the LAD in nine patients. Within the coronary arteries no lesions were identified with TEE which was in accordance with the angiographic data available in eight of these patients.



A



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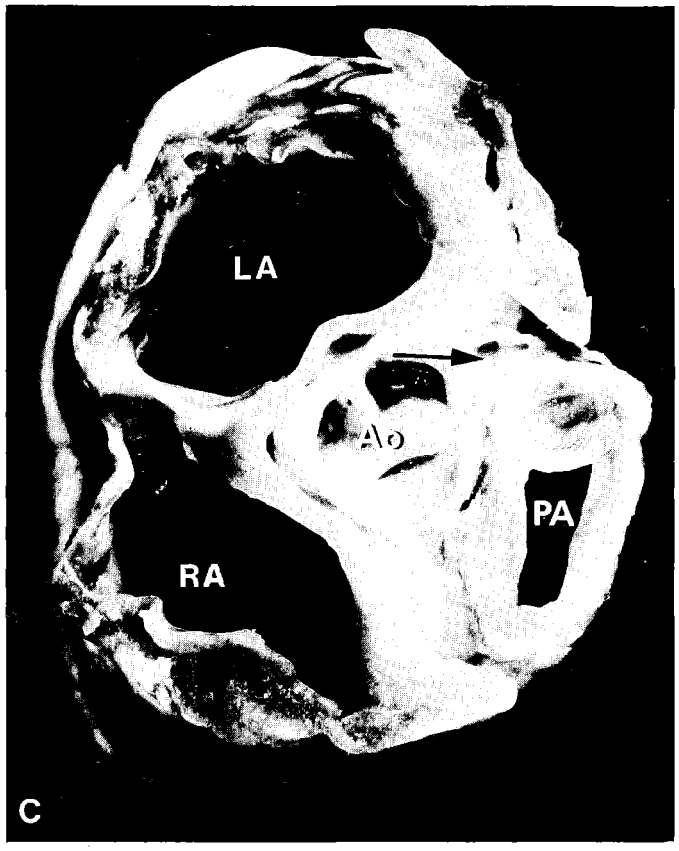

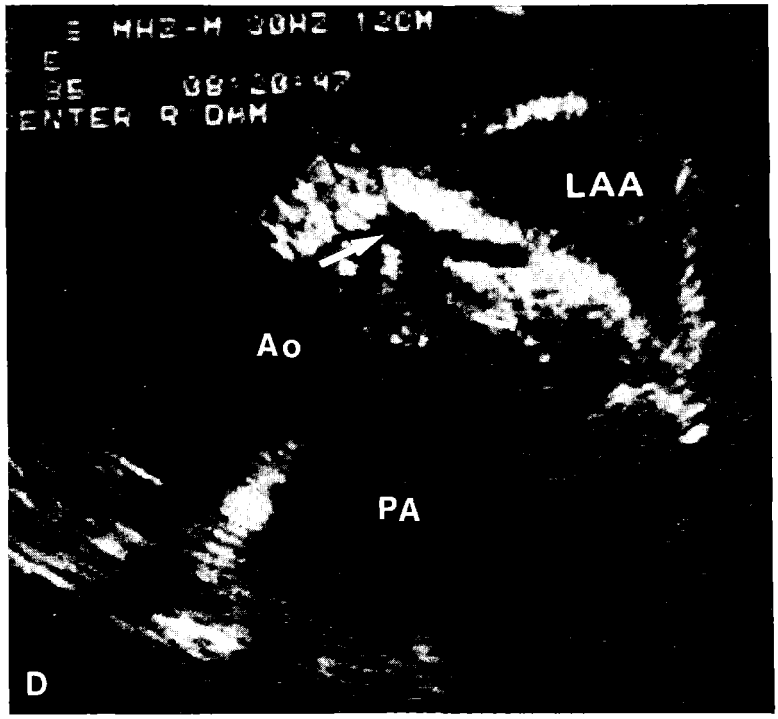

Fig. 1 A-B, Diagrams illustrating the plane of the echocardiographic section at the base of the aortic root and valve using the left atrium (LA) as the acoustic window. B, The left main coronary artery (1), together with its bifurcation (2) into the left circumflex (3) and left anterior descending coronary artery (4). C-D, The corresponding anatomical and echocardiographic cross-sections; the left main coronary artery is indicated by the arrow. LAA = left atrial appendage; RA = right atrium; Ao = aorta; PA = pulmonary artery.

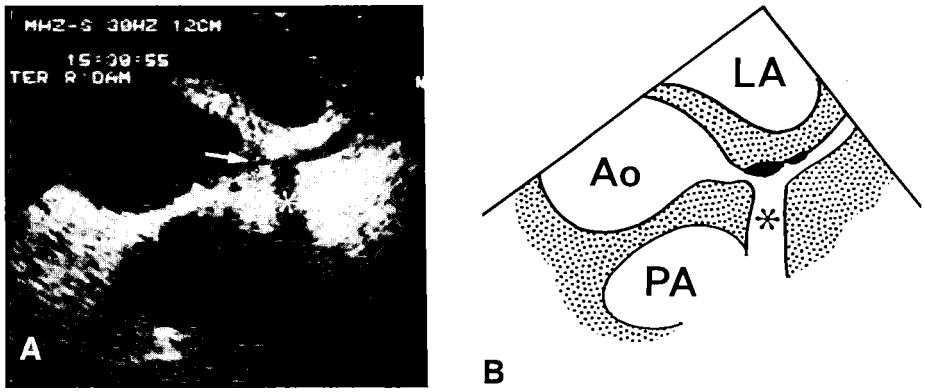

Fig. 2 Transesophageal echocardiogram (A) and the corresponding diagram (B) showing a 50-90% stenosis of the left main coronary artery (arrow; compare with Fig. 1-D). Note the absence of echoes posterior to the highly relective structure present in the coronary artery (asterisk). LA = left atrium; Ao = aorta; PA = pulmonary artery.

Group 2 (23 patients)

In all 23 patients both the LMCA and the CX were adequately imaged up to the left lateral atrioventricular junction. The LAD was visualized in three patients. Estimation of the degree of stenosis of the LMCA was in accordance with the angiographic data in 22 patients: patent in five, <50% stenosis in two, 50-90% stenosis in 13, and >90% stenosis in two patients (Figs 2 and 3). In one patient a discrepancy was noted in the assessment of the severity of the stenosis: TEE overestimated the degree of stenosis by one score. The degree of stenosis of the CX, interpreted from the TEE images, was in accordance with the angiographic data in 18 patients: normal calibre in nine, 50-90% stenosis in six, and >90% stenosis in three patients (Fig. 4). In five patients the degree of stenosis was overestimated by one score.

An LAD stenosis was correctly assessed by transesophageal analysis in one patient and in two other patients the degree of stenosis was underestimated by one score when compared to the data derived from the coronary angiograms.

Discussion

Despite initial optimism [5-7], widespread use of precordial cross-sectional echocardiography for visualization of the proximal left coronary arteries has been unsatisfactory and the success rate of these studies, even in experienced hands, is limited [2-4]. Although one study reports a success rate of 99% in

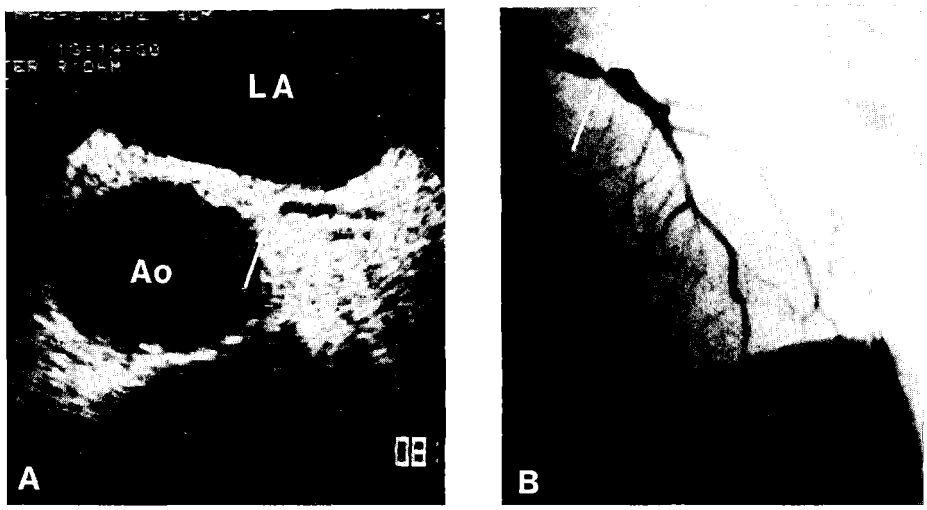

Fig. 3 Transesophageal echocardiogram (A) and the corresponding coronary angiogram (B) showing a 90% stenosis of the left main coronary artery (arrow). Ao = aorta; LA = left atrium.

imaging the LMCA [7], other studies have not achieved comparable success rates [3-6,9]. This is reported to be attributable to inadequate precordial imaging and to cardiac motion [2,6,7,9,10]. Attempts to improve the sensitivity and specificity in the detection of stenosis of the left main coronary artery by viewing still-frame images [2] or image-processing techniques [7,9] have also proved to be hampered by inadequate precordial images.

TEE offers a unique alternative approach [11,12]. The proximity of the transducer relative to the structures of interest and the absence of intervening chest-wall structures allow the application of a higher ultrasound frequency. This results in a better spatial resolution and hence more detailed structure imaging of the left coronary artery. The high success rate of imaging the patency of the LMCA in 60 patients studied retrospectively, supports the validity of this approach.

Thus, in contrast to conventional precordial echocardiography, transesophageal echocardiography permits a reliable visualization of the LMCA and the CX. Conversely, the ability to identify the LAD by this approach is limited as this artery disappears from the interrogating cross-sections. The results of the prospective study, which was primarily focused on the identification of the left coronary artery, revealed a 100% success rate in visualizing both the LMCA and the CX. The degree of stenosis of the LMCA and CX as determined by the

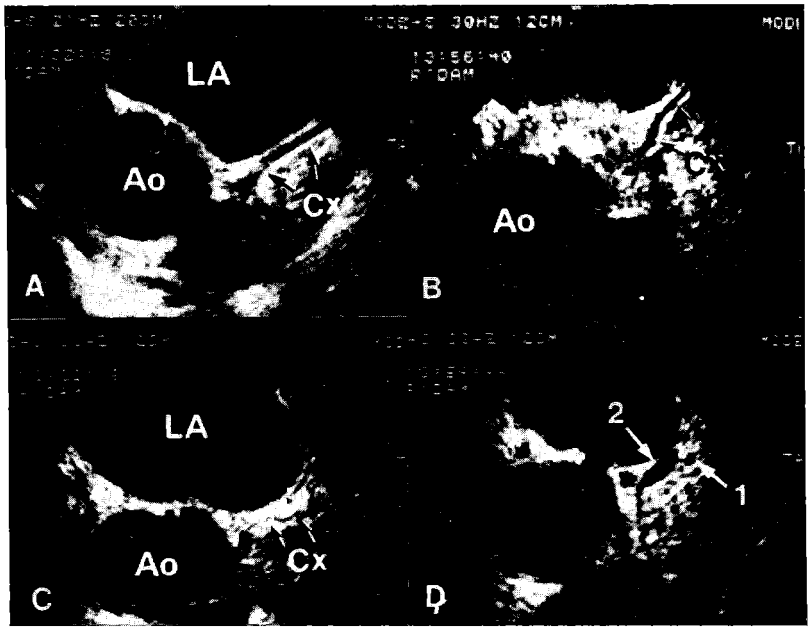

Fig. 4 Transesophageal echocardiograms showing the circumflex (CX) artery with a normal (A), a 50-90% stenosis (B), and > 90% stenosis (C). D, Fallacious echoes resulting from the great cardiac vein (arrow 2) may mimic a patent circumflex artery (arrow 1). LA = left atrium; Ao = aorta; CX = left circumflex artery.

esophageal approach was correctly assessed in the majority of patients. Overestimation, which occurred in five patients (both of the LMCA and CX in one patient and of the CX in four patients), is related to the resolution of the ultrasound technique. Similarly to the retrospective study, the prospective study also showed that the LAD was less amenable to visualization by the TEE approach.

Several important pitfalls in analyzing the coronary arteries using TEE images warrant attention. Visualization of a small amount of pericardial effusion between the left atrium and the aortic root may result in a confusing pattern of parallel linear echoes which mimic a coronary artery. Therefore, the identification of the LMCA and CX should be judged as positive only when the continuity of its lumen with the aorta is identified.

Fallacious echoes from the great cardiac vein should not be confused with the CX artery (Fig. 4). In addition, calcium deposits within the LMCA may result in absence of echoes posterior to the lesion, suggesting a patent LAD (Fig. 2). Experience and training in examining these structures is an important factor even with high-quality images from the TEE approach.

In summary, these results support the use of TEE as a screening method for the exclusion or detection of, especially, LMCA and CX stenosis, particularly when non-invasive tests are not diagnostic or are conflicting.

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Summary

The work in this thesis represents the evaluation of transesophageal echocardiography for decision making in clinical cardiology.

Chapter 1 presents a review of the developments in invasive and semi-invasive transducer technology, followed by information on prototypes of transesophageal phased array transducers, developed and clinically evaluated at the Thoraxcenter of the University Hospital Rotterdam. The normal transverse tomographic cardiac anatomy, viewed from the esophageal approach, is described. The examination technique, indications, contraindications, limitations and safety procedures of transesophageal echocardiography are discussed, along with technical perspectives, physician training and the Thoraxcenter experience.

In Chapter 2 the diagnostic value of transesophageal echocardiography for solving clinical problems is reviewed in adult patients with acquired heart disease in whom precordial echocardiography and/or angiography were inconclusive. Patients belonging to several diagnostic categories were studied, including: valvular or subvalvular aortic disease, thoracic aorta disease, native and prosthetic valve endocarditis, prosthetic valve dysfunction, intracardiac mass lesions and pulmonary/systemic embolism. Diagnoses made by transesophageal echocardiography were confirmed at surgery in most patients.

In Chapter 3 the unique value of transesophageal echocardiography for diagnosing thoracic aorta pathology is shown in 30 patients operated for aortic dissection or aneurysm. Transesophageal echocardiography established the DeBakey type of dissection in 14 of 15 patients. In all 15 patients with an aneurysm of the thoracic aorta the type of aneurysm could be differentiated. It is established that standard radiological methods have drawbacks; being time-consuming and employing contrast agents which are potentially hazardous for these critically ill patients. In contrast, transesophageal echocardiography is a safe and rapid procedure which can be performed at the bedside. Patients with acute aortic dissection have a 2% mortality rate per hour the first 24 hours if unoperated, thus rapid diagnosis is essential. A limitation of transesophageal echocardiography for visualization of thoracic vascular pathology became evident; involvement of the cephalic arteries was not always demonstrated with certainty. Additional independent information on the aortic arch vessels can be obtained with either conventional ultrasound or angiography. Although visua-

lization of the midportion of the ascending aorta can be concealed by the interposed right main bronchus, evaluation of the pathology of the thoracic aorta was not hindered. Thorough knowledge of the physics of ultrasound is mandatory to avoid false positive diagnoses of aortic dissection. The unique role of transesophageal echocardiography with integrated Doppler technique for diagnosing complex thoracic aorta pathology is exemplified in a case report. Finally, Chapter 3 presents the results of transesophageal echocardiographic examinations performed from January 1988-June 1989 in patients referred to our unit with (or suspected of) thoracic aorta pathology. Reasons for the increasing use and diagnostic value of transesophageal echocardiography in these patients are also discussed.

Chapter 4 presents the results of transesophageal color flow imaging to study mitral regurgitation in normal subjects, cardiac patients with a native valve, patients with clinically a normal functioning Björk-Shiley mitral prosthesis and patients with angiographically and/or surgically proven periprosthetic Björk-Shiley mitral valve regurgitation. It was found that transesophageal Doppler color flow imaging is extremely sensitive for the detection of mitral regurgitation. Two types of holosystolic mitral valve regurgitant flow jets were observed in both the native valve and Björk-Shiley prosthesis: type I, normal backflow observed in the healthy mitral valve as well as "physiologic" closure and leakage backflow in the normal functioning Björk-Shiley prosthesis; type II, pathologic mitral regurgitation. Our findings indicate that for detection of pathologic mitral regurgitation of the native mitral valve, transesophageal color flow imaging offers no substantial advantage over precordial continuous wave or color flow imaging. In patients with periprosthetic regurgitation, however, transesophageal color flow imaging was always superior to precordial examinations as the regurgitant jet in the left atrium is unobscured by the prosthesis. Although qualitative assessment of the degree of severity is feasible, quantitation with both approaches remains elusive.

In Chapter 5 the value of transesophageal echocardiography in patients with clinically suspected endocarditis is presented. Precordial echocardiography and angiography have limitations for studying the atrial surface of the mitral valve, especially in the presence of calcified or artificial heart valves. Transesophageal echocardiography offers an attractive alternative diagnostic approach for studying this potentially life-threatening disease. In patients with both native and prosthetic valve endocarditis, transesophageal echocardiography detected more vegetations as well as complications of the infective process than precordial echocardiography. Complications noted with transesophageal echocardiogra-

phy include: cordal rupture, cusp perforation, mycotic aneurysm, fistulation, valve dehiscence and abscess formation. A mycotic aneurysm posteriorly situated at the ring of an aortic prosthesis cannot be imaged from the precordium, while the transesophageal approach circumvents intervening cardiac prostheses and avoids the "ultrasound shadowing" due to prosthetic material. Conversely, the anterior aortic route remains best visualized from the precordium in the presence of an aortic prosthesis in patients without thoracic imaging limitations. From this study it was concluded that transesophageal echocardiography is the diagnostic method of choice in patients with suspected infective endocarditis of either a native or prosthetic valve.

Atrial appendages are rarely well-imaged with precordial echocardiography and image quality of these structures is often insufficient for morphologic analysis. In Chapter 6 the advantages of transesophageal echocardiography for study of the left atrium are demonstrated in a case report.

Chapter 7 presents a study on the potential of transesophageal echocardiography to visualize the proximal left coronary artery. This was evaluated, retrospectively, in 60 consecutive patients with no clinical evidence of coronary artery disease and, prospectively, in 23 consecutive patients with angiographically proven coronary artery disease. The degree of coronary artery stenosis was expressed as a percentage of the original lumen. The results of the retrospective study showed adequate imaging of the left main coronary artery (LMCA) in most patients, often including the circumflex artery (CX). The proximal left anterior descending artery was rarely imaged. These findings are explained by the physics of ultrasound and the coronary anatomy. The prospective study primarily focused on the proximal left coronary artery and resulted in a 100% success rate in visualizing both the LMCA and CX. In 96% of patients, coronary angiography and transesophageal echocardiography concurred in assessing the severity of LMCA stenosis. In 78% of patients, coronary arteriography and transesophageal echocardiography concurred in assessing the severity of CX stenosis. Pitfalls in the analysis of transesophageal echocardiographic images of coronary arteries are stressed.

The information from this study suggests that visualization of the proximal left coronary artery as an integral part of a transesophageal study is feasible. With further refinements, standardization may be possible and reach clinical usefulness in selected or specific conditions.

Samenvatting

Deze dissertatie behandelt de toepassing van transoesofagale echocardiografie voor het maken van klinische beslissingen in de cardiologie.

Hoofdstuk 1 geeft een globaal overzicht van de ontwikkelingen in invasieve en semi-invasieve transducer technologie. De prototypes transoesofagale phased-array transducers waarmee patiënten werden onderzocht zijn ontwikkeld en klinisch geëvalueerd in het Thoraxcentrum van het Academisch Ziekenhuis Rotterdam. De cardiale anatomie waargenomen vanuit de slokdarm wordt beschreven alsmede de uitvoering van het onderzoek, indicaties, contraindicaties, beperkingen, veiligheids-procedures, technische toekomstperspectieven en training. Tot slot volgt een overzicht van de ervaring met transoesofagale echocardiografie opgedaan in het Thoraxcentrum.

Hoofdstuk 2 geeft een overzicht van de diagnostische waarde van transoesofagale echocardiografie in het oplossen van klinische problemen bij volwassen patiënten met een verworven hartziekte bij wie precordiale echocardiografie of angiografie niet diagnostisch waren. De diagnostische voordelen van transoesofagale echocardiografie worden aangegeven bij patiënten met de volgende aandoeningen: valvulaire en subvalvulaire aortaklep pathologie, thoracale aorta pathologie, natieve- en kunstklep endocarditis, kunstklep dysfunctie, cardiale ruimte-innemende processen en in de anamnese systeem- of longembolieën. Bij het merendeel van de patiënten werd de d.m.v. transoesofagale echocardiografie verkregen diagnose bevestigd bij operatie.

In hoofdstuk 3 wordt de unieke diagnostische waarde van transoesofagale echocardiografie voor thoracale aorta pathologie besproken aan de hand van 30 patiënten die geopereerd werden wegens een thoracale aorta dissectie of aneurysma. Het type aorta dissectie werd bij 14 van de 15 patiënten correct vastgesteld. Bij alle 15 patiënten met een aneurysma kon correct het type aneurysma worden vastgesteld. Een beperking van radiologische technieken is dat deze tijdrovend zijn en röntgencontrast potentieel schadelijk is voor ernstig zieke patiënten verdacht van aorta dissectie. Daarentegen is transoesofagale echocardiografie een veilige en snelle onderzoeksmethode die aan het bed kan worden uitgevoerd. Zonder operatie hebben patiënten met een acute aorta dissectie een mortaliteit van 2% per uur in de eerste 24 uur; snelle diagnostiek is dus van levensbelang. Transoesofagale echocardiografie heeft echter ook zijn beperking voor de visualisatie van thoracale aorta pathologie. Immers niet altijd kon

uitbreiding van de dissectie in relatie tot de hoofd-hals vaten worden aangetoond. Aanvullende informatie over de hoofd-hals vaten kon worden verkregen middels conventionele echografie of angiografie. Hoewel visualisatie van het middelste deel van de aorta ascendens vanuit de slokdarm kan worden belemmerd door de tussenliggende rechter hoofdbronchus, was het in dit onderzoek geen beperking voor de evaluatie van de aorta pathologie. Kennis van de fysica van geluidsgolven met ultrahoge frequentie kan valspositieve diagnostiek van aorta dissectie voorkomen. De waarde van transoesofagale echocardiografie gecombineerd met Doppler techniek voor de diagnostiek van gecompliceerde thoracale aorta pathologie wordt verder geillustreerd met een patiënt-voorbeeld. Tot slot wordt een overzicht gegeven van de resultaten van transoesofagale echocardiografisch onderzoek verricht bij patiënten verdacht van thoracale aorta pathologie onderzocht in de periode januari 1988 - juni 1989. Er worden redenen aangegeven voor de toegenomen toepassing en de diagnostische waarde van deze techniek bij deze groep patiënten.

In hoofdstuk 4 worden de resultaten beschreven van de toepassing van transoesofagale kleuren Doppler echocardiografie voor de bestudering van de mitralisklep bij gezonde vrijwilligers, bij patiënten met een natieve mitralisklep, en bij patiënten met een Björk-Shiley mitralisprothese. Er werd aangetoond dat transoesofagale kleuren Doppler echocardiografie een zeer gevoelige methode is om mitralisklep insufficiëntie te visualiseren. Twee types holosystolische mitralisklep insufficiëntie jets van zowel de natieve mitralisklep als de Björk-Shiley mitralisprothese werden waargenomen. Type I, fysiologische regurgitatie bij natieve mitraliskleppen en fysiologische sluitingsregurgitatie bij de normaal functionerende Björk-Shiley prothese. Type II, pathologische mitralis insufficiëntie. Het onderzoek toonde aan dat transoesofagale kleuren Doppler echocardiografie geen extra informatie oplevert boven precordiaal continuous wave of kleuren Doppler echocardiografie voor het vaststellen van natieve mitralis insufficiëntie. Voor het visualiseren van mitralis-kunstklep insufficiëntie blijkt transoesofagale kleuren Doppler echocardiografie evenwel superieur te zijn aan precordiale echocardiografie omdat de insufficiëntie jets ongehinderd door prothese materiaal in het linker atrium worden waargenomen.

In hoofdstuk 5 wordt de unieke waarde besproken van transoesofagale echocardiografie bij patiënten met klinische verdenking op infectieuze endocarditis. Diagnostiek van de atriale zijde van de mitralisklep d.m.v. precordiale echocardiografie en angiografie is beperkt, vooral bij aanwezigheid van een verkalkte klep of kunstklep(pen). Transoesofagale echocardiografie biedt een aantrekkelijke alternatieve diagnostische benadering om deze potentieel levens-

bedreigende aandoening te evalueren. In tegenstelling tot precordiale echocardiografie werden d.m.v. transoesofagale echocardiografie frequenter vegetaties en/of complicaties van het infectieuze proces bij patiënten met een natieve klep of een kunstklep gezien. Het betrof o.a. chorda ruptuur, klep perforatie, mycotisch aneurysma, fistel vorming, klepdehiscentie of abcedering. Een mycotisch aneurysma aan de achterzijde van een aortaklep prothese kan niet vanaf het precordium worden gevisualiseerd, terwijl het onderzoek via de slokdarm niet gehinderd wordt door een slagschaduw veroorzaakt door het prothese materiaal. Daarentegen blijft precordiale echocardiografie bij patiënten zonder beeldvormingproblemen via de thorax de aangewezen methode om de voorzijde van een aortakunstklep te bestuderen. De conclusie van deze studie is dat transoesofagale echocardiografie de diagnostische benadering "par excellence" is wanneer verdenking bestaat op infectieuze endocarditis, bij patiënten met natieve- of kunstklep endocarditis.

Hartoortjes worden zelden goed gezien met precordiale echocardiografie en de beeldkwaliteit van deze structuren is vaak onvoldoende voor morfologische analyse. In hoofdstuk 6 wordt het belang van transoesofagale echocardiografie voor de diagnostiek van linker atrium pathologie geillustreerd aan de hand van een patiënt-voorbeeld.

In hoofdstuk 7 wordt de potentiële waarde van transoesofagale echocardiografie geëvalueerd om de proximale linker coronairarterie zichtbaar te maken. Retrospectieve evaluatie vond plaats bij 60 opeenvolgende patiënten die geen klinische aanwijzingen hadden voor coronaire hartziekte. Prospectief werden 23 opeenvolgende patiënten bestudeerd die angiografisch bewezen coronairlijden hadden. Het percentage coronairstenose werd bepaald door het coronair lumen proximaal en distaal van de stenose te vergelijken.

In de retrospectieve studie werd de linker coronair hoofdstam in de meeste patiënten adequaat gevisualiseerd terwijl de ramus circumflex minder vaak gezien werd. De proximale ramus descendens anterior werd zelden waargenomen. Deze bevindingen kunnen worden verklaard uit de fysica van het ultrageluid in relatie tot de coronair anatomie.

De prospectieve studie, primair gericht op de proximale linker hoofdstam, gaf een succespercentage van 100% voor het visualiseren van de linker hoofdstam en de ramus circumflex. Bij 96% van de patiënten kwamen coronair angiografie en transoesofagale echocardiografie met elkaar overeen in de gradering van een hoofdstam stenose. Wanneer het een circumflex letsel betrof werd deze overeenstemming gevonden bij 78% van de patiënten. Drogbeelden

die bij de analyse van de transoesofagale echocardiografiebeelden van coronair-arterieën parten kunnen spelen worden beschreven.

Ervaring opgedaan in deze studie ondersteunt de bevinding dat visualisatie van de proximale linker coronair arterie, als integraal onderdeel van een transoesofagaal echocardiografisch onderzoek, goed mogelijk is. Met verdere verfijning lijkt standaardisatie mogelijk om de techniek klinisch bruikbaar te maken in geselecteerde patiënten.

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Curriculum vitae

De auteur van dit proefschrift studeerde geneeskunde aan de Erasmus Universiteit te Rotterdam waar in 1972 het artsexamen werd afgelegd. Na het volgen van de stages Inwendige Geneeskunde bij Prof. Dr. C. van der Meer in het Academisch Ziekenhuis van de Vrije Universiteit te Amsterdam en bij Prof. Dr. J.C. Birkenhäger in het Academisch Ziekenhuis Rotterdam Dijkzigt, werd de opleiding tot cardioloog vanaf 1976 gevolgd in het Thoraxcentrum te Rotterdam onder leiding van Prof. P.G. Hugenholtz. Sinds 1979 is hij ingeschreven in het Specialistenregister voor het specialisme Cardiologie.

Daarna volgden aanstellingen in het Baragwanath Hospital te Soweto en het St.Ignatius Ziekenhuis te Breda. Sedert 1985 is hij verbonden als cardioloog aan het Thoraxcentrum te Rotterdam (hoofd, Prof. Dr. J.R.T.C. Roelandt). Diverse publicaties en voordrachten met betrekking tot de klinische en polikliniische toepassing van de transoesofagale echocardiografie vormden de basis voor dit proefschrift.