Value of Transesophageal Color Doppler Echocardiography in the Evaluation of Coronary Artery Anatomy and Blood Flow

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The purpose of this study was to test the efficacy of newly developed biplane transesophageal color Doppler and two-dimensional echocardiography in the evaluation of coronary artery anatomy and blood flow. Using these two techniques, high quality images of the entire main left coronary artery (from the left coronary ostium to the bifurcation of the left anterior descending and circumflex coronary arteries), adequate for assessment of luminal diameter and percent stenosis, were obtained in 34 (89%) out of 38 patients. Transesophageal color Doppler echocardiography visualized coronary blood flow in 32 (84%) of the 38 patients. Transesophageal two-dimensional echocardiography clearly showed significant (50% of greater) narrowing of the coronary lumen in 10 out of 12 patients (sensitivity; 83%) and insignificant narrowing or no abnormalities of the coronary lumen in 23 of 26 normal individuals (specificity; 88%). This preliminary study suggests that biplane transesophageal color Doppler and two-dimensional echocardiography are feasible, noninvasive techniques for imaging the main left coronary artery and blood flow.

Recent advances in transesophageal color Doppler and two-dimensional echocardiography1-9 offer a promising means to circumvent the problems of the conventional transthoracic approach. Without the chest wall intervening between transducer and heart, transesophageal two-dimensional images are generally of high quality. This allows the use of higher frequency transducers and results in much better definition of cardiac structures. The purpose of this study was to test the efficacy of biplane transesophageal color Doppler and two-dimensional echocardiography in the evaluation of coronary artery anatomy and blood flow.

Key words:
Imaging of coronary artery
Biplane transesophageal color Doppler echocardiography

MATERIALS AND METHODS
The study group consisted of 38 consecutive patients referred to our medical center for coronary arteriography for suspected coronary artery disease. Only patients with clinically apparent significant aortic stenosis and those with prior aortic valve replacement were excluded, because of the difficulty in clearly imaging the aortic root in these patients. There were 30 men and 8 women, aged 39 to 68 years (mean 50 years).

Transesophageal echocardiography: Transesophageal echocardiographic studies were performed using an Aloka SSD-870 system with the use of a newly developed transesophageal Doppler probe, which included two 5 MHz transducers (one used for horizontal planes and the other for longitudinal planes) mounted on the end of a flexible endoscope from which the
Fig.1. Transesophageal color Doppler (left) and pulsed Doppler (right) echocardiograms.
Left panel: Short-axis view of the aortic root shows bluish green signals in the main left coronary artery, indicating coronary blood flow. Right panel: When the sample volume is set in the distal main left coronary artery (near the bifurcation of the anterior descending and circumflex coronary arteries), a characteristic biphasic coronary blood flow pattern can be identified. Ao, aorta; LMCA, left main coronary artery.

Fiberoptics had been removed. Patients were conscious at the time of the study and the endoscope was introduced into the esophagus with the patient in the left decubitus position. After the orientational landmark of the aortic valve had been demonstrated at a distance of 30 cm from the patient's teeth, the main left coronary artery was identified by counterclockwise rotation of the endoscope as two parallel echoes. A complete scan of the main left coronary artery was performed by tilting and alternatively withdrawing and advancing the tip of the endoscope. Coronary arteries were looked for on the transesophageal two-dimensional image, under the guidance of color-coded Doppler echocardiography, subsequent magnification of any area of interest providing high resolution of anatomic details. Adequate visualization of the main left coronary artery was considered accomplished if 2 parallel echoes were seen to emerge from the left coronary ostium to the bifurcation of the left anterior descending and circumflex coronary arteries. Real time images were memorized in a cine loop, permitting frame by frame review. Imaging and recording time averaged 10 to 15 min per patient. Stopped frame images were analyzed by two independent observers who were unaware of the patient's data. The diameter of the main left coronary artery was digitized manually. For measurements of the diameter of the main left coronary artery, the values of 5 measurements were averaged. The degree of echocardiographic stenosis was expressed as a percentage of the original lumen and designated as 1) normal, 2) <50%, 3) 50%.

Coronary arteriography: Coronary arteriography was performed by standard catheterization techniques using the Judkins femoral artery approach, and the results were interpreted independently by a separate group of physicians, who had no knowledge of each patient's in-
volvement in our study. Significant stenosis of the main left coronary artery was defined as stenosis causing 50% or greater occlusion, luminal diameter narrowing corresponding to an approximately 70% narrowing of the luminal cross-sectional area.

**Statistical analysis:** Standard methods were used for calculation of sensitivity, specificity, positive predictive accuracy and negative predictive accuracy. Observer variability in our laboratory, in measurements of the diameter of main left coronary artery was determined in 20 randomly selected patients. Average intra-observer variability found to be was 2.7% of the mean value, while average interobserver variability was 3.8% of the mean.

**RESULTS**

Images of at least a part of the main left coronary artery were obtained in all 38 subjects. Satisfactory images of the entire main left coronary artery (from the left coronary ostium to the bifurcation of the anterior descending and

![Fig.2. Transesophageal two-dimensional echocardiogram (short-axis view of the aortic root) from a subject with normal main left coronary artery. The main left coronary artery and left anterior descending and left circumflex coronary arteries can be clearly seen. Ao, aorta; LA, left atrium; LMCA, left main coronary artery; LAD, left anterior descending coronary artery; CX, circumflex coronary artery.](image1)

![Fig.3. Transesophageal two-dimensional echocardiogram (short-axis view of the aortic root) from a patient with significant main left coronary artery stenosis. A narrowed segment (arrows) in the main left coronary artery can be observed. Ao, aorta; LA, left atrium.](image2)

**TABLE 1 TRANSESOPHAGEAL ECHOCARDIOGRAPHIC AND ANGIOGRAPHIC DATA**

<table>
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<th>Angiography</th>
<th>50% ≥</th>
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circumflex coronary arteries), adequate for assessment of luminal diameter and percent stenosis, were obtained using transesophageal echocardiography in 23 (88%) of 26 patients with either less than 50% stenosis or a normal artery, and in 10 (89%) of 12 patients with more than 50% stenosis. Using transesophageal color Doppler echocardiography, coronary blood flow was detected in 32 (84%) of 38 patients. Peak velocity of the coronary blood flow (Fig. 1) was detected in early diastole and ranged from 31 to 102 cm/sec (mean 66 ± 18). Transesophageal echocardiography showed either insignificant (less than 50% stenosis) narrowing or no abnormalities (Fig. 2, Table 1) of the coronary lumen in 34 of the 38 above patients (specificity; 89%), and significant (50% or greater) narrowing (Fig. 3) of the coronary lumen in 10 out of the 12 patients (sensitivity; 83%). If the transesophageal echocardiogram visualized a satisfactory image (the entire main left coronary artery), the sensitivity was 91% and the specificity 100%. The predictive value of an adequate echocardiogram for main left coronary artery disease was 100%.

**DISCUSSION**

This study demonstrates that high quality images of the main left coronary artery and blood flow can be obtained using transesophageal color Doppler and two-dimensional echocardiography. Satisfactory examinations of the entire main left coronary artery were obtained in 89% to 92% of the patients, and the sensitivity of transesophageal echocardiography in the detection of significant main left coronary artery stenosis was 83%, while specificity was 89%.

Diagnosis of main left coronary artery disease is important in the management of patients with symptomatic coronary artery disease. Prediction of main left coronary artery obstruction before coronary arteriography is important in light of the potential for sudden death, or at least greater morbidity, during arteriography in patients with such an obstruction.\(^1\)\(^-\)\(^12\) Several investigators\(^13\)\(^-\)\(^18\) have reported the usefulness of imaging the main left coronary artery and assessing the presence of significant stenosis using transthoracic two-dimensional echocardiography. Weyman et al\(^12\) first described a technique for visualizing the main left coronary artery with two-dimensional echocardiography. They emphasized the need to visualize the lumen of the vessel both proximally and distally to the lesion. Rogers et al\(^14\) used a standard two-dimensional echocardiographic system with signal processing to detect proximal coronary arterial calcifications primarily in the left coronary, proximal left anterior descending, and left circumflex coronary arteries in closed chest patients. The yield of adequate images of the main left coronary artery by transthoracic two-dimensional echocardiography ranges from 57% to 99%.\(^14\)\(^-\)\(^17\) Rogers\(^18\) imaged this vessel in its entirety in only 70% of cases in vitro. Imaging of just the origins of the left anterior descending and circumflex arteries has been more difficult, being reported in 53 and 34% of patients, respectively.\(^14\)\(^,\(^15\)\) Despite the optimism generated by these studies, the technique never became popular. In many cases, the imaging quality is too poor to allow an anatomic evaluation. Some of the difficulties encountered in obtaining adequate coronary artery images using transthoracic echocardiography are those inherent in any echocardiographic study, and include obesity, unfavorable chest wall configuration, chronic obstructive lung disease and advanced age.

During the last few years, transesophageal echocardiography has been shown to provide optimal imaging quality in virtually all patients and all cardiac structures, including the coronary arteries.\(^1\)\(^-\)\(^9\) To our knowledge, however, studies into the evaluation of coronary artery stenosis using transesophageal two-dimensional echocardiography have not been published. Imaging from the esophagus overcomes difficulties in obtaining good image quality though the chest wall, as are encountered in obese patients and those with emphysema. The advantage of the transesophageal over the transthoracic approach in evaluation of main left coronary artery disease are: 1) absence of anatomic obstacles between the ultrasound transducer and the main left coronary artery; 2) nearly perpendicular alignment of ultrasound beam with the main left coronary artery; 3) better resolution characteristics due to use of higher frequency (5 MHz) transducers. These result in a superior recording quality and greater sensitivity in demonstrating the main left coronary artery anatomy. Furthermore, under the guidance of a color-coded flow pattern, the coronary arteries can be easily identified.

Because echocardiographic imaging is tomographic by nature, and because epicardial vessels follow the curving surface of the heart, description of a long portion of a single vessel can only

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be accomplished through use of multiple views, each with a slightly different transducer angulation. Furthermore, the vessels move continuously in and out of the imaging plane in concert with normal cardiac motion, and may only by visible briefly during the cardiac cycle. For any given cardiac cycle the coronary arteries are probably in view less than one-third of the time. Under these circumstances it is difficult to analyze echocardiograms of coronary arteries in real-time. The viewer is distracted by the noncoronary artery information that dominates the recording. Thus, the examiner has to locate, in a tedious frame-by-frame scan of the videotape, those few frames where the coronary arteries are visible. Using the transesophageal approach, the longer examination time is more invasive for the patients. Our present study overcome these problems using digital image processing and cine loop review. Digitizing the ultrasonic examination has simplified the situation dramatically. Those frames that contain the coronary artery images can be isolated more easily once the examination is recorded digitally, and the examiner is not distracted by noncoronary artery images. Playing these frames over in a repetitive fashion gives the examiner an overview of the coronary artery anatomy.

Limitations: Our present study has some important limitations. Although we successfully obtained at least part of the main left coronary artery images in all subjects, views were sometimes limited and complete examination of the entire main left coronary artery was not possible in 4 (10%) of 36 patients. Because only a part of the main left coronary artery was visible in any single view, evaluation of long sections of the main left coronary artery requires piecing together successive views of adjacent segments. Furthermore, transesophageal echocardiography is limited in scanning planes (horizontal and longitudinal views). Variability in the scanning plane inclination may be required to further improve the capability of the transesophageal approach.

REFERENCES