ECHOCARDIOGRAPHY OF LEFT MAIN DISEASE/Rink et al.  719

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ALTHOUGH the effect of coronary bypass surgery on the natural history of coronary artery disease is controversial, there is a consensus that surgery improves life expectancy in patients with left main coronary artery (LMCA) obstruction.1-8 This observation and the usually ominous prognosis for patients with LMCA obstruction* have made the detection of this form of coronary artery disease extremely important. Selective coronary cineangiography provides the only reliable diagnosis of LMCA obstruction despite the efforts of many investigators using a variety of noninvasive techniques.5,9 Thus, a practical noninvasive procedure is needed for detecting or excluding LMCA obstruction.

Since Weyman et al.7 first reported that the LMCA could be detected by two-dimensional echocardiography, there has been increasing interest in using this technique to detect LMCA obstructions.8-10 All of the studies have shown that an LMCA obstruction can be detected by two-dimensional echocardiography.7-10 However, the technical difficulty of this diagnosis renders the echocardiographic examination relatively impractical. The purpose of this study was to determine whether recent technical advances would make two-dimensional echocardiography a practical and reliable means of detecting LMCA obstructions.

Methods

All patients were examined with an Advanced Technology Laboratories 600 B two-dimensional sector scanner. The recordings were analyzed by an

clicks and associated mitral systolic murmurs: emphasis on the billowing mitral leaflet syndrome. Am Heart J 90: 636, 1975


Echocardiographic Detection of Left Main Coronary Artery Obstruction

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SUMMARY Advances in two-dimensional echocardiography have improved the prospects of using this technique to detect left main coronary artery (LMCA) obstruction. Using an echocardiograph that had digital gray scale, a 3-MHz transducer and strobe freeze-frame capability and reviewing recordings on an off-line videotape-vidoe freeze-frame analyzer, we retrospectively examined the LMCA in 72 patients who underwent coronary cineangiography. Angiography showed 50% or greater LMCA obstruction in seven patients. All seven had high-intensity echoes in the walls of the LMCA. The high-intensity echoes were irregularly located in the artery and partially occluded it. The LMCA could frequently be recorded proximal and distal to the obstruction. A blinded observer reviewed 28 randomly selected patients from this group and correctly identified the four patients with LMCA obstruction. There was one true and two questionable false-positive diagnoses. In a prospective study of 31 patients, two independent observers correctly identified the three patients with LMCA obstruction. There were no false negatives, and one observer had one false positive. All of the false positives were in patients with proximal left anterior descending coronary artery obstructions. Echocardiography may be a practical means of identifying patients with the LMCA obstruction.

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off-line videotape-videodisc system developed by Microsonics. Several features of this system facilitate echocardiographic examination of the LMCA. Echocardiograms are displayed digitally, with a wide dynamic range and good gray scale. The high-intensity echoes appear as bright spots on the recording and can be easily distinguished from the surrounding echoes. The standard 3.0-MHz transducer offers better resolution than the usual 2.25-MHz transducer. The strobefreeze-frame feature permits the examiner to examine a certain part of the cardiac cycle. The instrument freezes that particular frame until the same time in the next cardiac cycle. Because the LMCA constantly moves in and out of the examining plane, the strobefreeze-frame greatly improves the examiner's ability to see the coronary artery as it traverses the examining ultrasonic plane by eliminating extraneous echoes. The gray-scale capability of this instrument permits us to take advantage of the fact that atherosclerotic plaques within the coronary arteries produce high-intensity echoes that are easily seen even in the realtime examination.11, 12 The digital display of the gray scale further enhances the examiner's ability to identify the high-intensity echoes by making the differences between the brightness of the echoes more distinct.

The off-line analysis system using both videotape and videodisc recorders permits a detailed analysis of the coronary artery, which was not possible with older videotape systems, which require tedious frame-by-frame analysis. The videotape recorder used in this study can scan the recording at twice normal speed, which reduces the analysis time.

Patients underwent coronary cineangiography to evaluate known or suspected coronary artery disease. The echocardiographic examinations were done by one investigator within 24 hours of the cineangiographic studies. The echocardiographic examinations were done with the patient in the supine or left lateral position. The transducer was placed in the parasternal position in the third or fourth left intercostal space. The LMCA was detected by first obtaining a short-axis examination at the level of the aorta and aortic valve. The transducer was then rotated slightly clockwise to identify the ostium of the LMCA.7 The angulation and rotation of the transducer were adjusted to obtain the best recording of the LMCA (fig. 1). The LMCA appeared as two linear echoes originating from the left coronary sinus, which was the posterior half of the left side of the aorta. There were usually two other linear echoes above and below the LMCA. The more anterior echo originated from the posterior wall of the pulmonary artery (small arrow, fig. 1). The linear echo posterior to the LMCA probably originated from the mitral annulus (double arrows, fig. 1). This more posterior or annular echo frequently blended with the posterior wall of the LMCA, and both would be continuous with the posterior wall of the aorta (fig. 2A). We always attempted to identify the bifurcation of the LMCA. Usually, the bifurcation was seen as a gradual expansion of the distal portion of the LMCA as the two walls separated to form its two major branches (figs. 1 and 2A). With experience, we could clearly identify the origin of the left anterior descending and left circumflex coronary arteries (fig. 2B) by altering the plane of the examination slightly and by analyzing the recording using the videodisc analyzer. Figure 2 shows that the LMCA is frequently curved. The ostium can be at a different plane than the bifurcation.

This study was done in three phases. In phase 1, 72 consecutive patients (60 males and 12 females) were examined by coronary cineangiography and echocardiography. Their average age was 60 years. The coronary cineangiography was performed to document the existence of coronary artery disease in patients being evaluated for chest pain or possible coronary artery bypass surgery. Some of these patients also had other cardiac problems, such as valvular heart disease. The two-dimensional echocardiographic examinations were analyzed retrospectively by one investigator who had knowledge of the coronary cineangiography. This retrospective study was used to determine how often it was possible to identify the LMCA and to develop echocardiographic criteria for diagnosing LMCA obstruction.

Phase 2 consisted of a blinded analysis of some of the patients studied in phase 1. Once the echocardiographic criteria for LMCA obstruction were developed, 28 of the 72 studies from phase 1 were randomly chosen and reviewed by one blinded investigator who had no knowledge of the patients or their cineangiographic findings. He determined whether the patient had obstruction of the LMCA. In phase 3, 31 additional patients were studied prospectively in a
curred near end-diastole. Thus, the strobe freeze-frame indicator was usually placed around this portion of the cardiac cycle as indicated on the ECG (fig. 1).

Angiographic studies of the 72 patients revealed that 20 had normal coronary arteries and 52 had coronary artery disease. Seven of the 52 patients had a 50% or greater obstruction of the LMCA. In all seven patients with LMCA obstruction, high-intensity echoes (figs. 3 and 4) were irregularly situated in the anterior or posterior wall of the LMCA. All seven patients had partial or complete narrowing of the vessel lumen in several frames in several cardiac cycles (figs. 3 and 4). In five of these seven patients, the lumen of the artery could be seen both proximal and distal to the obstruction. High-intensity echoes could also be seen in the LMCA in patients with coronary artery disease but without left main obstruction. In these patients, the high-intensity echoes did not obstruct the lumen and only made the walls of the artery brighter than normal.

From the experience of phase 1, the criteria for diagnosing LMCA obstruction were established: (1) High-intensity echoes must be seen within the walls of the LMCA. (2) The high-intensity echoes are consecutive fashion. These patients included 26 males and five females, average age 56 years. The echocardiographic examinations were analyzed prospectively by two of the investigators, who had no knowledge of the patient, the cineangiographic findings, the opinions of the technician who did the examination, or the interpretation of the other blinded investigator.

Results

Phase 1

The ostium of the LMCA and at least some segment of the artery were identified in 71 of 72 patients. The normal left main coronary artery appeared as two parallel linear echoes separated by a relatively echo-free lumen and was approximately 1 cm long (figs. 1 and 2). The optimal image of the LMCA usually occurred near end-diastole. Thus, the strobe freeze-frame indicator was usually placed around this portion of the cardiac cycle as indicated on the ECG (fig. 1).

Angiographic studies of the 72 patients revealed that 20 had normal coronary arteries and 52 had coronary artery disease. Seven of the 52 patients had a 50% or greater obstruction of the LMCA. In all seven patients with LMCA obstruction, high-intensity echoes (figs. 3 and 4) were irregularly situated in the anterior or posterior wall of the LMCA. All seven patients had partial or complete narrowing of the vessel lumen in several frames in several cardiac cycles (figs. 3 and 4). In five of these seven patients, the lumen of the artery could be seen both proximal and distal to the obstruction. High-intensity echoes could also be seen in the LMCA in patients with coronary artery disease but without left main obstruction. In these patients, the high-intensity echoes did not obstruct the lumen and only made the walls of the artery brighter than normal.

From the experience of phase 1, the criteria for diagnosing LMCA obstruction were established: (1) High-intensity echoes must be seen within the walls of the LMCA. (2) The high-intensity echoes are
irregularly located within the LMCA. (3) Partial or complete obstruction of the lumen of the LMCA is seen on several frames and in several cardiac cycles. (4) If possible, the coronary artery lumen should be imaged proximal and distal to the obstruction. The first three criteria were essential for the diagnosis. The fourth criterion was helpful if present.

Phase 2

Using the criteria developed in phase 1, one of the investigators who had no knowledge of the patients in phase 1 was asked to review the recordings from 28 patients chosen at random and determine whether the patients had LMCA obstruction. Four of the 28 patients had LMCA obstruction as determined angiographically. The blinded investigator identified all four patients (table 1) and there were no false negatives. Twelve patients without obstruction of the LMCA had obstructions of the left anterior descending coronary artery proximal to the first septal perforator. The investigator correctly stated that nine of these 12 patients did not have LMCA obstruction. Two of the remaining three patients had high-intensity echoes within the walls of the LMCA, but the lumen of the LMCA was not consistently narrowed. The investigator described these patients as having LMCA disease, but he could not be certain of obstruction. The one remaining patient was identified by the investigator as having LMCA obstruction and thus represents a true false-positive diagnosis. Twelve patients had coronary artery disease but no obstruction in either the LMCA or the proximal left anterior descending coronary artery. The investigator correctly stated that none of these patients had LMCA obstruction. Five patients who had no coronary artery disease were correctly identified as having no obstruction of the LMCA.

Phase 3

Thirty-one additional patients were examined consecutively and prospectively by one of the investigators. The recordings were then reviewed by two different investigators. No investigator had any knowledge of the patient, the cineangiographic data or the impressions of the other investigators. Three of the 31 patients had obstructions of the LMCA as determined angiographically. All three patients were correctly identified by both blinded investigators who analyzed the recordings (table 2). Thus, no false-negative results occurred. Thirteen patients had proximal left anterior descending coronary artery obstructions and no LMCA obstruction. One investigator correctly determined that none of the patients had LMCA obstruction; however, the other investigator thought that one of the 13 patients had LMCA obstruction. Thus, this investigator had one false-positive diagnosis. There were 12 patients with coronary artery disease, but no obstruction of the LMCA or the proximal left anterior descending coronary artery. Both blinded investigators correctly identified that none of these patients had LMCA obstruction. Three of the 31 patients had no evidence of coronary artery disease and both investigators correctly identified the absence of LMCA obstruction.

Since the false-positives in phase 2 and phase 3 were in patients with obstruction to the proximal left anterior descending coronary artery, it was apparent that the differentiation between obstruction of the LMCA and the proximal left anterior descending coronary artery required identification of the bifurcation of the LMCA. Thus, the blinded investigators were asked to identify the bifurcation. One investigator identified the bifurcation in 23 of 31 patients (74%). The other in-
vestigator identified the bifurcation in 22 patients (71%). The one false-positive diagnosis in phase 3 was in a patient in whom the bifurcation was not identified.

**Discussion**

These results are the most optimistic with regard to the possibility of using echocardiography to detect or exclude LMCA obstruction. In the two blinded phases of this study, there were no false-negative results, and false-positive results were rare. All of the false-positive results were in patients who had proximal left anterior descending coronary artery disease. The false-positive results probably occurred because the bifurcation of the LMCA could be identified in only 70–75% of the patients. Thus, in some patients, it will be difficult to distinguish an obstruction in the distal portion of the LMCA from one in the proximal portion of the left anterior descending coronary artery. In figures 3 and 4, the obstructing lesions are in the distal LMCA. Only when the bifurcation can be clearly identified (fig. 2B) can one be certain that the obstruction is in the LMCA. Although a proximal left anterior descending coronary artery obstruction does not have the ominous prognosis of an LMCA obstruction, these patients obviously have significant disease and might be candidates for coronary bypass surgery. Thus, a false-positive diagnosis may not cause serious mismanagement of the patient. Because there were no false-negative results and false-positive results were rare, our method of detecting LMCA obstruction is better than any other noninvasive procedure reported so far. 

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Abbreviations: LMCA = left main coronary artery; LAD = left anterior descending coronary artery; CAD = coronary artery disease.

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Abbreviations: See table 1.
than normal. As noted in an earlier study, non-obstructing, high-intensity echoes in the LMCA are frequently seen in all patients with arteriosclerotic disease of the left coronary artery.

The improved resolution of the 3-MHz transducer also affected our results. The coronary arteries are small structures and resolution of the instrument is an important factor.

One of the most difficult problems in examining the coronary arteries is that the vessels are small and constantly moving. The coronary arteries are within the examining plane for a relatively brief period of time during the cardiac cycle. Trying to find the appropriate frames for visualizing the coronary arteries with a standard videotape recorder is extremely tedious and makes the examination totally impractical. The strobe freeze-frame feature has partially solved this problem. The strobe is extremely helpful for identifying the LMCA within the mass of echoes to the left of the aorta. The strobe freeze-frame capability was undoubtedly an important factor in the ability to identify the LMCA in 71 of 72 patients in phase 1. The recording of the LMCA was also enhanced by the knowledge that the two parallel echoes from this vessel were usually found between two additional parallel echoes. One echo originates from the posterior wall of the pulmonary artery and the other probably is from some part of the mitral annulus. Another development that has made the echocardiographic examination of the coronary arteries more practical is the off-line analysis system, which uses a new tape recorder and a video-disc recorder that permits detailed forward, reverse, slow-motion and frame-by-frame analysis.

Other investigators using echocardiography to detect LMCA obstruction have reported false-positive results other than proximal left anterior descending coronary artery obstruction, including prostatic valves and calcified aortic and mitral valves. In phase 1, one patient had a prosthetic aortic valve and two patients had aortic stenosis. None of the three patients met the criteria for LMCA obstruction. In phase 3, one patient had severe aortic stenosis and was correctly identified as not having LMCA obstruction.

The results of this study should be confirmed independently by other investigators; however, these findings are encouraging and strongly indicate that echocardiography can be a practical means of detecting or excluding obstruction of the LMCA.

References
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