Cross-sectional Echocardiographic Examination of the Interatrial Septum

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SUMMARY The interatrial septum has not been readily appreciated by M-mode echocardiography. Cross-sectional echocardiography has the capability of recording the shape and location of the interatrial septum. Real-time cross-sectional echograms using a mechanically oscillating transducer were obtained on 100 consecutive patients. Echocardiographic examination of the left atrium and aorta was obtained in a plane perpendicular to the long axis of the atria. In 15 normal patients and 17 patients with atrial septal defects (ASD) and 51 patients with other forms of heart disease, the interatrial septum was recorded as a linear echo from the aorta to the posterior wall of the left atrium. In six patients who had ostium primum ASDs, the echoes from the interatrial septum disappeared near its expected junction with the interventricular septum. Drop out of echoes in the mid portion of the septum was noted in those patients who had ostium secundum atrial septal defects but this could not be differentiated from normal. These preliminary data indicate that examination of the interatrial septum is feasible and may be specific in those few patients examined so far with ostium primum atrial septal defect. The ability to locate and record the shape of the interatrial septum could have many investigative and clinical uses.

DEFECTS IN THE INTERATRIAL SEPTUM are commonly encountered in cardiology. Large defects may impose a chronic volume overload on the right ventricle and may lead to more serious complications such as pulmonary hypertension and right ventricular failure. Echocardiographic criteria for the diagnosis of interatrial septal defects such as dilatation of the right ventricle, paradoxical motion of the interventricular septum, and increased amplitude of opening motion of the tricuspid valve relative to the mitral valve have been described.1-7 In some hands these criteria have been very useful8,9 and reliable while others have found them to be lacking in sensitivity and specificity.8 Although reports have suggested that the interatrial septum could be viewed directly by M-mode or B-mode echocardiography,9,10 direct visualization of atrial septal defects has not been generally possible. Echocardiographic contrast studies using centrally or peripherally injected cardiogreen dye have helped to localize the level of shunting in patients with right-to-left shunts but have not been helpful in patients with left-to-right shunts who represent the vast majority of cases. In addition to providing potential aid in the diagnosis of atrial septal defect, the ability to record the interatrial septum would aid in the further definition of the boundaries of the left atrium and should permit improved left atrial volume determinations. Cross-sectional echocardiography, by providing an enlarged field of vision and correct spatial orientation, appears to have the capability of recording the shape and location of the interatrial septum. The purpose of this paper is to report our experience in recording the interatrial septum in a large number of unsselected patients using cross-sectional echocardiography.

Methods
Cross-sectional or two-dimensional echocardiographic studies were performed attempting to visualize the interatrial septum in 100 patients. The study group consisted of 15 patients who were known to be free of any heart disease, 11 who had secundum atrial septal defects, six with primum atrial septal defects, and 68 patients with other forms of heart disease. Cardiac catheterization and angiography were utilized to establish a diagnosis in all patients with heart disease. The 15 normal patients were not catheterized and were considered to be clinically normal. The patients range from very small infants to sixth and seventh decade adults.

Cross-sectional echocardiographic studies were performed in either the supine or left lateral position. The transducer was initially placed in the third or fourth intercostal space to the left of the sternum. The sweep of the cross-sectional probe was aligned perpendicular to the long axis or parallel to the short axis of the heart. The probe was then angled to record the aortic root at the level of the aortic valve. Once the aortic root at the valve level was localized the probe was rotated to record the short axis of the aortic root. Optimization of the short axis recording was felt to occur at a point when the aortic root achieved its most circular configuration. Having localized the aortic root the probe was then angled medially to record the entire medial wall of the aorta along with the posterior wall of the left atrium and portions of the lateral margins of the right atrium. With the probe in this position it was frequently possible to visualize the interatrial septum extending from the inferior medial border of the aortic root to the junction of the posterior left and right atrial walls. If the interatrial septum was not visualized from this probe position, the transducer was then moved laterally as far as possible and the ultrasonic beam was directed medially toward the area of the interatrial septum. If these latter methods did not result in adequate recording, an alternative method was utilized. This involved directing the probe toward the interventricular septum, then sweeping the beam up along the medial margin of the interventricular septum to a point where its leftward curvature gave way to the more vertical and slightly rightward curvature of the interatrial septum. This abrupt, although slight, change in direction of curvature of the two septa facilitated both visualization and localization of the interatrial septum. The normal interrelationships of the left and right atrium as well as the aorta and right ventricular outflow tract are diagrammatically illustrated in figure 1. The left hand panel of
The real-time two-dimensional echocardiographic instrument used in this study was a mechanical sector scanner developed in conjunction with the Fortune-Fry Research Laboratories at Indiana University. This echocardiograph consisted of a modified Eoline 20 echograph with a pulse repetition rate of 4.5 kc/sec. The scanner probe contained a 2.25 or 3.5 MHz transducer mechanically driven through a 30 degree sector at a variable rate of between 0 and 35 cycles/second. This system was routinely operated at a frame rate of approximately 40 frames/second (20 cycles/second) which yielded a line density of approximately 112 lines/frame. The images thus produced were photographed using a standard portable television camera GBC-CTC-6000 and recorded on ½ inch video cassettes using a Sanyo VTC-7100 cassette recorder. Cross-sectional images could be viewed in real time during the examination or subsequently from the video tape in real time, slow motion or single frame presentation. Individual frames were converted to hard copy using either a video scan converter and a modified Honeywell 1856 strip chart recorder or were photographed directly from a television monitor with a standard Polaroid photographic system. Further details of this system have been previously reported.10–15

Results

During the course of this study we were successful in recording the interatrial septum in 83 of 100 patients examined. We were able to record the interatrial septum in each of the patients with atrial septal defect, all normal subjects, and in 34 of 36 subjects under the age of 18. In normals the interatrial septum was seen to arise from the inferomedial border of the aortic root and to extend posteriorly and slightly rightward to join the posterior left atrial wall at a point almost directly beneath the medial margin of the aortic root. Figure 2 is a representative normal study demonstrating the interatrial septum and its relationship to the aorta and both atria. In all normal subjects and in 51 of the 68 patients with other forms of heart disease the appearance of the interatrial septum was similar to that demonstrated in figure 2. That is, the septum appeared as a series of linear echoes extending from the aorta to the posterior wall of the atria. Figure 3 is a recording from a patient with rheumatic mitral valve disease and a dilated left atrium. The interatrial septum again appears as a series of linear echoes from the posterior atrial wall to the inferomedial boundary of the aorta. In patients with left atrial dilatation the septum curved slightly inward toward the right atrium as demonstrated in this figure. Dilatation of the left atrium generally made the interatrial septum more prominent and easier to record.

In order to further define the two atria and the interatrial septum, cardiogreen dye was injected in five of these patients. The injection was performed either using a peripheral vein or directly into the right or left atrium during cardiac catheterization. By injection of dye into both the right and left atria during cardiac catheterization it was possible to establish clearly that the structure recorded was in fact the interatrial septum.

Atrial Septal Defect

In each of the 17 patients with atrial septal defects a discontinuity in the echoes from the interatrial septum was noted. The location of this gap in the septal echo differed in patients with ostium primum defects and with ostium secundum defects. This difference could be demonstrated by

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**Figure 1.** Left) Line drawing showing the long axis of the heart and the path of the cross-sectional scan. Right) The short axis presentation with the left atrium (LA) on the right, the right atrium (RA) on the left. The atrial septum (IAS) is seen. The right ventricular outflow tract (RVOT) as well as the aorta (AO) are noted.

**Figure 2.** An echogram in the short axis from a normal individual demonstrating the left atrium, right atrium, aorta and interatrial septum. Note that the septum is a band of echoes running from the posterior wall to its attachment with the aorta anteriorly.
sweeping the ultrasonic beam up along the interventricular septum from the body of the left ventricle into the left atrium. In patients with ostium primum defects a loss of septal echo occurred at the junction between the interventricular and interatrial septa. The normal abrupt shift in septal direction, which occurs as the beam leaves the interventricular septum and encounters the interatrial septum, was not visualized in these cases. As the beam was swept further superiorly the intact interatrial septum would be visualized. In contrast, in patients with ostium secundum defects the normal junction between the interventricular and interatrial septa with the characteristic shift in septal direction was well recorded. The defect in the interatrial septum was not visualized in these cases until the beam was swept more superiorly into the body of the left atrium. Figure 4 is a characteristic cross-sectional echogram from a patient with an ostium primum atrial septal defect. In figure 4A the interatrial septal echo can be seen to arise from the posterior atrial wall and continue anteriorly only a short distance. The echo then disappears in the area which would be expected to represent the body of the interatrial septum and is seen again at its insertion into the inferior border of the aorta. Figure 4B is a recording from the same patient after repair of the atrial septal defect. The interatrial septal echo is now continuous from the posterior atrial wall to the aortic root. The patch itself, which is a strong reflector, is prominently recorded in the postoperative study. Enlargement of the left atrium postoperatively was due to uncorrected residual mitral insufficiency. Figure 5 is a recording from a patient with an ostium primum atrial septal defect which had previously been repaired. In this case the septal patch broke down and a residual defect was present. Figure 5A illustrates the area of the defect stretching from the inferior border of the aorta to the superior margin of the residual patch. In figure 5B and 5C cardiogreen dye has been injected into a peripheral vein and allowed to stream into the defect.

As previously noted in patients with ostium secundum atrial septal defects, the location of the defect is more superior than ostium primum defects. Figure 6 is a recording from a patient with a known ostium secundum atrial septal defect. The left and right atria are visualized as well as the aorta and right ventricular outflow tract. In this recording the superior portion of the septum at its origin from the inferior border of the aortic root is visualized; the mid portion of the septal echo is absent. Although this type of presentation is characteristic of secundum defects, a similar pattern can be produced in normals.

In 17 patients we were unable to visualize adequately the interatrial septum. This difficulty was due to either technical limitations or lack of patient cooperation. In the 15 adult patients failure to record the interatrial septum was a result of an inability to approach the basal portion of the heart with the ultrasonic beam. The majority of these patients had either coronary artery disease or some form of chronic lung disease. Inability to record the septum in the two children resulted from a narrow intercostal space in one subject and lack of patient cooperation in the other.

Discussion

Cross-sectional echocardiography permits visualization of the interatrial septum in a large percentage of unselected patients. Difficulties encountered in recording the interatrial septum were not unique to this structure but were similar to those commonly encountered in performing ultra-
sonic examinations of the heart. These included lack of patient cooperation when recording young children, obstruction of the ultrasonic beam by intervening lung parenchyma in patients with chronic obstructive pulmonary disease and coronary artery disease, and difficulty in recording structures which are parallel to the plane of the ultrasonic beam. Although the orientation of the interatrial septum is relatively parallel to the ultrasonic beam, the normal curvature of the septum and flexibility of the lightweight, hand-held ultrasonic transducer permitted an appropriate angle between the septum and the ultrasonic beam to be achieved allowing this structure to be recorded in a high percentage of patients.

In normal subjects the interatrial septal echoes appear as a relatively straight line stretching from the inferomedial border of the aortic root, posteriorly and rightward to the posterior atrial wall at the junction of the left and right atria. As the left atrium dilates, the septal echo elongates and is pushed outward away from the left atrium so that it appears to bulge inward toward the right atrium. In this situation, however, the anteroposterior relationships of the septum tend to remain the same. Conversely, in patients with right atrial dilatation the aortic root appears to be shifted leftward relative to the insertion of the septum into the posterior atrial wall. The septum then loses its normal anteroposterior orientation and appears to angle more sharply leftward from the posterior atrial wall to the aortic root.

Obviously the pathologic condition of greatest interest in examining the interatrial septum is atrial septal defect. An atrial septal defect appears on cross-sectional study as a localized gap in the normal septal echo. Although the area of the atrial septal defect can be readily recorded using cross-sectional echocardiography it is always difficult to use negative data in establishing an echocardiographic diagnosis. Thus it is hazardous to say that a structure or a portion of a structure is not present because we fail to record it echocardiographically.

Ostium primum atrial septal defects have certain unique characteristics which aid in their identification and help separate them from secundum defects. 1) Ostium primum defects lie at the junction of the interventricular and atrial septa in an area readily visualized by the ultrasonic beam. 2) The normal shift in direction of septal curvature as one scans from the interventricular to the interatrial septum further localizes the area of the primum defect. 3) The intact portion of the interatrial septum can generally be visualized superior to the ostium primum defect providing an area for comparison. 4) The characteristic abnormal insertion of the anterior mitral leaflet high up on the interventricular septum alerts the observer to the likely presence of an ostium primum defect. Ostium secundum defects lie in a more superior portion of the interatrial septum which is generally more difficult to record. It may be impossible to distinguish the loss of echoes seen in the presence of secundum defects from the normal dropout of echoes which occasionally occurs in the mid portion of the interatrial septum where it lies almost directly parallel to the ultrasonic beam. In each of the 14 patients in this study with atrial septal defects we were able to visualize a gap in the septal echoes in an area appropriate for the anatomic location of the defect. In five of these cases we were able to confirm that this gap in the septal
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Figure 6. An ostium secundum atrial septal defect in which the left and right atria are noted. A remnant of the interatrial septum hangs down from its attachment with the aorta; below this point the septum is noted to drop out. This could not be differentiated from normals.

sectional echocardiography permits real-time visualization of dye through the defect, this is sufficient to make the diagnosis. We have noted in patients with left-to-right shunts that in addition to the passing of dye across the septum due to mixing of blood one can frequently record a rather prominent negative shadow along the right atrial border of the defect during diastole. This occurs at a time when the remainder of the right atrium is filled by a clouded echo produced by the peripheral dye injection. It appears to represent blood, which does not contain dye, flowing through the defect from left to right and thus stands out in contrast to the dye-containing blood in the rest of the right atrium. These patterns of dye flow in patients with ostium secundum defects and left-to-right shunts provide subter information than that resulting from the use of cardiogreen dye to detect right-to-left shunts; however, careful study of the motion of the dye in the right atrium in real-time may prove valuable in the relatively noninvasive diagnosis of these defects.

In addition to detecting intracardiac shunts, cardiogreen dye may also be extremely valuable in outlining cardiac chambers and in confirming structure identification. The density of the green dye echoes and the contrast with which the chamber is outlined is dependent upon the site of injection, the volume of dye injected, and the velocity of blood flow.

This study shows that cross-sectional echocardiography permits recording of the interatrial septum in a large percentage of patients, confirms by cardiogreen injection that the structure visualized is indeed the interatrial septum, and demonstrates the ability of cross-sectional echocardiography to visualize defects in the interatrial septum.

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Two-dimensional Echocardiographic Assessment of Mitral Stenosis

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Summary A real-time, phased-array, two-dimensional echocardiography system was used to assess mitral valve motion in 30 catheterized patients with pure mitral stenosis. Suitable images for analysis of mitral valve motion were obtained in 25 patients. The valve leaflets were most thickened and immobile at the leaflet tips while maximum mobility was at the leaflet body. Diastolic movement of anterior mitral leaflet toward the septum pulled the posterior mitral leaflet mid-portion inferiorly. Systolic bulging of the mid-portion of the anterior mitral leaflet into the left atrium was seen in 40% (10 of 25). Movement of the anterior mitral leaflet in diastole is primarily due to movement of the whole mitral apparatus in patients with mitral stenosis. The anterior mitral leaflet E to F slopes did not correlate (r = 0.38) with the mitral valve area determined at catheterization. Planimetry of the mitral valve area directly from the videotape images compared favorably to the valve area determined at catheterization (r = 0.95). Thus, mitral valve area determined by this technique is an accurate noninvasive method for assessing the severity of mitral stenosis.

Methods

Patients

Over a nine-month period, 30 patients with pure mitral stenosis or mitral stenosis with insignificant mitral insufficiency underwent both two-dimensional echocardiographic examination and cardiac catheterization within three days of each other. Twenty-five of these patients had adequate two-dimensional echoes for analysis of the mitral leaflets throughout the cardiac cycle. Fifteen of these patients had time-motion echocardiograms.

Echocardiographic Methods

Two-dimensional echoes were obtained using a previously described real-time, phased-array, imaging system. This system uses a hand-held, 24-element, 2.25 MHz transducer array that measures 14 x 24 mm at the site of skin contact and relies upon phased-array principles to electronically steer and focus the sound beam through the structures under investigation. Real-time, cross-sectional images of cardiac structures are presented in circular sector format, 50, 60, or 90 degrees in azimuth. Images are permanently recorded on videotape for later playback and analysis.

Figure 1 schematically shows the planes of view used for examination of the long axis of the mitral valve and left ventricle and the short axis of the left ventricle and mitral valve orifice. These views were obtained using previously described techniques. A diastolic, single-plane photograph and schematic illustration of the long axis of a normal mitral valve are shown in figure 2. A diastolic, single-plane photograph of the short axis of the left ventricle at the level...
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