Echocardiography of the Intra-atrial Baffle in Dextro-transposition of the Great Vessels

By Navin C. Nanda, M.D., Scott Stewart, M.D., Raymond Gramiak, M.D., and James A. Manning, M.D.

SUMMARY
Twelve patients with dextro-transposition of the great vessels (age eight months to four years) were studied by echocardiography following Mustard's procedure. Nine of them had also been studied preoperatively. Postoperatively all patients demonstrated structural echoes in the atrial cavity behind the pulmonary root. In ten, the motion pattern generally resembled that of a stenotic atrioventricular valve with a sharp anterior movement followed by flattening in diastole and rapid posterior excision in systole. The maximum amplitude of motion ranged from 4 to 9 mm (average 6.6 mm). In the remaining two cases, the anterior diastolic movement was attenuated. Similar moving, linear echoes with larger amplitudes of motion (10-14 mm) were observed behind the tricuspid valve in four patients while poorly moving, multiple or thick conglomerate echoes (2-11 mm wide) were detected in seven cases. Echocardiographic contrast studies performed by injecting indocyanine green via catheters placed on either side of the intra-atrial baffle identified it as the source of these echoes. Following operation, coarse diastolic undulations of the mitral valve (ten cases) and the tricuspid valve (nine cases) were noted. Also, fine flutter of both atrioventricular valves, not present before, appeared after operation in three patients. These findings may be related to the altered pathway of blood flow and turbulence resulting from the insertion of the baffle in the atria. Echocardiography appears useful in delineating the character and movement pattern of the intra-atrial baffle and this may have potential in evaluating its long-term functional status.

Additional Indexing Words:
Ultrasound Mitral valve diastolic flutter Ultrasonic contrast studies Echoes in left atrium Mustard's operation Tricuspid valve diastolic flutter

THE OUTLOOK FOR CHILDREN with complete transposition of the great vessels has improved greatly since the introduction of the Mustard procedure.1, 2 This technique involves placement of a patch or baffle, constructed from the pericardium or a synthetic material, in the atria to achieve physiologic correction. Pulmonary venous blood is directed to the aorta through the tricuspid valve while the systemic venous return is directed into the pulmonary artery through the mitral orifice (fig. 1). Complications can occur as a consequence of the use of the intra-atrial baffle. These are systemic venous obstruction, pulmonary venous obstruction and defects in the patch resulting from shrinkage and calcification.3, 4 A noninvasive technique for the evaluation of the baffle would therefore be of considerable value. This report describes the echocardiographic patterns presented by the intra-atrial baffle as well as validation of its identification using ultrasonic contrast studies.

Materials and Methods
Twelve patients with dextro-transposition of the great vessels were studied by echocardiography following Mustard's procedure. Nine of them were also studied preoperatively. There were eight males and four females. Their ages varied from eight months to four years, the average being 2.7 years. Associated lesions included ventricular septal defect in three patients, patent ductus arteriosus in one, subpulmonic stenosis in three and pulmonary vascular disease in one case. The intra-atrial baffle was constructed from the pericardium in eleven cases while a dacron patch was used in one. All patients had undergone balloon septostomy and/or a Blalock-Hanlon procedure with satisfactory palliation.

The echocardiographic examinations were performed using a commercially available echograph (Picker) and a 2 MHz collimated transducer. Continuous records were made on 35 mm film by means of a Fairchild Oscilloscope Record camera and a dual beam oscilloscope operating as a slave. Routine echocardiographic studies of the cardiac valves and chambers were performed.5, 6 The mitral valve was located by placing the transducer in a left parasternal position in the third to fifth intercostal space and directing it straight posteriorly or slightly medially. The tricuspid valve was located by angling or moving the transducer medially and inferiorly from the mitral valve position. Echoes from the

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anteriorly placed aortic root were obtained by medial transducer direction while those from the posteriorly placed pulmonary root were detected by relatively lateral beam angulation.7 Particular attention was paid to the presence of unusual echoes in the atrial chambers behind the great vessels and in the vicinity of the atrioventricular valves. The atrioventricular valves were examined for evidence of diastolic flutter. The motion pattern of the ventricular septum was noted. In three patients echocardiographic studies were obtained using indocyanine green injections5 via two catheters placed at surgery, one in the pulmonary venous atrium in front of the baffle and the other in the superior vena cava near its junction with the systemic venous atrium.

Results

The most impressive finding in patients who had undergone insertion of the intra-atrial baffle (Mustard’s operation) was the presence of a moving linear echo in the atrial cavity behind the pulmonary root (fig. 2) not present preoperatively. The movement pattern generally resembled that produced by a stenotic atrioventricular valve. A sharp anterior movement which occurred at the onset of diastole was followed by flattening in mid and late diastole in ten cases. With the beginning of ventricular systole, a rapid posterior movement was observed and this was followed by no movement or very gradual anterior motion during the remainder of systole. The maximum excursion varied from 4 to 9 mm, average 6.6 mm (table 1). Occasionally this echo presented a multilayered appearance. In the remaining two patients (one of whom had a dacron baffle), the diastolic anterior movement was markedly attenuated and the echo pattern appeared to follow the course of the posterior pulmonary artery wall. A similar though in-

Table 1

Echocardiographic Features of Intra-atrial Baffle

<table>
<thead>
<tr>
<th>Amplitude of motion</th>
<th>Baffle position</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Behind PA</td>
</tr>
<tr>
<td>&lt;3 mm</td>
<td>0</td>
</tr>
<tr>
<td>4–9 mm</td>
<td>12</td>
</tr>
<tr>
<td>10–14 mm</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviations: TV = tricuspid valve; PA = pulmonary artery; AO = aorta.
constant echo behind the pulmonary artery was detected preoperatively in one patient (fig. 3).

Echoes showing similar diastolic and systolic movement patterns with amplitudes in the range of 5–14 mm could also be observed behind the aortic root in four patients following Mustard’s operation. In four instances a prominent echo showing a large amplitude of motion could also be demonstrated posterior to the tricuspid valve. The maximal excursion, which was in the range of 10–14 mm, was usually obtained by angling the ultrasonic beam so that it passed just beyond the valve deeper into the atrial cavity (fig. 4). The motion pattern appeared to resemble that obtained from the linear echo observed behind the pulmonary or aortic root except that the posterior rapid motion occurred later in systole. The rapid component was occasionally preceded by a notch or slow posterior movement at the onset of systole. In seven other patients, multilayered or thick conglomerate echoes (2–11 mm wide) could be detected behind the tricuspid valve, usually exhibiting only slight anterior diastolic motion (fig. 5). These echoes were not observed preoperatively.

Echocardiographic studies of the tricuspid valve region during injection of indocyanine green through a catheter placed at surgery in the pulmonary venous atrium in front of the intra-atrial baffle showed the appearance of contrast echoes in front of the linear atrial echo and were limited by it posteriorly. Injection into the systemic venous atrium through a catheter situated at the lower end of the superior vena cava produced heavy opacification which was localized posteriorly (fig. 6). The intra-atrial baffle was thus outlined as the source of the echoes observed behind the tricuspid valve. Absence of contrast echoes in the systemic venous-pulmonary artery circuit following injection into the pulmonary venous atrium served to establish the functional competence of the intra-atrial baffle in the early postoperative period.

Diastolic flutter of the atrioventricular valves was a frequent finding in patients in the present study (table 2, fig. 7). High frequency, low amplitude diastolic mitral flutter, present preoperatively in six cases, persisted unchanged following surgery. It developed after operation in the remaining three patients. In addition, all but two also demonstrated coarse diastolic undulations following operation. These were not present prior to surgery. The incidence of tricuspid diastolic valve flutter was lower preoperatively. It was present in three of seven patients in whom adequate studies of the tricuspid valve were obtained. Postoperatively, it was observed in ten cases. Coarse undulations of the tricuspid valve in diastole were noted in nine patients following surgery.

Abnormal ventricular septal motion of the type seen in patients with right sided volume overload was detected in seven of nine patients preoperatively. It remained unaltered following operation. Two of them

Figure 3
Preoperative pulmonary artery echocardiogram in dextro-transposition of the great vessels. A thin, inconstant echo (shown by arrows) moving parallel to the posterior pulmonary artery wall is seen in the left atrium. Its origin is obscure. The pulmonary valve at autopsy consisted of one large leaflet and two miniscule cusps and this may explain the marked diastolic eccentricity of the cusp echoes. PA = pulmonary artery; ECG = electrocardiogram.

Figure 4
Postoperative echocardiographic study in dextro-transposition of the great arteries. A large amplitude linear echo from the intra-atrial baffle (BA) is obtained by angling the ultrasonic beam so that it passes just beyond the tricuspid valve deeper into the atrial cavity. Note that the rapid posterior motion occurs well after the onset of systole. ECG = electrocardiogram.
have been followed for a period of three years. None had clinical evidence of tricuspid incompetence. Cardiac catheterization studies following operation in three patients with persistent abnormal septal motion showed evidence of small left-to-right shunts at the atrial level with the pulmonic to systemic blood flow ratios not exceeding 1.3:1.

Discussion

Echocardiography has been successfully used in the diagnosis of dextro-transposition of the great vessels\(^7,\)\(^8\) as well as in the identification of coexisting sub-pulmonic obstruction.\(^9\) The detection and delineation of normal movement pattern of the intra-atrial baffle using this technique represents another extension of the usefulness of echocardiography in this entity. The baffle is easily identified by ultrasound as it is placed at right angles to the plane of the excised inter-atrial septum and therefore moves in a general direction perpendicular to the ultrasonic beam. Echoes from the intra-atrial baffle are most commonly identified behind the pulmonary root. In general they consist of one or two linear echoes resembling the motion pattern of a stenotic atrioventricular valve with amplitudes in the range of 4 to 9 mm. The characteristics of the baffle echoes observed behind the aortic root are also similar but the baffle detection rate is low in that location. The echocardiographic features of the intra-atrial baffle in the region of the tricuspid valve differ from those observed behind the great vessels. The images tend to have larger amplitudes (10 mm or more) and the occurrence of rapid posterior motion takes place later in systole. Signals of this type are seen in a relatively small proportion of patients. More commonly single thick echoes or multilayered complexes with little detectable motion are seen directly behind the tricuspid valve. The resemblance of the movement pattern of the echoes from the intra-atrial baffle to that produced by an atrioventricular valve may be due to the fact that it is subject to nearly similar pressures and blood flow patterns.

Echoes showing little motion or moving parallel to the posterior wall of the aortic root have been seen in the left atrium of some apparently normal subjects.\(^10\) Their origin remains obscure but they do not show

**Figure 5**

Postoperative tricuspid valve echocardiograms in dextro-transposition of the great vessels. Multilayered images (left) as well as a large amplitude echo (right) from the intra-atrial baffle (BA) are observed behind the tricuspid valve (TV). ECG = electrocardiogram.

**Figure 6**

Ultrasonic contrast studies. Injection of indocyanine green into the pulmonary venous atrium produces echoes in front of the intra-atrial baffle (BA) and are limited by it posteriorly (left), while injection into the systemic venous atrium results in opacification which is confined behind the baffle (right). ECG = electrocardiogram.
Table 2

Abnormalities of Atrio-ventricular Valves

<table>
<thead>
<tr>
<th>Atrioventricular valve abnormality</th>
<th>Before operation (9 cases)</th>
<th>After operation (12 cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV flutter</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>MV undulations</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>TV flutter</td>
<td>3*</td>
<td>10</td>
</tr>
<tr>
<td>TV undulations</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

*Adequate echoes of the TV were obtained in seven patients preoperatively.

Abbreviations: MV = mitral valve; TV = tricuspid valve.

sharp prominent anterior movements in diastole observed in the patients in the present study following Mustard’s operation. A similar inconstant echo was observed in the left atrium behind the pulmonary artery in one of our patients with dextro-transposition of the great vessels preoperatively. Following operation, this abnormal echo could no longer be detected and instead typical echoes from the intra-atrial baffle were noted. The reason for the atypical movement pattern of echoes in two of our patients is not clear. The baffle was constructed from dacron in one of them and might be expected to show decreased motion. Subsequent autopsy in this patient did not show any abnormalities of the baffle. The other patient had a very large pulmonary artery with a very small left atrial space behind it. Hemodynamic studies in this patient revealed severe pulmonary hypertension and a small bidirectional shunt at the atrial level. It is possible that the atypical movement is related to the shallow left atrial space behind the great vessel as no major baffle dysfunction could be detected hemodynamically or angiographically.

Indocyanine green has been used for anatomic validation of various cardiac structures detected by ultrasound.11 In the present study, echo contrast studies with indocyanine green were used for structural identification of the echoes emanating from the intra-atrial baffle detected in the vicinity of the tricuspid valve. Injection in the pulmonary venous atrium may produce echoes behind the baffle if the catheter is located in the region of the origin of the pulmonary veins away from the tricuspid valve (fig. 1). This technique may also serve to establish the functional competence of the intra-atrial baffle in the immediate postoperative period. Appearance of echoes in the pulmonary artery following injection of indocyanine green in the pulmonary venous atrium would indicate the presence of a defect in the baffle.

Diastolic flutter of the atrioventricular valves has been commonly observed in semilunar valve insufficiency and is believed to be produced by mechanical vibrations resulting from the regurgitant jet striking the open leaflets.12, 8 Tricuspid valve flutter has also been observed in large atrial septal defects and may represent increased blood flow across the valve in diastole.13 The mechanism of diastolic flutter in our patients is not clear. None had clinical evidence of semilunar valve insufficiency. The bidirectional shunting through the atrial septal defect2, 14 created by Rashkind’s procedure may result in abnormal direction of flow through both atria and produce diastolic flutter of both atrioventricular valves. Two patients studied prior to balloon septostomy did not show atrioventricular valve flutter. Persistence of flutter following Mustard’s procedure, appearance of flutter in patients who did not have it before, and the new finding of coarse, undulating diastolic movements following surgery may be related to the altered pathway of blood flow and turbulence resulting from the interposition of the pericardial patch in the atria. We have observed diastolic flutter of both atrioventricular valves in some infants who are apparently normal, but have not seen this phenomenon at other ages. Only two patients in the present study were less than one year old.

An interesting finding in the present study was the persistence of abnormal ventricular septal motion following operation. None of the patients had clinical evidence of tricuspid incompetence or large left-to-right shunts at the atrial level. Failure of reversal of the ventricular septal motion toward normal has also

Figure 7

Atrioventricular valve abnormalities in dextro-transposition of the great vessels. Postoperative study. The tricuspid valve (TV) shows undulating diastolic movements while the mitral valve (MV) shows fine diastolic flutter. PHO = phonocardiogram; ECG = electrocardiogram.
been noted in some patients with isolated atrial septal defects following closure.\textsuperscript{16} The reason for this is not clear. In the present study, it is possible that the presence of the intra-atrial baffle may be contributing to the persistence of the abnormal septal motion seen following surgery.

Although the insertion of the intra-atrial baffle in Mustard's operation achieves physiologic correction in dextro-transposition of the great vessels, the procedure cannot be considered a curative operation as the heart is still very abnormal and certain areas of concern remain.\textsuperscript{16} Surgical complications related to the placement of the intra-atrial baffle include superior and inferior vena caval obstruction, pulmonary venous obstruction as well as defects in the patch leading to atrial shunting. These complications result from shrinkage and contraction of the baffle. Calcification of the pericardial baffle is another complication.\textsuperscript{4} This is especially important since the baffle operation is now done at a younger age\textsuperscript{17} and the chances of long-term complications from shrinkage of the pericardial baffle may be greater.

Echocardiography appears useful not only in identification of the intra-atrial baffle but also in the delineation of its character and movement patterns. As it is a noninvasive, nontraumatic, repeatable technique, follow-up studies can be performed to assess any changes in the intensity or motion characteristics of the intra-atrial baffle as compared with the baseline patterns. Although we have not studied any patient with baffle dysfunction, excessive shrinkage or calcification of the intra-atrial baffle would be expected to result in a significant decrease in the amplitude as well as an alteration in the character of echoes obtained from it. Thus, echocardiographic studies of the intra-atrial baffle may have a potential in evaluating its long-term functional status.

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References

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