Echocardiographic Features of Patients with and Without Residual Defects After Mustard’s Procedure for Transposition of the Great Vessels

KATHERINE THOMPSON, M.D., AND GERALD A. SERWER, M.D.

SUMMARY The usefulness of echocardiography in evaluating patients who have undergone Mustard’s procedure for d-transposition of the great vessels was investigated by examining the M-mode studies and cardiac catheterization data of 20 patients at least 1 year after operation. The patients were separated into two groups using the findings at cardiac catheterization. The 12 patients in group 1 were asymptomatic, were not taking cardiac medications and were free of significant residual hemodynamic defects. Echocardiographically, left ventricular diastolic dimension (LVDD) and posterior wall size (PW) were smaller than normal in these children, whereas right ventricular diastolic dimension (RVDD) and anterior wall thickness (AW) were greater than normal. The percent fractional shortening of the left ventricle (%FS) was elevated. Systemic venous atrial-to-pulmonary venous atrial dimension ratios (SVA/PVA) fell into a narrow range regardless of patient size (mean 1.00 ± 0.06 (SD). All patients in group 1 had diastolic flutter of both atrioventricular valves and abnormal septal motion. Two patients had systolic flutter of the pulmonary valve and nine had systolic anterior motion of the mitral valve. The eight patients in group 2 had significant residual defects. In all five patients with baffle obstruction of systemic venous return and in the patient with baffle obstruction of pulmonary venous return, SVA/PVA was well outside group 1 limits. RVDD was above group 1 limits in one patient with RV dysfunction and two with tricuspid insufficiency. Pulmonary artery diameter, LVDD, and PW were above the respective group 1 ranges in two patients with elevated pulmonary artery pressure, while pulmonary artery diameter was below group 1 limits in the patient with pulmonic stenosis. All group 2 patients were easily distinguishable from group 1 patients by at least one variable. Thus, while marked echocardiographic differences exist between group 1 and normal patients, patients with residual defects after the Mustard procedure can be readily identified, indicating a useful role for echocardiography in the postoperative management of patients with transposition of the great vessels.

SURGICAL CORRECTION of d-transposition of the great vessels (TGV) using Mustard’s procedure has dramatically improved the prognosis of infants with this cardiac abnormality, generating a new population of postoperative patients who have structurally abnormal hearts but physiologically normal blood flow. Although follow-up studies have shown promising long-term clinical results, there is also a significant incidence of postoperative residual hemodynamic abnormalities. These include obstruction of systemic or pulmonary venous return, residual atrial level shunting, left ventricular outflow tract obstruction, tricuspid insufficiency, pulmonary vascular obstructive disease, and right ventricular dysfunction. Early detection and treatment of such abnormalities are necessary if the complications they produce are to be avoided.

The importance of echocardiography in the diagnosis and evaluation of the preoperative patient with TGV is well recognized. The unusual echocardiographic features of patients who have undergone the Mustard procedure have also been described and it is clear that many echocardiographic findings in these patients are different from those of normal patients. However, it has not been determined whether echocardiography is useful in distinguishing patients who have residual defects after Mustard’s procedure from those who do not.

In this study, we further define and characterize the echocardiographic features of patients who were free of significant hemodynamic abnormalities after Mustard’s procedure and compare these features with those of patients who had significant residual defects at cardiac catheterization.

Methods

Patients

Twenty patients who had undergone Mustard’s operation were included in the study group. All patients underwent diagnostic cardiac catheterization and echocardiographic examination at least 1 year after operation (range 12–111 months, mean 40.3 months). Based solely on the findings at cardiac catheterization, patients were separated into two groups. The criteria for inclusion in each group were established before review of catheterization data, and patients were assigned to groups before review of the echocardiographic findings.

Group 1

Group 1 consisted of 12 patients, ages 16–176 months (mean 69.9 months), who were shown at cardiac catheterization to have good surgical results (table 1). At surgery, the patients were 2–136 months old (mean 34.7 months); postoperative follow-up

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Table 1. Cardiac Catheterization Data

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<th>Gradients (mm Hg)</th>
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*Shunts detected only by cineangiography: Qp/Qs < 1.2/1.
†Cineangiographic findings.

Abbreviations: LV = left ventricle; SVC = systemic venous atrium; RV = right ventricle; PVA = pulmonary venous atrium; PA = pulmonary artery; PV = pulmonary vein; SVC = superior vena cava; RVEF = right ventricular ejection fraction; IVC = inferior vena cava; TI = tricuspid insufficiency; MI = mitral insufficiency; PVR = pulmonary vascular resistance (in Wood units); BP = blood pressure (mm Hg).

Table 1 shows the cardiac catheterization data for patients with systemic to pulmonary arterial shunts. The data includes age, time postoperatively, pressures, gradients, right ventricular ejection fraction (RVEF), and other findings. The patients were followed-up for 12-111 months, with an average of 42.9 months.

Patients in group 1 were asymptomatic and did not take cardiac medications. They met the following criteria: (1) systolic gradient no greater than 25 mm Hg; (2) mean pulmonary artery pressure no greater than 15 mm Hg; (3) no residual atrial or ventricular left-to-right shunting producing a Qp/Qs ratio greater than 1.2:1; (4) no systemic desaturation; (5) no valvular insufficiency greater than 1+ as defined angiographically; (6) no evidence of narrowing in either arm of the intraatrial baffle that produced either a mean gradient from the systemic to pulmonary arterial shunts greater than 4 mm Hg or angiographic evidence of such narrowing with dilatation of the azygos system; and (7) right ventricular end-diastolic pressure less than 10 mm Hg or a right ventricular ejection fraction of at least 41%. In addition, all group 1 patients had 1:1 atrioventricular conduction except one who had surgically induced complete atrioventricular block and a permanent pacemaker.

Group 2

The remaining eight patients, ages 40-92 months (mean 65.1 months), had significant hemodynamic abnormalities at postoperative cardiac catheterization by failing to meet one or more of the above criteria.
(table 1). At surgery, these children were 12–40 months old (mean 28.9 months); the postoperative follow-up was 12–65 months (mean 36.2 months). Patients 1–5 had obstruction to systemic venous return by the intraatrial baffle. Four had obstruction between the superior vena cava and the systemic venous atrium and one between the inferior vena cava and the systemic venous atrium. Patient 5 had a mild increase in pulmonary vascular resistance and patient 4 had pulmonic stenosis. Patient 6 had a large residual left-to-right atrial shunt, mild pulmonary venous baffle obstruction and markedly elevated pulmonary artery pressure. Patients 4 and 7 had 2+ tricuspid insufficiency. Finally, patient 8 had poor right ventricular function, elevated right ventricular end-diastolic pressure and a depressed ejection fraction. Patient 1 had complete ativoventricular block with a permanent pacemaker; the remaining patients had 1:1 ativoventricular conduction.

Only patients 1 and 7 were doing well clinically. Patients 2 and 3 had intermittent periorbital edema requiring diuretic therapy, patient 5 had hepatomegaly and patients 4, 6 and 8 had significant exercise limitations. Only patient 8 was receiving digoxin.

Echocardiographic Examination

M-mode echocardiograms were obtained on all patients within 48 hours before cardiac catheterization using an EchoCardioVisor 0–1 echocardiograph interfaced with a Honeywell LS-6 strip-chart recorder. A 2.25-MHz or 4.5-MHz transducer was used for each study as appropriate for the patient’s size. Examinations were performed using standard techniques, with the transducer positioned along the left sternal border with the patient in the supine position. A simultaneous limb lead II ECG was also recorded. Tracings were recorded at a paper speed of 50 mm/sec. Measurements of left and right ventricular end-diastolic dimensions, posterior and anterior wall thickness, and interventricular septal thickness were measured at the onset of QRS (fig. 1) in the standard manner. Left ventricular systolic dimension was measured at the smallest echocardiographic minor-axis dimension during ventricular systole and percent fractional shortening of the left ventricle (%FS) was calculated in the standard manner.

Measurements of the pulmonary artery diameter and systemic venous and pulmonary venous atrial dimensions (SVA, PVA) were also made at the onset of QRS at a point where the pulmonary valve was clearly visualized after a sweep from the left ventricle to the pulmonary artery (figs. 2 and 3). The systemic venous atrium was measured from the posterior wall of the pulmonary artery to the top one of the two persistent linear echoes representing the intraatrial baffle, as shown previously. The pulmonary venous atrium was measured from the second linear echo to the posterior wall of the atrial chamber. It was necessary to perform these measurements at the termination of a sweep to correctly visualize the baffle echoes arising from the posterior wall at the mitral valve annulus and thus obtain reproducible atrial measurements within a single study (fig. 3). All measurements were made from the leading edge of the echo. Attempts to visualize the intraatrial baffle posterior to the tricuspid valve as reported by Nanda et al. were not uniformly successful. The baffle could be seen, but not well enough in some patients to permit accurate measurements. In other patients, repeated evaluations of the baffle in this view produced widely varying measurements. Therefore, all measurements of the systemic venous atrium and pulmonary venous atrium were made of that portion of the atria that was posterior to the pulmonary artery. These measurements were consistent and reproducible. This was the same position used by several other workers in which the systemic venous atrium is anterior to the pulmonary venous atrium.

Contrast echocardiographic techniques confirm that drainage from the chamber anterior to the baffle echo appears in the left ventricle and drainage from the chamber posterior to the baffle echo appears in the right ventricle. The anterior chamber cannot be either the inferior or superior vena cava and must be an atrial chamber. However, to be certain that the posterior chamber was indeed a confluence of the pulmonary veins (i.e., a pulmonary venous atrium rather than a pulmonary vein), we evaluated cineangiograms of all patients in the study and studied several pathologic specimens. Surgical technique of baffle placement involves placing the inferior rim of the baffle to the left of the pulmonary veins and attaching the superior portion of the baffle to the remnant of the atrial septum between the mitral and tricuspid valves. Thus, the baffle courses obliquely from a left inferior to a right anterior position. The total atrial cavity is thereby divided into a left anterior and right posterior compartment. Two-dimensional cross-sectional echocardiography was performed in
nary valve motion were noted. Because the aorta was often poorly visualized, its diameter was not measured often enough to be included in the study. The systolic time intervals of the pulmonary and aortic valve were also too inconsistently measurable for inclusion in this study.

Cardiac Catheterization

Cardiac catheterization and cineangiography were performed under either meperidine, promethazine, and chlorpromazine or morphine and diazepam sedation. All hemodynamic data were obtained before angiography using a fluid-filled catheter system. Zero reference for all pressures was taken at the midchest level. Shunt calculations were performed using either the Fick method, indicator-dilution techniques, or radionuclide angiography. Right ventricular volumes were calculated from biplane right ventricular angiograms using the method of Graham et al. Pulmonary and systemic blood flows were calculated by indocyanine green dye curve technique when intracardiac shunting was absent and by the Fick method when shunting was present. Angiograms of the inferior and superior vena cava were obtained in all patients.

Surgical Procedure

All patients underwent Mustard's procedure for correction of TGV using standard cardiopulmonary bypass techniques. Pericardium was used as the baffle material in all patients except patient 2 in group 1 and patients 1, 4, 5, 6 and 8 in group 2, in whom woven Dacron was used. In addition to intraatrial baffle

![Figure 2. Representative tracing showing the measurement technique for pulmonary artery (PA) diameter and systemic venous atrium (SVA) and pulmonary venous atrial (PVA) dimensions at the level of the pulmonary valve (PV). The typical appearance and motion of the baffle is shown.](image)

![Figure 3. Echocardiographic sweep from the left ventricle (LV) to the pulmonary artery (PA), with the baffle echoes arising from the posterior wall at the level of the mitral valve (MV) annulus. SVA = systemic venous atrium; PVA = pulmonary venous atrium; RV = right ventricle.](image)
placement, patient 4 in group 1 required patch closure of a ventricular septal defect. Patient 1 in group 2 had undergone two Mustard procedures to correct obstruction of the superior vena cava.

**Statistical Analysis**

Linear regression analyses were performed using the least-squares method.\(^28\) In addition, 90\% confidence intervals for individual data points were constructed about the linear estimates for the group 1 data to produce a normal or expected range of values. No statistical analysis was performed on the data from group 2.

**Results**

**Group 1**

Data from group 1 were used to produce a range of expected values for each echocardiographic variable studied in patients judged at catheterization to have excellent surgical results. First, left and right ventricular minor-axis dimensions in group 1 patients were compared with the various indexes of body growth (height, weight, body surface area [BSA]). The results of linear regression analyses indicated that ventricular growth patterns in these patients correlated best with BSA. This is comparable to cardiac growth in normal patients, in whom left ventricular dimension also correlated best with BSA.\(^24\) Based on these results, all further correlations of echocardiographic variables were made only with BSA.

Echocardiographic data for the group 1 patients are presented in table 2 and figures 5–8. In figures 5–7, each linear mean is presented with a 90\% confidence interval for the individual data points and, where applicable, the mean is compared with a 90\% confidence interval of the mean values for the respective dimension vs BSA in normal patients.\(^29\) In figure 8, the

**Table 2. Group 1: Echocardiographic Data**

<table>
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<tr>
<th>Pt</th>
<th>BSA (m(^2))</th>
<th>LVDD (cm)</th>
<th>RVDD (cm)</th>
<th>SW (cm)</th>
<th>PW (cm)</th>
<th>AW (cm)</th>
<th>PA (cm)</th>
<th>SVA (cm)</th>
<th>PVA (cm)</th>
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Abbreviations: RVDD = right ventricular diastolic dimension; %FS = left ventricular percent fractional shortening; PW = left ventricular posterior wall; SW = interventricular septal wall; LVDD = left ventricular diastolic dimension; AW = right ventricular anterior wall; PVA = pulmonary venous atrium; PA = pulmonary artery; BSA = body surface area; SVA = systemic venous atrium.
mean ± 2 standard deviations is presented, and for %FS, this is compared with a similar interval for normal patients, as derived in our laboratory, which is comparable to published data.14

The left ventricular end-diastolic dimension and posterior wall thickness were smaller in patients who underwent Mustard's procedure than in normal patients, while right ventricular end-diastolic dimension and anterior wall thickness were greater than in the normal patients. Septal wall thickness showed a variable relationship to that in normal patients, and was less than normal in smaller patients and greater than normal in larger patients. Pulmonary artery diameter also increased in a linear fashion with BSA, but it was not compared with any structure of the heart of normal children, as pulmonary artery diam-

**Figure 5.** Group I data for left ventricular diastolic dimension (LVDD) (A) and posterior wall thickness (PW) (B) plotted against body surface area (BSA), showing the linear regression mean (straight dashed line) and a 90% confidence interval (solid lines) for each. The curved dashed line represents the lower limit of a 90% confidence interval for the mean value of each variable vs BSA in normal patients. Triangle indicates the patient with a pacemaker.

**Figure 6.** Linear regression mean (straight dashed line) and a 90% confidence interval (solid lines) for group I values of right ventricular diastolic dimension (RVDD) (A) and anterior wall thickness (AW) (B) plotted against body surface area (BSA). Comparison was made to the upper limit of a 90% confidence interval for mean values of each variable vs BSA in normal patients (curved dashed line). In panel B, this line fell entirely below the graphical range displayed for AW. Triangle indicates the patient with a pacemaker.

**Figure 7.** Group I values of septal wall thickness (SW) (A) and pulmonary artery diameter (PA) (B) plotted against body surface area (BSA). The mean (straight dashed line) and a 90% confidence interval (solid lines) are shown for each variable. The entire 90% confidence interval for mean SW vs BSA in normal patients is shown (curved dashed lines). The triangle indicates the patients with a pacemaker.
TABLE 3. Group 2: Echocardiographic Data

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| Expected range for BSA derived from group 1 data is indicated for variables falling outside this range. All other variables were within the group 1 range. Abbreviations: RVDD = right ventricular diastolic dimension; TI = tricuspid insufficiency; %FS = left ventricular percent fractional shortening; PW = left ventricular posterior wall; SW = interventricular septal wall; LVDD = left ventricular diastolic dimension; IVC = inferior vena cava; AW = right ventricular anterior wall; PVA = pulmonary venous atrium; PA = pulmonary artery; PV = pulmonary vein; BSA = body surface area; SVA = systemic venous atrium. |

Measurements of the systemic and pulmonary venous atrial dimensions did not correlate with BSA. However, in all patients, the ratio of the two was very consistent (average 1.00 ± 0.06) and did not correlate with BSA, but remained constant. The %FS of the left ventricular minor-axis dimension averaged 48.3% ± 6.2. These values did not correlate with BSA. Individual values clustered into a narrow range that was greater than normal. The value for the patient with a pacemaker was well outside of the group 1 limits. This finding was expected because the altered sequence of ventricular activation induced by ventricular pacing altered septal motion.

Unusual septal motion with posterior followed by early anterior movement during systole (fig. 1) and coarse fluttering of both tricuspid and mitral valves were noted in all group 1 patients. In addition, nine patients had systolic anterior motion of the mitral valve and two had systolic fluttering of the pulmonary valve. No group 1 patient had significant left-to-right shunting, semilunar valvular insufficiency, or pulmonic stenosis.

Group 2

Comparison of the echocardiographic data revealed differences between groups 1 and 2 (table 3). Two patients with elevated pulmonary artery pressure had values for left ventricular end-diastolic dimension, posterior wall thickness and pulmonary artery dimension greater than the group 1 90% confidence intervals, and the patient with pulmonic stenosis had a value for pulmonary artery diameter less than the group 1 range. The patient with right ventricular dysfunction had an increased right ventricular end-diastolic dimension that was much greater than the group 1 range and a left ventricular diastolic dimension less than the group 1 range. Right ventricular end-diastolic dimension values of the two patients with tricuspid insufficiency were also much greater than the group 1 range.

![FIGURE 8. Systemic venous atrial-to-pulmonary venous atrial ratios (SVA/PVA) (A) and left ventricular percent fractional shortening (%FS) (B) for group 1 patients plotted against body surface area (BSA). In panel A, the mean (dashed line) ± 2 standard deviations (solid lines) are shown; in panel B, the mean ± 2 standard deviations for group 1 patients (solid lines) and normal patients (dashed lines) are shown.](http://circ.ahajournals.org/doi/abs/10.1161/01.CIR.64.5.1038)
The most dramatic abnormality was present in the five cases of systemic venous baffle obstruction. For these patients and the patient with mild pulmonary venous obstruction and significant residual shunting, the systemic venous atrial-to-pulmonary venous atrial ratio was greater than the narrow range of the group 1 patients. The ratio did not correlate with the site of obstruction.

The values for %FS in the group 2 patients tended to cluster in the lower half of the group 1 range, except for the patient with complete atrioventricular block and a pacemaker. Thus, all group 2 patients could be distinguished from the group 1 patients by an abnormality in at least one variable that correlated with the defect present.

All group 2 patients had the abnormal septal motion and coarse diastolic fluttering of both atrioventricular valves seen in the group 1 patients. Four had systolic anterior motion of the mitral valve and six had systolic fluttering of the pulmonary valve. These findings bore no consistent relationship to any documented hemodynamic abnormality.

### Discussion

The usefulness of echocardiography in assessing the hemodynamic results of Mustard’s operation was investigated by examining the M-mode echocardiograms of patients shown at cardiac catheterization to have excellent repairs and comparing these results with those of patients who had residual defects. Although all patients in the study group had characteristics that were markedly different from normal, the echocardiographic features of patients with good surgical results were rather uniform within the group, and a distinct profile emerged.

Except for systemic venous atrial and pulmonary venous atrial dimensions, each echocardiographic variable measured in the group 1 patients increased linearly with BSA, and individual data points fell into a discrete range about the linear estimate. Comparison of the group 1 data with data for normal patients tended to reflect the altered physiologic state; right ventricular chamber and wall dimensions were greater than normal and left ventricular chamber and posterior wall dimensions were less than normal. These results are consistent with published data.19, 20

The chamber dimensions also correlated well with the angiographic ventricular volume studies of Jamarkani and Canent21 and Graham et al.,20, 81 who found that the average right ventricular end-diastolic volume was 119–123% of normal and that the average left ventricular end-diastolic volume was 65–100% of normal. The angiographic findings are less dramatic than the echocardiographic changes because echocardiographic dimensions are more influenced by alterations in the geometric relationship between the heart and chest wall than are angiographic volume calculations.

With regard to septal wall thickness, our data are in general agreement with previous studies. Silverman et al.20 reported that septal thickness tended to be normal, whereas in our study, there was a discrepancy between the normal growth curve and the growth pattern in patients who underwent the Mustard procedure. The data of Silverman et al.20 show that values for septal thickness increase more rapidly with BSA than the normal values, which is consistent with our data. However, our normal values fall into a narrower range, which accentuates this difference in growth rate and may well account for the discrepancy between the two works. Park et al.19 reported considerable variation in the value of septal thickness within a given echocardiogram in their patients. However, we found that septal thickness was relatively constant for each patient, which is consistent with the data of Silverman et al.20

Values for %FS of the left ventricle in group 1 patients were generally greater than normal. Because the afterload of the left ventricle (i.e., the pulmonary vascular resistance) is lower than systemic vascular resistance, one would anticipate an increased %FS due to the decreased afterload. Only the patient with a permanent pacemaker had a value below the group 1
range, which is not surprising in view of the altered sequence of ventricular activation in such patients.

The intraatrial baffle was easily visualized behind the pulmonary artery in all but two group 1 patients. Measurements of SVA and PVA showed a strikingly consistent 1:1 ratio in each patient. Other workers have described the baffle position postoperatively as occupying the middle of the atrial chamber. However, actual measurements of the atrial dimensions by Aziz et al. did not result in a consistent 1:1 SVA/PVA ratio. Aziz et al. measured the atrial chambers at end-systole, when the baffle undergoes a variable amount of anterior motion. It is more reliable to measure atrial dimensions at end-diastole, when the baffle has assumed a relatively flattened position before its rapid anterior movement after the onset of the QRS. This allows for more reproducible measurements of the atrial chambers within a given echocardiogram. Aziz et al. also described the baffle's appearance as a single linear echo and provided no precise pictorial representation of how the atrial dimensions were measured with respect to this echo. Other workers have described the baffle's appearance as consisting of a variable number of echoes. However, after careful examination of our postoperative echocardiograms, we feel that the true boundaries of the baffle are represented by two persistent linear echoes, allowing for the technical variation and occasional difficulty encountered in visualizing this structure. Indeed, this is what one would expect because of endothelialization that has occurred on each surface of the baffle. It is clear that meaningful values for systemic venous atrial and pulmonary venous atrial dimensions can be obtained only with careful measuring techniques and proper identification of the baffle. Again, we emphasize the importance of performing these measurements only after sweeping from the left ventricle to the pulmonary artery up to the pulmonary valve so as to obtain a reproducible anatomic location.

The qualitative characteristics of diastolic fluttering of the ativoventricular valves, systolic fluttering of the pulmonary valve and systolic anterior motion of the mitral valve were found to occur in the group 1 patients, and their presence postoperatively has been frequently reported in earlier studies. Their occurrence in patients with excellent surgical results indicates a lack of correlation with the hemodynamic abnormalities of semilunar valve insufficiency or pulmonic stenosis with which they are associated in normal patients. Rather, these features appear to be related to the presence of the altered anatomic structures and turbulence resulting from altered flow patterns, as suggested by previous workers. In addition, the abnormal septal motion in these patients resembles the paradoxic movement seen with right ventricular volume overload and probably reflects the reversed physiologic roles of the two ventricles. Removal of the pericardium for use as the baffle may also contribute to the abnormal motion of the septum.

Despite the marked differences between the echocardiographic findings in patients who undergo the Mustard procedure and those in normal patients, the range of abnormalities in patients with excellent surgical results was relatively narrow. Therefore, all other patients in the study group with significant hemodynamic abnormalities postoperatively (group 2) were easily separable from group 1 patients. One or more echocardiographic variables were significantly different from the range of values in group 1 patients. The type of echocardiographic abnormality did not necessarily allow one to predict the specific hemodynamic abnormality. However, one was alerted to the possibility that some residual defect did exist, which could subsequently permit more accurate selection of patients who require further investigation.

The most striking abnormality among the group 2 patients was the marked deviation of the SVA/PVA ratios from the group 1 range in patients with baffle obstruction or residual shunting. Hunter et al. reported limitation of baffle motion and thickening of the baffle appearance with an increased number of echoes in patients with caval obstruction. However, we and other workers have found that baffle motion may be very attenuated in the absence of any obstruction. We observed no thickening of baffle width in patients with obstruction, but this finding may well be a legitimate signal for such a complication due to the shrinkage or calcification that may occur with baffle obstruction. Nanda et al. described several features of baffle detachment, including a prominent anterior deflection by the baffle during atrial systole and enlargement of the systemic venous atrium in the presence of a large shunt. The patient in group 2 with residual shunting had a SVA/PVA ratio of 2.55. However, this patient also had mild pulmonary venous obstruction by the baffle, and it would be impossible to say whether the shunt or the obstruction or both caused this value for the ratio. The fact that both superior vena caval obstruction and inferior vena caval obstruction produced the same abnormal ratio is not surprising given the segment of the intraatrial baffle being visualized. Because the baffle was visualized posterior to the pulmonary artery, this portion of the baffle is the segment that receives blood from both the inferior vena cava and the superior vena cava. Thus, shrinkage of either could have the same effect upon this common portion of the baffle. Had we visualized the baffle inferior to the tricuspid valve as proposed by Nanda et al., the results might have been different, because this portion of the baffle is intimately related to the inferior vena cava rather than the superior vena cava.

M-mode echocardiography clearly identifies patients in whom residual abnormalities exist after the Mustard procedure. Coupled with pulsed Doppler echocardiography, which has been used to detect turbulence produced by either pulmonic stenosis or obstruction of systemic venous return and radio-
cEDURE, and to determine whether cardiac catheterization should be performed.

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