Hemodynamic Studies in Children Four to Ten Years after the Mustard Operation for Transposition of the Great Arteries


SUMMARY
Fourteen patients have been studied hemodynamically 4-10 years (mean 5.5 years) after the Mustard operation for transposition of the great arteries. Investigation was directed principally at 1) the detection of baffle obstruction by catheterization of the pulmonary veins (PV) and venae cavae and recording of simultaneous right ventricular (RV) and pulmonary capillary wedge pressures (PCW); 2) the detection of intra-atrial baffle leaks by dye curves and selective angiography; 3) the assessment of RV and LV function by calculating peak VCE (dp/dt/28p) from high fidelity recordings in 11 patients. Severe baffle obstruction was found in only one patient. The others had no or minimal gradients between RV end-diastolic and PCW pressures (mean 1.3 ± 0.69 mm Hg). Cardiac output was normal at rest (4.1 ± .22) and increased to 7.1 ± .62 L/min/m² (+73%) but the gradient between the RV end-diastolic and PCW pressures remained insignificant (2.2 ± 1.13 mm Hg). No evidence of caval obstruction was found in any patient. Baffle leaks were found in five patients with mild bidirectional shunting. All arterial oxygen saturations were above 90%. Mild tricuspid regurgitation was demonstrated in two patients by RV angiography and was absent in 12 others. The contractility index peak VCE averaged 1.87 ± .122 sec⁻¹ for the RV and was significantly lower in the LV (1.53 ± 1.35 sec⁻¹, P < 0.01). Only one patient presented significantly decreased RV contractility with a peak VCE of 1.07 sec⁻¹ and poor contraction on the RV angiogram. These data indicate that the long-term prognosis after the Mustard operation should be good in most patients and that the right ventricle is capable of functioning at the level of contractility of a normal left ventricle.

The prognosis for patients with complete D-transposition of the great arteries (TGA) has improved markedly since the introduction and acceptance of balloon septostomy and the intra-atrial baffle operation. The intra-atrial baffle redirects venous return to the heart, producing functional but not anatomical correction of the defect. Clinical studies of early and late postoperative survival are well documented and have shown the modification of the natural history of TGA, which may follow a successful intra-atrial baffle operation. A previous report of the clinical course of long-term survivors followed at the Hospital for Sick Children, Toronto for up to eight-and-a-half years postoperatively, suggested that 73 of 80 long-term survivors were leading a normal life. Reported hemodynamic studies, however, have been few in number and have principally involved patients who were in the early postoperative period when investigated or who had postoperative complications requiring hemodynamic assessment.

In this paper we report the results of hemodynamic and angiographic studies in 14 children four to ten years after the intra-atrial baffle operation for TGA.

Patient Material and Methods
The 14 children represented all patients at the Sick Childrens Hospital, Toronto who had a complete right and left heart catheterization study at an interval greater than four-and-a-half years following the intra-atrial baffle repair.
operation. Their clinical course paralleled that of other long-term survivors reported previously from this hospital.\(^a\) The ages of the 14 children at the time of the intra-atrial baffle repair ranged from 18 months to 4\(\frac{1}{2}\) years. The interval between surgery and investigation ranged from 4.4 to 10 years with a mean of 5.5 years. Thirteen of the children had TGA alone and one child had TGA associated with an interventricular septal defect. The preoperative clinical and hemodynamic data are summarized in table 1. Eleven of the 14 children had had Blalock Hanlon procedures, and two had had Sterling Edwards procedures. The pulmonary artery pressure was measured in only two preoperatively. The majority of these patients had been investigated preoperatively and treated palliatively before Rashkind balloon septostomy was an accepted procedure and before current techniques for entering the pulmonary artery had been refined. Pericardium was used in all cases for construction of the atrial baffle. The operative techniques employed have been reported previously.\(^a\)

**Procedure**

All the children were lightly sedated with a standard premedication containing demerol, phenergan and chlorpromazine.

In 11 of the 14 children venous catheterization was performed by the percutaneous technique through the femoral vein. In the remaining three children a catheter was passed from a right sided antecubital vein in two cases and a left sided antecubital vein in one. The venous catheter was passed to the systemic venous atrium and then to the left ventricle. Systemic venous obstruction was assessed by pressure recordings as the catheter was withdrawn from the right atrium to the venae cavae or vice versa. In all 14 patients the main pulmonary artery (MPA) was entered from the left ventricle with either an end hole catheter and guide wire or a flow guided Swan-Ganz balloon catheter and pulmonary artery wedge pressures were obtained.

In all 14 cases a femoral artery was catheterized percutaneously and an end hole or angio catheter passed retrogradely to the ascending aorta, right ventricle and across the tricuspid valve to the new pulmonary venous atrium. In all 14 cases the right and left pulmonary veins were probed and pressure recordings obtained as the catheter was withdrawn from the pulmonary veins to the right ventricle. Simultaneous pressure recordings were made of 1) the pulmonary venous atrial and systemic venous atrial pressures, and 2) the pulmonary capillary wedge and right ventricular end-diastolic pressures.

All pressures were measured by Statham strain gauge transducers placed at a level one-third of the chest thickness below the sternal angle.

To detect any residual shunt, measurements of \(O_2\) content were made in all chambers by a Waters cuvette oximeter and in 12 patients indocyanine green dye was injected into the superior and inferior venae cavae and dye curves recorded from the femoral artery.

Cardiac output measurements were made by indicator dilution technique, using indocyanine green dye, a Harvard constant withdrawal pump and a Waters 250 densitometer. The dye was injected into the MPA and sampled from the aorta.

Observations of pressures and cardiac output were repeated following intravenous infusion of isoproterenol. The rate of infusion of isoproterenol was adjusted to give an increase in heart rate of at least 50%. Cardiac output determinations were repeated at what was judged to be the sustained peak effect of the drug and simultaneous pulmonary venous capillary and RV end-diastolic pressures were recorded.

Right ventricular and left ventricular function was assessed by calculating the peak velocity of the contractile element (peak VCE); this was obtained from high fidelity pressure tracings using a transducer-tipped catheter (Statham p86 No. 5F). The tracings were analyzed on an X-Y digitizing table and the value dp/dt/28p (from total pressure) calculated every 5 msec during the isovolumic phase for three consecutive contractions. An average peak value for VCE was then obtained from the plot dp/dt/28p against pressure.

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**Table 1. Preoperative Hemodynamics and Clinical Data**

<table>
<thead>
<tr>
<th>RA (mean)</th>
<th>LA (mean)</th>
<th>LV</th>
<th>RV</th>
<th>MPA</th>
<th>SaO₂ (%)</th>
<th>Type</th>
<th>Age</th>
<th>Mustard repair</th>
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<td>BH</td>
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<td>5 days 13.2</td>
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<td>NE</td>
<td>55</td>
<td>BH</td>
<td>5 wk 12.2</td>
</tr>
</tbody>
</table>

\(^a\) Abbreviations: RA = right atrium; LA = left atrium; LV = left ventricle; RV = right ventricle; MPA = main pulmonary artery; SaO₂ = systemic arterial oxygen saturation; BH = Blalock Hanlon; SE = Sterling Edwards; NE = not entered.
### Table 2. Postoperative Hemodynamic Data

| Interval postop. | Age at restudy | SVC | IVC | PVA | SVV | RV | LV | MPA | PA wedge | PV wedge | Cardiac index (L/min/m²) | At rest | Post-isoproterenol | SaO₂ (%) | Rhythm | Shunt R-L | L-R | Angiogram |
|------------------|----------------|-----|-----|-----|-----|-----|-----|-----|-------|---------|-----------|-------------------|--------|-------------------|---------|--------|-----------|-----|-----------|
| C.H.             | 4½ yr 7 yr     | m = 5 | m = 5 | cv = 11 | cv = 8 | 94/6 | 24/4 | 22/7 | cv = 11 | m = 4 | 4.1 | 11.4 | 92 | Nodal | + 0 | Baflie leak |
| M.S.             | 5 yr 8½ yr     | m = 6 | m = 6 | a = 6 | a = 10 | 80/5 | 75/4 | 75/45 | a = 12 | a = 6 | 4.4 | 6.8 | 91 | SR | 0 0 | Baflie leak |
| V.P.             | 5 yr 7½ yr     | m = 6 | m = 6 | cv = 6 | cv = 6 | 95/4 | 37/2 | 17/4 | cv = 7 | cv = 7 | 3.4 | 8 | 93 | Nodal | + 0 | Baflie leak, LV outflow narrowing, Mod. T.I |
| M.P.             | 7 yr 9 yr      | m = 2 | m = 2 | cv = 10 | cv = 6 | 88/4 | 29/2 | 19/6 | cv = 6 | cv = 6 | 4.5 | 8 | 94 | Nodal | 0 0 | Baflie leak |
| M.S.             | 10 yr 12 yr    | m = 3 | m = 3 | a = 3 | a = 3 | 90/4 | 30/2 | 30/10 | a = 3 | a = 3 | — | — | 100 | SR | + 0 | Baflie leak |
| G.T.             | 8 yr 10½ yr    | m = 5 | m = 5 | a = 10 | a = 7 | 105/4 | 80/6 | 22/10 | a = 10 | a = 8 | — | — | 95 | SR | 0 0 | LV outflow tract narrowing |
| G.S.             | 6 yr 9 yr      | m = 2 | m = 2 | a = 3 | a = 5 | 110/4 | 28/3 | 18/8 | a = 4 | a = 4 | 4.7 | 6.2 | 100 | SR | 0 0 | No baffle defect |
| C.B.             | 9 yr 11 yr     | m = 7 | m = 8 | a = 6 | a = 6 | 93/5 | 77/6 | 75/45 | v = 40 | v = 40 | — | — | 91 | SR and intermittent nodal | 0 0 | Small VSD, pulmonary venous obstruction |
| N.F.             | 4½ yr 7 yr     | m = 2 | m = 5 | a = 5 | a = 3 | 85/5 | 30/5 | 20/10 | a = 5 | a = 5 | 5 | 8 | 99 | SR | 0 0 | Baflie leak |
| A.O’L.           | 5 yr 7½ yr     | m = 6 | m = 6 | a = 10 | a = 8 | 93/6 | 25/3 | 16/8 | a = 10 | a = 10 | 5 | 7.3 | 93 | SR | 0 0 | No baffle leak |
| D.G.             | 5 yr 8 yr      | m = 2 | m = 2 | a = 7 | a = 3 | 110/2 | 20/3 | 20/8 | a = 8 | a = 8 | 3.2 | 5 | 93 | SR | 0 0 | No baffle leak |
| F.G.             | 4½ yr 7½ yr    | m = 6 | m = 6 | a = 6 | a = 7 | 104/3 | 48/3 | 16/5 | a = 6 | a = 6 | 3.6 | 4.5 | 92 | SR | 0 0 | Mod. T.I, no baffle leak |
| D.Mc.            | 6 yr 10½ yr    | m = 3 | m = 3 | a = 8 | a = 8 | 103/4 | 27/3 | 21/10 | a = 8 | a = 8 | 3.3 | 5.8 | 99 | SR and intermittent nodal | 0 0 | No baffle leak |
| F.S.             | 4 yr 5½ yr     | m = 2 | m = 2 | a = 9 | a = 1 | 110/10 | 49/4 | 45/22 | v = 13 | v = 13 | — | — | 93 | SR | 0 0 | Baflie leak |

Abbreviations: SVC = superior vena cava; IVC = inferior vena cava; PVA = pulmonary venous atrium; SVV = systemic venous atrium; RV = right ventricle; SR = sinus rhythm; LV = left ventricle; MPA = main pulmonary artery; FV = pulmonary vein; SaO₂ = systemic arterial oxygen saturation; TI = tricuspid incompetence.
Results

The hemodynamic findings in the 14 children at the time of postoperative study are shown in table 2.

Intra-atrial Baffle Function

There was no evidence of systemic venous obstruction in any of the 14 patients. The pressure difference between the venae cavae and the new systemic venous atrium did not exceed 2 mm Hg in any child. In two patients superior vena caval angiography suggested slight narrowing at the superior vena cava-atrial junction but no pressure difference was found in either case (fig. 1).

In seven patients the mean pulmonary venous atrial and systemic venous atrial pressures were identical; five of the seven had small intra-atrial baffle defects. In two of the seven patients the pulmonary and systemic venous atrial a and v waves were identical; in the remaining five the a wave or a cv wave was greater in the pulmonary venous atrium than in the systemic venous atrium.

Only one patient had evidence of pulmonary venous obstruction (C.B.). This boy was first studied seven years postoperatively. He had been suspected on clinical grounds of having pulmonary hypertension and this diagnosis was confirmed at cardiac catheterization. However, the diagnosis of pulmonary venous obstruction had not been made because neither a pulmonary venous nor reliable pulmonary artery wedge pressure was obtained. At restudy, nine years postoperatively, the pulmonary artery wedge pressure was elevated (table 2). An end-hole catheter was passed retrogradely across the tricuspid valve into the pulmonary venous atrium, which appeared to be divided into two chambers. The catheter passed into the pulmonary veins and a withdrawal recording demonstrated a high pressure chamber proximally communicating via a small orifice with a low pressure chamber distally (fig. 2). An angiogram was performed with the catheter positioned at the orifice of the left upper pulmonary vein and demonstrated a diaphragm-like structure to be the site of obstruction within the pulmonary venous atrium (fig. 3). In spite of the severe baffle obstruction demonstrated at catheterization, this boy only became dyspneic on severe exertion and clinically was judged to have only mild impairment of his effort tolerance. Another patient (M.S.) had pulmonary hypertension when restudied five years postoperatively but no evidence of pulmonary venous obstruction. The left ventricular pressure preoperatively was 32/2 mmHg and there was no evidence angiographically of a ventricular septal defect. The interval between his preoperative study and operation was 18 months.

Seven of the 14 children had intra-atrial baffle defects

![Figure 1](image1.png) **Figure 1.** Superior vena caval angiogram demonstrating narrowing at the superior vena caval-atrial junction in the absence of a pressure difference. The uppermost arrow indicates an intra-atrial baffle defect.

![Figure 2](image2.png) **Figure 2.** Pressure record obtained within the new pulmonary venous atrium as the catheter is withdrawn through the narrow orifice produced by intra-atrial baffle obstruction.

![Figure 3](image3.png) **Figure 3.** Angiogram with a catheter positioned just below the orifice of the left upper pulmonary vein demonstrating that a diaphragm-like structure appears to be the site of obstruction within the pulmonary venous atrium.
demonstrated by angiography (fig. 1) or dye curves. None was cyanotic and none had an arterial saturation below 90%. The most common site of deficiency in the atrial baffle was at the superior vena cava-atrial junction and this was in four of the seven cases. One child with angiographic evidence of a baffle leak had no evidence of intra-cardiac shunting, as determined by oximetry or dye curves; mild bidirectional shunting was present in the other six children (table 2).

Tricuspid Regurgitation

Two patients had a trivial degree of tricuspid regurgitation. Both had an intact ventricular septum when investigated preoperatively and tricuspid regurgitation was not noted at that time. Neither was in sinus rhythm postoperatively.

Main Pulmonary Artery — Left Ventricular Pressure Differences

Three patients had systolic pressure differences of greater than 20 mm Hg between the main pulmonary artery and the left ventricle. In one patient (G.T.) studied in the early postoperative period, the left ventricular pressure was 49/0 mm Hg; this increased to 80/6 mm Hg at restudy eight years postoperatively and was associated with a pressure difference of 60 mm Hg between the left ventricle and the main pulmonary artery.

**Figure 4.** Peak VCE for the right and left ventricles in patients with transposition of the great vessels following the intra-atrial baffle operation. The horizontal bars represent the mean values and standard error of the estimate for the right and left ventricles, respectively. The hatched areas represent the expected values for the right and left ventricles in normal children. The black circle represents the single postoperative patient studied who had a peak VCE depressed below the level expected for a normal RV. The mean value for peak VCE for the RV following the intra-atrial baffle operation can be seen to be within the range of a normally functioning LV. The mean value for the LV peak VCE following operation is lower than that found in a normal LV and approaches the value found in the normal RV.

Ventricular Function

Cardiac Output

The cardiac index at rest was measured in ten of the 14 patients and ranged from 3.2 to 5.1 L/min/m². The cardiac index was measured in the same subjects following administration of isoproterenol. The mean cardiac index for the group rose from 4.1 L/min/m² to 7.9 L/min/m². The increase in cardiac output usually resulted in a small diastolic pressure difference around the baffle but this did not exceed 5 mm Hg in any patient (mean 2.2 ± 1.13).

Contractility

For the right ventricle peak VCE averaged 1.87 ± .122 sec⁻¹. Only one child had a significant decrease in the right ventricular peak VCE with a value of 1.07 sec⁻¹; poor performance was also observed on the right ventricular angiogram in this child. Right ventricular angiography in the other ten children suggested a good performance in seven and a slight decrease in performance in two cases; in one case multiple premature ventricular contractions made assessment of performance impossible. For the left ventricle there was a somewhat larger scatter but the mean value for peak VCE was 1.53 ± .135 sec⁻¹ and was significantly lower than for the right ventricle (P < 0.01) (fig. 4).

Discussion

Although the intra-atrial baffle operation may result in a striking clinical improvement of the patient’s condition, concern has existed about the long-term fate and function of the pericardial baffle and the ability of the right ventricle and tricuspid valve to operate at a systemic workload.

Complications relating to the placement of the pericardial baffle are now well recognized. The incidence of isolated superior vena caval obstruction is probably low and in our experience this complication does not usually require treatment.6 Stark et al. have emphasized the importance of preserving the azygos system at palliative surgery since this probably provides an adequate collateral circulation.8 When superior vena caval obstruction is sufficiently severe to require surgery it usually presents as an early problem within the first year after operation.9, 10, 12 None of the 14 patients investigated in the present study had any evidence of superior vena caval obstruction up to ten years postoperatively. Pulmonary venous obstruction due to the intra-atrial baffle is a much more serious complication and is almost invariably associated with severe symptoms. Like superior vena caval obstruction it has usually been a complication recognized fairly early after surgery and in most reported experience has occurred within six months of operation.9, 10, 11 One of the 14 patients in this study had evidence of severe pulmonary venous obstruction when studied nine years postoperatively. An earlier study, performed seven years postoperatively, documented the presence of pulmonary artery hypertension but a reliable pulmonary artery wedge pressure was not obtained nor were the pulmonary veins entered. This case emphasizes the importance of attempting to selectively catheterize the pulmonary veins in any patient with unexplained pulmonary hypertension postoperatively. In view of the boy’s relative
well-being throughout the postoperative period, it is difficult
to speculate as to when the pulmonary venous obstruction
developed.

The mechanisms responsible for baffle obstruction have not
yet been well delineated. Mohri et al. experimentally
confirmed graft shrinkage and thought it likely that some
degree of obstruction of the patch occurred in all patients
after the intra-atrial baffle operation.\textsuperscript{14} They also
demonstrated, however, the growth potential of adjacent
atrial tissue without any deleterious effects on the growth
and function of the heart. The evidence of the present study
suggests that graft shrinkage was not a problem and perhaps
supports the concept of the growth potential of adjacent
atrial tissue. Graft shrinkage has been the most commonly
postulated mechanism for the production of baffle obstruc-
tion, but we believe that the stenosis could also result from
adhesions between the pericardial baffle and adjacent right
lateral atrial wall, producing a posterior and anterior
pulmonary venous chamber as seen in fig. 3. The experience
of several reports that baffle obstruction is more likely to oc-
cur in infancy may well reflect the greater importance in this
group of patients who have smaller atria of tailoring the baf-
ffe precisely and paying careful attention to its geometry.
Our experience with obstructive problems from the intra-
atrial baffle has been reported previously and suggests that
this should be an uncommon clinical problem.\textsuperscript{14} The present
study reinforces our clinical impression that problems
associated with shrinkage of the baffle are unlikely beyond
one year postoperatively.

Like Rodriguez-Fernandez et al. we found that baffle
leaks were common and these occurred in seven of our 14
patients.\textsuperscript{10} These leaks were not associated with any signifi-
cant degree of intracardiac shunting in any patient and in
particular no patient was cyanotic because of a baffle leak.
The most common site of baffle detachment was at the
superior vena cava and atrial junction, but in no patient was
there any evidence of associated superior vena caval obstruc-
tion.

Waldhausen et al. reported tricuspid regurgitation after
the intra-atrial baffle operation\textsuperscript{8} and Tyan et al. found tri-
cuspid regurgitation in 17 of 21 survivors studied up to six
years postoperatively.\textsuperscript{9} In our experience this has been a rare
complication\textsuperscript{9} and in this study only two cases of mild tri-
cuspid regurgitation were noted. In contrast to the patients
reported by Tyan, 13 of the 14 patients studied by us were
transpositions with an intact ventricular septum. Nine of the
patients studied by Tyan had a ventricular septal defect
preoperatively. One may therefore suspect a link between
closure of a ventricular septal defect and tricuspid regurgita-
tion. Tyan, however, found that there was no significant
difference in the frequency of tricuspid regurgitation in his
patients with an intact ventricular septum; the two patients
with mild tricuspid regurgitation in this report also had an
intact ventricular septum. Tyan suggested that pre-existing
tricuspid regurgitation and postoperative arrhythmias were
the main determinants of the postoperative tricuspid regurgita-
tion; neither of the two patients in our study with tricuspid regurgitation was in sinus rhythm when in-
vigated postoperatively. The mean age of Tyan's
patients, both at operation and restudy, was considerably
greater than the mean age of the patients in this study, and it
may be that deterioration in right ventricular function and
tricuspid valve competence with age prior to operation ac-
counts for some of the difference.

Only three patients in this study had a systolic pressure
difference greater than 20 mm Hg between the left ventricle
and the main pulmonary artery. In one of these patients it
appears possible that the degree of subvalvar obstruction
had increased postoperatively since the left ventricular
pressure in the early postoperative period was 49 mm Hg
compared with 80 mm Hg at the time of restudy. Rodriguez-
Fernandez et al. reported a case of left ventricular sub-
valvar stenosis which appeared progressive in the post-
operative period. This complication, however, seems to be
very rare.\textsuperscript{16}

We believe that the present study also provides some ob-
jective evidence that the long-term functional capacity of the
heart, following the intra-atrial baffle operation, is well
maintained, despite the presence of arrhythmias and small
residual defects in the atrial baffle. The pulmonary venous
atrial pressures and right ventricular end-diastolic pressures
were normal at rest, and were not significantly altered after
isoproterenol infusion. Despite a substantial rise in cardiac
index following isoproterenol from a mean of 4.1 ± 22
1.71 ± 0.7 L/min/m², the gradient between the right ven-
tricular end-diastolic and pulmonary capillary wedge pres-
sures remained insignificant (2.2 ± 1.13 mm Hg).

Right ventricular function assessed by the contractility in-
dex peak VCE was within normal limits for all but one
patient. This seems to be at variance with the findings of Jar-
makani and Canent who, using angiographic techniques to
measure the ejection fraction (EF), found depressed RV
function in all their patients with TGA before as well as after
operation;\textsuperscript{16} similar results have been reported by Graham et al.\textsuperscript{16}
Although a good correlation exists between peak VCE
and EF, these two parameters measure different characteris-
tics of ventricular contraction.\textsuperscript{16} EF is con-
cerned with the "pump" function of the heart and is
measured during the ejection period while peak VCE
measures the level of contractile state from pressure record-
ings made during the isovolumic period. Krayenbuehl et al.
have shown that EF depends not only upon myocardial con-
tractility, but also upon physical determinants of ventricu-
lar contraction. Changes in the ejection fraction and
alterations of the contractile state can occur independently
of each other and in opposite directions.\textsuperscript{16} Thus concordance
of results is not necessarily to be expected.

We are aware that no entirely satisfactory measurement
of ventricular function exists at present, and that theoretical
objections have been expressed about peak VCE and Vmax as
measurements of the contractile state.\textsuperscript{16} It is still believed,
however, that these parameters are among the most sensitive
in assessing ventricular function and they have proven useful
in assessing the ventricular function in various types of
congenital heart disease.\textsuperscript{16} We did not try to calculate ejection
fraction in our cases as we found it difficult to evaluate
right ventricular volumes in the heavily trabeculated RV
typically seen in TGA. The values for EF found by others in
TGA are very low indeed, comparable only to those seen in
diffuse myocardial disease such as myocarditis or cardio-
myopathy and other signs of ventricular failure might have
been expected.\textsuperscript{16} Most of our postoperative patients had
normal physical activities, their cardiac output and RV end-diastolic pressures were normal and none required digitalis. We therefore feel that in our patients the clinical status as well as the hemodynamic findings are in agreement with the good RV function measured by peak VCE.

Although the right ventricle in transposition patients pre and postoperatively appears to function at the same peak VCE, this does not seem to be the case for the left ventricle. The contractility index for the left ventricle in a group of preoperative transposition patients reported previously from this laboratory was significantly higher than the peak VCE for the left ventricle in the patients reported in this study. One may speculate that the left ventricle in transposition of the great arteries goes through a slow process of involution, characterized not only by changes in wall thickness, as shown by Pasternac et al., but also by change in its contractile properties. Indeed, in the patients in this study the peak VCE for the left ventricle was close to the index found for the right ventricle in a group of children of a similar age without transposition. Thus both ventricles seem to adapt to their reversed function, the RV from an early age, the LV with the passage of time.

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