Hemodynamic Response to Exercise in Patients 2 to 6 Years after Rastelli Operation

Makoto Nakazawa, M.D., Hirofumi Okuda, M.D., Yasuharu Imai, M.D.
Yoshinori Takanashi, M.D., Hiromi Kurosawa, M.D.
and Atsuyoshi Takao, M.D.

We studied hemodynamic response to exercise in eight patients who had undergone Rastelli operation 2 to 6 years before this study. Endurance time for the treadmill test was below the low limit of two standard deviations of our normal value in 5 out of 7 patients. On bicycle ergometer exercise test during catheterization, cardiac output increased from $3.8 \pm 0.96$ liter/min/m$^2$ to $6.5 \pm 1.7$ liter/min/m$^2$ when heart rate increased $81 \pm 10$ to $123 \pm 17$, the latter reaching $71\%$ of the maximum value. Right ventricular pressure increased from $85 \pm 38$ mmHg to $114 \pm 45$ mmHg, along with elevation of the enddiastolic pressure ($+5 \pm 4$ mmHg). Right-sided ventricular ejection fraction increased in 3 out of 6 patients, while left-sided ventricular ejection fraction increased in 4 out of 7 patients. Thus, ventricular pump function does not respond normally to physical activity in many patients after Rastelli operation.

The long term results of Rastelli operation for cyanotic congenital heart disease are often complicated by conduit obstruction, arrhythmias, congestive heart failure, residual shunt, pulmonary hypertension, ventricular dysfunction, endocarditis, or sudden death. However, there is evidence that patients show tremendous clinical improvement after this operation. For adequate management of these patients it is therefore important to know the hemodynamic response to physical activity, and this was the purpose of the present study.

SUBJECTS AND METHODS
The subjects were 8 patients, aged $13 \pm 4$ (SD) years, 2 to 6 years after Rastelli operation; 5 had concordant atrioventricular connection and 3 had discordant connection, i.e. congenitally corrected transposition of the great arteries. They underwent the Scheffeld program treadmill test and were catheterised. The patients performed a supine bicycle ergometer exercise test with a load of 20 to 40 watts while intracardiac pressures were measured, and cardiac output was monitored by a thermodilution method. The exercise was repeated at the same level after the heart rate returned to pre-exercise control value, and on this occasion right and left ventricular cineangiographies were recorded via right-sided ventricular ("R"V) injection. From these cines, ventricular volumes were calculated as reported previously.

RESULTS
The results were as presented in the Table.
<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Age (y)</th>
<th>Treadmill test</th>
<th>Hemodynamic data</th>
<th>Volume data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>op. cath (min)</td>
<td>Rest Ex Rest Ex</td>
<td>&quot;R&quot;V EDV* Rest Ex</td>
</tr>
<tr>
<td>1. d-TGA</td>
<td>10 12</td>
<td>13.9 154 VPB ST</td>
<td>75 110</td>
<td>3.4 5.8 83 110</td>
</tr>
<tr>
<td>2. TF</td>
<td>8 11</td>
<td>13.0 173 n.p.</td>
<td>75 120</td>
<td>2.8 5.2 58 72</td>
</tr>
<tr>
<td>3. TB</td>
<td>6 12</td>
<td>13.7 163 VPB ST</td>
<td>100 160</td>
<td>5.2 7.7 146 180</td>
</tr>
<tr>
<td>4. TB</td>
<td>6 12</td>
<td>15.0 187 VPB</td>
<td>90 130</td>
<td>4.3 7.8 82 115</td>
</tr>
<tr>
<td>5. TF</td>
<td>4 9</td>
<td>not performed</td>
<td>75 120</td>
<td>4.5 6.8 50 90</td>
</tr>
<tr>
<td>6. 1-TGA</td>
<td>9 13</td>
<td>14.5 173 APB</td>
<td>85 120</td>
<td>2.8 4.9 52 80</td>
</tr>
<tr>
<td>7. 1-TGA</td>
<td>16 21</td>
<td>16.0 185 APB</td>
<td>73 110</td>
<td>4.4 9.4 70 80</td>
</tr>
<tr>
<td>8. 1-TGA</td>
<td>6 12</td>
<td>15.0 184 VPB</td>
<td>75 110</td>
<td>2.7 4.4 140 185</td>
</tr>
</tbody>
</table>

**Mean**

|           |        |                   |         | 123 | 3.8 | 6.5 | 85 114 |

**Standard deviation**

|           |        |                   |         | 10 17 | 0.96 | 1.7 | 38 45 |

**Abbreviations: d-TGA = complete transposition of the great arteries; TF = tetralogy of Fallot; TB = Taussig-Bing anomaly, 1-TGA = congenitally corrected transposition of the great arteries; (y) = years of age; op. = operation; cath = catheterisation; ET = endurance time; HR = heart rate; EKG = electrocardiogram; Ex = exercise; "R"VP = right-sided ventricular pressure; "R"VEDP = right-sided ventricular end-diastolic pressure; PCWP = pulmonary capillary wedge pressure; EDV* = enddiastolic volume, expressed as percent of normal; EF = ejection fraction; VPB = ventricular premature beat; APB = atrial premature beat; ST = ST depression
Cardiac output increased by $74 \pm 21\%$ when the heart rate increased by $51 \pm 8\%$ on the ergometer. Right-sided ventricular pressure increased by $38 \pm 21\%$ and the enddiastolic pressure by $5 \pm 4$ mmHg. The "R"V enddiastolic volume (EDV) increased by $10 \pm 11\%$, and the ejection fraction (EF) increased by more than 0.05 in 3 out of 6 patients. The left-sided ventricular ("L"V) EDV did not change and the EF increased in 4 out of 7 patients. Endurance time for the treadmill test was below the low limit of two standard deviations of our normal value in 5 of 7 patients on whom the test was performed. Ventricular premature beats were induced or increased by exercise in 4 patients, whose "R"V pressure exceeded 100 mmHg on the bicycle ergometer, and two of them also showed electrocardiographic findings of myocardial ischemia on the treadmill test. No differences were observed in any of the parameters according to ventricular loop.

DISCUSSION

The physical load during catheterisation was obviously not at the maximum level. Boucher et al. reported that left ventricular ejection fraction constantly increased at the load level before anaerobic threshold in normal subjects, while heart rate averaged 78% of the maximum value. Heart rate during the bicycle ergometer exercise test in the present study averaged 71% of the maximum rate on the treadmill test. Although it should be questioned whether the load on the treadmill test reached the maximum beyond anaerobic threshold in each patient, it would not be too unreasonable to say that the work load of the ergometer could result in an increase in ejection fraction if ventricular function was normal.

Percentage increase in cardiac output in response to exercise was similar to that seen in patients who had undergone a classical repair for tetralogy of Fallot. However, the absolute values were lower in the Rastelli patients than in the tetralogy patients, in whom cardiac index increased from $4.7 \pm 0.5$ L/min/m² to $8.1 \pm 1.9$ L/min/m² when heart rate increased $91 \pm 20$ to $132 \pm 20$ (unpublished data). This may be related to the lower-than-normal physical fitness of our patients. However, it is known that fitness can be improved by physical training in patients following open heart surgery, thus hemodynamic characteristics do not necessarily have a direct relationship to this.

There have been no reports of right ventricular functional response to exercise. In the present study, we adopted an ejection fraction increasing by more than 0.05 on exercise as normal. We then found that the right ventricle responded abnormally to exercise in many of the patients. Two patients who showed normal response of ejection fraction itself nevertheless showed a simultaneous increase in enddiastolic pressure, indicating that ventricular function was not completely normal. In addition, volume data during exercise could not be obtained because of inadequate angiograms in the two patients (#3, 4) who had the lowest ejection fraction at rest. In these patients, ejection fraction may have further decreased with exercise. This poor right ventricular function could be catastrophic in association with exercise-induced ventricular arrhythmias.

The response of left ventricular ejection fraction was surprisingly good in more than half of the patients. Graham et al. reported a study of patients after Rastelli operation using radionuclide angiography, in which two cases showed a decreased ejection fraction in response to exercise. We had no patients whose ejection fraction declined on exercise but had some poor responders. We could not identify the basic mechanism for this difference from the present data alone.

We conclude that ventricular pump function does not respond normally to physical activity in many patients after Rastelli operation. This fact needs to be taken into account in the long term management of these patients.

REFERENCES

2. MCGOON DC, DANIELSON GK, PUGA FJ, RITTER DG, MAIR DD, ILSTRUP DM: Late results after extracardiac conduit repair for congenital cardiac defects. Am J Cardiol 49: 1741, 1982
conduit repair. *Heart (Sinzo)* 17: 521, 1985 (in Japanese)


7. BOUCHER CA, ANDERSON MD, SCHNEIDER MS, MURPHY JH, OKADA RD, KANAREK DJ: Left ventricular function before and after reaching the anaerobic threshold. *Chest* 87: 145, 1985
