Two-dimensional echocardiographic detection of pulmonary venous channel stenosis after Senning's operation

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ABSTRACT   Stenosis of the common pulmonary venous (PV) channel after Senning’s operation for complete transposition of the great arteries is a serious problem, and a method for noninvasive diagnosis is highly desirable. Therefore, our purpose was to devise a method to diagnose PV channel stenosis noninvasively. The newly created common PV channels were measured and the short-axis views of the left ventricle were observed by means of two-dimensional echocardiography in 16 patients who had undergone Senning’s procedure. In seven patients we used the original procedure and in nine patients we used a modified procedure with a pedicled pericardial patch. The shape of the left ventricle became round abruptly when the width of the PV channel decreased below a critical value (a range of 6 to 9 mm). Three patients with a relatively round-shaped left ventricle and a narrow PV channel (below 9 mm) were all confirmed to have PV channel stenosis at reoperation. All of the patients with a wide PV channel (above 10 mm) and a flat-shaped left ventricle were in good condition both clinically and as determined from the catheterization data. After the operation, patients who had tricuspid regurgitation, pulmonary vascular obstruction, or residual left ventricular outflow tract stenosis had a relatively round-shaped left ventricle even though the PV channel was wide enough (above 10 mm). Measurement of the PV channel confirmed the effects of these conditions. Correct diagnosis of PV channel stenosis can therefore be made by observing the shape of the left ventricle and by measuring the PV channel.


AS OUR EXPERIENCE with Senning’s procedure for the complete transposition of the great arteries (TGA) increases, we recognize that stenosis of the newly created common pulmonary venous (PV) channel leads to grave consequences. The purpose of this study was to devise a method to diagnose PV channel stenosis noninvasively.

Methods   Patients. Our study group consisted of 16 patients with complete TGA after Senning’s operation. There were 13 male and three female patients. Seven patients underwent Senning’s original procedure. In the other nine patients, a modified Senning’s operation was carried out, in which a pedicled pericardial patch for the enlargement of the functional left atrial cavity is used. The ages of the patients ranged from 7 months to 9 years, with a median age of 27 months. The body surface area ranged from 0.31 to 0.87 m², with a median value of 0.46 m². The follow-up periods ranged from 20 days to 25 months, with a mean value of 6 months (table 1).

Instruments. The ultrasonic instrument used was a Toshiba sonolayergraph model SSH-11A with a 2.4 MHz transducer or an ATL Mark III mechanical sectorscanner. First we measured the width of the PV channel by two-dimensional echocardiography. Next, deformity of the left ventricle was evaluated from the short-axis view at the level of the papillary muscles. This information was compared with catheterization data obtained within 48 hr after the echocardiographic study.

The ultrasonic planes used for this study are shown in figure 1. From the first view (top) the width of the PV channel can be measured. The transducer was placed on the second or third left intercostal space at a parasternal position with a slight angulation along the line between the left shoulder and the right hip. This provided a long-axis view of the PV channel at the base of the heart. The second view (bottom) is the short-axis view of the left ventricle at the level of the papillary muscle. This view is used for the estimation of left ventricular deformity.

On the first view, identification of the pulmonary vein, PV channel, functional left atrium, and right ventricle was confirmed by a contrast medium injected at the pulmonary arterial wedge position during right heart catheterization (figure 2). On these serial echocardiographic pictures, the contrast appeared from the posterior vessels and passed through the PV channel to the right ventricle. From these maneuvers, identifica-
tion of the first view was made as shown in figure 3, top. The newly created PV channel is seen passing around the systemic venous channel.

The widest PV channel was discovered by shifting the two-dimensional echocardiographic plane from the caudal to the cephalad projection. In this view the measurement was made at the shortest internal dimension of the PV channel, where it passes behind the systemic venous channel, as shown on figure 3, bottom.

Deformity of the ventricle is used for estimation of left ventricular pressure. In the second view, the distance between the two septoparietal junctions of the interventricular septum was designated as “b” and the distance of the septal to the left ventricular free wall dimension perpendicular to b was designated as “a”; the a/b ratio was then calculated (figure 4). We calculated the a/b ratio at the end-systolic phase ([a/b]s) by replaying the videotape recorder with frame-by-frame stop motion and a motion analyzer (Sony model SVM-1110) when the internal left ventricular space was smallest.

Results

The long-axis views from two patients are illustrated in figure 5. One view (top) is from a patient with a
wide PV channel measuring 12 mm. At cardiac catheterization this patient had a low pulmonary arterial wedge pressure of 10 mm Hg. The other view (bottom) is from a patient with a narrow PV channel measuring only 6 mm. In this patient the pulmonary arterial wedge pressure was very high at 36 mm Hg at catheterization.

Figure 6 shows short-axis views from a patient with low left ventricular pressure (top) and from a patient with high left ventricular pressure (bottom). For the first patient, the (a/b)s ratio is 0.43 and the peak left ventricular pressure at cardiac catheterization was 32.5 mm Hg. The (a/b)s ratio for the other patient is 0.89, and a very high left ventricular pressure of 96.5 mm Hg was recorded at catheterization.

The relationship between mean pulmonary arterial wedge pressure and the two-dimensional echocardiographic measurement of the PV channel width is shown in figure 7. The mean pulmonary arterial wedge pressure showed a tendency to increase abruptly when the diameter of the PV channel (as measured by two dimensional echocardiography) decreases below a critical value (6 to 9 mm).

These points appear on the dotted curve in figure 7, with the exception of data for those patients with tricuspid regurgitation.

When the (a/b)s ratio is plotted against the peak left ventricular pressure, a good linear correlation is revealed (figure 8). The correlation coefficient is very high at .86.

Discussion

Stenosis of the newly created PV channel was found in some patients after Senning’s operation for com-
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**PA wedge pressure (mean) vs PV channel width**

(TGA, post Senning’s op.)

![Diagram](image)

**FIGURE 7.** Mean pulmonary arterial wedge pressure (PA-W) vs pulmonary venous channel (PV-C) width. The PA-W shows a tendency to increase abruptly when the PV-C width decreases below a critical value (6 to 9 mm). TR = tricuspid regurgitation.

**peak LVP vs (a/b)s**

(TGA, post Senning’s op.)

![Diagram](image)

**FIGURE 8.** Peak left ventricular pressure (LVP) vs (a/b)s; (a/b)s ratio correlates well with peak LVP (r = .86).

**PA-W(m)**

<table>
<thead>
<tr>
<th>PV-C (mm)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
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<tr>
<td>PA-W(m)</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
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</table>

The relationship between the (a/b)s ratio and the PV channel is shown in figure 9. These data were obtained noninvasively by two-dimensional echocardiography.

The patients with PV channel stenosis were all grouped in area A (patients 3, 5, and 10). In all patients, we performed reoperation for enlargement of the stenotic PV channel and we confirmed that in each patient the PV channel was very narrow. The patients with tricuspid regurgitation (patients 1, 4, and 14) and a patient with pulmonary vascular obstruction (patient...
TABLE 1

Patient data

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>BSA (m²)</th>
<th>Operation</th>
<th>PV-C (mm)</th>
<th>(a/b)s</th>
<th>PA-W (mm Hg)</th>
<th>LVP (mm Hg)</th>
<th>Complications</th>
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<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>6 yr</td>
<td>0.73</td>
<td>OS</td>
<td>21</td>
<td>0.61</td>
<td>14</td>
<td>90</td>
<td>TR mild</td>
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<tr>
<td>2</td>
<td>M</td>
<td>1 yr</td>
<td>0.43</td>
<td>MS</td>
<td>10</td>
<td>0.53</td>
<td>5.5</td>
<td>42</td>
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</tr>
<tr>
<td>3</td>
<td>M</td>
<td>7 mo</td>
<td>0.35</td>
<td>MS</td>
<td>6</td>
<td>0.94</td>
<td>36</td>
<td>106.5</td>
<td>PV-C stenosis</td>
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<tr>
<td>4</td>
<td>F</td>
<td>11 mo</td>
<td>0.37</td>
<td>MS</td>
<td>18</td>
<td>0.79</td>
<td>29</td>
<td>98</td>
<td>TR severe</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>2 yr</td>
<td>0.42</td>
<td>MS</td>
<td>3</td>
<td>0.89</td>
<td>42</td>
<td>96.5</td>
<td>PV-C stenosis</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>10 mo</td>
<td>0.31</td>
<td>OS</td>
<td>12</td>
<td>0.43</td>
<td>10</td>
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</tr>
<tr>
<td>7</td>
<td>M</td>
<td>3 yr</td>
<td>0.55</td>
<td>MS</td>
<td>15</td>
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<td>10.5</td>
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<tr>
<td>8</td>
<td>F</td>
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<td>OS</td>
<td>12</td>
<td>0.55</td>
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<td>MS</td>
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<td>PV-C stenosis</td>
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<tr>
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<td>M</td>
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<td>0.36</td>
<td>MS</td>
<td>10</td>
<td>0.44</td>
<td>11</td>
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<td></td>
</tr>
<tr>
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<td>0.52</td>
<td>MS</td>
<td>20</td>
<td>0.41</td>
<td>12.5</td>
<td>53</td>
<td>TR mild</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>2 yr</td>
<td>0.41</td>
<td>OS</td>
<td>10</td>
<td>0.15</td>
<td>7.5</td>
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</tr>
<tr>
<td>14</td>
<td>M</td>
<td>9 yr</td>
<td>0.87</td>
<td>MS</td>
<td>18</td>
<td>0.57</td>
<td>13</td>
<td>87</td>
<td>TR mild</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>1 yr</td>
<td>0.41</td>
<td>OS</td>
<td>10</td>
<td>0.35</td>
<td>10</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>9 mo</td>
<td>0.37</td>
<td>OS</td>
<td>11</td>
<td>0.17</td>
<td>11</td>
<td>33.5</td>
<td></td>
</tr>
</tbody>
</table>

BSA = body surface area; operation = operation method; 2-DE = two-dimensional echocardiography; PV-C = pulmonary venous channel; PA-W = pulmonary arterial wedge pressure; LVP = peak left ventricular pressure; Cath. = catheterization data; OS = original Senning’s operation; MS = modified Senning’s operation; TR = tricuspid regurgitation; PVO = pulmonary vascular obstruction.

9) were grouped in area B. A patient with residual left ventricular outflow stenosis would also be in area B but no such patient was found in our study. The patients whose PV channel diameters were over 10 mm and had (a/b) ratios below 0.6 were all in good condition postoperatively, including one patient with very mild tricuspid regurgitation (patient 12).

Thus, left ventricular hypertension secondary to PV channel stenosis (shown in area A), can be differentiated noninvasively from that due to tricuspid regurgitation, pulmonary vascular obstruction, or residual left ventricular outflow stenosis. We conclude that our findings have established and verified a noninvasive method to diagnose PV channel stenosis after TGA by Senning’s operation.

References
Two-dimensional echocardiographic detection of pulmonary venous channel stenosis after Senning's operation.
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