Cross sectional and Doppler echocardiographic evaluation of aortopulmonary shunts

Yasunori Horiguchi, Satoshi Hiraishi, Hitoshi Misawa, Youtarou Agata, Seimei Nakae

Abstract
Background—Shunt vessels were imaged and shunt flow was analysed by cross sectional and Doppler echocardiography in 12 patients who had had 14 shunt procedures (nine left Blalock-Taussig shunts, three right Blalock-Taussig shunts, one modified Waterston shunt, and one central shunt).

Methods—The shunt vessels were classified by echocardiography as uniformly patent, segmentally stenosed, and uniformly stenosed. These findings were compared with those of angiography. Also the peak flow velocities at the aortic and the pulmonary ends of the shunt vessels were measured by Doppler echocardiography and the ratio of these values was calculated for each shunt.

Results—Twelve (85-7%) of 14 shunt vessels were imaged along their entire length by cross sectional echocardiography. The two remaining shunt vessels were only partially imaged. In 10 patients who also had angiography the echocardiographic and angiographic images of the shunt vessels were identical. The ratio of the peak flow velocity measured at the aortic and the pulmonary ends of the shunt vessel was significantly larger in the segmentally stenosed shunt vessels than in the uniformly patent shunt vessels \( (p < 0.001) \). The ratio in the two shunt vessels only partially imaged by cross sectional echocardiography indicated that they were segmentally stenosed.

Conclusion—The combination of cross sectional and Doppler echocardiography may be useful for determining either the patency or the morphology of an aortopulmonary shunt.

Patients and methods

Patients
We studied 12 patients with various cyanotic congenital heart diseases who had shunt operations performed in our hospital. Two of them had had repeat operations because their first shunt operations were clinically not effective. Diagnoses were confirmed by diagnostic cardiac catheterisation. The shunt operations were left Blalock-Taussig shunt operation (nine patients), right Blalock-Taussig shunt (three patients), modified Waterston shunt (one patient), and a central shunt (ascending aorta to main pulmonary artery anastomosis) (one patient). Only one (patient 6) of the nine patients with a left Blalock-Taussig shunt had a modified Blalock-Taussig shunt operation with a polytetrafluoroethylene graft (table 1).

Doppler echocardiographic technique
We used a commercially available cross sectional echocardiograph. Hewlett Packard Model 77020AC, that incorporated a pulsed Doppler flow meter in an ultrasonic wide angle phased array system. Ultrasonic frequencies of 5 MHz (shallow focus) and 3-5 MHz were used. We also used continuous Doppler methods when aliasing occurred with the pulsed Doppler method.

The examination was performed with the patient in a supine position. If necessary, a small pillow was placed under the shoulder in order to extend the neck.

Cross sectional and Doppler echocardiographic examinations were performed through suprasternal or high parasternal windows for patients with left Blalock-Taussig shunt. The transducer was directed to image the aortic arch and to search for the aortic orifice of the shunt vessel, the left subclavian artery, or the left brachiocephalic artery. Once the orifice was located the distal portion of the shunt vessel was imaged by rotating the beam clockwise through 20° to 30° (fig 1). The suprasternal approach was also used in the patient with a right Blalock-Taussig shunt. The transducer was directed at the aortic arch in the long axis plane in order to detect the orifice of the shunt vessel. Shunt vessels could then be imaged by...
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Table 1 Data on the study patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Shunt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>5 mnth</td>
<td>TOF</td>
<td>l-BT</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>5 mnth</td>
<td>TOP, Dorn's syndrome</td>
<td>l-BT</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>5 yr</td>
<td>TOP</td>
<td>l-BT</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>5 yr 6 mnth</td>
<td>TA (la), PDA</td>
<td>l-BT</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>5 yr 10 mnth</td>
<td>TA (la)</td>
<td>l-BT, central</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>9 yr 4 mnth</td>
<td>TA (lb)</td>
<td>l-BT</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>2 mnth</td>
<td>TGA, ASD, VSD, Co/Ao</td>
<td>r-BT</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>6 yr 5 mnth</td>
<td>TGA, VSD, PS</td>
<td>l-BT</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>2 mnth</td>
<td>Dextro, UVH, Malposition GA, PA, PDA, r-Ao A</td>
<td>l-BT</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>3 mnth</td>
<td>CAVC, TGA, SA, PDA, asplenia</td>
<td>r-BT</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>3 mnth</td>
<td>Dextro, SA, UVH, PA, r-Ao A</td>
<td>l-BT</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>8 yr 5 mnth</td>
<td>UVH, Malposition GA, PA, PDA, r-Ao A</td>
<td>l-BT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Modified Waterston</td>
</tr>
</tbody>
</table>

ASD, atrial septal defect; CAVC, common atrioventricular canal; Co/Ao, coarctation of the aorta; dextro, dextrocardia; l-BT, left Blalock-Taussig shunt; GA, malposition of the great arteries; PA, pulmonary atresia; PDA, patent ductus arteriosus; PPO, patent foramen ovale; PLSVC, patent left superior vena cava; PS, pulmonary stenosis; r-Ao A, right aortic arch; r-BT, right Blalock-Taussig shunt; SA, single atrium; TA, tricuspid atresia; TGA, transposition of the great arteries; TOF, tetralogy of Fallot; UVH, univentricular heart; VSD, ventricular septal defect.

Figure 1  Echocardiogram of a left Blalock-Taussig shunt vessel (patient 11). Ao, aorta; l-Br, left brachiocephalic artery; l-BT, left Blalock-Taussig shunt vessel; l-CC, left common carotid artery; l-PA, left pulmonary artery.

Figure 2  Echocardiogram of a right Blalock-Taussig shunt vessel from the suprasternal window (patient 7). Colour Doppler showed flow away from the transducer (blue signal) in the shunt vessel. A red signal was seen in the distal portion of the shunt vessel because of the high shunt flow velocity. Ao, aorta; r-BT, right Blalock-Taussig shunt vessel; Br, brachiocephalic artery; r-PA, right pulmonary artery.

tilting the transducer by 10°–20° laterally to the right (fig 2). The parasternal approach was used in the patient with a central shunt or modified Waterstone shunt. The transducer was placed at the mid left sternal border and directed transversely at the ascending aorta. The shunt vessel was imaged beyond the transversely sectioned ascending aorta in the patient with a modified Waterstone shunt (fig 3).

Colour Doppler echocardiography was also used to aid the detection of the shunt vessels in 10 patients examined towards the end of this study. Flow directed toward the transducer was conventionally coded in red and flow away from the transducer was coded in blue.

When the shunt vessel was detected, the internal diameter was measured (from inner edge to inner edge) with the callipers incorporated in the equipment and the Doppler sample volume was then positioned within the shunt vessel. The shunt flow was recorded with the electrocardiogram and a video recorder. The peak flow velocity (cm/s) was measured at proximal and distal sites in the shunt vessels. In a few patients where the flow velocity at the distal site exceeded the highest range that could be recorded by the pulsed Doppler method we measured the peak flow velocity by the continuous Doppler method. In addition, the peak flow velocity at the proximal and intermediate sites was measured at the same time to confirm that the value measured by the continuous Doppler method was being recorded at the distal site.

The peak flow velocity measured in the distal portion of the shunt vessel was compared with that measured in the proximal portion. The ratio between the peak flow velocity at the distal portion and at the proximal portion was then calculated.

ANGIOGRAPHY
Cardiac catheterisation and angiography were performed in 10 patients a few days after the Doppler and echocardiographic examination. The shunt vessels were selectively imaged by biplanar cineangiography.

STATISTICAL ANALYSIS
Grouped data were compared by the unpaired Student's t test. A p value of ≤0.05 was regarded as significant.

Results
Twelve of 14 shunt vessels were imaged along their entire length (85–7% success rate). The distal portions of the shunt vessels were not detected in two patients (cases 5 and 8, both with a left Blalock-Taussig shunt). In the 10 patients who also had angiography the echocardiographic and angiographic appearances of the shunt vessels were identical (fig 4). Figure 4 shows the cross-sectional echocardiogram of a left Blalock-Taussig shunt (patient 11). Shunt flow was detected in both the proximal and distal portions (fig 4). Right Blalock-Taussig shunts, the modified Waterstone shunt, and the central shunt were also clearly imaged.

Stenosis of the shunt vessel was tentatively
Figure 3  Echocardiogram of a modified Waterston shunt (patient 12) from the parasternal window. The transducer was transversely directed towards the ascending aorta. The shunt vessel was detected beyond the ascending aorta. Ao, ascending aorta; r-PA, right pulmonary artery; Shunt, modified Waterston shunt.

Figure 4  Angiogram and echocardiogram of a left Blalock-Taussig shunt vessel. The entire shunt vessel was imaged by the cross sectional echocardiography. The shape shown by echocardiography was almost identical to that shown by angiography. Shunt flow was detected by a pulsed Doppler method not only in the proximal portion (right upper) but also at the distal portion (right lower). Because peak flow velocity at the distal site was so high the continuous Doppler method was used to detect the shunt flow. l-BT, left Blalock-Taussig shunt vessel; l-PA, left pulmonary artery.

diagnosed when the diameter of the shunt vessel was less than 2.5 mm. Six of 12 shunt vessels had diameters of >2.5 mm along their entire length by cross sectional echocardiography (uniformly patent shunt vessels). The diameter of four other shunt vessels was <2.5 mm at their distal sites (segmentally stenosed shunt vessels), and the diameters of the remaining two shunts were <2.5 mm along their entire length (uniformly stenosed shunt vessels).

The ratio of the peak flow velocity in the distal portion to that in the proximal portion was 0.89-1.46 in uniformly patent shunt vessels (n = 6), 1.87-2.82 in segmentally stenosed shunt vessels (n = 4), and 1.38 and 2.41 in the two patients with uniformly stenosed shunt vessels (table 2). Segmentally stenosed shunt vessels had significantly larger ratios than uniformly patent shunt vessels (p < 0.001).

In the two patients in whom the distal portions of the shunt vessels were not imaged by cross sectional echocardiography (patients 5 and 8, both with left Blalock-Taussig shunt) the peak flow velocity was also measured by the continuous Doppler method at the distal sites. The ratio of the peak flow velocity measured by the continuous Doppler method in the distal portion to that in the proximal portion indicated segmentally stenosed shunt vessels. Angiograms in these two patients showed stenosis at the distal sites.

Discussion

Identification of the Shunt Vessels

The shunt vessels were clearly imaged by our cross sectional echocardiographic method, although in two patients the distal portion was not imaged. The echocardiographic and angiographic findings showed similar shunt vessel morphology.

Patency of the Shunt Vessels and Flow Velocities

Continuous left-to-right shunt flow was detected within all the shunt vessels. Shunt flow velocity was measured in the proximal and distal portions of the 12 shunt vessels. Peak flow velocity was very high in the distal portion of segmentally stenosed shunt vessels. The ratio of peak flow velocity in the distal portion to the peak flow velocity in the proximal portion in this group was larger than that of uniformly patent shunt vessels. The ratios were 1.38 and 2.41 in two patients with uniformly stenosed shunt vessels. The diameter of the left Blalock-Taussig shunt in the patient with a ratio of 1.38 was 2.0 mm at the proximal portion and 1.9 mm at the distal portion. In the patient with a ratio of 2.41 the diameters were 2.1 mm and 1.3 mm respectively. The tapering shape of this shunt vessel is thought to have caused the high ratio. In the two patients with uniformly stenotic shunts, oxygenation had not improved and second palliative operations were performed.

These findings indicate that measurement of the ratio of the peak flow velocity at the distal portion to the peak flow velocity at the proximal portion will improve the accuracy of the evaluation of shunt vessel morphology.

Moreover, in the patients in whom the distal site could not be detected by cross sectional echocardiography, we were able to assess the segmental stenosis at the distal site of the shunt vessels by taking the peak flow velocity at the distal site to be the same value as that detected by the continuous Doppler method. These cases illustrate the usefulness of combining the pulsed Doppler and continuous Doppler methods to assess shunt vessel morphology.
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PLANTS IN CARDIOLOGY

Aconitine and arrhythmias

Various species of aconite, Aconitum (Ranunculaceae), such as wolfsbane and monkshood, have been known as deadly poisons since the time of ancient Greece (Medea used aconite to kill Theseus). Soon after the leaf or root is eaten a characteristic tingling spreads over the body, the voluntary muscles twitch, the pulse becomes irregular and weak, and death inexorably follows in a few hours. Animal studies in the nineteenth century showed that the alkaloid aconitine produced vagal slowing followed by an irregular rhythm; and in 1897 S A Matthews at Ann Arbor, using the myocardiograph, became the first to show that it causes atrial and ventricular fibrillation (Journal of Experimental Medicine 1897;2:593–606). In 1909 in the first paper of the new journal Heart A R Cushny showed that it caused pulsus alternans in dogs.

Despite its reputation aconite became a popular medicine and was used to treat neuralgia, fever, pericarditis, and nervous palpitation. In 1869 Sydney Ringer wrote “Perhaps no drug is more valuable than aconite.” But in 1880 a patient became very ill when the source of his tincture was unknowingly changed to a different aconite root, and his physician Dr Meyer died after taking a dose to justify the safety of his prescription.

It was the work of David Scherf that established the special place of aconitine in experimental arrhythmias. In 1947 he showed that when aconitine was injected into the sinus node of dogs it was better than faradisation in producing episodes of atrial fibrillation or flutter that were long enough to assess the effect of antiarrhythmic drugs. Myron Prinzmetal used topical aconitine for his high-speed cinematograph studies of atrial arrhythmias in 1952.

The family Ranunculaceae has 58 genera and 1750 species mostly in temperate regions.

Marx et al reported that continuous Doppler echocardiography could detect shunt flow and could be used to estimate the drop in pressure across aorta to pulmonary artery shunts. They used the suprasternal notch or the supraclavicular window for Blalock-Taussig shunts and the left parasternal window for Waterston shunts. They did not, however, mention the morphology or size of the shunt vessels. Our study shows that the beam direction is vital when the peak flow velocity is being measured especially in patients with a segmentally stenotic shunt vessel.

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Table 2 Ratio of the peak flow velocity in the distal portion to that in the proximal portion

<table>
<thead>
<tr>
<th>Patient no (type)</th>
<th>D/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniformly patent</td>
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<tr>
<td>4 (I-BT)</td>
<td>0.98</td>
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<tr>
<td>5 (central)</td>
<td>1.44</td>
</tr>
<tr>
<td>6 (I-BT)</td>
<td>1.19</td>
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<tr>
<td>7 (I-BT)</td>
<td>1.46</td>
</tr>
<tr>
<td>10 (r-BT)</td>
<td>1.20</td>
</tr>
<tr>
<td>12 (central)</td>
<td>0.89</td>
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<tr>
<td>Segmentally stenosed</td>
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<tr>
<td>2 (r-BT)</td>
<td>1.95</td>
</tr>
<tr>
<td>3 (I-BT)</td>
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<td>9 (I-BT)</td>
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<tr>
<td>11 (I-BT)</td>
<td>2.82</td>
</tr>
<tr>
<td>1 (I-BT)</td>
<td>2.41</td>
</tr>
<tr>
<td>2 (I-BT)</td>
<td>1.39</td>
</tr>
</tbody>
</table>

D/P, ratio of proximal peak flow to distal peak flow. See footnote to table 1 for other abbreviations.


1750 species


Many of them are poisonous because they contain benzyl isouquinoline and other alkaloids, and some species of Ranunculus (buttercup) cause photodermatitis. The genera Adonis (pheasant's eye) and Helleborus (Christmas rose) contain cardiac glycosides but they are not used medicinally and neither are any other species.

It could still be rewarding to study the cellular mechanism of aconitine induced arrhythmias.

A HOLLMAN
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