Aortography by Radial Artery Injection in Infants with Anomalies of the Aortic Arch

TAKU KATO, JUN-ICHI FUJIYAMA, OSAMU KUDEKEN, KOTARO OYAMA and YOSHIRO YOSHIDA

Department of Pediatrics, Tohoku University School of Medicine, Sendai 980

KATO, T., FUJIYAMA, J., KUDEKEN, O., OYAMA, K. and YOSHIDA, Y. Aortography by Radial Artery Injection in Infants with Anomalies of the Aortic Arch. Tohoku J. exp. Med., 1983, 140 (2), 171–180 — Aortography by radial artery injection was performed in 22 infants and one child with congenital heart disease. The left radial artery was used in 20 cases and the right radial artery was used in 3 cases. This method visualized the following aortic arch anomalies: coarctation of the aorta in 4 patients, interrupted aortic arch in one, patent ductus arteriosus in 10, patency of the left Blalock-Taussig shunt in one and anomalous origin of the right subclavian artery in one. An injection of the contrast material into the right radial artery in one case failed to visualize coarctation of the aorta, which was confirmed by retrograde catheterization. Retrograde aortography has been necessary for diagnosis of aortic arch anomalies, but it is not so easy to perform and carries a risk of arterial thrombosis. Aortography by radial artery injection is relatively easy to perform, less invasive and has no severe complications. It is concluded that aortography by radial artery injection is a useful method for diagnosis of anomalies of the aortic arch in neonates and children. — — — aortography; anomalies of the aortic arch

Retrograde cardiac catheterization and aortography are frequently necessary for diagnosis of coarctation of the aorta, patent ductus arteriosus and interrupted aortic arch, but they are not so easy to perform in neonates and infants and have a definite risk of arterial thrombosis. Percutaneous catheterization of the radial artery has been used for blood gas sampling and blood pressure monitoring during catheterization and surgical treatment in neonates and infants. Utilizing this method, we performed aortography by radial artery countercurrent injection of contrast material to see if the aortic arch could be visualized well enough for diagnosis of aortic arch anomalies.

MATERIALS AND METHODS

From February 1981 to February 1982, aortography by radial artery injection was performed in 23 patients with congenital heart disease at the Department of Pediatrics, Tohoku University School of Medicine. The ages of the patients at the time of aortography ranged from 9 days to 14 months. Their body weights ranged from 1,400 g to 7,140 g (average 4,145 g).

A modified Allen test was performed to assess ulnar collateral flow to the entire hand.

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Catheterization of the radial artery was then performed. With the hand immobilized in slight dorsiflex position an Angiocath 22G (Deseret Pharmaceutical Company, Sandy, Utah, USA) was placed through a puncture site at an angle of 30 degrees to horizontal and was passed through the artery to transfix it. The inner needle was then withdrawn. The cannula was very slowly withdrawn until free flow of blood occurred and at this point, the cannula was advanced. Pressure dressing was placed over the puncture site and strips of adhesive tape were used to fasten the cannula. The cannula was firmly attached to an extension tubing with a three-way stopcock and a syringe filled with saline containing 5 units of heparin/ml. Blood was allowed to run back into the plastic tubing and air bubbles were removed from the system. The cannula was flushed with the heparin solution. The arm and the hand were fixed to the splint so that the fingers and thumb could be clearly seen. A 10 ml syringe filled with 76% Urografin was attached to the three-way stopcock and air bubbles were completely removed. Biplane cineangiography by manual injection of 76% Urografin (1.0–2.0 ml/kg of body weight) into the radial artery was obtained. Filming was made at 75 frames/sec.

The left radial artery was chosen in 20 patients who were suspected to have patent ductus arteriosus or coarctation of the aorta, and the right radial artery was used in 3 patients; 2 patients with previous Blalock-Taussig shunt operation to detect patency of the anastomosis, and one patient because of failure to cannulate the left radial artery.

**RESULTS**

The results are shown in Table 1. The final diagnosis was made by two-dimensional echocardiography, aortography by radial artery injection and in some cases by cardiac catheterization and cineangiography, surgical inspection and autopsy. The aortography by radial artery injection visualized coarctation of the aorta in 4 patients, interrupted aortic arch in one, patent ductus arteriosus in 10, patency of the left Blalock-Taussig shunt in one and anomalous origin of the right subclavian artery in one. Right radial artery injection failed to visualize the aortic arch well enough in one case of coarctation of the aorta and the diagnosis was made by left ventriculogram (Case 2). Loss of contrast medium off to the head was too much and opacification of the aortic arch was poor. Normal aortic arch was confirmed in 5 patients. There were no serious complications. In one infant there was a permanent occlusion of the radial artery. Transient occlusion was seen in a few cases and blanching of skin around the catheter site occurred in almost all patients during injection of contrast medium. No known ischemic damage to extremities occurred. Eleven patients underwent cardiac catheterization; 2 prior to, 6 after and 3 at the same time with the aortography. Fourteen patients were operated on and 7 of them without prior cardiac catheterization.

Case 3 was a 14-month-old girl with coarctation of the aorta, ventricular septal defect, patent ductus arteriosus and pulmonary hypertension. At cardiac catheterization and cineangiography, a 5F pig tail catheter could not be advanced to the aortic arch from the descending aorta but was advanced to the pulmonary artery through patent ductus arteriosus. Left ventriculograms obtained by venous catheter which was passed into the left ventricle via the patent foramen ovale failed to reveal coarctation of the aorta. Thrombosis of the femoral artery developed requiring thrombectomy. Aortography by left radial artery injection
revealed coarctation of the aorta (Fig. 1).

Case 4 was a 30-day-old male infant with coarctation of the aorta, ventricular septal defect and patent ductus arteriosus. Two-dimensional echocardiography revealed ventricular septal defect. Aortography by left radial artery injection revealed coarctation of the aorta and patent ductus arteriosus. Because of his critical condition he underwent aortoplasty by the subclavian flap method without cardiac catheterization.

Case 6 was a 30-day-old male infant with interrupted aortic arch. Aortography by left radial artery injection revealed a type A interrupted aortic arch (Fig. 2). He underwent aortoplasty without cardiac catheterization because of his serious condition, but expired. Autopsy demonstrated interrupted aortic arch, double outlet right ventricle, ventricular septal defect and patent ductus arteriosus.

### Table 1. Aortography by radial artery injection in 23 patients

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Weight (g)</th>
<th>Site of injection</th>
<th>Findings of aortogram</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18 days</td>
<td>3,512</td>
<td>LRA</td>
<td>Co/Ao, PDA</td>
<td>Co/Ao, PDA, MS, AS, PH</td>
</tr>
<tr>
<td>2</td>
<td>40 days</td>
<td>3,240</td>
<td>RRA</td>
<td>Questionable Co/Ao</td>
<td>Co/Ao, VSD, PDA, PH</td>
</tr>
<tr>
<td>3</td>
<td>14 months</td>
<td>7,369</td>
<td>LRA</td>
<td>Co/Ao, PDA</td>
<td>Co/Ao, VSD, PDA, PH</td>
</tr>
<tr>
<td>4</td>
<td>30 days</td>
<td>3,980</td>
<td>LRA</td>
<td>Co/Ao, PDA</td>
<td>Co/Ao, VSD, PDA, PH</td>
</tr>
<tr>
<td>5</td>
<td>3 months</td>
<td>4,850</td>
<td>LRA</td>
<td>Co/Ao, PDA</td>
<td>Co/Ao, VSD, PDA, PH</td>
</tr>
<tr>
<td>6</td>
<td>30 days</td>
<td>3,350</td>
<td>LRA</td>
<td>Int/Ao, PDA</td>
<td>Int/Ao, DORV, VSD, PDA</td>
</tr>
<tr>
<td>7</td>
<td>9 days</td>
<td>1,830</td>
<td>LRA</td>
<td>PDA, right aortic arch</td>
<td>PA with VSD, PDA, right aortic arch</td>
</tr>
<tr>
<td>8</td>
<td>39 days</td>
<td>3,624</td>
<td>LRA</td>
<td>PDA, central PS</td>
<td>PA with VSD, PDA, central PS</td>
</tr>
<tr>
<td>9</td>
<td>5 months</td>
<td>5,123</td>
<td>RRA</td>
<td>Anomalous origin of RSA</td>
<td>PA with VSD, anomalous origin of RSA, status post-left B-T shunt</td>
</tr>
<tr>
<td>10</td>
<td>11 months</td>
<td>6,346</td>
<td>RRA</td>
<td>Patency of left B-T shunt</td>
<td>DORV, VSD, PS, functioning left B-T shunt</td>
</tr>
<tr>
<td>11</td>
<td>14 days</td>
<td>2,840</td>
<td>LRA</td>
<td>PDA</td>
<td>PA with IVS, PDA, TR</td>
</tr>
<tr>
<td>12</td>
<td>39 days</td>
<td>1,400</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA, premature baby</td>
</tr>
<tr>
<td>13</td>
<td>40 days</td>
<td>2,680</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA</td>
</tr>
<tr>
<td>14</td>
<td>16 days</td>
<td>2,580</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA, PH</td>
</tr>
<tr>
<td>15</td>
<td>19 days</td>
<td>2,015</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA</td>
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<tr>
<td>16</td>
<td>11 months</td>
<td>6,175</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA, premature baby</td>
</tr>
<tr>
<td>17</td>
<td>11 months</td>
<td>7,140</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA, ASD, PH, PLSVC</td>
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<tr>
<td>18</td>
<td>6 months</td>
<td>5,230</td>
<td>LRA</td>
<td>PDA</td>
<td>PDA, PH, Down's syndrome</td>
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<tr>
<td>19</td>
<td>3 months</td>
<td>4,135</td>
<td>LRA</td>
<td>Normal aortic arch</td>
<td>VSD, PH</td>
</tr>
<tr>
<td>20</td>
<td>4 months</td>
<td>5,380</td>
<td>LRA</td>
<td>Normal aortic arch</td>
<td>VSD, PH</td>
</tr>
<tr>
<td>21</td>
<td>34 days</td>
<td>3,580</td>
<td>LRA</td>
<td>Normal aortic arch</td>
<td>VSD, PH</td>
</tr>
<tr>
<td>22</td>
<td>4 months</td>
<td>5,900</td>
<td>LRA</td>
<td>Normal aortic arch</td>
<td>VSD, PH</td>
</tr>
<tr>
<td>23</td>
<td>27 days</td>
<td>3,085</td>
<td>LRA</td>
<td>Normal aortic arch</td>
<td>VSD, PH</td>
</tr>
</tbody>
</table>

Abbreviations: AS, aortic stenosis; ASD, atrial septal defect; B-T, Blalock-Taussig; Co/Ao, coarctation of the aorta; DORV, double outlet right ventricle; Int/Ao, interrupted aortic arch; IVS, intact ventricular septum; MS, mitral stenosis; PA, pulmonary atresia; PDA, patent ductus arteriosus; PH, pulmonary hypertension; PLSVC, persistent left superior vena cava; PS, pulmonary stenosis; RSA, right subclavian artery; TR, tricuspid regurgitation; VSD, ventricular septal defect.
Case 7 was a 9-day-old male infant with pulmonary atresia, ventricular septal defect and patent ductus arteriosus. At 8 days of age he was referred to our hospital because of cyanosis. Echocardiographic findings were suggestive of pulmonary atresia with ventricular septal defect. Administration of prostaglandin
E₁ improved hypoxemia. Aortography by left radial artery injection demonstrated a right aortic arch and filling of the pulmonary artery via patent ductus arteriosus (Fig. 3). After aortography hypoxemia got worse and an increase in the dose of prostaglandin E₁ was necessitated. He underwent modified Waterston shunt procedure.

Case 8 was a 39-day-old male infant with pulmonary atresia with ventricular septal defect, patent ductus arteriosus and central pulmonary artery stenosis (Fig. 4). He underwent left Blalock-Taussig anastomosis without cardiac catheterization.

Case 9 was a 5-month-old male infant with pulmonary atresia with ventricular septal defect and anomalous origin of the right subclavian artery. He had undergone left Blalock-Taussig procedure at 2 months of age. Aortography by right radial artery injection was performed, but the right subclavian artery originated distal to the left subclavian artery which had been anastomosed to the left pulmonary artery, and the patency of the anastomosis could not be determined.

Case 10 was an 11-month-old male infant with double outlet right ventricle, ventricular septal defect, d-malposition of the great arteries, pulmonary stenosis and previous left Blalock-Taussig shunt. Aortography by right radial artery injection showed the patency of the shunt (Fig. 5).

Case 12 was a 39-year-old female infant with patent ductus arteriosus. She was born after a 28-week-gestation and weighed 1,196 g. At 38 days of age she was referred to our hospital because of congestive heart failure and continuous heart murmur. Aortography by left radial artery injection showed patent ductus arteriosus (Fig. 6), which was successfully ligated.
Case 16 was an 11-month-old male infant with patent ductus arteriosus and pulmonary hypertension. He was suspected to have ventricular septal defect and pulmonary hypertension by physical examination, chest roentgenogram and

Fig. 4. Case 8. Aortogram by left radial artery injection in frontal view. Right and left pulmonary arteries are revealed via patent ductus arteriosus. There is central pulmonary stenosis (arrow) to which patent ductus arteriosus connects. AO, aortic arch; LPA, left pulmonary artery; PDA, patent ductus arteriosus; RPA, right pulmonary artery.

Fig. 5. Case 10. Aortogram by right radial artery injection in frontal view. Pulmonary artery (arrowheads) is revealed via left Blalock-Taussig anastomosis (arrow). AO, aortic arch; IA, innominate artery; LSA, left subclavian artery; PA, pulmonary artery; RSA, right subclavian artery.

Case 16 was an 11-month-old male infant with patent ductus arteriosus and pulmonary hypertension. He was suspected to have ventricular septal defect and pulmonary hypertension by physical examination, chest roentgenogram and
electrocardiogram. Two-dimensional echocardiography did not reveal ventricular septal defect. Aortography by left radial artery injection revealed patent ductus arteriosus. Subsequent cardiac catheterization confirmed the presence of patent ductus arteriosus and pulmonary hypertension. A normal aortic arch was also confirmed in five infants with ventricular septal defect and pulmonary hypertension.

**DISCUSSION**

In spite of recent advances in the noninvasive diagnostic techniques such as two-dimensional echocardiography and nuclear cardiology, cardiac catheterization and angiocardiography are frequently needed for the diagnosis of congenital heart disease and its surgical management.

Cardiac catheterization and angiocardiography during the first week of life can be easily accomplished in many instances via the umbilical vessels (Sapin et al. 1963; Linde et al. 1966; Keith 1978). The percutaneous method of catheter insertion into the femoral vessels has been widely used for cardiac catheterization in older infants and in neonates in whom the umbilical routes are not feasible (Takahashi et al. 1970; Carter et al. 1975; Gay 1975; Porter et al. 1978). In these instances, the venous catheter usually passes through the foramen ovale or an atrial septal defect to the left atrium and ventricle, and sufficient information can be obtained, thus obviating the retrograde left heart catheterization.

In some cases, however, left sided procedures and retrograde aortography are
required for the diagnosis of certain congenital heart diseases, such as large ventricular septal defect, patent ductus arteriosus, coarctation of the aorta, interrupted aortic arch and their various combinations (Vlad et al. 1964; Simonovitch et al. 1970). Retrograde arterial catheterization and aortography in these infants are accomplished by percutaneous approach or arteriotomy (Sanger et al. 1974). These procedures, however, are not easy to perform and have a high risk of arterial thrombosis (Kirkpatrick et al. 1970; Hurwitz et al. 1977).

Brown et al. (1969) published a method of percutaneous radial artery cannulation in patients undergoing major arterial or open-heart surgery, and in patients in whom serial monitoring of arterial blood gases was required. Subsequently, percutaneous radial artery cannulation has been widely used for continuous monitoring of blood gases and blood pressure (Furman et al. 1972; Adams and Rudolph 1975; Todress et al. 1975; Sunderland et al. 1976; Cole et al. 1978; Pearse 1978). It is a relatively safe procedure and easy to master.

Single film aortography by radial artery injection was recently reported by Ueda et al. (1982). We applied cineangiocardiography during radial artery injection with 75 frames/sec, in order to obtain a more reliable and consistent opacification of the aortic arch. Even by cine-method only a few of the frames showed diagnostic images. The “single film method” is not as reliable in obtaining consistently diagnostic pictures.

There are definitive advantages with this aortographic technique: (1) It is less invasive than the conventional retrograde aortography, and it could save cardiac catheterization and cineangiocardiography in critically ill infants who need surgical treatment without further deterioration. (2) The risk of thrombosis of a major artery (femoral or axillary) and its long term sequelae are avoided.

This method is indicated in suspected cases of anomalies of aortic arch. In our experience left radial artery injection was most useful, but in rare cases, e.g., aortic atresia and interrupted aortic arch, the right radial artery should be chosen for injection site (Allen 1929). Lowenstein et al. (1971) reported that in adults the volume necessary to reach the central circulation ranged from 3 to 12 ml with an average of 6.6±3.2 (mean±s.D.) ml. Manual injection of 1.0~2.0 ml/kg body weight of contrast material was more than adequate to obtain satisfactory aortogram in this group of patients.

Serious complication of this procedure is ischemic damage to extremities, and it is prevented by assessing adequate ulnar collateral flow to the entire hand before cannulation (Bedford and Wolman 1973; Downs et al. 1973; Ryan et al. 1973; Wyatt et al. 1974; Bedford 1978). Cerebral embolization is reported by Gann et al. (1969). It is prevented by complete removal of air bubbles in the arterial line system and by avoiding use of catheter which was previously inserted because of the risk of cerebral emboli arising from the detached clot (Lowenstein et al. 1971). We had no severe complications; one case had permanent occlusion of the radial artery and a few cases had temporary occlusion, but no ischemic complications were observed.
Aortography by Radial Artery Injection

It is concluded that aortography by radial artery injection is a very useful method for diagnosis of anomalies of the aortic arch and is void of severe complications.

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References

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