Nonvisualization by Aortography of Patent Ductus Arteriosus Associated with a Large Proximal Left-to-Right Shunt*

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Three cases are presented in which aortography failed to demonstrate the presence of a moderate-sized patent ductus arteriosus in association with a large proximal left to right shunt, but without other circumstances which would tend to diminish left to right shunt flow through the ductus. The ductus was not clinically apparent in any of these cases. Failure of expression of the distal lesion is most readily explained on hemodynamic grounds. A ductus was easily demonstrated in a fourth, otherwise similar, case. It is concluded that variability of expression makes it risky to exclude the possibility of a patent ductus arteriosus on the basis of a negative aortogram in the presence of a large proximal left to right shunt. It is possible that aorta-pulmonary artery indicator dilution curves would demonstrate the distal communication.

The diagnosis of a clinically suspected patent ductus arteriosus with left to right shunt is supported in the cardiac catheterization laboratory by the detection of arterialized blood in the pulmonary artery, and the demonstration of a left to right shunt at the great vessel level by indicator dilution techniques. The diagnosis is confirmed by passage of the cardiac catheter into the descending aorta from the main or left pulmonary artery, or by visualization of the patent ductus and pulmonary artery by ascending or retrograde aortography. Of these methods, aortography is considered the method of choice for proving the presence of a patent ductus.1–5

This report deals with three patients in whom a patent ductus was not visualized by ascending aortography. In two cases, the ductus was associated with a left to right shunt at the ventricular level and in the third case, with a right coronary artery-right atrial fistula. Also reported is a contrasting case in which aortography revealed the patent ductus arteriosus in conjunction with a large proximal left to right shunt.

During the years from 1962 to 1969, the total number of patients with various left to right shunts undergoing cardiac catheterization at Michael Reese Hospital and Medical Center was 825; of these, there were 317 cases of interventricular septal defect and 139 cases of patent ductus arteriosus. Of these 139 patients, aortography failed to reveal an otherwise demonstrated ductus only in the three cases reported here.

Case Reports

Case 1

A newborn infant was delivered of a 15-year-old mother, gravida 1, para 1. This infant was the product of a normal pregnancy and uneventful delivery. Mild congestive heart failure was diagnosed at the age of two days. Response to digitalization and other anticongestive measures was not satisfactory. Physical examination of the heart revealed an active precordium suggesting right ventricular hypertrophy, with unremarkable heart sounds and a harsh pansystolic murmur (grade II/VI) along the left sternal border and widely transmitted. No diastolic murmur was heard. The electrocardiogram (ECG) revealed combined ventricular
Table 1—Hemodynamic Data.

<table>
<thead>
<tr>
<th>Case</th>
<th>IVC</th>
<th>SVC</th>
<th>RA</th>
<th>RV</th>
<th>PA</th>
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<th>SYST.</th>
<th>L to R</th>
<th>Qp/Qs</th>
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<td>12.9</td>
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<td>11.7</td>
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<td>16.9</td>
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<td></td>
<td>8.1</td>
<td>8.6</td>
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<td>8.2</td>
<td>10.6</td>
<td>—</td>
<td>12.4</td>
<td>62%</td>
<td>2.7</td>
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<td></td>
<td>75.5</td>
<td>77.0</td>
<td>76.0</td>
<td>85.5</td>
<td>89.5</td>
<td>—</td>
<td>94.5</td>
<td>60%</td>
<td>2.5</td>
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</table>

S/D (M) = Systolic/diastolic (mean).

Sampling sites = Inferior vena cava, superior vena cava, right atrium, right ventricle, pulmonary artery, left atrium or pulmonary artery wedge, systemic artery.

L to R % TPF = Percent of total pulmonary flow which is shunt flow.

Qp/Qs = Ratio of pulmonary flow to systemic flow.

Rp/Rs = Ratio of pulmonary vascular resistance to systemic vascular resistance.

Hypertrophy. The chest roentgenogram revealed cardiomegaly, left ventricular enlargement and increased pulmonary vasculature. The clinical impression was that of interventricular septal defect. Cardiac catheterization was performed at 11 days of age, on July 5, 1965, and the hemodynamic results are summarized in Table 1. The overall left to right shunt obviously was very large, so that the figures for shunt size, Qp/Qs and Rp/Rs, are undoubtedly exaggerated. There is a clear step-up in oxygen content of the right ventricular blood sample over upstream samples, and there is a further step-up in oxygen content of the pulmonary arterial sample over that of the right ventricular sample. There was moderate pulmonary hypertension relative to systemic pressure and the pulmonary arterial pulse pressure was wide. The catheter was advanced from the right atrium to the left atrium, apparently through a patent foramen ovale, and from the right ventricle across an interventricular septal defect into the ascending aorta. A left atrial cineangiogram in the left anterior oblique projection revealed an intracardiac left to right shunt, presumably at the ventricular level. An ascending aortogram in the left anterior oblique projection, using the catheter which had traversed the interventricular septal defect, did not reveal a patent ductus arteriosus (Fig 1), but contrast medium opacifying a "whiff" of aortic regurgitation was promptly carried anteriorly to the right ventricle. Some days later, the infant died and an interventricular septal defect (0.5 cm in diameter) was found at autopsy, as well as a moderate-sized patent ductus arteriosus (0.6 cm in internal diameter) and a patent foramen ovale.

Case 2

A six-year-old girl, essentially asymptomatic, was referred to the Pediatric Cardiac Clinic for evaluation of a heart murmur discovered during a school physical examination. She had a history of frequent upper respiratory infections in early infancy. Her peripheral pulses were bounding in character and blood pressure was 100/60. A grade IV/VI, continuous murmur was heard best at the fourth right intercostal space and was transmitted widely over the precordium and back. The ECG was normal. The chest roentgenogram revealed cardiomegaly and increased vascular markings. Cardiac catheterization on June 23, 1960, revealed an overall left to right shunt calculated to make up about 40 percent of total pulmonary flow (Qp/Qs about 1.7). This was localized at the right atrial level by venous dye curves. Pressures were normal in the lesser circulation and the Rp/Rs was about 0.07. There was no step-up in oxygen content of pulmonary arterial samples over the right ventricular samples. During preparation for aortography, the aortic catheter entered the pulmonary artery and right ventricle in retrograde fashion from the aorta through a patent ductus arteriosus. The catheter was repositioned and the aortogram then revealed a dilated, tortuous right coronary artery draining into the right atrium, but the patent ductus and pulmonary artery did not opacify. A moderate-sized ductus was found and ligated during surgical correction of the coronary arteriovenous fistula. This case has been reported previously in detail.6

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shunt; this would suggest that left to right shunting of blood through the ductus was relatively small, if present. Pulmonary angiography in the posteroanterior projection revealed a large intracardiac left to right shunt, at the ventricular level. Aortography was carried out in the right lateral projection through the catheter which had passed to the aorta via the interventricular septal defect and in the left anterior oblique projection by means of the catheter which had passed through the ductus. The first of these revealed no passage of contrast material through the patent ductus. A small amount of contrast material passed to the left ventricle towards the end of the injection and the right ventricle and pulmonary artery then opacified. The second aortogram also was negative during the initial part of the injection, although the aorta was densely opacified (Fig 2). Towards the end of the injection, the catheter refluxed into the pulmonary artery which then densely opacified. Subsequently, the patient underwent surgery at which a moderate sized ductus was ligated and the main pulmonary artery was banded. A later left ventriculogram revealed a large interventricular septal defect.

**CASE 4**

The patient was a six-year-old girl with features of congestive heart failure in early infancy. There was a recent history of easy fatigability and exertional dyspnea. Physical examination revealed a physically retarded child with a systolic thrill and a grade VI/VI holosystolic murmur along the left sternal border, and a mid-diastolic inflow rumble at the apex. In addition, there was a continuous murmur, grade II/VI, over the left infraclavicular area. The heart sounds were unremarkable. The electrocardiogram revealed left axis deviation, as well as left atrial and left ventricular hypertrophy. The chest roentgenogram revealed moderate cardiomegaly with
left ventricular enlargement, a prominent main pulmonary artery segment, and increased lung vascularity. The clinical impression of interventricular septal defect and patent ductus arteriosus was confirmed by cardiac catheterization on September 28, 1969. The catheter was advanced from the right ventricle across the interventricular communication into the ascending aorta and also from the pulmonary artery through a patent ductus arteriosus into the descending aorta. The hemodynamic data are summarized in Table 1. The overall left to right shunt was calculated to be 60 percent of total pulmonary flow. There was a clear rise in the oxygen saturation of right ventricular samples over upstream samples and no further rise in oxygen saturation was noted at the pulmonary artery level. Mean pulmonary artery wedge pressure was somewhat elevated and there was moderate pulmonary hypertension. Left ventriculography in the left anterior oblique projection revealed the passage of a considerable amount of contrast medium across a large interventricular septal defect and there was faint opacification of the patent ductus. Angiography clearly visualized the patent ductus arteriosus and pulmonary artery.

**DISCUSSION**

A prime purpose of diagnostic cardiac catheterization is to elucidate the abnormal hemodynamics and morphology when more than one congenital cardiovascular anomaly may be present in the same patient. This is of great practical importance when surgical correction of the congenital anomalies is under consideration. The present report is concerned mainly with three patients (cases 1 to 3) who had left to right shunts through large proximal communications (two with interventricular septal defect; one with a coronary arteriovenous fistula), each in association with a patent ductus arteriosus of moderate size. In all three cases, ascending angiography failed to reveal the patent ductus arteriosus which, if unsuspected or not otherwise detected, would have been missed. Case 4 illustrates that this is not a constant pitfall.

Marked elevation of pulmonary vascular resistance is the usual cause of diminished or reversed shunting through a patent ductus arteriosus; however, there was no evidence in the present hemodynamic data that this was a factor preventing easily recognizable left to right shunt through the ductus, the ratio of pulmonary to systemic vascular resistance being normal, or near normal, in all cases. Furthermore, in no instance could the ductus be termed "small" or "probe patent." Yet, it must be concluded from the angiographic data in each of the first three cases, and from the indicator dilution data in case 3, that the proximal left to right shunt is large, while left to right shunt flow through the ductus is not demonstrated, presumably because it is relatively small, or absent. The consistent absence of a ductus murmur, at least in cases 1 and 3, also is suggestive of this.

The data do not permit a definitive explanation for nonvisualization of a moderate-sized ductus by aortography in these circumstances, but two hemodynamic factors can be postulated which may explain this phenomenon, at least in part.

Firstly, it is possible, when two uncomplicated communications between the two sides of the circulation coexist, that shunt flow through the more proximal of these will be favored, perhaps at the expense of the more distal communication. This would apply best if the combined cross-sectional area of the two communications was relatively large. The magnitude of the overall left to right shunt then would be determined mainly by the differences between the systemic and pulmonary vascular resistances, and the volume-elastic properties of the two sides of the circulation. In the present cases, a large total pulmonary flow returning to the left side communicates with a relatively small systemic venous return to the right heart. The resulting increased left ventricular filling pressure would favor left to right shunting at the ventricular level in cases 1 and 3; this also might be true of the large proximal aortic flow in case 2. Further downstream, at the site of the second defect, systemic flow has been diminished and pulmonary flow increased by the amount of the proximal left to right shunt.

Secondly, the contrast medium (equal in amount to the product of ductus flow and concentration of contrast medium in the aorta) crossing the ductus during the aortogram, perhaps already small in quantity, will be diluted promptly by the large pulmonary flow which is equal to the sum of systemic venous return and the proximal left to right shunt. The resulting change in density of the pulmonary artery shadow may be too small to recognize. In this regard, it is possible that a left to right shunt at the ductus level might be recognized by some quantitative measure of the density of the pulmonary artery shadow, i.e., as may be determined by videodensitometric methods, or by means of an indicator dilution curve obtained by injection of dye into the ascending aorta with sampling in the pulmonary artery, in which case a relatively small amount of a completely foreign substance might easily be detected.

From these considerations, it is reasonable to suppose that left to right shunt flow through a ductus, or its expression, can be affected by a proximal left to right shunt. Should the proximal defect be surgically closed without knowledge of the ductus, as could have occurred in case 2, in which cardiopulmonary bypass was not employed, then it is very likely that the ductus would become
hemodynamically more important, with the left to right shunt through it perhaps approaching the magnitude of the previous overall left to right shunt.

In each of the described cases, the appearance of a left to right shunt at the proximal level was discernible in the oxygen contents of the diagnostic series of blood samples. A secondary rise in the oxygen content of pulmonary arterial samples over that of right ventricular samples was noted in cases 1 and 3. This has been regarded as indicating a second left to right shunt distal to another known shunt, but is actually unsatisfactory for this purpose. Random blood sampling through the catheter among streamlines of flow in the right ventricle could fail to detect a significant increase in blood oxygenation due to a ventricular septal defect, but this evidence of increased oxygenation might be picked up at the pulmonary artery level in the absence of a second shunt. Further, a high blood oxygen content, due to a relatively small interventricular septal defect, as measured by chance in the right ventricle, might be sustained without further rise by a second left to right shunt arising distally. It is noteworthy that a secondary rise in oxygen content was not noted in case 4, in which a patent ductus arteriosus was clinically evident and demonstrable by aortography.

Other factors have been suggested to account for instances of intermittent, spontaneous disappearance of a typical machinery murmur in cases of proved patency of the ductus arteriosus, or to account for possible intermittent ductal impatency. There is no reason to assume that these play any special role in the present phenomenon, as is also true of any possible specific effects on a ductus of the arterial blood gas milieu or of the catecholamine level in the circulation.

One might expect that the smaller the proximal defect, the less likely it would be to interfere in the expression of the ductus. However, the interventricular septal defect, and the shunt through it, appear large in case 4, and no underlying cause for the different behavior in this case was demonstrable by the techniques employed. This also was the only case in which the typical clinical features of the patent ductus were present, although these may have been masked by those of the coronary arteriovenous fistula in case 2. It is possible that the ductus was of a relatively larger size in case 4 than in others.

An additional case can be briefly cited to illustrate another facet of this problem.

This patient was a 20-month-old girl with clinical findings typical of a hemodynamically significant ventricular septal defect, but with no diastolic murmur. At catheterization, on February 6, 1967, all cardiovascular pressures were normal. There was an overall left to right shunt such that Qp/Qs=2, Rp/Re=0.1. An indicator dilution curve obtained by aortic root injection with pulmonary artery sampling strongly indicated an aortico-pulmonary left to right shunt in the proved absence of aortic valve insufficiency. Left ventriculography demonstrated a ventricular septal defect of moderate size. Aortography in the left anterior oblique projection resulted in a very faint and transient opacification of the pulmonary artery. The catheterization diagnosis was ventricular septal defect with "small" patent ductus arteriosus. At subsequent surgery, performed in March, 1970, a ventricular septal defect (0.9 cm in diameter) and a ductus (0.6 cm in internal diameter) were closed. In this case the expression of the ductus was less than might be expected.

These observations demonstrate the variability of expression of a patent ductus arteriosus of significant size in the presence of a large proximal left to right shunt. It can be concluded that a negative ascending aortogram may be insufficient to exclude a possible ductus, even if not clinically demonstrable, in these circumstances.

REFERENCES


6 Shaffer AB, St Ville J, Mackler SA: Coronary arteriovenous fistula with patent ductus arteriosus. Amer Heart J 65:758-765, 1963


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