Aortography in Infants

By John D. Keith, M.D., and Constance Forsyth, M.D., M.R.C.P.

Making a diagnosis of a patency of a ductus arteriosus is often difficult in the first few months or first year of life. When the diagnosis is in doubt, one may profitably turn to angiocardiography for help. In this paper a method of demonstrating the patent ductus by the injection of contrast medium is described. The practical importance of the correct diagnosis is presented with reference to 4 cases treated surgically in the early months of life. Demonstration of coarctation of the aorta by this method is also discussed.

To anyone interested in angiocardiography in infants, the studies of Barclay and his co-workers on the fetal circulation are most stimulating. Their investigations of the circulatory changes at birth, in lambs, provide a most useful background in studying similar processes in man. The clarity of their methods, using contrast media to demonstrate the ductus arteriosus, makes one wish it were possible to investigate human subjects as thoroughly. Although this is not possible, much can be done to investigate infants in the first year of life, and especially in the new-born period, by similar methods.

Probably the chief value of the method to be described is in the study of patent ductus arteriosus, but one may also investigate coarctation of the aorta and other anomalies of the aortic arch by this method. Patency of the ductus arteriosus has been demonstrated in infants by clinical means and by examination. Sometimes the presence of a continuous murmur in the pulmonary area indicates this anomaly. Such a murmur has been noted in a few premature babies. However, there may be simply a systolic murmur and the presence of a patent ductus can only be suspected.

The necessity of early diagnosis has become more imperative now that surgical closure of the ductus can be performed with relative ease and safety. The problem was brought forcibly to our attention recently, when an infant of 2 months was admitted to hospital with cardiac failure. The presence of a patent ductus was suspected, and the diagnosis was confirmed by aortography. The baby was successfully operated upon at 3 months of age with subsequent cure of the heart failure.

As surgical technic improves, it may be possible to operate on coarctation of the aorta, and on other anomalies of the aortic arch, in infancy. With these observations in mind, it was decided to study suspected cases of patent ductus arteriosus and coarctation of the aorta in infants by angiocardiography and relate the results to the clinical findings.

Method

In 1942, Castellanos referred to the injection of contrast media up the brachial artery into the aorta. We have adapted this method for our use in studying the aorta and vessels arising from it, in infants.

A short longitudinal incision is made in the skin above the antecubital space of the left arm, and the tissues dissected down until the brachial artery is exposed. It is then ligated distally, and a number 18 needle, or larger if possible, is inserted up into the artery. The baby is then placed in the left anterior oblique position on the angiocardiography table, beneath the x-ray tube. A syringe is prepared containing 3 to 6 cc. of 35 per cent Diodrast, the stylet is removed from the needle and the syringe is attached to it. A small amount of blood is allowed to flow out from the artery into the syringe to make sure the needle is patent, and that no air is present. The instrument for taking x-ray films is then started, and the injection is made in as short a time as possible. The developed serial x-ray films taken at the rate of about three or four a second show the contrast medium in the aorta and great vessels. This contrast medium clears very rapidly and has usually disappeared within two to three seconds.

The left arm is used almost invariably because the left subclavian artery arises directly from the aorta. When the right arm is used a large proportion of the

From the Hospital for Sick Children and the Department of Paediatrics, University of Toronto, under the direction of Alan Brown, M.D., F.R.C.P.

Aided by a Grant from the President's Research Fund—University of Toronto.

907 Circulation, Volume II, December, 1940
contrast medium goes into the carotid artery and the cerebral vessels. If dye is injected into the left arm rapidly enough, a considerable amount of the contrast medium will reach the aorta proximal to the entrance of the subclavian artery, and may reveal the whole aortic arch to the aortic valve, as well as the descending aorta. An example of this technic is shown in figure 1 which illustrates a normal aorta.

**Observations**

Twenty-six aortograms have been made on infants and young children. Most of these infants were in the first few months of life, although 2 children were over 2 years of age. In studying the findings in these infants, there are two obvious groups: (1) those with a normal aortogram, and (2) those with evidence of patent ductus arteriosus, persistent trunceans, or coarctation of the aorta.

**Group 1.** In the first group there were 13 patients who had no evidence of any abnormality in the aortogram. Most of these were in the first few weeks or months of life. The average age was 3 months, apart from one child of 2 years and one of 4 years. The youngest was 5 days old. These infants had a variety of conditions that led to the making of the aortogram. In 6 patients in group 1 the diagnoses made clinically or at necropsy were as follows: tricuspid valve opening into the left ventricle, atrioventricularis communis, pulmonary veins emptying into the right auricle, left coronary arising from the pulmonary artery, idiopathic dilatation of the pulmonary artery and tetralogy of Fallot. In 2 patients the diagnosis was ventricular septal defect. In 2 patients Lutemacher's syndrome was thought to be present. In 3 infants the hearts were considered to be normal.

Certain normal findings were common to all children in group 1. In all cases the brachial and left subclavian arteries were clearly visible. Many small branches arising from the subclavian artery were also clearly delineated. The vertebral artery stood out with clarity. The descending aorta could be seen from the point of entrance of the subclavian artery down into the lower abdomen. A short portion of the aortic arch beyond the entrance of the subclavian was visible in each case; the amount of the arch showing largely depended upon the rapidity with which the injection was made into the brachial artery. The left carotid artery did not show unless the contrast medium backed up into the aortic arch. In some cases the whole aortic arch was visible and then all the great vessels arising from it were seen. The left internal mammary artery was outlined in every case. The intercostal vessels were frequently visible but not invariably so. The superior and inferior mesenteric arteries could be seen but the hepatic arteries and renal arteries could not be identified with any certainty.

One case was a baby of 5 days who had a normal aortogram with the exception of a bulge at the site of the entrance of the ductus arteriosus into the aorta. There was no evidence of filling of the ductus or the pulmonary vessels with Diodrast. The bulge was therefore taken to be associated with the antenatal channel of blood through the open ductus. It was concluded that the ductus had closed some time in the five days preceding the aortogram. (See fig. 1.)

**Group 2.** In this group there were 14 cases. Their findings have been summarized in table 1. There were 8 cases of patent ductus arteriosus studied by aortography. One infant was added to the group because the clinical diagnosis was confirmed at operation, although no aortogram was done. There were 4 cases of
coarctation of the aorta, and one of persistent truncus arteriosus.

In the 8 infants in whom the ductus was delineated by the contrast medium, the ages varied from 10 days to 15 months, the average being 4 months. Two of these infants had cyanosis, and 6 had no evidence of cyanosis. Three had dyspnea and signs of early failure, and 5 had no dyspnea and no signs of failure. A thrill was palpable in one patient. This occurred in a 15 month old child and was palpable in the pulmonary area. In 2 instances the murmur was continuous, in 2 it was present in systole and extended into early diastole,

in 2 it was heard in systole only, and in 2 no murmur was heard. Under the fluoroscope 3 showed grossly enlarged hearts, 2 moderately enlarged hearts, and 3 showed slightly enlarged hearts.

The aortogram showed filling of the pulmonary artery from the aorta in all 8 infants, but in only one could the ductus itself be outlined as it filled with contrast medium from the aorta (fig 2). In this patient the ductus was abnormally long and the aorta and pulmonary arteries were distinctly separated. In the other cases the aorta and pulmonary artery were within a few millimeters of each other, and the shadow of the two vessels overlapped sufficiently to prevent the recording of a clear-cut image of the ductus. However, the filling of the pulmonary artery from the aorta at the usual site of the ductus permitted the diagnosis to be made (fig. 3). The diagnosis of a patent ductus arteriosus was confirmed definitely in 5 of the 8 infants; 2 died at a later date and at postmortem examination a patent ductus was readily demonstrated; in 3, the ductus was exposed at operation and successfully ligated.

The presence of other congenital defects of the heart was noted in 3 of the patients with patent ductus arteriosus. Two of the 3 had tricuspid atresia and the third was a mongolian idiot with a ventricular septal defect as
<table>
<thead>
<tr>
<th>Name</th>
<th>Sex</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Signs &amp; Symptoms</th>
<th>Murmur</th>
<th>Heart Enlargement</th>
<th>Aortogram</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.W.</td>
<td>F.</td>
<td>10 days</td>
<td>Patent ductus; V.S. defect</td>
<td>None</td>
<td>Systolic in 2nd, 3rd and 4th spaces.</td>
<td>Slight</td>
<td>Pulmonary vessels filled from aorta.</td>
<td>Associated V.S. defect. Mongol</td>
</tr>
<tr>
<td>F.H.</td>
<td>M.</td>
<td>3 wks.</td>
<td>Patent ductus; Tricuspid atresia</td>
<td>Cyanosis</td>
<td>No murmur</td>
<td>Slight</td>
<td>Pulmonary vessels filled from aorta, and ductus itself was clearly outlined.</td>
<td>Necropsy, Diagnosis confirmed.</td>
</tr>
</tbody>
</table>
### Table 1—Continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Sex</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Signs &amp; Symptoms</th>
<th>Murmur</th>
<th>Heart Enlargement</th>
<th>Aortogram</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>K.C.</td>
<td>M</td>
<td>2½ yrs.</td>
<td>Coarctation; V.S. defect; Patent duc-</td>
<td>None</td>
<td>Systolic murmur in 4th</td>
<td>Moderate</td>
<td>Coarctation outlined distal to subclavian</td>
<td>At operation patent ductus ligated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>alrable.</td>
<td></td>
<td>type)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coarctation outlined distal to subclavian</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A.S.</td>
<td>M</td>
<td>7 mos.</td>
<td>Coarctation and (?) asso-</td>
<td>None</td>
<td>Systolic murmur be-</td>
<td>Moderate</td>
<td>artery.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ciated defect.</td>
<td></td>
<td>tween scapulae and in</td>
<td></td>
<td>(Adult-type)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>mitral area. Fe-</td>
<td></td>
<td>Coarctation outlined distal to subclavian</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>moral arteries not</td>
<td></td>
<td>artery. (Adult-type)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>palpable.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coarctation outlined distal to subclavian</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>J.McD.</td>
<td>F</td>
<td>1 wk.</td>
<td>Coarctation of aorta (infantile); Dextra-</td>
<td>None</td>
<td>Faint systolic murmu-</td>
<td>Moderate</td>
<td>artery.</td>
<td>Died at 2 wks. Patient ductus was continu-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>position of aorta; V.S. de-</td>
<td></td>
<td>r between apex and</td>
<td></td>
<td>Coarctation distal to left subclavian</td>
<td>ous with descending aorta distal to coarct-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>fect</td>
<td></td>
<td>sternum.</td>
<td></td>
<td>artery (Infantile type)</td>
<td>ation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ductus was patent but not shown</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In 4 cases it was possible to demonstrate a coarctation of the aorta by the aortogram. (See fig. 4.) In none of these children were the femoral arteries palpable. In the older child no blood pressure readings were obtainable in the leg, and in the arm the blood pressure reading was 125/80. All had moderate cardiac enlargement and none were considered to be cases of pure coarctation. The presence of coarctation was proved at postmortem examination in 2 babies, and at operation in a third. The fourth has not been operated on yet.

**Discussion**

The method of aortography which has been described appears to be a reliable one for demonstrating the presence or absence of a patent ductus arteriosus, provided the ductus is filling from the aorta as was the case in 8 of the infants studied. In one patient with coarctation a ductus was delivering blood from the right ventricle and pulmonary artery into the aorta, hence there was no reflux into the ductus and its patency was not evident by angiocardiography.

It may be difficult at times to eliminate the possibility of a persistent truncus by this method, but there are certain features that help to differentiate the two conditions. When the ductus fills from the pulmonary artery, the latter usually shows as a large vessel close to the aorta. On the other hand, the vessels arising from the aorta, in persistent truncus, are apt to be smaller than the main pulmonary artery. In persistent truncus, one may detect that the vessels going to the lung arise from

---

**Notes:**

- Table 1: Continued
- Description of cases and methods used.
- Discussion on coarctation and aortography.
- Reference to persistent truncus.

---

**References:**

- McD, J.M.
- McD, J.McD.
- Forsyth, C.
- Keith, J.D.

---

**Additional Notes:**

- Coarctation: Systolic murmur.
- Heart Enlargement: Moderate.
- Aortogram: Coarctation outlined...
- Comment: At operation...

---

**Additional Mathematical Figures:**

- Table 1: Continued
- Mathematical calculations and clinical observations.

---
the ascending aorta and in this way be able to distinguish them from the ductus which arises from the descending aorta. In most instances, persistent truncus is accompanied by cyanosis, while patent ductus arteriosus is not.

There are both academic and practical reasons for studying patency of the ductus arteriosus in early life. From the academic point of view, it is of interest to know whether the finding by Barclay and associates, of closure of the ductus in the first few moments of life in the lamb is applicable to man. Our work does not shed much light on this point since we have not had an opportunity to do angiograms in the first few moments of life. However, we have studied 2 patients each 5 days old, who had no evidence of patency of the ductus. According to Patten the human ductus closes anatomically between the seventh and ninth week of life. The absence of patency in 2 infants under this age indicates that closure had already taken place in these instances at least.

Another aspect of the problem of the early closure of the ductus in man, concerns the presence or absence of murmurs in the neonatal period. We have observed 3 babies in the newborn period who have had the typical continuous murmur of patent ductus. Two of these were premature infants. In one case the murmur disappeared as the baby grew older, and in the other, the baby died and the tetralogy of Fallot was found with a patent ductus postmortem. It would appear to be of significance that a continuous murmur was heard in these premature babies since this leads one to the conclusion that the normal absence of murmurs in healthy infants, during the neonatal period, is in favor of the belief that the ductus closes functionally at birth.

We have been able to study the relationship of the presence or absence of murmurs to patency of the ductus arteriosus by using the angiogram. Out of 9 cases of proved patency of the ductus, a typically continuous murmur was present in 3; in 2 the murmur occurred in systole and at times could be heard in early diastole; in 2 a systolic murmur only was heard in the pulmonary area; in 2 no murmur was noted at all. Thus one can have a variety of murmurs or none at all, and still have a patent ductus. A murmur does not depend on the degree of difference in pressure between the aorta and the pulmonary artery, because in the infant who had no murmur a great difference in pressure existed, since there was tricuspid atresia and a very small opening into the vestigial right ventricle. Furthermore the pulmonary artery was hypoplastic. Postmortem examination suggested that the absence of murmur in the pulmonary area, in this case, was probably due to the unusual length of the ductus. It was at least 12 mm. in length.

In infants, a murmur heard in the pulmonary area, lasting through systole and appearing to extend into early diastole is probably due to patent ductus arteriosus. A systolic murmur alone in the pulmonary area, in an infant, could be caused by a variety of congenital defects but patent ductus is the commonest. Functional murmurs must always be eliminated.

The practical importance of early diagnosis of patent ductus is emphasized by our findings of 4 cases, who in early life required operation. The diagnosis was suspected on clinical examination in each case. The angiogram confirmed

Fig. 4. J. W., age 10 days. Coarctation of the aorta. Marked constriction of the aorta is shown.
the diagnosis in the 3 cases where the diagnosis was not sufficiently clear-cut to recommend operation without it. All 4 patients recovered satisfactorily from the operation thus demonstrating that the ductus can be treated surgically in the first 15 months of life and even as young as 3 months of age, when cardiac failure makes operation imperative.

The clinical findings of these 4 cases are summarized in the table. All had murmurs in the pulmonary area. In 2 there was a continuous murmur and in 2 a systolic murmur was questionably prolonged into early diastole.

We have not included the many cases of patent ductus diagnosed by their murmurs alone and who had no other signs and symptoms. Such infants have little or no enlargement of the heart as a rule. The 4 cases under discussion had grossly enlarged hearts, enlarged to a degree that suggested the presence of some other associated anomaly of the heart. A very large ductus was found in each case. They all improved after operation and the murmurs disappeared. No specific evidence of another anomaly has been found yet, but further observations over the years may reveal a second defect.

In the 4 cases with failure, all had a rapid respiratory rate of 60 to 80 per minute. The liver was enlarged in all and 2 had rales in the chest. On administration of Digoxin, 2 showed improvement of their heart failure before operation. In all, the signs of failure cleared up rapidly after operation. X-ray films made before and after ligation of the ductus showed marked diminution in heart size over a period of three or four months. From the preoperative size of the heart in these infants and from their course before operation, there seems to be little doubt now that surgery was a life-saving measure.

Of the 4 cases of coarctation of the aorta presented in table 1, 3 were of the adult type. The fourth had a patent ductus that was delivering blood into the aorta. Our interest is primarily in the first 3, since they are amenable to surgery. Out of the 13 cases of coarctation recognized in the first year of life and coming to necropsy at this hospital in the past 10 years, 3 were of the adult type. For this reason we should search carefully for evidence of this anomaly, especially in infants whose hearts are enlarged, and who might thus require surgery at an early age. However, the average case of coarctation of the aorta is symptom-free until late childhood or adult life.

Palpation of the femoral artery is the most important clinical lead to the diagnosis and should be part of any examination of the heart. The diagnosis is not as easily made in infants as in older children because the femoral artery may be difficult to feel even in a normal infant. Blood pressure readings in the arms and legs are not as accurate in infants, and there is no notch of the ribs seen in the x-ray film. Other congenital defects of the heart may be present which will make the diagnosis of coarctation extremely difficult. For these reasons it is felt that aortography has a valuable place in establishing an accurate diagnosis and in indicating the exact site of the narrowing of the aorta. Figure 4 indicates how clearly the coarctation can be outlined by this technic.

**Summary**

A method of visualizing the aorta of infants with contrast medium is described. It requires the introduction of a number 18 needle into the brachial artery and the rapid injection through it of 5 cc. of 35 per cent Diodrast solution. While the injection proceeds, serial x-rays are taken at the rate of three or four a second. The aorta is clearly outlined for approximately one second by this method. This has proved useful in demonstrating the ductus arteriosus, when it is patent, and coarctation of the aorta. A continuous murmur, a systolic murmur or no murmur at all was found in various patients with patent ductus arteriosus. Thus aortography has proved useful in making a diagnosis in doubtful or obscure cases.

The findings in 4 infants with patent ductus arteriosus are described. These infants had grossly enlarged hearts, all of them have had
serious heart failure due to the congenital anomaly. All 4 were operated on successfully.

Coarctation of the aorta can be clearly delineated by this method in infants.

REFERENCES

Aortography in Infants
JOHN D. KEITH and CONSTANCE FORSYTH

Circulation. 1950;2:907-914
doi: 10.1161/01.CIR.2.6.907
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1950 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on
the World Wide Web at:
http://circ.ahajournals.org/content/2/6/907

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally
published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not
the Editorial Office. Once the online version of the published article for which permission is being
requested is located, click Request Permissions in the middle column of the Web page under Services.
Further information about this process is available in the Permissions and Rights Question and Answer
document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/