Descending aortography with balloon inflation

A technique for evaluating the size of persistent ductus arteriosus in infants with large proximal left to right shunts

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SUMMARY Six infants underwent angiography of the aortic root and the descending aorta with balloon inflation during diagnostic cardiac catheterisation and angiography. In these infants with large proximal left to right shunts, descending aortography with balloon inflation resulted in better opacification of the persistent ductus arteriosus than aortic root angiography, thereby enabling accurate measurement of the persistent ductus arteriosus. Similar systemic and pulmonary vascular impedances had been speculated as the cause of poor or non-opacification of the ductus after ascending aortography. Balloon inflation may have altered the aortic impedance with resulting opacification of the ductus. Descending aortic angiography with balloon inflation is also useful in opacifying the isolated ductus and in demonstrating aortopulmonary collaterals in patients with pulmonary atresia.

Persistent ductus arteriosus in patients with large ventricular septal defects predisposes to pulmonary vascular obstructive disease unless early intervention is carried out.^{1,2} Selective aortic root angiography has, therefore, been recommended in all patients with large ventricular septal defect to diagnose the presence of persistent ductus arteriosus.^{2,3} Rao *et al*⁴ and others³ have previously shown that selective aortography does not uniformly detect the ductus in the presence of a large proximal shunt (ventricular septal defect or atrioventricular canal). We suggested that in this group of patients a persistent ductus might be diagnosed best by passing a catheter across the ductus arteriosus and specifically probing for it.⁴ Although diagnosis can be made by passage of the catheter across the ductus, the size of the ductus cannot be assessed. The purpose of this study was to assess the ability of descending aortography with balloon inflation to determine the exact size of the persistent ductus arteriosus.

Patients and methods

Six infants aged 2 to 8 months underwent diagnostic catheterisation and angiography for evaluating large ventricular septal defect and suspected additional ductus arteriosus. All but one had normally related great arteries; one had transposition of the great arteries. A common atrioventricular canal was present in one infant. A No 5 French gauge catheter with multiple side holes was advanced from the right ventricle into the ascending aorta via the ventricular defect. In the infant with transposition the catheter was advanced directly from the right ventricle into the ascending aorta. Renografin (76%), 1 ml/kg body weight, was injected over 1.5 s into the aortic root, while cineangiograms were recorded in the posteroanterior and lateral projections. The catheter was then replaced with a No 5 French gauge balloon angiographic catheter (with injection holes proximal to the balloon) and was advanced from the main pulmonary artery into the descending aorta via the ductus. In the patient with transposition, the catheter was advanced from the ascending aorta into the descending aorta. The catheter tip was positioned in the mid-thoracic aorta, and the balloon was inflated with carbon dioxide during the initial phases of cine-

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Fig. 1 A selected cineangiographic frame from an aortogram in the lateral view (a). The catheter (C) has been advanced into the aorta (Ao) from the right ventricle via ventricular septal defect. There was no visualisation of a ductus arteriosus on careful review of the cineangiogram. A cineangiographic frame that best opacifies the entire aorta was chosen for illustration. The same infant's descending aortogram (b) with the balloon (B) inflated shows the persistent ductus arteriosus (PDA) clearly. The catheter had been advanced into the descending aorta (DAo) from the main pulmonary artery through a PDA.

Fig. 2 A cineangiographic frame from the lateral view of an aortogram (a) of an infant with transposition of the great arteries and a large ventricular septal defect. The catheter (C) had been advanced into the ascending aorta (Ao) directly from the right ventricle. Note the threadlike, small persistent ductus arteriosus (PDA). In the same infant the catheter had been advanced into the descending aorta (DAo) and the balloon (B) was inflated during the initial phases of the angiography (b). Note the clear cut delineation of the PDA and pronounced opacification of the main pulmonary artery (MPA).

Fig. 3 Aortogram (a) showing opacification of persistent ductus arteriosus (PDA). When a descending aortogram (b) was performed with the balloon (B) inflated, a large PDA with opacification of pulmonary arteries (PA) was seen. Note the discrepancy in the size of PDA between both aortograms. The course of the catheter (C) was similar to that described in Fig. 1.

angiography while exactly the same amount of contrast material was used as in the aortic root angiography; the total calculated contrast material was injected over 1.5 s. Descending aortography was also recorded in the posteroanterior and lateral projections. No complications were encountered during the procedure.

To evaluate any adverse effects of balloon inflation in the descending aorta, aortic pressure (proximal to the balloon) and an electrocardiogram were recorded before and during balloon inflation in five other infants.

Results

During aortic root angiography faint or partial opacification of the persistent ductus occurred in four infants and no opacification in the remaining two. During descending aortic angiography the ductus arteriosus was opacified in all infants, was seen more clearly, and was much larger in each case (Figs. 1–3). The ductus was either not visualised or only partially visualised in the ascending aortic angiogram; in the descending aortic angiogram with the balloon inflated the size of the ductus could be clearly determined.

The mean (SD) systolic pressure (90 (8) mm Hg) in the descending aorta proximal to the inflated bal-

loon increased (110 (5) mm Hg) significantly ($p < 0.01$) during balloon inflation, whereas the diastolic and mean blood pressures did not change significantly ($p > 0.1$). A decrease in mean (SD) heart rate (114 (7) to 96 (17) beats/min) was noted, but this difference did not attain statistical significance. In addition, no clinically detectable adverse side effects were noted either in these infants in whom both the aortic pressure and electrocardiogram were recorded during balloon inflation or in the infants in whom descending aortography with balloon inflation was performed.

Discussion

The possible explanations for non-opacification of a ductus arteriosus during aortic root angiography in patients with large proximal left to right shunts have been discussed elsewhere.^{3,4} We looked at the known physiological determinants of left to right shunting—namely, pulmonary vascular resistance, the ratio of pulmonary vascular resistance to systemic vascular resistance, and the ratio of pulmonary artery pressure to aortic pressure—and found that these could not account for the non-opacification of a ductus arteriosus.⁴ Many other physiological variables determined at cardiac catheterisation and technical aspects of angiography were scrutinised, but

Fig. 4 Descending aortograms with balloon inflation in patients with isolated persistent ductus arteriosus (PDA). Note the clearly demonstrated size and shape of the PDA in each case. B, balloon; C, catheter; DAo, descending aorta; PA, pulmonary artery.

none explained the phenomenon. Poor visualisation of the ductus during aortic root angiography may have been related to the small size of the catheter (No 5 French gauge) and the "small" dose (1 ml/kg) of contrast medium used. With regard to the size of the catheter: firstly, the infants were very young (2–8 months) and their weight was low; but secondly, and more importantly, the calculated contrast material was delivered over 1.5 s. Furthermore, the descending aortography was also performed with a similar sized catheter. The amount of contrast material used (1 ml/kg) was comparable to that recommended for standard aortography (0.75 to 1.0 ml/kg) by several groups of workers in this field.^{5–7} Again, the same quantity of contrast material was used during descending aortography. For these reasons neither the size of the catheter nor the amount of contrast material used was responsible for faint or non-opacification of the ductus during aortic root angiography. We have speculated that the lack of difference in the vascular impedance (the instantaneous pressure to flow relation) between the interconnected circulations (systemic and pulmonary) may help explain the non-opacification of a ductus arteriosus.⁴ In the present study, inflation of the balloon during angiography with a resulting increase in

the systemic pressure may have altered the aortic impedance, producing more complete opacification of the ductus arteriosus.

Other methods of demonstrating ductus arteriosus include aortography at the level of ductus after the catheter has been advanced from the pulmonary artery via the ductus into the aorta, retrograde femoral artery catheterisation,^{8–10} aortography by countercurrent injection via the radial artery,^{11,12} and transductal aortic arch angiography.^{13,14} In my experience, aortography with the catheter positioned at the level of the ductus arteriosus after having crossed it does not produce consistent visualisation of the ductus arteriosus. Despite recent advances in retrograde arterial catheterisation and countercurrent injection in small infants and children,^{15,16} these procedures are sometimes associated with complications and technical difficulties.^{15–23} Transductal aortic arch angiography that Mardini and Rao previously described,^{13,14} although useful, did not produce as good an opacification of the ductus as did descending aortography with balloon inflation. This technique of descending aortography with balloon inflation is safe. When the aortic pressure and heart rate were recorded during balloon inflation there

Fig. 5 An aortogram (a) showing opacification of several aortopulmonary collateral vessels. Although many of these vessels are seen, there is no clear cut demonstration of these vessels. A descending aortogram (b) with balloon (B) inflation clearly opacified several aortopulmonary collateral vessels. A somewhat delayed phase of this aortogram (c) shows the opacification of the left and right pulmonary arteries (LPA and RPA).

was only a minimal increase in aortic systolic pressure proximal to the balloon and a slight, if any, decrease in heart rate. The latter is probably vagus mediated. No other complications were encountered. Because of the safety and better visualisation of the ductus arteriosus, this technique is recommended for evaluating the size of the ductus arteriosus in patients with large proximal left to right shunts.

CLINICAL APPLICATIONS

Encouraged by the results of descending aortic angiography with balloon inflation in demonstrating the size of the ductus arteriosus, I have since applied this technique to other lesions. Several patients with a clinical diagnosis of ductus arteriosus but with additional abnormal findings were studied to exclude any other associated cardiac defects. Figure 4 shows several examples of descending aortograms with balloon inflation. The size and shape of the ductus were clearly visualised in these cine-angiograms. Such information is of great value during transcatheter closure of a persistent ductus.²⁴⁻²⁸

I recommend descending aortography before transcatheter ductal closure so that an appropriate sized ductal plunging device can be chosen/prepared for ductal closure.

It is important to evaluate the pulmonary arterial anatomy in patients with pulmonary atresia with ventricular septal defect ("pseudotruncus") and type IV truncus.²⁹⁻³³ Figure 5a shows an aortic root angiogram with reasonable opacification of the collateral vessel supply to both lungs; but, as can be seen, the collateral vessels were clearly visualised when descending aortography was performed with balloon inflation (Fig. 5b). Furthermore, delayed opacification of the pulmonary arteries (Fig. 5c) was seen after descending aortography. I recommend descending aortography with balloon inflation for delineating the number, location, and size of the aortopulmonary collateral vessels in patients with pulmonary atresia. This should be performed before selective catheterisation and contrast injection of these aortopulmonary collateral vessels.

In conclusion, descending aortography with balloon inflation during the initial phase of the angio-

graphy is a useful and safe technique for evaluating the size of the persistent ductus arteriosus in patients with large proximal left to right shunts. Other clinical applications of this technique include clear cut opacification and anatomical delineation of the isolated ductus before transcatheter closure of the ductus and demonstration of aortopulmonary collateral vessels in patients with pulmonary atresia.

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