

## TECHNIQUE

## End-on aortogram: improved identification of important coronary artery anomalies in tetralogy of Fallot

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### Abstract

**Objective**—To identify coronary artery anomalies in patients with tetralogy of Fallot with an aortogram taken with steep caudal and left oblique angulation ("end-on" aortogram).

**Design**—Prospective evaluation of end-on aortogram in the preoperative angiographic assessment of consecutive patients with tetralogy of Fallot.

**Setting**—Regional paediatric cardiology centre.

**Patients**—34 patients, aged 3 months to 12 years (median age 9 months).

**Methods**—An aortogram was performed with steep caudal (38°–45°) and left oblique (0°–30°) angulation under general anaesthetic as part of routine preoperative angiographic assessment.

**Results**—The origins and courses of the coronary arteries were visualised in all patients and important coronary artery anomalies were identified in four patients: single left coronary artery; single right coronary artery (two patients); separate high origin of left anterior descending. These anomalous coronary vessels crossed the right ventricular outflow tract.

**Conclusions**—It is important to identify preoperatively coronary arteries that may interfere with right ventricular outflow tract reconstruction. An aortogram with steep caudal and left oblique angulation is useful in identifying anomalous coronary arteries and more importantly it defines the relation of these vessels to the right ventricular outflow tract.

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Important anomalies of the coronary arteries are reported in up to 9% of patients with tetralogy of Fallot.<sup>1-4</sup> Any coronary artery that crosses the right ventricular outflow tract will affect the type and timing of surgical repair. It is therefore important to identify these vessels preoperatively. Aortic angiography in standard projections often fails to show the coro-

nary arteries clearly enough to identify anomalies with confidence. The origins of the coronary arteries are often not clear and, more importantly, their relation with the right ventricular outflow tract is difficult to assess. We use an angiographic projection with steep caudal and left oblique angulation to view the aorta end-on. In this projection the right ventricular outflow tract is anterior and to the left of the aortic valve and the relation of the coronary vessels to the right ventricular outflow tract can be assessed (fig 1).

### Patients and methods

Thirty four consecutive patients with tetralogy of Fallot underwent preoperative cardiac catheterisation under general anaesthetic. They ranged in age from 3 months to 12 years (median 9 months) and in weight from 3.5 kg to 26 kg (median 7.4 kg). One patient also had a complete atrioventricular septal defect and two patients had functioning aortopulmonary shunts. The aortic arch was right sided in nine patients. Aortic angiography was performed retrogradely in 20 patients and anterogradely in 14.

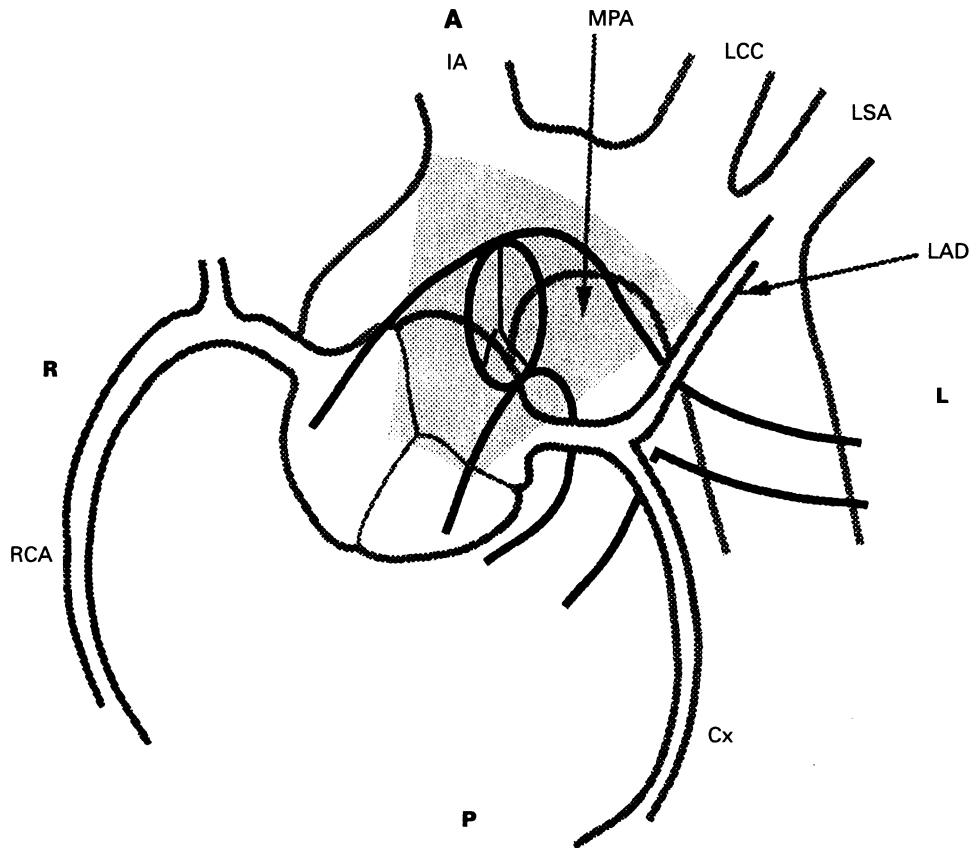
When the catheter was inserted from the femoral vein a 5 or 6 French NIH catheter was used and when performed from the arterial side a 4 French NIH catheter was used if the child's weight was less than 10 kg. Siemens SIRECON image intensifiers mounted on a BICOR system were used and images were processed with a digital angiography unit (Digitron 3 VACI). The anteroposterior image intensifier was tilted to maximum caudal angulation (38°–45°) with a varying degree (0°–30°) of left oblique tilt. Small test injections were used to ensure that the aorta was visualised "end-on". One ml/kg of contrast (Ultravist 370) was injected at a flow rate of 1 ml/kg/s. In three patients the aortogram had to be repeated because of poor positioning of the catheter. After studying the first three patients we found that the coronary arteries were more easily seen by placing a foam wedge underneath the patient's buttocks to increase caudal angulation and this was used for all subsequent patients (fig 2).

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Figure 1 Diagrammatic view of end-on aortogram. The right ventricular outflow tract (stippled) is anterior and to the left of the aortic valve. With normal coronary arteries no vessel will cross this area. IA, innominate artery; LCC, left common carotid; LSA, left subclavian artery; MPA, main pulmonary artery; LAD, left anterior descending; RCA, right coronary artery; Cx, circumflex artery; A, anterior; P, posterior; L, left; R, right.



### Results

The course of the coronary arteries and their origins were clearly identified in all patients. The quality of images and the ease of positioning of patients and catheters improved after the first six patients. In the early cases a catheter was placed in the right ventricular outflow tract to confirm its relation to the aorta (fig 3). In 30 patients the coronary arteries took a normal course with no vessel in front of the right ventricular outflow tract (fig 4). In four patients (11%) a significant abnormality was identified in which a coronary artery crossed in front of this area. These were:

(a) a single left coronary arterial system.

The left main stem was in a normal position and gave rise to the right coronary artery, which crossed in front of the right ventricular outflow area to reach the atrioventricular groove (fig 5).

(b) A single right coronary arterial system was found in two patients. The left anterior descending coronary artery arose from the right coronary artery just distal to the ostium and crossed in front of the right ventricular outflow tract. The circumflex arose separately from the left coronary sinus of Valsalva (fig 6).

(c) An anomalous left anterior descending coronary artery that originated high on the ascending aorta above the aortic sinuses and passed directly in front of the right ventricular outflow tract to reach the anterior interventricular groove. The right coronary artery and circumflex artery had a common origin from the left coronary sinus. The right coronary artery crossed behind the aorta to reach the atrioventricular groove whereas the circumflex artery took a normal course (fig 7).

In two patients a large conus branch of the right coronary artery was identified but did not run in front of the right ventricular outflow tract (fig 8).

There were no complications. All findings of normal or abnormal coronary arteries were confirmed at operation. Two patients with anomalous coronary arteries underwent palliative procedures. In the patient with a single left coronary arterial system and one of the patients with a single right sided system the pulmonary valve anulus was large enough to allow a primary repair through a right atriotomy.



Figure 2 Child with wedge placed underneath the sacral area to improve the effective caudal angulation.

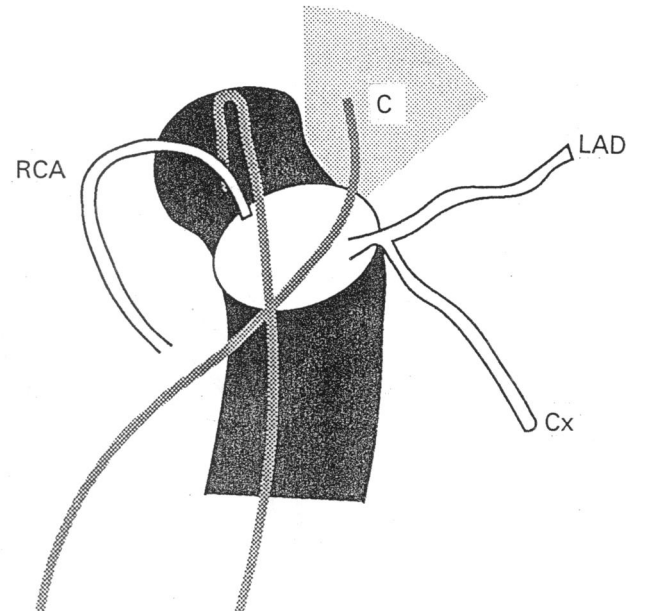
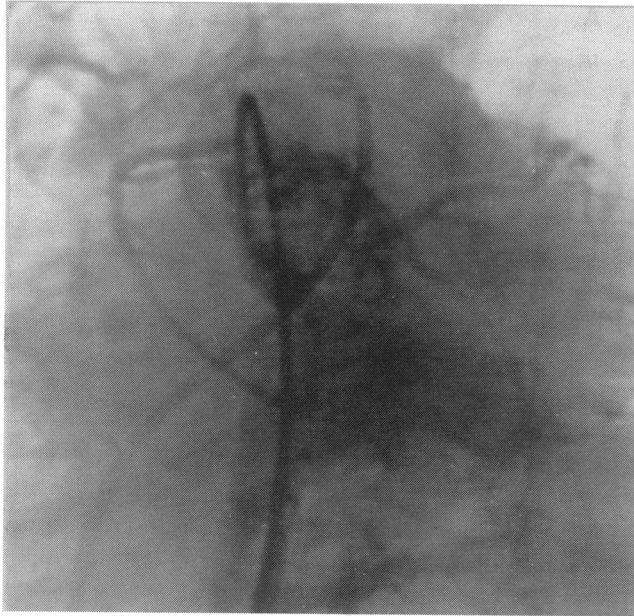


Figure 3 End-on aortogram with catheter (C) in main pulmonary artery. This verifies the relation of the right ventricular outflow area (stippled) to the coronary arteries in this projection.

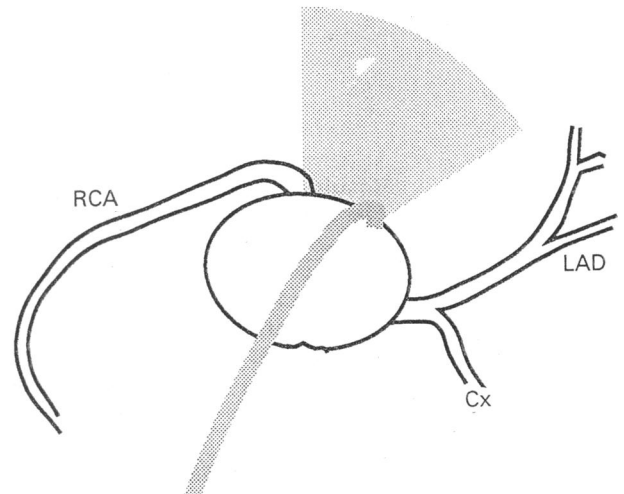
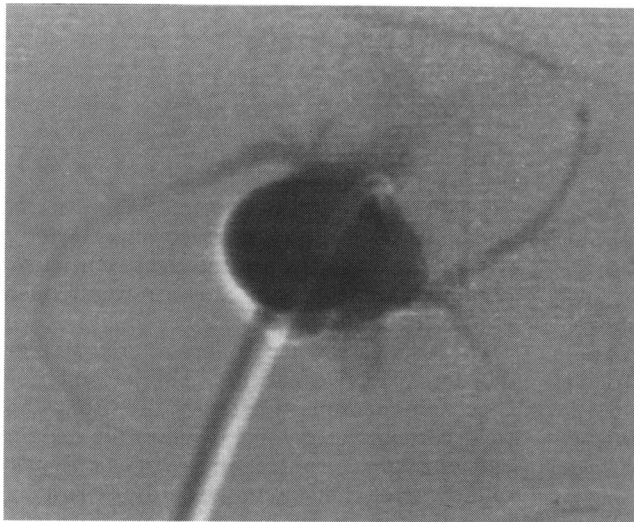


Figure 4 End-on aortogram showing the normal origin and course of the LAD, Cx, and RCA. This is an early frame taken before filling of the head and neck vessels. Abbreviations as for fig 1.

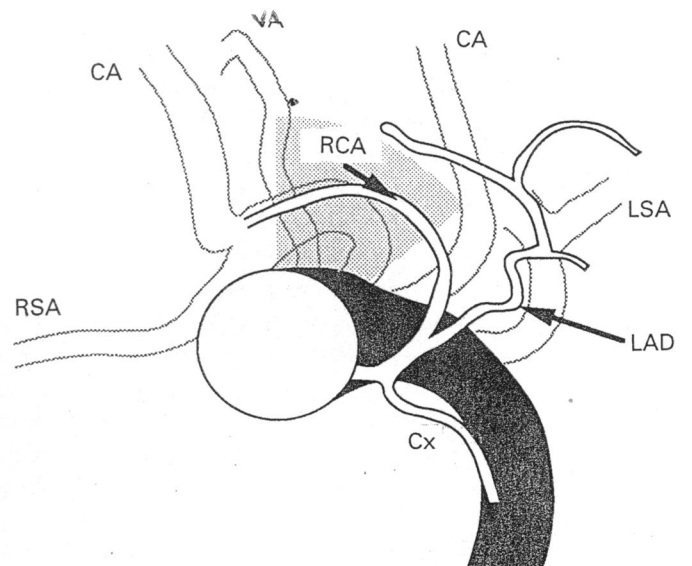


Figure 5 End-on aortogram in the patient with a single left coronary system giving rise to the right coronary artery (RCA) which crosses the right ventricular outflow tract (stippled). RSA, right subclavian artery; Car A, carotid artery; VA, vertebral artery; other abbreviations as for fig 1.

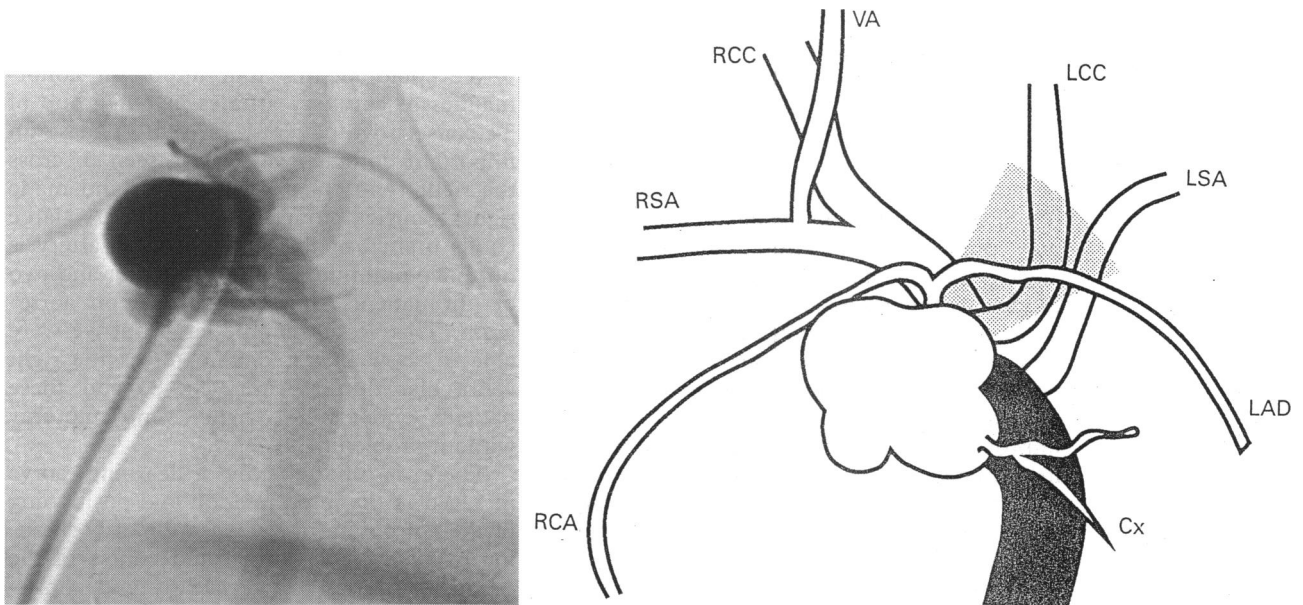


Figure 6 End-on aortogram in a patient with a single right coronary arterial system. The LAD arises from near the origin of the RCA and crosses the right ventricular outflow tract (stippled). RCC, right common carotid artery, other abbreviations as for figs 1 and 5.

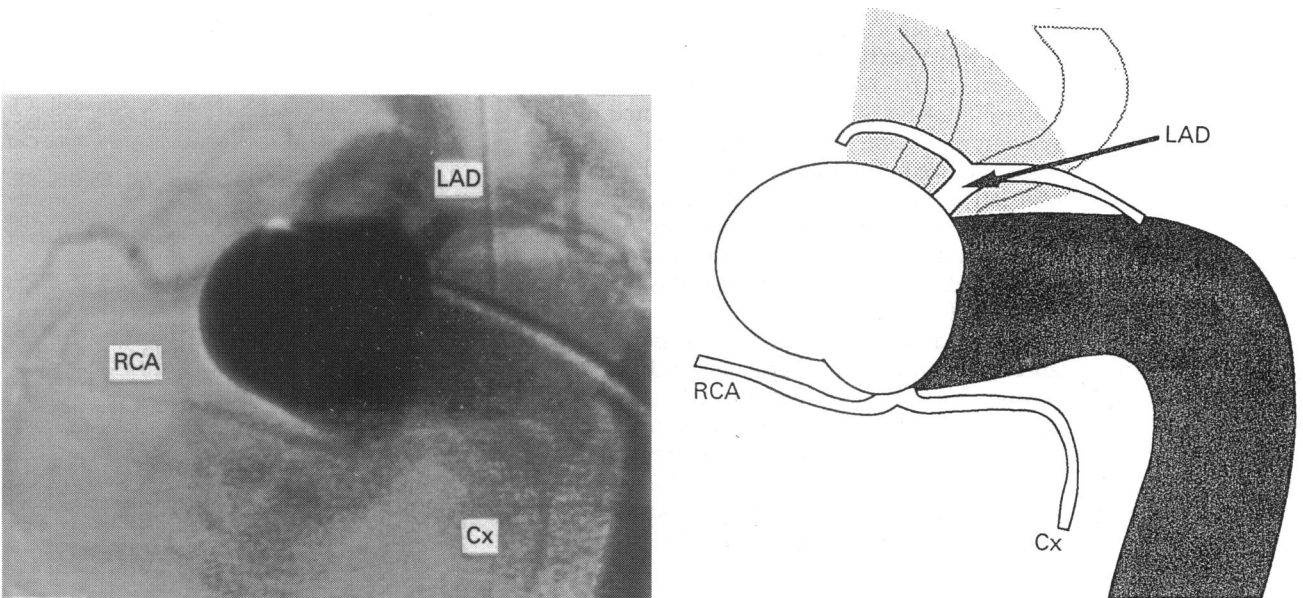


Figure 7 End-on aortogram of the patient with a separate LAD arising from the aorta and crossing directly in front of right ventricular outflow tract (stippled). The RCA and Cx arise together from the left coronary sinus. Abbreviations as for fig 1.

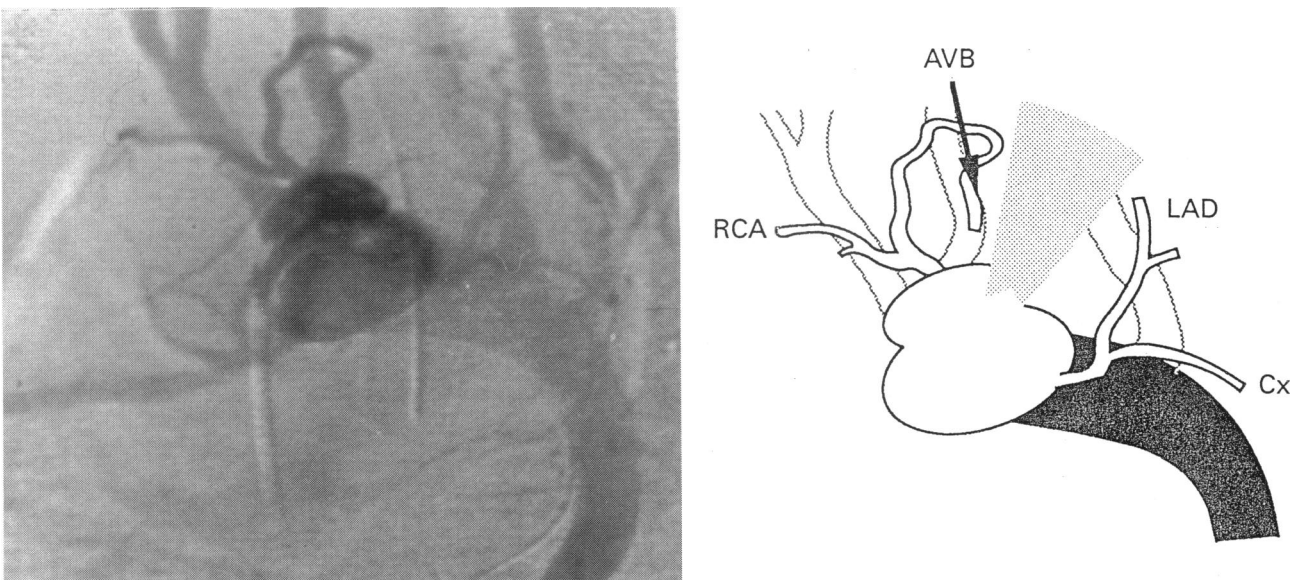


Figure 8 End-on aortogram showing a prominent anterior ventricular branch (AVB) of the RCA. It does not cross the right ventricular outflow tract area (stippled). The left system arises normally. Abbreviations as for fig 1.

### Discussion

Coronary vessels that would interfere with right ventriculotomy or resection of outflow obstruction must be identified preoperatively, partly because a sternotomy may not be the approach of choice for palliation and partly because the coronary arteries may be obscured by previous palliative surgery or may pursue an intramural course.<sup>5</sup> Aortic angiography in oblique projections often fails to identify the origins of the coronary arteries, or their relation to the right ventricular outflow tract. Selective coronary angiography poses technical difficulties in infants.

The angiographic projection we describe improves visualisation of the coronary arteries in tetralogy of Fallot and helps define their relation with the right ventricular outflow tract, without the need for selective angiography.

In transposition of the great arteries a similar aortogram has proved useful in identifying the course of the coronary arteries and takes advantage of the anterior angulation of the ascending aorta.<sup>6</sup> As the aorta is also angled more anterior than normal in tetralogy of Fallot, we expected that a similar view might show the coronary anatomy clearly. Achieving an end-on view of the aorta is facilitated by a maximum caudal tilt supplemented with a wedge placed underneath the child (fig 2) and left oblique angulation of up to 30°. In this projection the right ventricular outflow tract is anterior and to the left of the aortic valve and any vessel crossing this area is identifiable (fig 1).

The end-on aortogram can be performed anterogradely or retrogradely and careful positioning of the catheter is vital. If advanced too far towards the arch or if recoil to the ventricle occurs, poor quality images will result. Careful viewing of the moving images with digital subtraction makes it easy to separate out the coronary arteries from the

head and neck vessels as the coronary arteries will obviously move with the heart.

We could identify four important abnormalities of coronary arteries in our group of 34 consecutive patients. In each of these an important coronary vessel was seen to cross the right ventricular outflow tract and made right ventriculotomy impossible. A large conus branch of the right coronary artery is not uncommon in tetralogy of Fallot and two of our patients showed this well on aortogram. This vessel may be large but we were able to show that it did not cross the right ventricular outflow area (fig 8) and these patients underwent right ventriculotomy without problem.

There is undoubtedly a learning curve involved in the interpretation and positioning of the aortogram but when optimal positioning is achieved the origin and course of the coronary arteries can be clearly and consistently delineated. This angiographic projection enables normal and abnormal coronary arteries in tetralogy of Fallot to be identified reliably and obviates the need for selective angiography.

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