CASE REPORT

Transaortic Occlusion of Collateral Arteries to the Lung by Detachable Valved Balloons in a Patient with Tetralogy of Fallot

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SUMMARY A 5-year-old boy with tetralogy of Fallot, near-atresia of the right ventricular outflow tract and large collateral arteries to the lungs underwent an infundibulectomy without closure of the ventricular septal defect. Further surgery required preliminary reduction of the collateral circulation. The collateral arteries were successfully occluded by metrizimide-filled balloons. There was no change in arterial oxygen saturation, nor were there any complications. This new technique has significant advantages over existing alternatives.

LARGE SYSTEMIC arterial collaterals supplying the lungs in patients with tetralogy of Fallot may present severe problems at surgical closure of the ventricular septal defect. During cardiopulmonary bypass, they permit flow from aorta to lungs, which results in flooding of the surgical field and underperfusion of the patient. Postoperatively, such shunts may cause acute hypoperfusion and chronic cardiac failure. These large collateral flows may also cause pulmonary hemorrhages, resulting in marked difficulties in the postoperative period.

In the presence of severe or complete pulmonary outflow obstruction or very small pulmonary vessels, these collaterals may be the only source of blood to the lungs. However, after correction of the pulmonary obstruction, these collaterals become a hazard. Surgical ligation may be difficult, and may require a lateral thoracotomy if the necessary exposure cannot be obtained through the median sternotomy performed for intracardiac repair. Even with good preoperative angiography, the collaterals may be difficult to find. Some may arise from below the diaphragm.

We successfully occluded such systemic collaterals by a transvascular method that has many advantages over the surgical approach.

Case Report

Soon after birth, the patient was moderately cyanotic. Continuous murmurs were heard throughout the chest. Cardiac catheterization demonstrated pulmonary atresia, ventricular septal defect, and pulmonary blood supply from numerous tortuous systemic arteries. At age 3 years, exploratory surgery revealed a diminutive but patent right ventricular outflow tract in continuity with a diminutive pulmonic valve orifice and small pulmonary trunk. Leaving the ventricular septal defect open, the surgeon resected the pulmonic valve, opened the infundibulum, and placed a pericardial graft across the outflow tract and pulmonary trunk.

When first seen at Children's Hospital of Los Angeles at the age of 4 years, the patient was in good health and taking no medications. He had mildly impaired exercise tolerance and mild cyanosis. Continuous murmurs were present bilaterally. There were no signs of congestive heart failure. The chest x-ray showed a dilated main pulmonary artery. Cardiac catheterization at age 5 years showed a bidirectional shunt through a large ventricular septal defect, an arterial oxygen saturation of 89% and pulmonary-to-systemic flow ratio of 1.5. The main pulmonary artery was markedly dilated, with no discernible valve tissue, and the pressure was equal to that in right and left ventricles. The right pulmonary artery pressure was 22/12 mm Hg. The left pulmonary artery could not be entered. On the pulmonary arteriogram, the right and left pulmonary arteries arborized normally, but were small at their origins. Aortography showed six large, tortuous arteries coursing from the descending aorta to both lungs. One of these entered the main pulmonary artery and the others anastomosed with secondary and tertiary branch pulmonary arteries.

We concluded that when the ventricular septal defect was closed, the collateral arteries could prove troublesome both intraoperatively (by flooding the operative field and deviating aortic blood to the lungs, causing systemic hypoperfusion) and postoperatively (by causing hypoperfusion acutely and congestive failure chronically). The shunting of aortic blood into the main pulmonary artery and the absence of the pulmonic valve led to uncertainty as to how necessary the collaterals were for the patient's oxygenation.

We therefore eliminated the collaterals in a tentative, stepwise fashion and observed oxygen saturation constantly. This necessity and the number and complexity of the collaterals prompted consideration of...
balloon occlusion as an alternative to surgical closure of the collaterals before or during correction of the ventricular septal defect.

The balloon is made of silicone, contains a miter valve in its neck, and is manufactured in sizes ranging from 5–13 mm inflated diameter (Heyer-Schulte Corp.); the 6-mm balloon was used in this case. It has an uninflated diameter of 1 mm and is delivered on the end of a #2F polyethylene catheter manually inserted through the miter valve. The catheter lies in a #4F polyethylene catheter that is advanced and torqued in the aorta to select the origin of the vessel desired. Then the balloon is partially inflated and flow directed down the artery by advancing the #2F catheter to the desired site of occlusion. The balloon is then further inflated to occlude the vessel and the #4F catheter advanced until it reaches the balloon. The balloon is detached by withdrawing the #2F catheter while the balloon is buttressed against the #4F catheter.

The balloon is filled with metrizamide at a concentration of 220 mg iodine/ml and so is clearly visible during fluoroscopy and on follow-up plain films. Details of the design and use of the balloon have been reported.2

Under local anesthesia, aortography was repeated using a percutaneous femoral technique. The aortogram showed the large collaterals, one of which originated below the diaphragm (fig. 1). Three silicone balloons were inserted, flow-directed into the three largest collateral arteries, and detached (fig. 2). Some difficulty was encountered entering the middle artery (short arrow), which had a stenotic origin. The largest bronchial collateral on the right is an early branch of this artery and remains patent because a second balloon could not be passed across the stenosis. Arterial oxygen varied insignificantly during the procedure and was 86% at the conclusion. The patient suffered no untoward effects, and after embolization, his exercise tolerance was unchanged as evaluated by the family. The continuous murmurs were still audible.

Plain films 4 weeks later showed no evidence of the left upper balloon. Aortography was repeated (fig. 3) and showed that this balloon had deflated, but the artery in which it was lodged remained occluded (long straight arrow).

**Discussion**

Two cases of successful preoperative embolization of collateral arteries to the lungs in tetralogy of Fallot have been reported. The first used liquid isobutyl cyanoacrylate glue, which solidified on contact with blood. The glue was delivered by a double-lumen nondetachable balloon catheter.8 The balloon was inflated proximally in the artery during embolization to provide stasis and prevent escape of glue through the shunt. Because the patient had minimal pulmonary outflow, part of the embolization was carried out in the operating room after cardiopulmonary bypass had been started.

Yamamoto et al.4 reported embolization of three collaterals with a combination of gelfoam particles and Gianturco coils. Although their patient had un-
corrected infundibular stenosis, all three arteries were occluded without pulmonary symptoms or change in the patient's PO₂.

Neither of these patients nor ours suffered any complications of embolization. However, the possibility of significant pulmonary infarction should be considered. Large connections between the collateral arteries and the pulmonary vessels are often present, as in our case; these should be searched for on the preembolization angiogram. If they are present, emboli small enough to pass into the pulmonary vessels should not be used. This is an advantage of large, easily controlled emboli, such as balloons over gelfoam and glue.

Another consideration is that paralysis can be caused by embolization of spinal cord collaterals arising off bronchial arteries. This is a recognized complication of embolization of enlarged bronchial arteries for treatment of hemoptysis from chronic inflammatory lung disease or tumors. However, the large systemic collaterals to the lung in tetralogy of Fallot are thought not to be true bronchial arteries, but persistent embryonic intersegmental arteries and may not give rise to spinal branches as bronchial arteries do. If angiography showed a proximal branch that might be supplying the spinal cord, the balloon could be maneuvered distally to spare it.

To our knowledge, no case of detachable balloon occlusion of systemic arteries to the lung has been reported. However, the Heyer-Schulte balloon has been used in the head and neck, renal arteries, and pelvic arteries; a similar balloon has been used in the distal pulmonary arteries to treat pulmonary arteriovenous fistulas. The balloon is inert and the only difficulty we encountered was occasional premature deflation and possible migration of the balloon. However, there is experimental evidence that if the balloon remains inflated for as long as 10 days, as in our patient, permanent occlusion results.

The advantages of this technique over surgical closure are that it can be done stepwise in a stable patient, which permits constant evaluation of arterial saturation and it eliminates operating time, difficult dissection, and potential bleeding. Advantages over other modes of transvascular embolization are the relatively innocuous nature of the deflated Silastic balloon in event of migration as contrasted with other foreign substances that have been used. The #2F catheter is small and flow directed, which facilitates entry into the desired vessels.

References

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