Transcatheter Embolization in the Treatment of Coronary Artery Fistulas

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Seven patients with a coronary artery fistula underwent percutaneous transcatheter embolization (five were male and two female; the age range was 2 to 67 years [median 17]). Three patients were symptomatic. The left to right shunt ranged from 1.6 to 2.6:1. In six patients, the fistula was an isolated congenital anomaly; in one, it was acquired. The fistula arose from branches of the left (n = 5) and right (n = 2) coronary arteries and drained to the right ventricle (n = 2), right atrium (n = 2), coronary sinus (n = 1), pulmonary artery (n = 1) and a bronchial artery (n = 1).

Different embolization techniques were used to occlude eight feeding arteries. The embolization materials included a detachable balloon (n = 3), coaxial embolization with platinum microcoils (n = 3), a combination of detachable balloon and microcoil (n = 1) and standard steel coils (n = 1). Satisfactory occlusion was achieved in six patients. In one case, the valve of the detachable balloon was damaged, resulting in early balloon deflation and a residual fistula. There were no associated complications in any patient.

Follow-up investigation by Doppler ultrasound or coronary angiography 4 months to 4 years later showed that permanent occlusion was achieved in all six patients in whom embolization was initially successful. Transcatheter embolization should be considered the treatment of choice for coronary artery fistulas.


Methods

Study patients (Table 1). Between December 1982 and June 1989, seven patients ranging in age between 2 and 67 years (median 17) underwent percutaneous transcatheter embolization of a coronary artery fistula; there were five male and two female patients. In six patients, the fistula was congenital in origin and in one (Case 3), it was acquired after aortic valve replacement. The three oldest patients were symptomatic, suffering from angina (n = 2) and dyspnea (n = 1); the other four patients were asymptomatic. One of the patients with angina (Case 1) had additional coronary artery disease and was undergoing medical treatment. The patient with dyspnea had additional mild mitral regurgitation and had previously undergone aortic valve replacement for aortic regurgitation. An exercise thallium-201 myocardial perfusion scan performed in five patients revealed reversible myocardial ischemia in three (Cases 2, 4 and 7).

Coronary angiography (Table 2). Cardiac catheterization was performed by percutaneous femoral vein and artery approach. General anesthesia was used in all children and local anesthesia was used in the three adults (Cases 1, 3 and 7). On oximetric analysis in four of the patients, the left to right shunt ranged from 1.6 to 2.6:1. An initial coronary angiogram was performed to demonstrate the anatomy of the anomalous vessels and coronary arteries. The site of origin and drainage of the fistulas is shown in Table 2. All but one patient had a single feeding artery to the fistula. In Case 5, the initial arteriogram showed a single large feeding artery...
Table 1. Clinical Data in Seven Cases of Coronary Artery Fistula Before Embolization

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yr)</th>
<th>Gender</th>
<th>Symptoms</th>
<th>Sign</th>
<th>Thallium Scan</th>
<th>Qp/Qs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67</td>
<td>M</td>
<td>Angina</td>
<td></td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>M</td>
<td>None</td>
<td>Continuous murmur</td>
<td>Reversible ischemia</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>F</td>
<td>Dyspnea</td>
<td>Continuous murmur</td>
<td>Normal</td>
<td>1.6</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>M</td>
<td>None</td>
<td>Continuous murmur</td>
<td>Reversible ischemia</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>M</td>
<td>None</td>
<td>Continuous murmur</td>
<td>Normal</td>
<td>2.6</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>M</td>
<td>None</td>
<td>Continuous murmur</td>
<td>—</td>
<td>1.8</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>F</td>
<td>Angina, palpitation</td>
<td></td>
<td>Reversible ischemia</td>
<td>—</td>
</tr>
</tbody>
</table>

F = female; M = male; Qp/Qs = pulmonary to systemic flow ratio; — = not available.

Table 2. Anatomic and Technical Details in Seven Cases of Coronary Embolization

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Fistula Origin</th>
<th>Drainage</th>
<th>Occlusion Technique</th>
<th>Final Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LCA (distal LCx)</td>
<td>Bronchial artery</td>
<td>Silicone balloon</td>
<td>Occlusion</td>
</tr>
<tr>
<td>2</td>
<td>LCA (distal LCx)</td>
<td>Coronary sinus</td>
<td>Latex balloon</td>
<td>Occlusion</td>
</tr>
<tr>
<td>3</td>
<td>RCA</td>
<td>Right atrium</td>
<td>Latex balloon</td>
<td>Early balloon deflation</td>
</tr>
<tr>
<td>4</td>
<td>RCA</td>
<td>Right atrium</td>
<td>0.038 in. (0.097 cm) coil x 12</td>
<td>Occlusion</td>
</tr>
<tr>
<td>5</td>
<td>LCA (septal);</td>
<td>Right ventricle</td>
<td>Latex balloon/0.018 in. (0.046 cm) coil</td>
<td>Occlusion</td>
</tr>
<tr>
<td></td>
<td>LCA (diagonal)</td>
<td>Right ventricle</td>
<td>0.018 in. coil</td>
<td>Occlusion</td>
</tr>
<tr>
<td>6</td>
<td>LCA (diagonal)</td>
<td>Right ventricle</td>
<td>0.018 in. (0.046 cm) coil x 3</td>
<td>Occlusion</td>
</tr>
<tr>
<td>7</td>
<td>LCA (diagonal)</td>
<td>Pulmonary artery</td>
<td>0.018 in. (0.046 cm) coil x 7</td>
<td>Occlusion</td>
</tr>
</tbody>
</table>

LCA = left coronary artery; LCx = left circumflex coronary artery; RCA = right coronary artery.
Figure 1. Case 5. A, Left coronary angiogram (right anterior oblique view). There is a large coronary artery fistula arising from the septal branch of the left anterior descending artery and draining into the right ventricle. The other left coronary artery branches are filling poorly. B, A contrast-filled balloon has been detached in the septal branch (large white arrow) and a microcoil is positioned immediately proximal to the balloon (small white arrow). After the occlusion of this branch, a smaller diagonal branch was noted to supply the fistula and was occluded with another microcoil (black arrow).

Figure 2. Case 4. A, Right coronary angiogram (right anterior oblique projection). The catheter is in a large feeding artery that arises proximally from the right coronary artery. Note the three large aneurysmal dilations, with the terminal dilation draining into the right atrium. B, Six month follow-up study. Injection into the feeding artery shows that the fistula is occluded. The coils are tightly packed in the distal part of the terminal aneurysm.

Feeding artery with a single platinum coil failed to produce occlusion and a second procedure was necessary (which was successful). In Case 3, an immediate postembolization angiogram demonstrated successful occlusion, but a final angiogram showed that the detachable balloon had deflated and embolized to the peripheral lung field. This was not associated with any clinical sequelae and the patient was referred for elective surgery of the fistula. Of the remaining five patients, a final angiogram showed complete occlusion in four and minimal residual flow in one (Case 4).

Complications. Apart from the early balloon deflation in Case 3, no other major complications were associated with the procedures. In Case 5, minor complications consisted of transient T wave inversion that reverted to normal 3 days later. This was associated with a small increase in serum creatine kinase levels (peak 325 U/liter at 24 h, normal range...
A technetium 99m-labeled pyrophosphate scan 2 days after the procedure showed no evidence of myocardial infarction. Patient 2 had transient right bundle branch block that reverted to normal 2 days after the procedure. In the other five patients, no ECG abnormalities were detected after embolization. Apart from Patient 5, cardiac enzymes were measured in only one patient (Case 6) after embolization; no elevation of serum enzyme levels occurred. The mean hospital stay was 4 days (range 2 to 6).

**Follow-up.** The follow-up period ranged from 4 months to 4 years (mean 10 months). One of the previously symptomatic patients (Case 1) was asymptomatic 15 months after the procedure. The continuous murmur disappeared in all patients (except Patient 3, who underwent surgery). No residual flow was detected in the five patients who underwent Doppler ultrasound evaluation. The two patients (Cases 1 and 4) who underwent repeat coronary angiography had an occluded fistula (Fig. 2).

**Discussion**

Coronary artery fistulas. A congenital coronary artery fistula is a direct communication between a coronary artery and one of the cardiac chambers or vessels around the heart. These fistulas usually occur in isolation and are rare (2,11,12) although they are the most common hemodynamically significant congenital coronary artery anomaly (1). Six of our seven patients had a congenital fistula; in one, it was secondary to previous aortic valve surgery.

Although these fistulas occur early in life, they do not usually cause symptoms until after the 2nd decade. Our patients encompassed a wide age range, and only three patients were symptomatic; all three (Cases 1, 3 and 7) were adults and two had additional acquired cardiac disease. Among the four asymptomatic patients, a significant left to right shunt was demonstrated in three who had shunt estimation.

Clinical course. Even though most coronary artery fistulas are considered benign in the 1st 2 decades, complications do occur in later life. There is a risk of developing cardiac failure due to long-standing left ventricular volume overload and this risk increases with age (2). Myocardial ischemia and angina, from the "steal" effect of a large fistula (3), may potentiate the effect of any associated coronary artery disease (as in Case 1). Therefore, most investigators (2,6) advocate surgical closure of a hemodynamically significant fistula, even in the absence of symptoms. In three of our patients, reversible ischemia was noted on the thallium scan before the embolization procedure; in six patients, an injection into the coronary artery supplying the fistula showed much better filling of normal branches after the fistula had been occluded.

Spontaneous closure of coronary artery fistulas has occasionally occurred (13,14) in younger children with a relatively small fistula draining into the right ventricle. Two patients in our series were <10 years of age. Patient 5, aged 6 years, had been followed-up for 4 years with no evidence of reduction in the size of the fistula; Patient 6 was only 2 years old, but the fistula resulted in a significant left to right shunt.

**Surgical treatment.** The risks and complications of not treating a coronary artery fistula have usually been compared with the morbidity and mortality associated with cardiac surgery. Although one series (6) reported no operative death in 25 cases, other reports (2) demonstrate a 2.2% to 4% mortality rate. After surgery, myocardial infarction has been reported in 3.6% of cases and the true recurrence rate of the fistula is unknown (15). Furthermore, surgery for a coronary artery fistula involves a median sternotomy and, in most cases, cardiopulmonary bypass with its associated morbidity (6).

**Treatment with transcatheter embolization techniques.** These are now widely used in a great variety of clinical situations including arteriovenous fistulas. However, there are only isolated case reports (2,6) of therapeutic embolization of a coronary artery fistula. Several recent comprehensive reviews (16,17) of embolization procedures in congenital heart disease do not mention this treatment for such fistulas. This omission is related not only to their relative rarity, but also to the technical difficulties of occluding a large high flow fistula and the potential risks involved with catheter manipulations in coronary arteries. However, our experience shows that both of these concerns have been overestimated.

A coronary artery fistula is usually supplied by a large artery that may have a long and tortuous course around the heart before terminating in a chamber or a vessel. When a fistula has a large blood flow, normal coronary branches may not be clearly visualized because of the "steal" effect of the fistula. It is imperative that the feeding artery is occluded distal to all normal branches to the myocardium. The techniques used in embolization of such a fistula include a detachable balloon, steel coil and platinum microcoil.

A detachable balloon was used in four of our seven patients. This method usually allows a precise and immediate occlusion to be effected. However, there are disadvantages including the need for a large guiding catheter, the risk of early deflation of the balloon and inadvertent embolization to other sites. Detachable balloons can be inflated with either silicone or contrast medium. When a balloon is inflated with silicone, permanent occlusion results once polymerization has occurred and this process is irreversible. Inflating the balloon with contrast medium is safer and reversible, but there is always a possibility of early deflation when the fistula can revascularize.

When coils are used, it is essential for the tip of the catheter to be positioned at the point where occlusion is to be effected. This may be difficult using standard catheters, especially when the feeding arteries are tortuous or a very distal occlusion is needed. Coaxial embolization techniques with microcoils allow for a safer and distal occlusion. When there is a high level of flow in an artery, a collection of coils...
Figure 3. Case 6. A, Selective injection into the left coronary artery of a 2 year old child (left anterior oblique projection). Note the dilated and tortuous diagonal branch that drains into the right ventricle at the apex of the heart. The distal anterior descending and circumflex coronary arteries are poorly filled. B, The coaxial catheter (opacified with contrast medium) has been passed distally so that its tip is safely beyond any myocardial branches. Note the metallic marker at the tip. C, Postembolization angiogram. Seven microcoils have been positioned. The tightly grouped cluster of coils has achieved occlusion. One curved coil has passed more distally and has come to rest in the sharply angled curve. Note that better filling of the myocardial branches is seen.

packed together may be needed to occlude the fistula completely.

These technical concerns are highlighted in our series. In Patient 6, a detachable balloon could have been used, but it would have required a large guiding catheter in a 2 year old child. Coil embolization with a smaller guiding catheter was therefore used (Fig. 3). In Patient 4, the fusiform aneurysm communicating with the right atrium was too large to be occluded with a single detachable balloon. Despite packing the terminal aneurysm with 12 coils of assorted sizes, some residual flow persisted immediately after the procedure, but a follow-up angiogram 6 months later demonstrated that this nest of coils had achieved complete occlusion (Fig. 2B).

It is important to select an embolization technique suitable to the size and location of the fistula and to have a wide range of equipment available to cope with unexpected requirements. On occasion, a combination of techniques may be needed. In Patient 5, although the large septal feeding artery was ideal for balloon embolization (Fig. 1A), another smaller diagonal branch was much better suited to a coaxial
microcoil embolization technique. In addition to using a detachable balloon in the larger vessel, we placed another platinum microcoil proximal to the balloon as a safeguard against its early deflation (Fig. 1B). This case emphasizes a further advantage of being able to monitor the embolization procedure. The smaller feeding artery was not seen on initial angiography and would have gone unnoticed at surgery, resulting in possible recurrence of the fistula.

Complete occlusion was achieved in six of our seven patients with use of the techniques described. The one technical failure occurred soon after an apparently satisfactory result. The failure was due to early balloon deflation as a result of damage that occurred to the valve mechanism of the detachable balloon when it was pretested before its use.

Conclusions. When a hemodynamically significant coronary artery fistula is demonstrated, embolization with a detachable balloon or coils should be considered instead of surgery. The use of these techniques leads to a precise and effective occlusion of the fistula, resulting in less myocardial damage and reduced morbidity, making recurrence of the fistula less likely and resulting in a much shorter hospital stay.

References