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Interlocking Detachable Platinum Coils, A Controlled Embolization Device: Early Clinical Experience

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Abstract
Purpose: To present the early clinical experience of a new mechanically controlled-release embolization device—the interlocking detachable coil (IDC)—in complex embolization outside the head.
Methods: IDCs were used only when conventional embolization techniques were considered too risky or unsafe. The coils consist of unfibered coiled platinum (0.012 inch), mechanically connected to a pusher wire and deployed through a Tracker 18 catheter. IDCs come in a range of diameters (2–8 mm) and lengths (1–30 cm).
Results: A total of 87 IDCs were used for 27 procedures in 25 patients (mean 14.5 years) to occlude 31 arteries or vascular lesions. Control of the coil and its release were satisfactory and all coils were fully retrievable up to the point of deployment. Two IDC coils embolized inadvertently but were retrieved; there were no other complications. The IDC coils could not be satisfactorily placed in one high-flow arteriovenous (AV) fistula, and in another case there was a small residual fistula. Occlusion was produced in 29 of 31 lesions. Ancillary techniques were needed in 5 patients: temporary balloon occlusion in 2 and 0.038-inch coils in 3.
Conclusion: The IDC coil is an effective device that allows controlled embolization to be performed, especially in aneurysms and in high-flow AV fistulas in children.

Key words: Arteries—Therapeutic blockade—Arteriovenous malformations

The first coils used for embolization were standard Gianturco steel coils (0.038 inch) followed by ''mini'' steel coils (0.025 inch) [1, 2]. More recently, platinum microcoils (0.018 inch) have gained a place in more complex embolization procedures using coaxial catheter techniques [3, 4]. All these coils, once pushed from the cartridge into the introducer catheter, cannot be withdrawn, so the only way to abort the embolization is to withdraw the entire catheter. Once the coil emerges from the catheter tip, a stage of irreversibility is soon reached when catheter withdrawal means coil deployment.

Controlled-release coils have been developed to overcome this major limitation of coil embolization. Two main microcoils systems are available: 1) Electrolytically detachable coils or Guglielmi detachable coils (GDCs) are joined to platinum coils on a delivery wire with a small microsoldered joint [5–7]. Detachment occurs after passage of a small electrical current, which electrolyzes the solder. These coils have been used mainly to embolize intracerebral aneurysms. 2) Interlocking detachable coils (IDCs) use similar platinum coils, but a mechanical connection is made between the coil and its pusher wire. This new embolization technique and our clinical experience are described.

Methods

The coils available for IDC devices are similar to those used with the GDCs. Both have been developed by Target Therapeutics (Fremont, CA, USA) and are now commercially available in some countries. The coils are made of coiled platinum (diameter 0.012 inch) with a smooth fused distal end. They are wound in regular helices with a variety of lengths and diameters available [diameter/length (mm/cm): 2/1, 2/4, 3/6, 4/8, 5/15, 6/20, 7/20, 8/20, 8/30]. The coils come preloaded and attached to a pusher wire (175 cm). The proximal 130 cm of this pusher wire consist of a stainless steel core (0.016 inch), which provides proximal rigidity and good pushability. The distal 45 cm is flexible, allowing the coils to pass around tight bends. A lubricious fluoropolymer coating on this distal part further reduces friction. The distal end of the pusher wire and the proximal end of the coil interlock (Fig. 1). Provided this junction is within the lumen of the Tracker

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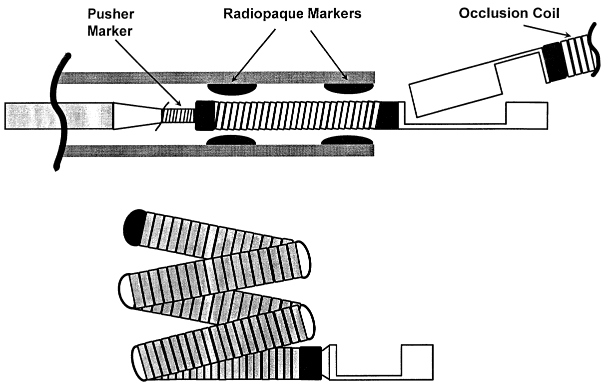


Fig. 1. IDC coil just after it has exited from the tip of a Tracker catheter. The mechanical attachment mechanism is seen but with the coil having detached itself. Having two radiopaque markers in the end of the Tracker avoids the possibility of the distal marker being obscured by any coils that have already been delivered.

catheter, the coil can be freely advanced or withdrawn; only when it is beyond the tip of the Tracker catheter does the coil automatically detach. The coils are nonfibered so that even coils as long as 30 cm produce little friction. Tracker 18 catheters (0.018 inch) were used routinely, but the Tracker 18 Unibody is recommended with its two radiopaque markers 3 cm apart at the distal end. Sometimes the tip of the Tracker is obscured by a released coil, which allows the interlocking point to be identified in relation to the second marker. It is recommended that a second hemostatic valve be used to enable continuous flushing of the Tracker catheter and around the IDC. IDC coils are flexible, and in high-flow situations (e.g., in large arteries) they tend to straighten. In such situations one or two 0.038-inch steel coils are first placed to act as an anchor point; alternatively, balloon occlusion techniques can be used to effect temporary occlusion.

Results

The IDC coils were deployed only in situations where the use of conventional coils was deemed to be unsafe or to carry an unnecessary risk. The most important indication was when there was a risk of inadvertent migration of a coil once it had been released. In many of our cases the use of conventional coils was thought to be technically impossible. When there was concern that passage of the coil could displace the catheter tip or when precise placement of the coil was necessary, the reversibility of IDC coils allowed a much greater margin of safety.

Interlocking detachable coils were used for 27 embolization procedures in 25 patients (age 7 months to 60 years, mean 14.5 years). There were 18 children under age 16 years; the remainder were adults. A total of 87 IDC coils was used to occlude 31 lesions or arteries. The vascular lesions embolized were comprised mainly of arteriovenous fistulas (AVFs) (n = 21). There were three aneurysms (one true, two false) and five abnormal arteries. The clinical abnormalities are shown in Table 1 (note the preponderance of children with congenital heart disease and associated vascular

Table 1. Vascular lesions embolized (n = 31) by interlocking detachable coils

Clinical lesions	No. of procedures
Coronary AVFs	13 (16 arteries)
Aortopulmonary collaterals (pulmonary atresia)	5[a]
Ductus arteriosus	4
Blalock-Taussig shunts	2
Renal artery aneurysm	1
Innominate AVF + false aneurysm	1
Saphenous vein graft AVF	1
Superior mesenteric artery pseudoaneurysm	1

[a] One patient had two collaterals

abnormalities). All of the coils were satisfactorily deployed and were potentially retrievable even when most of the coil was beyond the tip of the Tracker catheter. In a number of cases the arrangement of the IDC coil was not thought to be optimal for the lesions and the coil was pulled back and redeployed, sometimes with the tip of the Tracker 18 catheter positioned differently. This maneuver could be performed repeatedly to obtain the ''best fit'' for the IDC coil in the lesion. The compliant nature of the IDC coils allowed the use of multiple coils to form a localized platinum mass.

Among the 31 vascular lesions for which embolization with IDC coils was attempted, occlusion was effected in 29. In only one instance was deployment of the IDC thought to be unsatisfactory when it was withdrawn: in a high-flow coronary AVF, the coil, despite its diameter being greater than the artery, showed a tendency to straighten and to pass through the fistula. In one of the four cases of ductus arteriosus, little residual flow was seen on an early follow-up Doppler study, but in all the other cases occlusion was demonstrated on the immediate postembolization angiogram. In many cases, but especially the coronary AVFs, the arteries were tortuous. Despite this fact, in only one case did it prove impossible to pass the IDC coil to the most distal point of the fistula (Fig. 2A). Even there, though, it was possible to pass a shorter IDC coil to a more proximal location and effect a satisfactory occlusion (Fig. 2B, C).

Coronary AFVs (13 patients, 16 arteries) produced a particular problem when a large high-flow artery drained directly into a vein or cardiac chamber. Even IDC coils with a diameter greater than the artery tended to straighten with the high flow and would clearly have passed through the fistula if detached. Ancillary techniques were therefore required in five patients. In three patients, large-diameter 0.038-inch steel coils (William Cook, Bjaeverskov, Denmark) were placed to act as a

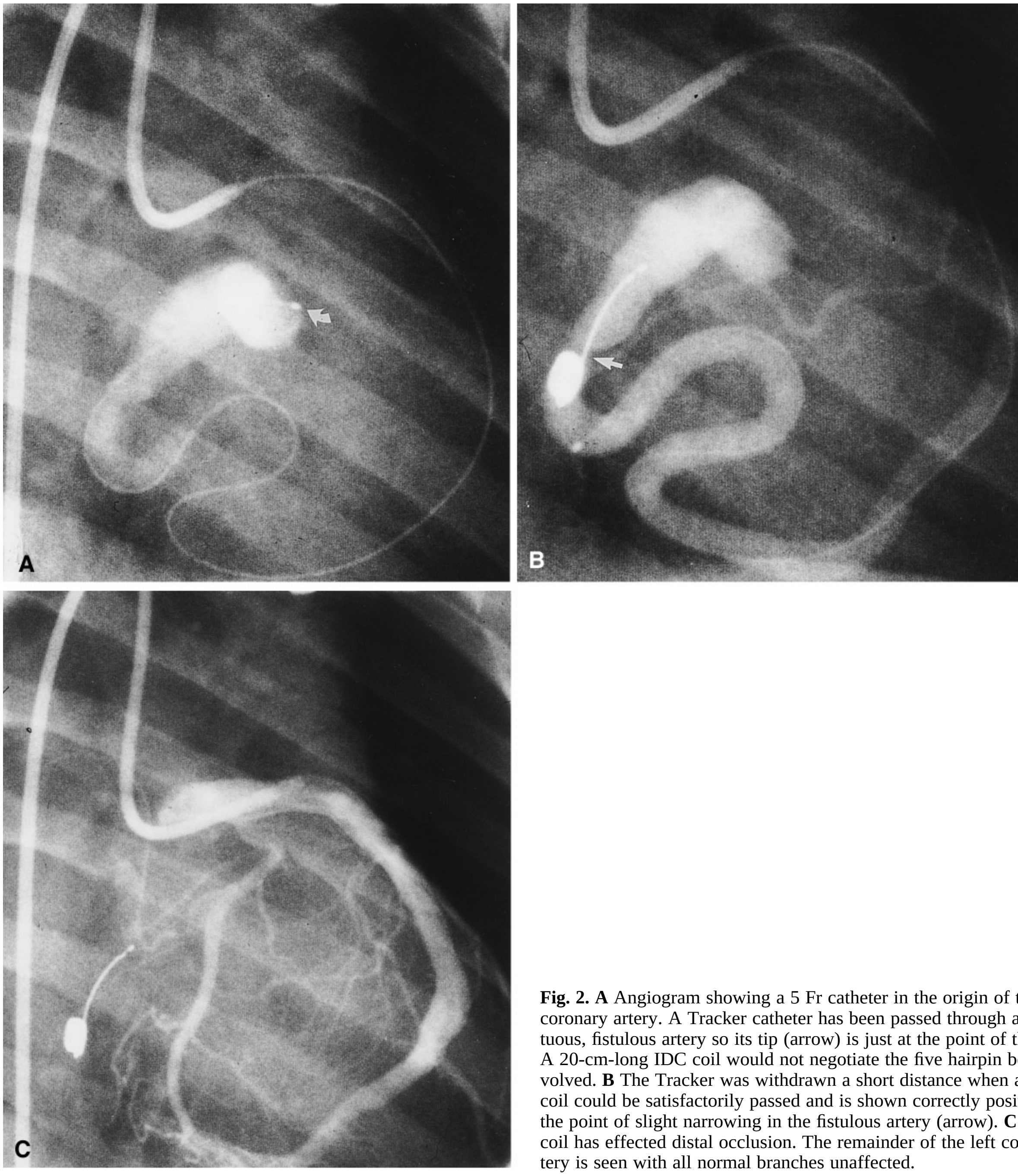


Fig. 2. A Angiogram showing a 5 Fr catheter in the origin of the left coronary artery. A Tracker catheter has been passed through a long, tortuous, fistulous artery so its tip (arrow) is just at the point of the fistula. A 20-cm-long IDC coil would not negotiate the five hairpin bends involved. **B** The Tracker was withdrawn a short distance when an 8-cm-coil could be satisfactorily passed and is shown correctly positioned at the point of slight narrowing in the fistulous artery (arrow). **C** The IDC coil has effected distal occlusion. The remainder of the left coronary artery is seen with all normal branches unaffected.

scaffold for subsequent IDC coils. In one child with a coronary AVF, a scaffold of 0.038-inch coils proved effective in occluding the fistulous artery, but in the other two patients additional IDC coils were needed. Moreover, 0.038-inch coils have a tendency to spread out and thus extend the point of arterial occlusion. We believe that a better technique (which we used in two later cases) is to insert balloon occlusion catheters to temporarily occlude the fistulous artery at a point just proximal to the point where IDC coils are used for occlusion. With the flow completely arrested, it is then possible to position a compact mass of platinum coils satisfactorily. After 30 min the balloon is deflated and removed. In both cases in which we used this technique the mass of coils proved to be stable and effected occlusion of the fistulas.

In two cases IDC coils that had been thought to be in a satisfactory position embolized distally and had to be retrieved. In one case a 5-mm-diameter, 10-cm-long coil was placed in a Blalock-Taussig shunt. The coil had been thought to be too small but was the only size available. Part of the coil prolapsed into the pulmonary artery, from where it was easily retrieved by a snare. Another IDC of the same size was then placed in a slightly different position; it proved stable and effected occlusion. In the second patient, with a large high-flow coronary fistula, an 8-mm-diameter, 20-cm-long IDC coil that had appeared stable embolized to the right atrium, from where it was retrieved. This fistula was then occluded with other IDC coils, forming a compact mass of platinum wire. Apart from these pateints there were no significant complications related to the use of these devices. In all cases, a radiograph (usually a chest film) on the following day showed that the coils had not changed position.

Discussion

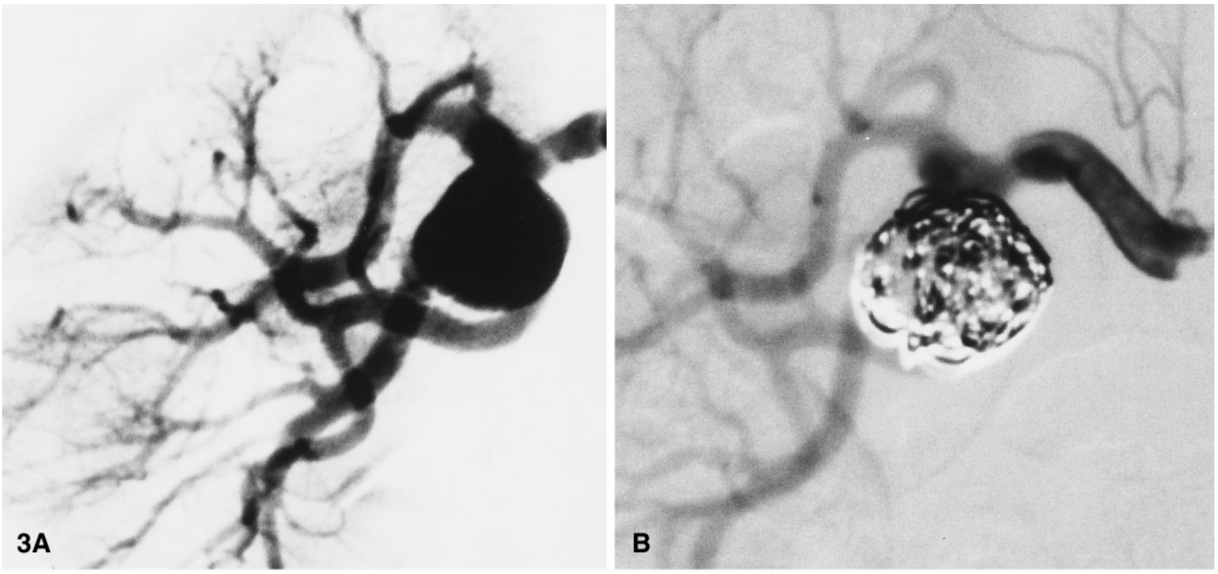
Conventional coils (0.038 inch and 0.018 inch) have proved effective for occluding an artery, especially when preceded by a more distal embolization that reduced the flow to the organ or tissue [8]. Occlusion of an AVF or an aneurysm is more difficult; unless a localized mass or ‘‘nest’’ of coils can be placed, the high flow prevents thrombosis. Sizing of the coils in such a situation is critical, as a coil of too small diameter may embolize distally whereas too large a coil may emerge from the catheter in a relatively straight fashion, rather than forming a coil. Until recently, there has been no control of these coils once they emerge from the catheter tip, with the process being irreversible. There are now detachable 0.038-inch steel coils with a controlled-release mechanism consisting of a spiral screw attachment (Cook). The 0.038-inch steel coils with Dacron fibers may be difficult to push out, particularly when there is a tortuous catheter course and and the coils are long and have a large diameter. Relatively large catheters (minimum 5 Fr) are required and can present problems especially in the cerebral and coronary arteries; this requirement plus the stiffness of these coils largely precludes their use in such situations.

There is no doubt that platinum microcoils (0.018 inch) have extended the capability of embolization procedures [3, 4, 9]. Once a superselective catheter position has been achieved, a coil can effectively occlude a small artery. The problem arises in high-flow tortuous arteries, as occurs in some AVFs and aneurysms. The 0.018-inch coils with fibers can be as difficult to push out of the catheter as the 0.038-inch steel coils, and short, unfibered coils are not particularly thrombogenic. Using longer unfibered coils results in a more thrombogenic mass of platinum, but of course there is still no control of the embolization.

We have used IDC coils only in situations where they were believed to offer real advantages. The major advantage is that the embolization process is reversible up to the stage of final detachment. There are additional advantages of these controlled-release devices, best illustrated by some of our 25 patients. One patient (Fig. 3) had a large renal artery aneurysm in the hilum of the kidney with a wide neck. On two occasions, nine IDC coils with a total length of 155 cm were used to fill the aneurysm. During the first procedure the aim was to safely position enough coils to produce a stable ‘‘scaffold’’ for subsequent coils. Even with the Tracker 18 catheter situated centrally in the aneurysm and surrounded by detached coils, it still proved possible to pass additional coils, all of which were potentially retrievable. The aneurysm was finally occluded, leaving the normal blood supply to the kidney unaffected. As has been shown with GDC coils in intracerebral aneurysms, the flexibility of these coils allows the platinum wire to be packed into the aneurysm with minimal risk of perforating or otherwise damaging the aneurysm wall. In a similar case, 95 cm of IDC coil was used to completely fill a false aneurysm (Fig. 4) of the innominate artery.

The variety of lengths and diameters of IDC coils available allowed a tailored approach to the occlusion of various lesions. For an aneurysm or high-flow AVF, a collection of long, large-diameter coils is required followed sometimes by small-diameter coils to effect a compact mass of platinum wire (Fig. 4). One 25-mm-diameter renal artery aneurysm required a total of 155 cm of IDCs to effect occlusion (Fig. 3A, B), in contrast to a small ductus arteriosus that required only a single 1-cm-long coil, and a small coronary AVF that needed a 3-mm-diameter, 5-cm-long coil.

Children with coronary AVFs are particularly difficult to treat. Often these young children and infants have large, tortuous feeding arteries (Fig. 2). Two technical problems present: 1) The high flow through the fistula means it is difficult to effect occlusion. 2) The high flow also means that normal coronary branches are poorly demonstrated because of the ‘‘steal’’ effect, yet it is vital that the occlusion be effected only distal to these branches (Fig. 2). Even when the diameter of an IDC coil is larger than the feeding artery, it may straighten as a result of the high flow and thus risk embolization through the fistula. The stiffer, less compliant 0.038-inch steel coils are much less likely to straighten, but they present problems when they are being passed, especially when the catheter takes a tortuous course. We have overcome this problem in two ways. If a large diameter 0.038-inch steel coil can be placed to act as a matrix, it effectively acts as an anchor against which long IDC coils can be safely added and packed in to effect the occlusion. An alternative (and we believe better)



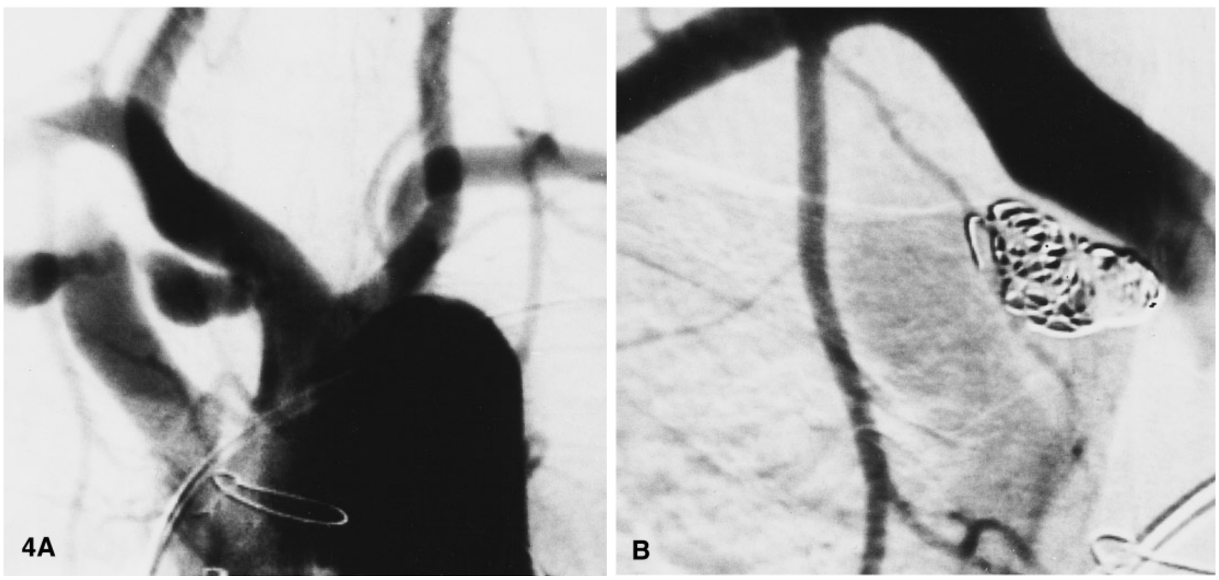


Fig. 3. A Right renal arteriogram in a 60-year-old woman with severe hypertension. A 2.5-cm saccular aneurysm is seen in the renal hilum with a fairly wide neck. **B** After two embolization procedures, a total of 155 cm of IDC coil has been place in the aneurysm, which is occluded. This mass of coils has filled the aneurysm without compromising the normal branch arteries.

Fig. 4. A 56-year-old women with a posttraumatic innominate AVF and false aneurysm. **A** Aortography demonstrates the fistula. The false aneurysm has a small neck on the arterial side. As it was not possible to catheterize it by the arterial route, a transvenous approach was utilized. **B** After placement of 85 cm of IDC coil, the false aneurysm and AVF are occluded. Note how the mass of platinum wire conforms to the shape of and completely fills the false aneurysm.

approach has been to occlude the large fistulous artery temporarily with a balloon placed in a more proximal location. It is then possible to pass a collection of IDC coils to form an occluding mass of platinum. Clearly there is concern that when the balloon is deflated, the mass of coils may move. However, the fistula usually has a distal narrowing, and with balloon occlusion for about 30 min after embolization we have had no problems treating two large coronary AVFs in this manner. We used a separate balloon occlusion catheter (no end-hole) in addition to the 5 Fr/Tracker 18 coaxial system. Clearly, a single occlusion balloon catheter with a 0.038-inch lumen to accommodate the Tracker would be simpler and more satisfactory. In two patients with AVFs, the point of the fistula was close to a normal coronary branch. In one 2-year-old child it was possible to place a small IDC coil, which formed a small compact ball at the point of stenosis at the fistula but spared a nearby myocardial branch [10].

In another patient, several loops of a long IDC coil were positioned on one side of the stenosis, with the remaining loops on the other side and just distal to the myocardial branch. The ability to withdraw IDC coils allows the coils to be withdrawn and repassed so as to effect a different coil configuration. Generally, IDC coils conform effectively to the space in which they are placed. Controlled-released coils have brought a degree of precision and control to coil embolization, so lesions that once proved difficult or impossible to treat can now be approached safely.

Two IDC coils were misplaced in our patients. In one of the earliest cases, a coil that was too small (larger coils were not available) was used to occlude a Blalock-Taussig shunt. When it prolapsed into the pulmonary artery, it was retrieved. In the second case, a patient with a high-flow coronary AVF, an 8-mm/20-cm coil embolized through the fistula, where it was retrieved from the right atrium. After this case we introduced techniques to avoid such situations.

For many embolizations the use of conventional coils, whether they be 0.038-inch steel coils or 0.018-inch platinum coils, is both effective and safe. When precise positioning of the coils is critical, and when it is important to test the position of the coil before releasing it, IDC coils have proved particularly valuable.

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