

Extracranial Aneurysm and Arteriovenous Fistula: Embolization with the Guglielmi Detachable Coil¹

PURPOSE: To evaluate the feasibility and safety of Guglielmi detachable coils for endovascular treatment of extracranial aneurysm and arteriovenous fistula.

MATERIALS AND METHODS: Embolization with Guglielmi detachable coils delivered through Tracker-18 microcatheters was performed in 16 patients. This patient group had eight renal artery aneurysms and 11 arteriovenous fistulas (three cases of patent ductus arteriosus, one associated with aneurysm; one fistula between the maxillary artery and jugular vein; two fistulas between the subclavian and pulmonary arteries; four fistulas between the pulmonary artery and vein; and one fistula between the anterior tibial artery and vein). Efficacy of the procedure was assessed by means of short-term follow-up (clinical examination, angiography, and/or Doppler sonography) 3 and 6 months later.

RESULTS: No complications were encountered. Embolization was technically and clinically successful in all eight aneurysms (100%) and in nine arteriovenous fistulas (82%). In two cases (fistula between the subclavian and pulmonary arteries and fistula between the anterior tibial artery and vein) endovascular placement of Guglielmi detachable coils failed to occlude the vessel. Results of short-term follow-up examinations confirmed the initial results in all cases.

CONCLUSION: Guglielmi detachable coils are feasible, safe, and effective for endovascular treatment of extracranial aneurysm and arteriovenous fistula.

ENDOVASCULAR embolization is a well-established nonsurgical treatment technique in neuroradiologic (1-3) and nonneuroradiologic (4-6) clinical contexts. The use of standard catheters is limited when distal vascular access is mandatory and/or superselective catheterization is impossible because of the tortuosity of the affected vessel (7-11). Furthermore, use of a stiff microcatheter in embolotherapy of certain vascular lesions, such as aneurysm, may carry the risk of rupture of the aneurysm (12).

With the development of microcatheter guide-wire systems, the advent of new embolic materials, primarily used in interventional neuroradiology (3,13,14), has also strengthened the capability of embolotherapy to increase the number of cases successfully treated for vascular abnormalities throughout the body (7-11,15,16). Embolotherapy with particles (15,17), liquid embolic materials (17,18), and microcoils (7-11,15,16) can be performed by using microcatheters. Delivery of these agents to the desired location cannot be controlled, however, and carries the risk of inadvertent occlusion of normal vessels and/or occlusion proximal to the area of abnormality with subsequent development of collateral flow to the abnormal circulation and recurrence

of symptoms (7,9). Embolization with microcoils through a Tracker catheter has been reported by several authors (7-11,15,16).

Currently, the Guglielmi detachable coil (GDC) has been used only for embolotherapy within the intracranial circulation (19-21). The main advantage of the GDC is controlled detachment, which allows more precise placement and a more successful, safer procedure. Furthermore, small peripheral vascular lesions can be negotiated easily with the microcatheter guide-wire system. To our knowledge, however, this is the first study to examine the feasibility, safety, and effectiveness of GDCs delivered through a microcatheter system for endovascular treatment of extracranial vascular lesions.

MATERIALS AND METHODS GDC Placement

GDCs are circular, soft platinum coils of different diameters and lengths (Fig 1). The manufacture and physical properties of the GDC are described in detail elsewhere (22).

GDCs are used as follows: A platinum coil with a circular memory is attached to a Teflon-coated stainless steel delivery wire by a short portion of noninsulated stainless steel. After angiography demonstrates the correct position of the im-

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Abbreviations: AVF = arteriovenous fistula, GDC = Guglielmi detachable coil, PDA = patent ductus arteriosus, RAA = renal artery aneurysm.

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² 9* indicates generalized vein and artery involvement.

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planted coil, a positive direct electric current (1.0–1.5 mA, 2.0–3.1 V) is applied to the proximal end of the stainless steel delivery wire. The negative ground pole is connected to a needle positioned in the patient's skin. In 1–10 minutes, the current dissolves the noninsulated stainless steel portion proximal to the platinum coil by means of electrolysis (22).

Patients

During a 2-year period, embolotherapy with GDCs (Target Therapeutics, Fremont, Calif) delivered through a Tracker-18 catheter (Target Therapeutics) was performed in 16 patients with renal artery aneurysm (RAA) or extracranial arteriovenous fistula (AVF). GDCs were used in cases of aneurysm or high-flow AVF when standard coils or other embolic agents carried a risk of inadvertent embolization. All patients gave written informed consent.

RAA cases.—Seven women and one man, aged 34–68 years (mean, 50 years), were treated for RAA. Four patients had hypertension, which was associated with hematuria in one case. Two patients had embolic renal infarct. In two asymptomatic patients, aneurysm was found incidentally. Table 1 summarizes the site and extent of the aneurysm, clinical signs and symptoms, and particulars of GDC embolotherapy in each patient. Successful occlusion was assessed with angiography, and patients were followed up clinically and with color Doppler ultrasonography (US) and/or angiography 3 and 6 months after endovascular treatment.

AVF cases.—Three female and five male patients, aged 1–43 years (mean, 13 years), were referred for embolization of AVF. One patient with AVF between the maxillary artery and jugular vein had attacks of unconsciousness caused by a steal syndrome. Two children with subclavian-pulmonary artery shunts were asymptomatic, although in one case, a vertebral artery steal phenomenon was diagnosed with color Doppler US. Three children with patent ductus arteriosus (PDA) were clinically asymptomatic. A male patient with posttraumatic anterior tibial artery AVF had signs and symptoms of ischemia and venous hypertension. One patient with multiple pulmonary AVFs detected at chest radiography and computed tomography (CT) was clinically asymptomatic, although laboratory findings showed a reduction in oxygen saturation of the blood. Clinical data, signs and symptoms, and particulars of GDC embolotherapy of patients with AVF are provided in Table 2.

Interventional Procedure

RAA cases.—Initially, intraarterial digital subtraction angiography of the abdominal aorta was performed with a marked 7-F pigtail catheter (Cordis, Miami, Fla) to visualize the origin of the renal arteries. Selective intraarterial digital subtraction angiography (anteroposterior and oblique views) of the renal arteries was performed

with a 6-F Simmons I catheter (Cordis) to assess the anatomic relationships among the renal arteries. Computer-assisted measurement of each aneurysm was used to select the appropriate size of GDC (Fig 2a). Subsequently, the diagnostic catheter was exchanged for a 6-F guide catheter (Balt, Paris, France). Superselective catheterization of the aneurysm was accomplished coaxially with a Tracker-18 microcatheter. Road mapping, which was helpful during this part of the procedure, was used in all cases.

Before embolization, the angioarchitecture of the aneurysm was assessed by means of superselective angiography of the aneurysm. One to 14 GDCs of different sizes (3–14 mm in diameter, 8–40 cm in length) were implanted by using the technique previously described for intracranial applications (21). GDC implantation was started with coils of the largest diameter in relation to the size of the aneurysm. Care was taken to place the first coils in a basketlike configuration within the aneurysm in order to occupy the whole cavity (Fig 2b). Further embolization was done with smaller coils, thereby filling up the remaining cavity until control angiograms showed the aneurysm densely packed with GDCs (Fig 2c).

After placement and before electrolytic detachment of each GDC, the correct location of the coil was confirmed by means of angiography through the guide catheter with hand-injection of iodixanol (Visipaque; Nycomed, Oslo, Norway).

AVF cases.—Selective catheterization of the feeding artery was done with a 5- or 6-F diagnostic catheter with headhunter configuration (Cordis). As in the technique used for embolization of RAA, the Tracker-18 microcatheter was used for GDC delivery and placed coaxially by way of a 5- or 6-F guide catheter (Balt) at the site of the fistula. One to five GDCs of different sizes (4–8 mm in diameter, 10–40 cm in length) were placed into the fistula (Fig 3). With the first coil, a stable position had to be achieved before electrolytic detachment was performed. Additional coils were placed within the network of the first coil. The implantation technique and interventional management were similar to those described above for embolization of RAA.

RESULTS

RAA Cases

Superselective catheterization with the Tracker-18 microcatheter and GDCs was possible in all cases. All RAAs (seven at the bifurcation of the main renal artery, one at the main renal artery [Table 1]) were successfully occluded with GDCs. No complications were encountered as a result of attempts at catheterization or GDC embolization. No episodes of inadvertent GDC embolization, coil migration, or vessel perforation occurred.

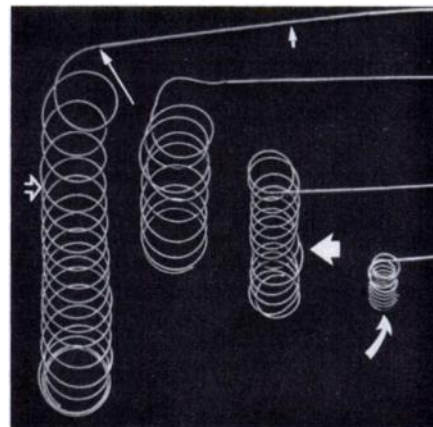


Figure 1. Photograph of Guglielmi detachable platinum coils with 8-mm (open arrow), 5-mm (thick straight solid arrow), and 3-mm (curved arrow) circular memory. Microsolder wire (thin straight solid arrow) and delivery wire (small straight solid arrow) are also shown.

No renal parenchymal infarct was observed. Endovascular occlusion was achieved by means of implantation of multiple GDCs in seven aneurysms (Fig 2). In one patient, however, only one GDC (3 mm in diameter, 8 cm in length) was implanted because of the small (4 mm) size of the aneurysm.

After embolotherapy, blood pressure remained unchanged in three patients and decreased in one patient. In the two patients with recurrent renal infarct, symptoms disappeared after embolization. In one patient with hematuria, control of hematuria was achieved immediately after embolotherapy. Serum creatinine level was normal in all patients before and after treatment. Follow-up examination (blood pressure measurements, urinalysis, and conventional or CT angiography) documented successful endovascular treatment of all RAAs at 3- and 6-month intervals.

AVF Cases

GDC embolotherapy of extracranial AVF succeeded in nine of 11 (82%) cases. One patient with attacks of unconsciousness secondary to a steal syndrome that resulted from a fistula between the maxillary artery and internal jugular vein was cured clinically (Fig 3). Attacks of unconsciousness disappeared after embolotherapy. Endovascular occlusion of PDA was successfully performed in all three children. Echocardiographic control studies 3 and 6 months later documented successful occlusion of the ductus arteriosus. In the patient with multiple pulmonary AVFs, an immediate and significant improvement in blood oxygen saturation

Table 1
RAAs in Eight Patients Treated with GDCs

Patient/ Sex/Age (y)	Location	Size of Aneurysm (mm)	Clinical Signs and Symptoms	No. of GDCs	Size of GDC* (mm/cm)	GDC Cost (\$)
1/F/55	Right, bifurcation	9	Hypertension	3	8/40, 7/30, 6/20	2,100
2/F/34	Right, bifurcation	4	Incidentally found, asymptomatic	1	3/8	700
3/F/37	Left main renal artery	9	Embolicism, pain	8	8/30, 5/20, 5/15, 4/6, 4/10 (3), 3/8	5,600
4/M/52	Right, bifurcation	18	Hypertension, incidentally found	4	14/30 (2), 10/30, 8/40	2,000
5/F/48	Right, bifurcation	16	Incidentally found	10	14/30 (3)	7,000
6/F/49	Left, bifurcation	17	Infarct, hypertension	14	14/30 (2), 12/30, 8/30 (2), 7/30 (4)	9,800
7/F/55	Left, bifurcation	12	Fibromuscular dysplasia, hematuria	4	12/30, 8/40, 5/30, 5/15	2,800
8/F/68	Left, bifurcation	15	Incidentally found	10	10/30, 8/30, 8/40, 5/20 (2), 7/30, 5/15 (2), 5/20, 4/10	7,000

* Diameter/length. Number of coils (if more than one) is in parentheses.

Table 2
AVFs in Eight Patients Treated with GDCs

Patient/ Sex/Age (y)	Location	Signs and Symptoms	No. of GDCs	Size of GDC* (mm/cm)	GDC Cost (\$)
1/M/12	Internal maxillary artery to jugular vein	Attacks of unconsciousness	5	10/30, 8/40, 7/30 (2)	3,500
2/F/8	Subclavian artery to pulmonary artery	Asymptomatic, steal phenomenon at US	2	5/20, 4/10	1,400
3/M/21	Pulmonary artery to vein	Reduction of blood oxygen saturation	12	8/30 (3), 5/20, 3/12 (2), 7/30 (3), 5/15 (4)	8,400
4/M/1	Subclavian artery to pulmonary artery	Asymptomatic	0 [†]	NA	NA
5/M/9	PDA	Asymptomatic	1	3/8	700
6/F/4	PDA	Asymptomatic	3	5/15 (2), 3/12	2,100
7/F/4	PDA	Asymptomatic	3	3/12 (2), 3/8	2,100
8/M/43	Anterior tibial artery	Ischemia; venous hypertension	0 [†]	NA	NA

Note.—NA = not applicable.

* Diameter/length. Number of coils (if more than one) is in parentheses.

[†] GDC placement impossible owing to unstable coil position within the fistula.

tion occurred after GDC occlusion (Fig 4).

In two AVFs, one between the subclavian and pulmonary arteries and one between the anterior tibial artery and vein (Fig 5), embolotherapy failed. In both cases, an instable coil position within the fistula made insertion of the coil impossible. Despite the use of different coil sizes, GDC placement was discontinued after several attempts, and the undetached coils were retrieved.

In all treated patients, no technical complications such as misembolization occurred.

DISCUSSION

RAA is a rare vascular abnormality that makes up 1% of all aneurysms and 15%–22% of visceral aneurysms (23,24). Because RAA poses risks, such as renovascular hypertension, renal artery thrombosis, renal infarct, and rupture, treatment is mandatory (24–29).

Because transcatheter embolization is less invasive than surgery, it has gained increased acceptance over the last 20 years (4–6,30). Endovascular

embolization of RAA by means of detachable balloons, steel coils, and particulate agents has been reported in a number of studies (26,30–33). However, a substantial disadvantage of all these embolic materials is that they can occlude the aneurysm and efferent and afferent arteries, which would result in tissue loss and higher complication rates (9–11,26,30,32, 34,35).

With the development of microcatheter guide-wire systems primarily designed for neuroradiologic interventions, complete occlusion of the aneurysm with preservation of the parent vessels has become possible (7,26). Catheterization of aneurysms can be achieved without risk of rupture or mechanical injury to the vessel wall, which may cause spasm.

Microcoils delivered through a microcatheter are superior embolic agents for selective occlusion of aneurysms because particulate agents or liquid embolic materials would be washed out of the aneurysm, resulting in peripheral embolism. Other authors (7,10,11,15,16) have shown that conventional minicoils can be safely used to treat small renal

pseudoaneurysm that occludes the afferent arteries. In true RAA, however, the use of conventional nondetachable microcoils has a number of disadvantages and risks. Uncontrolled delivery of the coils can result in renal infarct due to possible misembolization or coil migration into normal renal artery branches. The risk of coil migration is further related to the ratio of the size of the aneurysm to that of the aneurysmal neck; the risk increases proportionally as the size of the neck increases. Even in an aneurysm with a small neck, misembolization can occur when only a small part of the aneurysm remains.

Endovascular treatment of saccular cerebral aneurysm with electrolytically detachable platinum microcoils was first reported by Guglielmi et al (22,36) in 1991. A series of studies has since evaluated the use of the GDC in patients with cerebral aneurysm (19–21).

GDC embolotherapy is characterized by controlled delivery, which allows coil detachment immediately after angiographic documentation of the coil position. In case of an inadvertent coil position (eg, into the par-

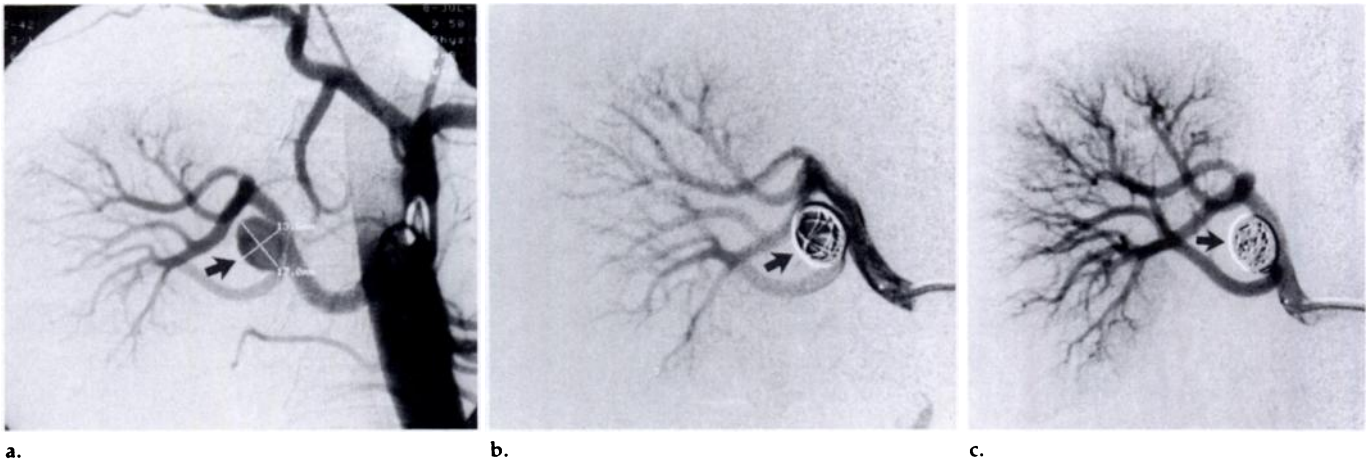


Figure 2. Aortograms show GDC embolization of RAA. (a) RAA is measured (arrow) with computer assistance. (b) First GDC is in place with a basketlike configuration (arrow). (c) Aneurysm is densely packed and occluded (arrow).

ent vessel), the coil can be withdrawn and reinserted. This capability and the high flexibility and softness of the GDC enable one to fully pack the aneurysm, to fill any irregular outpouching, and to isolate the aneurysm from the circulation without risk of rupture or misembolization. Furthermore, electrothrombosis occurs adjacent to the coil during electrolytic coil detachment and accelerates the thrombotic occlusion of the aneurysm (22).

Owing to the inherent advantages of the GDC over standard coils, treatment of cerebral aneurysm is now performed with GDCs. We believe that despite the lower cost of standard coils used in treatment of aneurysm, the application of GDCs is justified because of substantially lower predictable risks.

Embolotherapy is the treatment of choice for AVF; however, in large single-hole, high-flow situations, occlusion of the fistula carries a high risk of misembolization. Safe and efficient occlusion of AVF can be achieved only by performing therapeutic blockage at the site of the fistula. Proximal endovascular occlusion of the feeding vessel only, however, results in a high recurrence rate due to development of collateral vessels while normal tissue arteries are compromised.

Detachable balloons, which allow controlled detachment, have been used in such lesions as AVF but pose certain limitations (37). First, in high-flow conditions, balloons can be lost during the placement maneuver or because of spontaneous deflation of the balloon. Second, the balloon technique requires relatively large guide catheters, which limit the approach by way of small and/or tortuous vessels (37).

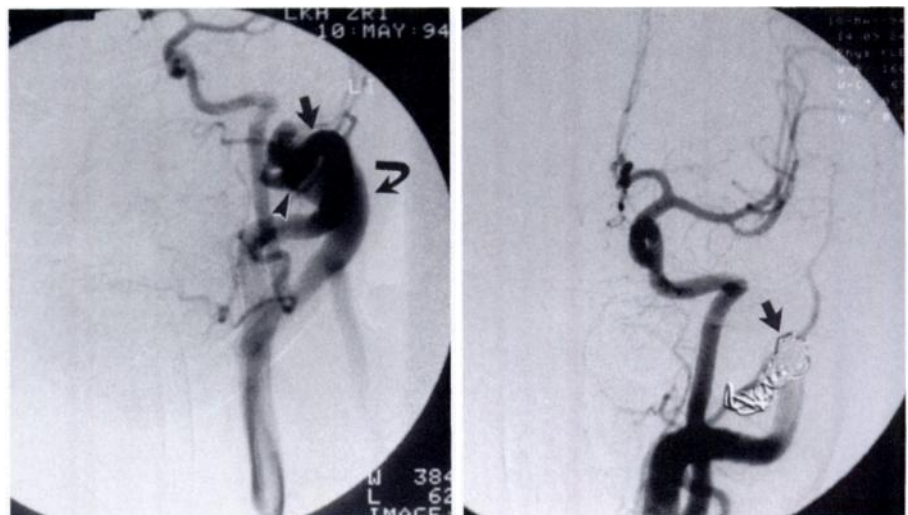


Figure 3. Arteriograms show the common carotid artery before and after embolization of AVF. (a) AVF (arrowhead) is between the internal maxillary artery (straight arrow) and jugular vein (curved arrow). (b) Fistula is completely occluded with GDC (arrow).

When nondetachable Gianturco coils or minicoils are used, selection of the appropriate size can often be difficult (38). The application of oversized coils may cause inadvertent occlusion of proximal large vessels, whereas the use of undersized coils bears a high risk of coil migration. Those problems might be solved with the GDC. Because GDC behavior before detachment is predictable, one can prevent migration in a high-flow fistula by withdrawing and repositioning the coil. The retrievability of the coil allows the choice of appropriate coil size without the risk of inadvertent migration.

To our knowledge, there are no reports of the use of GDCs through a Tracker catheter in extracranial AVF. The application of GDCs in patients with extracranial AVF, however, combines the advantages of detachable

balloons and conventional coils but without the disadvantages of those materials. Like detachable balloons, GDCs can be delivered under angiographic control.

The key to successful embolotherapy is to place the first coil in a stable position within the fistula. If this is possible, complete occlusion of the fistula can be achieved by placement of all further coils into the network of the first coil. If the coil is placed in an unstable or incorrect position, it can be repositioned. Once implanted, the GDC occludes safely and permanently, even in cases of single-hole, high-flow fistulas, as was shown in our patient with the congenital fistula between the maxillary artery and jugular vein (Fig 3).

PDA is usually occluded with a Rashkind umbrella as an alternative to surgical treatment (39). However,

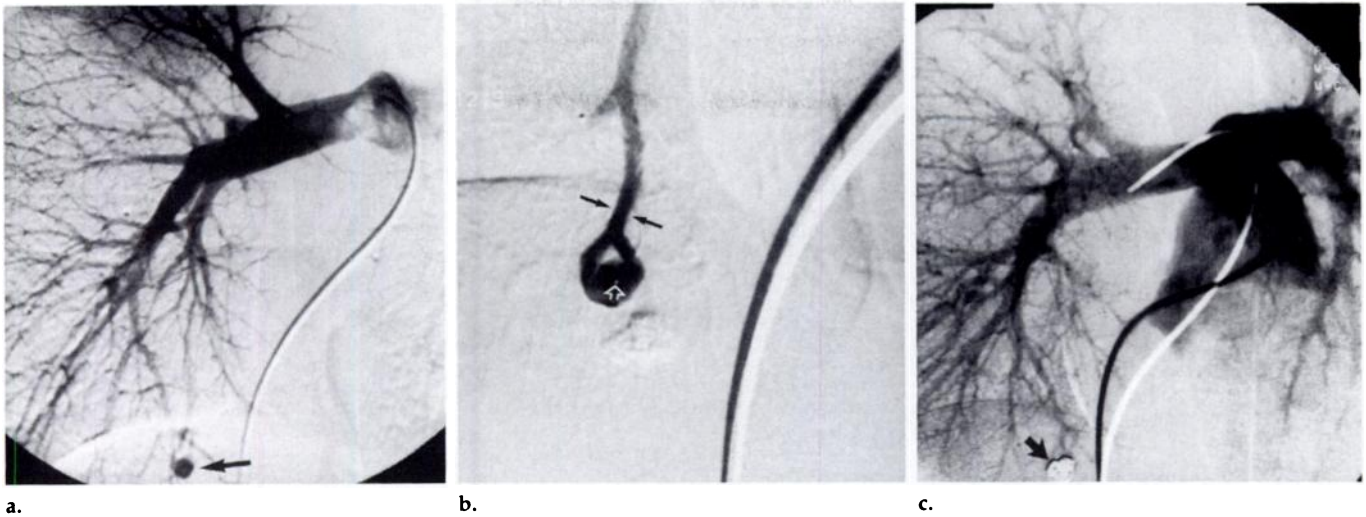


Figure 4. Pulmonary arteriograms show GDC embolization of AVF. (a) Small AVF is located in the right lower lobe (arrow). (b) Superselective angiogram shows the fistula with the Tracker catheter (open arrow) and opacification of the draining vein (solid arrows). (c) Complete occlusion of the AVF (arrow) is shown along with preservation of all normal arteries.

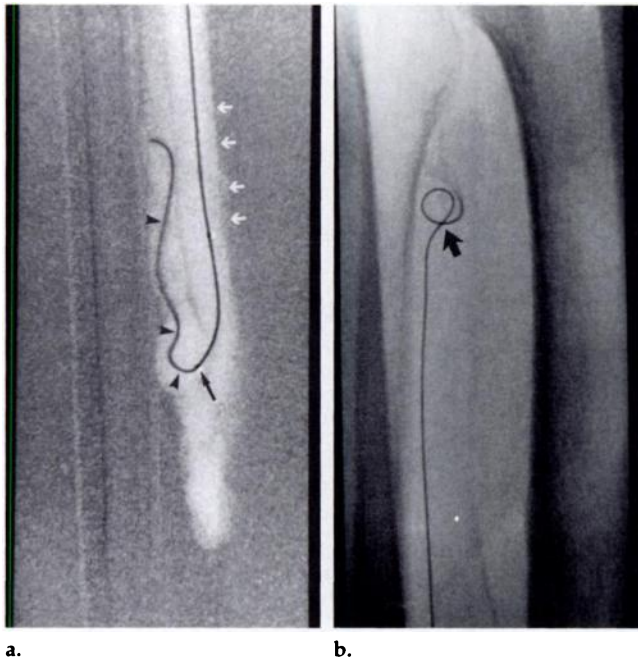


Figure 5. Intraarterial digital subtraction angiogram and digital image show an attempt at embolization of a posttraumatic fistula between the anterior tibial artery and vein. (a) Intraarterial road mapping shows the microcatheter in the anterior tibial artery (white arrows) with its tip (black arrow) in the vein. The GDC (arrowheads) is partially delivered. (b) Coil migration (arrow) into the proximal anterior tibial vein is shown.

the implantation of an umbrella can be hampered in small PDA (40). To our knowledge, there are only a few reports of coil occlusion of small PDA, and misembolization is a complication (41). To eliminate the risk of coil migration, PDA occlusion was performed with the GDC. In all three patients with small PDA, we successfully used GDCs delivered through a Tracker-18 microcatheter when the Rashkind method was not possible.

PDA with associated aneurysm could be occluded successfully by means of implantation of one GDC into the aneurysm. Endovascular treatment of pulmonary AVF has traditionally been performed with detachable balloons and/or Gianturco coils (37,42–44). More recently, to our knowledge, only one case of the use of a mechanically detachable microcoil has been reported (45). Three of our four pul-

monary AVFs were small and located peripherally, and the balloon technique could not be used owing to small feeding arteries. Negotiation of these distal fistulas could be achieved only with a microcatheter system. GDCs were placed directly into the fistula, and the procedure resulted in successful occlusion of all fistulas and preservation of the proximal artery branches.

In two cases, however, GDC embolotherapy of AVF failed. In the first patient, the subclavian-pulmonary artery graft shunt had a large inner diameter with a straight configuration and a smooth inner layer, which made stable placement of the first coil impossible. In the second patient, who had a posttraumatic fistula between the anterior tibial artery and vein, angiography revealed only a wide defect of the wall in both the artery and vein without any evidence of a connecting channel. Several attempts were made to place the coil into the venous part of the fistula, but again a stable position for the first coil could not be achieved. Thus, the coil was retrieved in both cases.

In conclusion, to our knowledge, this is the first study to report the use of the GDC in RAA and extracranial AVF. GDC embolism through a Tracker-18 catheter was technically successful in reaching all, often tortuous, distal vessels for delivery of the coils. The embolization procedure was clinically successful in all (100%) cases of RAA, and in nine of 11 (82%) cases of AVF. No complications were encountered. Therefore, the results of the current study indicate that the GDC can be used safely and successfully for endovascular treatment of

extracranial aneurysm and AVF. GDC embolotherapy, of proved value in the treatment of cerebral artery aneurysm, seems to be an excellent and less invasive alternative to surgery in patients with RAA. GDCs may prove easier to use and to deploy precisely than are other coils and, therefore, GDCs appear also to be a valuable and safer addition to the array of available embolic agents for extracranial AVF. ■

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