

Endovascular treatment of posterior circulation aneurysms by electrothrombosis using electrically detachable coils

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✓ In a multicenter study, 120 patients with intracranial aneurysms presenting a high surgical risk were treated using electrolytically detachable coils and electrothrombosis via an endovascular approach. The results of treatment in patients with posterior fossa aneurysms (42 patients with 43 aneurysms) are presented. The most frequent clinical presentation was subarachnoid hemorrhage (24 cases). The clinical follow-up periods ranged from 1 week to 18 months. Complete aneurysm occlusion was obtained in 13 of 16 aneurysms with a small neck and in four of 26 wide-necked aneurysms. A 70% to 98% thrombosis of the aneurysm was achieved in 22 of 26 aneurysms with a wide neck and in three of 16 small-necked aneurysms. One aneurysm could not be treated due to a technical complication. Two cases required postprocedural surgical clipping of a residual aneurysm.

One patient (originally in Hunt and Hess Grade V) experienced procedural rupture of the aneurysm requiring an emergency parent artery occlusion. He eventually died 5 days later. Another patient (originally in Grade IV) had coil migration and posterior cerebral artery territory ischemia. A third patient developed a permanent neurological deficit (hemianopsia) after complete occlusion of a wide-necked basilar bifurcation aneurysm. One patient, harboring an inoperable giant basilar bifurcation aneurysm, died from aneurysm bleeding 18 months after partial occlusion.

Overall morbidity and mortality rates related to treatment were 4.8% (two cases) and 2.4% (one case), respectively (2.6% and 0% if considering only patients in Hunt and Hess Grades I, II, and III).

It is suggested that this technique is a viable alternative in the management of patients with posterior fossa aneurysms associated with high surgical risk. Longer angiographic and clinical follow-up study is necessary to determine the long-term efficacy of this recently developed endovascular occlusion technique. Close postoperative angiographic and clinical monitoring of patients with wide-necked subtotally occluded aneurysms is mandatory to check for potential aneurysmal recanalization, regrowth, and rupture.

KEY WORDS • aneurysm • multicenter study • posterior circulation • endovascular therapy • electrothrombosis • electrolysis • detachable coil

ANEURYSMS of the posterior circulation account for 5% to 10% of all intracranial aneurysms.⁷ Because of the difficulties in surgical intervention in the posterior fossa, the outcome in these cases is poorer than for aneurysms of the anterior circula-

tion.^{5,11} In an effort to widen the alternatives for therapeutic management of intracranial aneurysms, an endovascular approach utilizing detachable platinum coils and electrothrombosis has been developed.^{1,2} To date, 120 patients have been treated with this technique in a

TABLE 1

Profile of 38 patients with posterior circulation aneurysms presenting in good neurological condition*

Case No.	Age (yrs), Sex	Clinical Presentation	Aneurysm Location	Aneurysm Size†		Indication for Treatment	Coil Length (cm)	Result (% Occlusion)	Complications Related to Technique	Time to Postop Angiogram	Result (% Occlusion)	Time to Follow-Up Angiogram	Result (% Occlusion)	Outcome
				Diameter	Neck									
1	33, F	SAH	PICA	small	small	MI	16	80	none	6 days	80	2.5 mos	80	good
2	60, F	mass	bas bif	giant	wide	inoperable	255	70	none	1 & 5 wks	70	8 mos	70	dead§
3	58, M	SAH	VB jct	large	wide	MI	180	95	none	1 wk	95	—	—	good
4	46, M	SAH	bas bif	large	wide	prev explored	120	70	none	3 wks	80	—	—	good
5	56, F	SAH	bas bif	small	wide	partially clipped	38	70	none	1 & 3 wks 6½ mos 1 yr	70 95 95	2 mos — —	70 — —	good good‡ good‡
6	69, F	SAH	bas bif	small	wide	prev explored	15	95	none	1 wk	95	7 mos	70	good
7	57, F	SAH	bas bif	small	small	prev explored	55	100	none	4 days/1 mo	100	14 mos	100	good
8	44, F	mass	bas bif	giant	wide	high risk	155	85	none	1 wk	—	—	95‡	good
9	70, F	SAH	SCA	small	wide	prev explored	115	90	none	5 mos	80	7 mos	95‡	good
10	56, M	SAH	bas bif	small	wide	med condit	120	80	thrombus progressing to PCA occlusion	6 hrs	100	—	—	hemi-anopsia
11	29, F	incid find	bas bif	small	small	high risk	23	100	none	1 & 3 wks	100	4 mos	100	good
12	34, M	mass	bas bif-P ₁ (PT)	giant	wide	inoperable	200	95	none	4 days	90	3 mos	85	good
13	42, F	SAH	VB jct	small	small	partially clipped	14	100	none	3 mos	100	—	—	good
		incid find	VB jct	small	small	prev explored	4	100	none	—	—	—	—	good
14	70, M	mass	bas bif (MT)	giant	wide	inoperable	53	98	none	3 wks	95	6 mos	95	good
15	56, F	mass	bas bif	large	wide	prev explored	255	98	none	1½ mos	95	7 mos	100‡	good
16	38, M	mass	VB jct	giant	wide	inoperable	400	50	none	3 & 8 days	85	4 mos	95	good
17	56, F	incid find	bas bif	large	small	endo-carditis	195	100	none	—	—	—	—	dead
18	52, F	SAH	AICA	small	small	high risk	41	98	none	7 days	98	—	—	good
19	62, M	mass	VB jct	large	wide	inoperable	60	80	none	1 mo	85	4 mos	98‡	good
20	47, F	mass	bas bif	large	wide	high risk	275	90	none	3 days	95	—	—	good
21	48, M	incid find	PICA	small	small	heart disease	18	100	none	6 days	100	—	—	good
22	43, F	mass	bas bif-P ₁	large	wide	high risk	150	90	none	4 days	95	—	—	good
23	55, F	mass	bas bif	large	small	prev explored	70	95	none	—	—	—	—	good
24	45, F	mass	bas bif-P ₁ (PT)	giant	wide	prev explored	335	80	none	—	—	—	—	good
25	50, M	incid find	SCA	small	small	high risk	60	100	none	—	—	—	—	good

* Patients in Hunt and Hess⁴ Grade I, II, or III. SAH = subarachnoid hemorrhage; PICA = posterior inferior cerebellar artery; MI = myocardial infarction; mass = mass effect; bas bif = basilar bifurcation; VB jct = vertebrobasilar junction; prev explored = previously explored; SCA = superior cerebellar artery; med condit = medical condition; PCA = posterior cerebral artery; incid find = incidental finding; P₁, P₂, P₃ = first, second, and third segments of PCA; AICA = anterior inferior cerebellar artery; PT = partially thrombosed; MT = mostly thrombosed. — = procedure not performed.

† Aneurysm size (diameter): small = < 12 mm; large = 12–25 mm; giant = > 25 mm. Aneurysm neck size: small = < 4 mm; wide = > 4 mm.

‡ Additional embolization procedure for more coils.

§ Died because of bleeding from aneurysm 18 months after treatment.

|| Died 1 month after treatment because of marantic endocarditis.

TABLE 1 (continued) →

Endovascular thrombosis of aneurysms

TABLE 1 (continued)*

Case No.	Age, (yrs), Sex	Clinical Presentation	Aneurysm Location	Aneurysm Size†		Indication for Treatment	Coil Length (cm)	Result (% Occlusion)	Complications Related to Technique	Time to Postop Angiogram	Result (% Occlusion)	Time to Follow-Up Angiogram	Result (% Occlusion)	Outcome
				Diameter	Neck									
26	53, F	SAH	bas bif	large	wide	prev explored	100	95	none	—	—	—	—	good
27	46, F	SAH	bas bif-P ₁	small	wide	high risk	28	95	none	—	—	—	—	good
28	74, F	SAH	bas bif (MT)	giant	wide	inoperable	90	90	none	—	—	—	—	good
29	51, F	SAH	bas bif (MT)	large	wide	prev explored	8	85	none	2 days	85	—	—	good
30	48, F	incidental find	bas bif	small	wide	high risk	10	90	none	7 days	100‡	—	—	good
31	51, F	mass	bas bif	giant	wide	high risk	245	95	none	—	—	—	—	good
32	52, M	SAH	bas bif	giant	wide	high risk	270	95	none	3 mos	90	—	—	good
33	57, M	SAH	bas bif	giant	wide	inoperable	230	90	none	1 mo	90	3 mos	90	good
34	45, F	SAH	P ₂ -P ₃	small	small	inoperable	23	100	none	2 mos	100	—	—	good
35	40, F	SAH	bas bif	large	wide	inoperable	85	100	none	—	—	—	—	good
36	65, F	mass	bas bif	large	wide	high risk	170	95	none	1½ mos	98	—	—	good
37	13, F	SAH	PICA (MT)	large	small	prev explored	35	100	none	1 mo	100	—	—	good
38	40, F	SAH	SCA	small	small	high risk	8	100	none	—	—	—	—	good

* Patients in Hunt and Hess⁴ Grade I, II, or III. SAH = subarachnoid hemorrhage; PICA = posterior inferior cerebellar artery; MI = myocardial infarction; mass = mass effect; bas bif = basilar bifurcation; VB jct = vertebrobasilar junction; prev explored = previously explored; SCA = superior cerebellar artery; med condit = medical condition; PCA = posterior cerebral artery; incidental find = incidental finding; P₁, P₂, P₃ = first, second, and third segments of PCA; AICA = anterior inferior cerebellar artery; PT = partially thrombosed; MT = mostly thrombosed. — = procedure not performed.

† Aneurysm size (diameter): small = < 12 mm; large = 12–25 mm; giant = > 25 mm. Aneurysm neck size: small = < 4 mm; wide = > 4 mm.

‡ Additional embolization procedure for more coils.

multicenter study. The results of treatment in a subset of 42 patients with 43 difficult posterior circulation aneurysms are presented.

Clinical Material and Methods

Case Material

This paper presents the operative results in a subgroup of patients enrolled in an ongoing multicenter clinical study for treatment of intracranial aneurysms using the Guglielmi detachable coil (GDC).^{*} Presently, the study is regulated by a protocol approved by the United States Food and Drug Administration, and the device is available only to those institutions approved to participate in the study to determine the safety and efficacy of the method.

Of the total 120 cases treated, 42 patients with 43 aneurysms involving the posterior circulation were operated on between April, 1990, and December, 1991, via an endovascular approach using the GDC (Tables 1 and 2). The technique, protocol, and preliminary clinical experience have been described elsewhere.¹ In

this series there were 30 females and 12 males, ranging in age from 13 to 74 years (mean 51 years).

Selection of patients for this treatment was based on six criteria: 1) failure of surgical exploration; 2) poor surgical candidates secondary to hemorrhage (Hunt and Hess⁴ Grade IV or V); 3) poor surgical candidates secondary to medical conditions; 4) inoperability secondary to anatomical considerations; 5) aneurysms considered to be difficult and to have too high a risk for surgery; and 6) regrowth of the aneurysm after surgery.

A total of 24 patients (57%) presented with intracranial hemorrhage, and 13 (31%) had symptoms secondary to mass effect. Five aneurysms were found incidentally. Of 24 patients presenting with hemorrhage, 17 were classified as in Hunt and Hess neurological Grade I or II, and three were in Grade III (Table 1). The remaining four were treated while in Grade IV or V (Table 2). Early treatment (up to 3 days post-hemorrhage) was performed in three cases, and 10 cases received treatment between 3 and 15 days after the hemorrhagic event.

The origin of the aneurysms was as follows: the basilar artery bifurcation in 23, the vertebrobasilar junction in six, the posterior inferior cerebellar artery (PICA)

* Guglielmi detachable coil manufactured by Target Therapeutics, San Jose, California.

TABLE 2

Profile of four patients with posterior circulation aneurysms presenting in poor neurological condition*

Case No.	Age (yrs). Sex	Clinical Presentation	Aneurysm Location	Aneurysm Size†		Indication for Treatment	Coil Length (cm)	Result (% Occlusion)	Complications Related to Technique	Time to Postop Angiogram	Result (% Occlusion)	Time to Follow-Up Angiogram	Result (% Occlusion)	Outcome
				Diameter	Neck									
39	67, F	SAH (Grade V)	PICA	small	small	grading	8	100	aneurysm rupture, parent vessel occlusion‡	—	—	—	—	dead
40	45, F	intrav hem (Grade IV)	bas bif	small	small	grading	93	100	none	—	—	—	—	dead
41	67, M	SAH (Grade IV)	VB jct	small	wide	grading	8	0	coil migration into lt P ₂	—	—	—	—	unchanged
42	48, F	SAH (Grade V)	PICA	small	small	grading	8	100	none	2 days	100	—	—	unchanged

* Patients in Hunt and Hess⁴ Grade IV or V. SAH = subarachnoid hemorrhage; PICA = posterior inferior cerebellar artery; intrav hem = intraventricular hemorrhage; bas bif = basilar bifurcation; VB jct = vertebrobasilar junction. P₂ = second segment of posterior cerebral artery. — = procedure not performed.

† Aneurysm size (diameter): small = < 12 mm; large 12–25 mm; giant = > 25 mm. Aneurysm neck size: small < 4 mm; wide = > 4 mm.

‡ Aneurysm rupture on detachment of first coil; parent vessel occlusion with straight platinum coils.

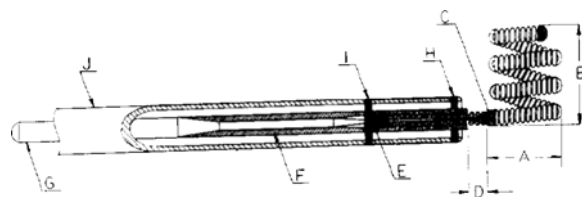


FIG. 1. Diagram of the Guglielmi detachable coil (GDC) and of the modified version of the Tracker microcatheter. A = diameter of the circular memory; B = the distal portion, a platinum coil (0.010 or 0.015 in. in diameter and 4 to 40 cm in length if straightened); C = microsolder connecting the platinum coil to the stainless steel delivery wire; D = detachable area; E = proximal (platinum) marker on the GDC; F = Teflon lamination; G = GDC shaft (diameter 0.010 in.); H = catheter tip marker; I = catheter proximal marker; J = catheter shaft.

in five, the P₁ segment of the posterior cerebral artery (PCA) in four, the superior cerebellar artery (SCA) in three, the anterior inferior cerebellar artery in one, and the junction of the P₂ and P₃ segments of the PCA in one. Twenty aneurysms were small (< 12 mm), 13 were large (12 to 25 mm), and 10 were giant (> 25 mm).

Operative Technique

Most procedures were performed with the patient under neuroleptic analgesia. General anesthesia was used in noncooperative patients or where catheterization of difficult small aneurysms required high-quality (motionless) "road mapping" and subtraction fluoroscopy.

A detailed description of the mechanical structure of the electrolytically detachable coils has already been published;² however, modifications have occurred since

that description. A 0.5-cm long radiopaque marker (made of platinum) has been added to the GDC (Fig. 1). It is positioned in the stainless steel delivery portion of the coil, 3 cm proximal to the platinum-stainless steel junction. Another radiopaque platinum marker, 3 cm proximal to the tip, has been added to a special version of the Tracker microcatheter† (Fig. 1). These markers, on both the coil and the microcatheter, have been added with the purpose of increasing the safety of the embolization procedure. After detachment of the first coil, it may be difficult to visualize the platinum-stainless steel junction of the second and subsequent coils within the coil mesh. The proximal radiopaque markers (outside the aneurysm) allow precise placement of the junction within the aneurysm even if the actual junction cannot be visualized. It is imperative that the junction emerges from the microcatheter for no more than 2 to 3 mm. Because of its relative stiffness, the stainless steel portion (Fig. 1, arrows C–E) could potentially perforate the aneurysm if it is advanced too far. Alignment of the proximal radiopaque markers on the microcatheter and the GDC (in the parent artery) assures that the junction is no more than 2 to 3 mm beyond the microcatheter.

A larger-diameter (0.015-in.) version of GDC has also been developed. These coils are used with the special Tracker-18 microcatheter primarily for unruptured large and giant aneurysms. For ruptured aneurysms and for small unruptured aneurysms the combination of the special Tracker-10 microcatheter and the smaller-diameter (0.010-in.) coils are preferred. The

† Modified version of Tracker-10 and Tracker-18 microcatheters manufactured by Target Therapeutics, San Jose, California.

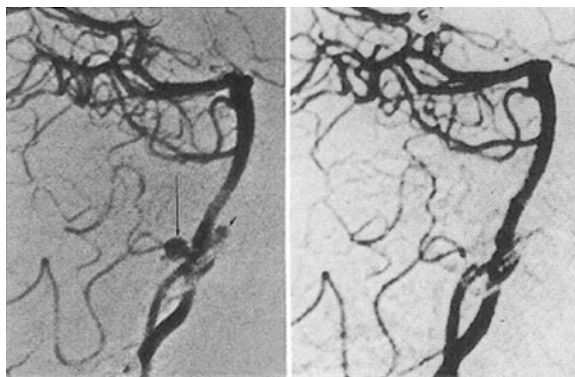


FIG. 2. Case 13. *Left:* Vertebral angiogram, lateral view, demonstrating a small vertebralbasilar junction aneurysm (*long arrow*). The residual portion of another (partially clipped) vertebralbasilar junction aneurysm is also visible (*short arrow*). *Right:* Arteriogram obtained 3 months after occlusion of the first aneurysm with two Guglielmi detachable coils (GDC's) (14 cm total length), and immediately after occlusion of the second (residual) aneurysm with one 4-cm long GDC. Both aneurysms are completely occluded while the normal arteries have been preserved.

0.015-in. coils are heavier and less malleable than the 0.010-in. coils. Since the 50% increase in coil diameter results in a 100% increase in volume, they are particularly useful for filling large and giant aneurysms in less time.

With the development of the 0.015-in. coils, there are now 10 types of GDC (the first number is the diameter of the circular memory in mm, the second is the length of the coil in cm when straightened): 2 × 4, 3 × 8, 4 × 10, 5 × 15, 6 × 20, 8 × 20, and 8 × 40, all 0.010 in. in diameter; and 5 × 15, 8 × 20, and 8 × 40, all 0.015 in. in diameter.

Illustrative Cases

Case 13: Small Vertebralbasilar Junction Aneurysms With SAH

This 42-year-old woman presented with a subarachnoid hemorrhage (SAH) from a vertebralbasilar junction aneurysm that was subsequently surgically clipped. The follow-up angiogram showed a residual portion of the clipped aneurysm and the presence of another small aneurysm of the vertebralbasilar junction (Fig. 2 *left*). This last aneurysm was initially treated endovascularly. Two GDC's with a total length of 14 cm were used to occlude this aneurysm completely. Three months later, the residual portion of the clipped aneurysm was occluded with one GDC of 2-mm circular memory and 4 cm long. The postembolization angiogram served also as a follow-up angiogram for the first treated aneurysm (Fig. 2 *right*). Both procedures, performed using a modified version of the Tracker-10 microcatheter, were very well tolerated by the patient.

Case 16: Giant Vertebralbasilar Junction Aneurysm With Mass Effect

This 38-year-old man presented with left-sided hearing loss, left-sided fifth nerve deficit, and gait ataxia. A cerebral angiogram demonstrated a giant vertebralbasilar junction aneurysm (Fig. 3A and B). This aneurysm was considered inoperable due to its size and location. Via a transfemoral approach, a modified version of a Tracker-18 microcatheter was positioned into the sac of the aneurysm. Ten GDC's, 0.015 in. in diameter, 8 mm in circular memory, and 40 cm long, were delivered and electrolytically detached within the sac of the aneurysm. Approximately 50% of the aneurysm was filled with coils. An angiogram performed 3 days postoperatively demonstrated that progressive thrombosis had occurred with occlusion of 85% to 90% of the aneurysm (Fig. 3C). Another follow-up angiogram performed at

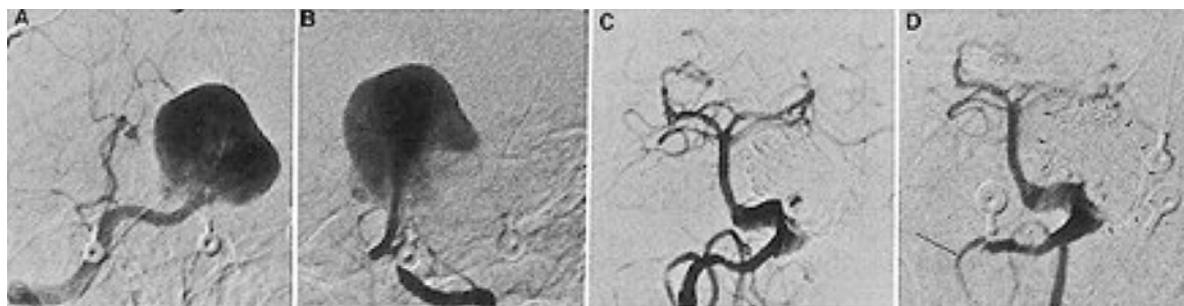


FIG. 3. Case 16. *A:* Right vertebral angiogram, anteroposterior view, demonstrating a giant vertebralbasilar junction aneurysm. *B:* Left vertebral angiogram demonstrating the giant aneurysm. *C:* Right vertebral angiogram performed 3 days after deposition of 10 Guglielmi detachable coils (0.015 in. in diameter, total length 4 m). Most of the aneurysm has undergone thrombosis. The distal vascular tree is now visible. *D:* Left vertebral angiogram obtained 8 days after coil deposition and immediately after balloon occlusion of the right vertebral artery. The right posterior inferior cerebellar artery (*long arrow*) is filling from the left. The (subtracted) meshwork of coils is barely visible (*short arrows*). Permanent occlusion of the right vertebral artery was performed to lessen the jet effect of the arterial flow in the residual aneurysm.

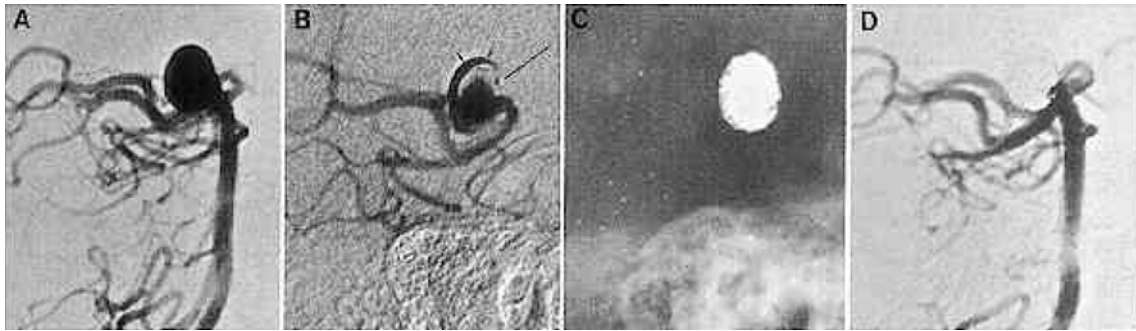


FIG. 4. Case 17. A: Vertebral angiogram, lateral view, demonstrating a large basilar bifurcation aneurysm. B: Intra-aneurysmal angiogram obtained while performing catheterization of the aneurysm with a modified version of a Tracker-18 microcatheter. Angiography was performed to determine proper positioning of the microcatheter tip (*long arrow*) and in an attempt to determine the size of the neck by comparing the position of the microcatheter (inflow zone at the neck) with the outflow. Note the contrast material depicting the flow pattern within the aneurysm (*two short arrows*). C: Plain skull x-ray film showing the network of coils placed within the aneurysm (total coil length 1.95 m). Coils both 0.010 in. and 0.015 in. in diameter were used in this case. D: Immediate postembolization vertebral angiogram showing the aneurysm completely occluded and the parent vessel preserved.

8 days confirmed this result. In the same session, permanent balloon occlusion of the right vertebral artery below the PICA origin was performed to diminish the arterial flow (jet effect) inside the residual aneurysm (Fig. 3D). A 4-month follow-up angiogram showed further reduction of the aneurysm. By that time, the fifth and eighth cranial nerve deficits had improved and the gait ataxia had almost completely resolved.

Case 17: Large Basilar Bifurcation Aneurysm Found Incidentally

This 56-year-old woman suffered multiple acute cerebral, pulmonary, renal, splenic, and lower-extremity emboli from acute endocarditis. A brain computerized tomography (CT) scan performed to assess the effects of cerebral embolism, also showed a basilar artery aneurysm. A cerebral angiogram confirmed the presence of a large basilar bifurcation aneurysm (Fig. 4A). Due to the medical condition of the patient, endovascular treatment was performed while she was under local anesthesia. After introduction of a transfemoral Tracker-18 microcatheter (modified version) into the aneurysmal sac, an intra-aneurysmal angiogram was performed to determine the proper placement of the microcatheter tip as well as the size of the aneurysm neck (Fig. 4B). Two GDC's (0.015 in. in diameter) with a total length of 80 cm, and six GDC's (0.010 in. in diameter) with a total length of 115 cm were deposited and electrolytically detached in the aneurysm (Fig. 4C). The immediate postthrombolysis angiogram showed complete aneurysm occlusion, patency of the basilar artery, and normal filling of the distal vascular tree (Fig. 4D). The procedure lasted 3 hours and was well tolerated by the patient. This patient, unfortunately, died 1 month later because of the devastating effects of marantic endocarditis.

Case 19: Wide-Necked Large Vertebrobasilar Junction Aneurysm With Mass Effect

This 62-year-old man presented with a 3-month history of headache and double vision. Neurological examination revealed the presence of a left abducens cranial nerve deficit. Cerebral angiography demonstrated a large vertebrobasilar artery junction aneurysm (Fig. 5 *left*), which was considered inoperable. A transvascular occlusion of the aneurysm was performed by delivering two GDC's (for a total length of 60 cm) through a transfemoral microcatheter into the sac. At the end of this procedure residual filling of the aneurysm base and portions of the dome was present. A 1-month control angiogram showed progression of intra-aneurysmal thrombosis. At 4 months a second occlusion procedure was performed, with deposition of two GDC's (each 15 cm in length). The postocclusion angiogram showed that, in spite of loose packing, most

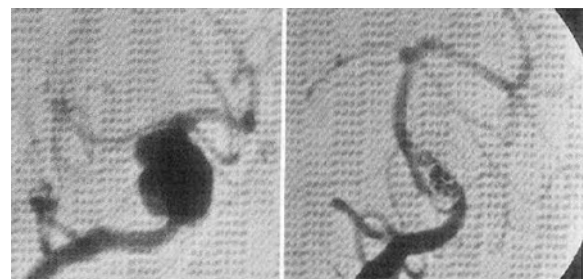


FIG. 5. Case 19. *Left*: Vertebral angiogram, anteroposterior view, showing a large inoperable vertebrobasilar junction aneurysm, irregular in shape. *Right*: Angiogram made after two embolization procedures using four coils with an overall length of 90 cm. In spite of loose packing, most of the aneurysm is occluded. The posttreatment clinical course was uneventful. (Procedure performed at the University of Wisconsin, Madison, Wisconsin.)

Endovascular thrombosis of aneurysms

of the aneurysm had been thrombosed, with preservation of the parent vessel (Fig. 5 *right*). Clinically, the headache in this patient had resolved and the sixth nerve deficit improved significantly.

Case 21: Small PICA Aneurysm With Small Neck

This 48-year-old man suffered an SAH from a posterior communicating artery (PCoA) aneurysm. A small aneurysm of the PICA was also present (Fig. 6 *left*). The PCoA aneurysm was successfully clipped surgically, but cardiac disease prevented surgical treatment of the PICA aneurysm; therefore, endovascular endosaccular treatment was performed. After catheterization of the aneurysm with a modified Tracker-10 microcatheter, two GDC's with a total length of 18 cm were used to occlude this aneurysm completely. The parent vessel had been preserved (Fig. 6 *right*).

Results

Tables 1 and 2 summarize the clinical presentation, anatomical location, therapeutic results, and complications in this series of 42 patients with 43 posterior circulation aneurysms. Endosaccular aneurysm occlusion ranging from 70% to 100% was achieved in 42 aneurysms. One patient could not be treated due to a technical complication (Case 41). A complete aneurysm occlusion was achieved in 13 of 16 aneurysms with a small neck and in four of 26 wide-necked aneurysms. Considerable thrombosis of the aneurysm (70% to 98%) was achieved in 22 aneurysms with a wide neck and in three small-necked aneurysms. Incomplete aneurysm occlusion resulted from partial coil filling of the aneurysm. In wide-necked aneurysms, complete coil filling was difficult because of the danger of occluding the parent vessel and of distal coil migration. The portions of the aneurysm filled with coils underwent thrombosis in 100% of cases.

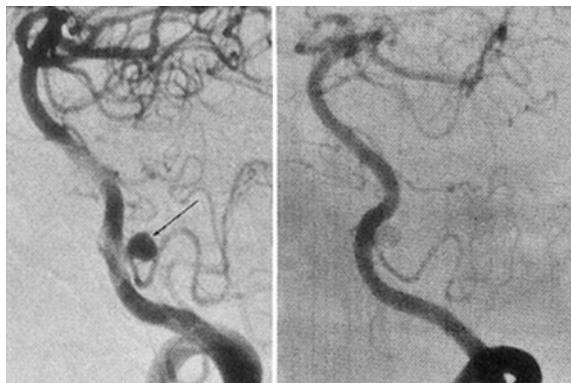


FIG. 6. Case 21. *Left*: Vertebral angiogram, lateral-oblique view, showing a small posterior inferior cerebellar artery aneurysm (*arrow*). *Right*: Vertebral angiogram taken after intra-aneurysmal deposition and detachment of two coils (total length 18 cm) via a modified Tracker-10 microcatheter. The aneurysm is completely occluded. (Procedure performed at New York University, New York, New York.)

The time of angiographic follow-up studies ranged from 6 hours to 14 months (mean 3 months) postoperatively (Tables 1 and 2). The clinical follow-up period ranged from 5 days to 18 months. In six cases, more than one procedure was necessary to achieve a satisfactory aneurysm occlusion (Cases 5, 8, 9, 15, 19, and 30). Several patients had posttherapy magnetic resonance (MR) imaging of the head; GDC's are MR imaging-compatible, and display less local field effect than MR imaging-compatible surgical clips.

In this series there were no transient and one permanent neurological deficits related to treatment. This patient (Case 10) developed a hemianopsia after complete occlusion of a wide-necked basilar bifurcation aneurysm. In one patient (Case 41) it has not been possible to assess the clinical impact of an untoward coil migration into the P₂ segment of the PCA due to pre-existing coma. However, CT scans demonstrated an ischemic zone in the left PCA territory.

One patient died in connection with the endovascular therapy. In this patient (Case 39), the aneurysm ruptured after detachment of a first coil, due to penetration of the fresh clot with the microcatheter. The patient, whose condition was originally classified as Grade V, died 5 days later.

The overall morbidity and mortality rates related to this technique were 4.8% (two cases) and 2.4% (one case), respectively. If considering only patients who presented in Grades I, II, and III, the morbidity rate is 2.6% (one case) and the mortality rate is 0%.

One patient (Case 17) died 1 month after treatment because of an unrelated disease. The autopsy showed that marantic endocarditis had produced multiple organ infarctions. One patient (Case 2) harboring a giant inoperable basilar bifurcation aneurysm died of SAH 18 months after partial aneurysm occlusion. The ostia of the PCA's and SCA's were incorporated in the neck of the aneurysm, precluding its surgical clipping or endovascular occlusion. This case has already been reported.¹

Discussion

The rationale for treatment of cerebral aneurysm is to avoid bleeding and to alleviate symptoms of mass effect in unruptured aneurysms, or to prevent rebleeding in ruptured ones. Currently, aneurysm treatment with preservation of the parent artery may be performed either by open surgical clipping or through an endovascular endosaccular technique. The advantages of the endovascular procedure are that craniotomy and brain manipulation are unnecessary, that the medical condition of the patient does not affect the timing or performance of the procedure, and that it may be applied in cases where direct clipping efforts have failed.

Posterior fossa aneurysms pose difficult surgical problems.^{6-8,10,12} Therefore, an alternative endovascular technique would be of great benefit in this group of patients. The GDC system was applied to this territory in 42 patients with 43 aneurysms.

Efficacy of Treatment

It was possible to enter all aneurysms with a microcatheter-microguidewire combination. Immediate complete occlusion could be achieved in 13 aneurysms with a small neck (Cases 7, 11, 13 (two aneurysms), 17, 21, 25, 35, 37-40, and 42). A narrow aneurysm neck holds the coils inside the aneurysm and allows dense coil packing without impinging on the parent vessel. Similar anatomical results (complete aneurysm occlusion) may be more difficult to achieve in aneurysms with a wide neck because of the lack of a natural barrier and the risk of coil impingement on the parent vessel and possible distal coil migration.

The majority of cases in this series had intracranial aneurysms considered to be technically difficult and with a high surgical risk. Some aneurysms were considered inoperable (10 cases) and some had already undergone unsuccessful surgical exploration (13 cases). Because of this, a partial treatment (70% to 98% occlusion of the aneurysm) was considered to be acceptable in wide-necked aneurysms. Some of these aneurysms may bleed or rebleed, as happened in Case 2. However, it is known that in 98% of cases the rupture site of a saccular aneurysm is located at its dome and sac and that only 2% of aneurysms rupture from their neck.⁹

More than one session was necessary to occlude some of these wide-necked aneurysms (Cases 5, 8, 9, 15, 19, and 30). This was due to the fact that, often, only loose coil packing is achieved in these aneurysms due to the risk of migration. This allows the coils to be pushed by the arterial flow (jet effect) and to become compacted inside the aneurysm. A second procedure was then necessary to reocclude the portions of neck and proximal sac re-exposed to the blood flow.

When the aneurysm appears to be well packed with coils (as visualized fluoroscopically or on a plain x-ray film), only one- to two-fifths of the volume of the aneurysm has actually been filled. This is the reason why the coils are susceptible to be compacted by the blood flow toward the sac and away from the neck of the aneurysm.

As already mentioned, it was possible to achieve denser packing (and complete occlusion) in aneurysms with a small neck. In these cases, due to the dense packing and to the smaller cross section of the neck area susceptible to blood flow, the phenomenon of coil remodeling by blood flow is less likely to occur. Furthermore, the smaller the neck, the higher the probability that the mesh of coils will bridge across the neck area, the neck being the location of the elastic lining defect initially responsible for aneurysm formation.

The follow-up angiograms in wide-necked aneurysms (Table 1) showed no aneurysm regrowth from the arterial wall defect. The phenomenon of coil mesh remodeling, as described above, did occur in many of these aneurysms. Recurrence (defined as recanalization of the aneurysm due to lysis of the thrombus within the meshwork of coils) was not observed.

Small-necked aneurysms that were completely oc-

cluded remained occluded in follow-up angiograms (Table 1). These data, of course, must be confirmed with longer-term angiographic follow-up studies. In one case (Case 7, Fig. 7) a follow-up angiogram at 14 months showed persistence of complete aneurysm occlusion. This case has already been reported¹ and represents the longest angiographic follow-up interval of the entire series.

Thirteen of 43 aneurysms presented with symptoms due to mass effect (Table 1). These aneurysms were treated with the goal of preventing an intracranial hemorrhage due to aneurysm rupture. Some of these patients improved clinically after treatment (clinical amelioration was particularly evident in Case 16 (Fig. 3) and in Case 19 (Fig. 5)). However, it is too soon to draw definitive conclusions on the outcome of mass effect with GDC treatment. After aneurysm occlusion, diminished pulsations and the possible retraction of the clot may decrease the compression upon the surrounding central nervous system structures. If technically feasible, surgical removal of the aneurysm may be the only possible treatment when symptoms due to mass effect worsen or do not improve. Postprocedure transient worsening of the symptoms was sometimes observed. This might be due to swelling of the aneurysmal wall. To prevent this occurrence, steroids may be administered before and after the procedure.

Safety of Treatment

Some technical and clinical complications were observed in this series (Tables 1 and 2). The entrance into the aneurysm with the microcatheter-microguidewire combination should be performed very carefully. Both the microcatheter and the guidewire are less soft than the platinum coils and there is a risk of aneurysm perforation if they are pushed against the aneurysmal wall. The tip of either the microcatheter or the guidewire should never touch the fragile wall of the aneurysm in order to avoid perforation of the wall or of the even more fragile fresh clot at the bleeding site. This complication occurred in one of 43 aneurysms (Case 39). The presence of the proximal markers, on both the microcatheter and the detachable coils, adds to the safety of the procedure.

It was always possible to retrieve the GDC from the aneurysm before detachment if it was inappropriate in size or position. Failure of electrolytic detachment never occurred.

In this series, unlike experience with other forms of endovascular treatment,³ no early bleeding or rebleeding was observed after partial or incomplete aneurysm occlusion. It may therefore be reasonable to stage the aneurysm treatment, as was done in the five cases described above.

Analysis of the Complications

In Case 10, untoward propagation of the intra-aneurysmal thrombus was observed a few hours after sub-

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FIG. 7. Case 7. A and B: Vertebral angiograms, anteroposterior (A) and lateral (B) views, showing a small basilar bifurcation aneurysm. C and D: The 14-month postocclusion follow-up angiograms showing persistence of complete aneurysm occlusion. (Angiogram courtesy of Drs. L. Chi and J. Bello, Montefiore Hospital, New York, New York.)

total embolization of a wide-neck basilar bifurcation aneurysm. This led to complete occlusion of the aneurysm but also of the ostia of both PCA's that were originating from the aneurysmal neck. After a stormy postembolization clinical course, the patient was left with a permanent hemianopsia.

Case 41, with a ruptured wide-necked vertebrobasilar junction aneurysm, was treated while the patient was neurologically in Grade IV. After several unsuccessful attempts to deliver a 4×10 GDC, the decision was made to detach a 2×8 GDC. This coil migrated, after detachment, into the P₂ portion of the left PCA. The clinical impact of this coil migration could not be assessed because of the persistent comatose state of the patient. A CT scan, however, showed a low-density region in the left occipital lobe consistent with ischemia. The aneurysm was subsequently surgically clipped. Due to this technical and clinical complication, the 2×8 GDC was withdrawn from clinical use and a 3×8 GDC was substituted.

One patient (Case 39), harboring a small ruptured PICA aneurysm, was treated while neurologically in Grade V. Severe vasospasm did not allow the utilization of the road-mapping capability during the procedure. After deposition and detachment of one coil, the microcatheter perforated the aneurysm, likely through the fresh clot. The parent vessel was then immediately occluded with straight platinum coils. The patient died 5 days later.

It is important to stress that two of the three complications occurred in patients presenting with severe neurological conditions (Hunt and Hess Grades IV and V). Both the severity of the patient's medical condition and the degree of surgical difficulty led us to use a more aggressive approach in an attempt to save these patients' lives. The limited experience related to this kind of patient precludes our being certain about the indications for the endovascular approach in Grade IV and

V patients. The question arises not from technical limitations but rather from the patient's poor medical condition.

In four patients, surgical intervention was performed after the thrombosis. In two patients (Cases 1 and 27), surgical clipping was performed at 1 week and 3 months, respectively, to exclude a neck remnant from the circulation. This allowed the two patients to recover from the effects of SAH. In another patient (Case 5) with a wide-necked basilar bifurcation aneurysm, surgical clipping of the mid-basilar artery was performed after three occlusion procedures, in order to decrease the jet flow into the aneurysm and enhance thrombosis. Temporary balloon occlusion of the basilar artery was performed prior to clipping in order to assess clinical tolerance. In another patient (Case 41) in whom endovascular treatment failed, surgical clipping of a vertebrobasilar junction aneurysm was performed.

This technique potentially may be used to occlude the aneurysm in the acute phase of SAH. This endovascular occlusion may eliminate the risk of rebleeding and would allow intensive therapy for vasospasm. In those cases in which an incomplete endovascular occlusion of the aneurysm occurred, an elective surgical clipping of the residual aneurysm may be performed.

Conclusions

The technique of endovascular endosaccular occlusion of intracranial aneurysms using GDC's has been developed with the aim of providing a therapeutic alternative. The Food and Drug Administration has limited and oriented the use of GDC's only to patients harboring aneurysms with a high risk of surgery. To date, 120 anterior and posterior circulation aneurysms have been treated with this technique; of these, 42 patients with 43 posterior circulation aneurysms are the subject of this paper.

With regard to safety, GDC's adapt to the shape of the aneurysm causing no significant trauma to the aneurysmal wall, due to the fact that they are very soft and pliable. No aneurysm perforation with the platinum coils was noted in the 43 aneurysms treated. The GDC's are easily controllable and retrievable. Softness, retrievability, and atraumatic detachment are the safety features of the technique. In this series, the morbidity and mortality rates related to treatment were 4.8% (two cases) and 2.4% (one case), respectively (2.6% morbidity and 0% mortality if considering only patients who presented in neurological Grades I, II, and III, according to Hunt and Hess classification).

As to efficacy, a consistent amount of thrombosis, ranging from 70% to 98%, was achieved in 22 of 26 wide-necked aneurysms and in three of 16 small-necked aneurysms. Complete aneurysm occlusion was achieved in 13 small-necked aneurysms and in four wide-necked aneurysms. One aneurysm could not be occluded due to a technical complication.

Electrothrombosis may be an important factor in the formation of a stable thrombus. It may play a role in eliciting celeritous thrombosis that may prevent coil migration. Further studies on the structure of the electrically produced thrombi are necessary. Longer angiographic and clinical follow-up studies are essential to ascertain the long-term efficacy of this recently developed endovascular occlusion technique.

Disclosure

A patent on the GDC coils is pending in the names of the first and last authors.

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