AJNR

Interlocking detachable coil occlusion in the endovascular treatment of intracranial aneurysms: preliminary results.

H S Cekirge, I Saatci, M M Firat, F Balkanci and A Besim

AJNR Am J Neuroradiol 1996, 17 (9) 1651-1657
http://www.ajnr.org/content/17/9/1651

Interlocking Detachable Coil Occlusion in the Endovascular Treatment of Intracranial Aneurysms: Preliminary Results

H. Saruhan Cekirge, Isil Saatci, Murat M. Firat, Ferhun Balkanci, and Aytekin Besim

PURPOSE: To present our preliminary experience with the recently developed interlocking detachable coils in the treatment of intracranial aneurysms. **METHODS:** Two aneurysms of the basilar tip, two of the internal carotid artery, and one of the posterior inferior cerebellar artery were treated by an endovascular technique using interlocking detachable coils. Three of the patients had undergone unsuccessful surgical clipping. Three-month and 1-year control angiograms were obtained. **RESULTS:** In all patients but one, who had an aneurysm of the internal carotid artery, the aneurysmal sac was occluded with preservation of the parent artery and did not show recanalization on the follow-up control angiograms. In the other patient who had a wide-necked aneurysm of the internal carotid artery, the sac could not be totally obliterated and showed contrast filling in the neck remnant at 3-month angiography. None of the patients experienced neurologic deficit after treatment. **CONCLUSION:** Because they are soft and retrievable, interlocking detachable coils, with their immediate coil release design, may provide an alternative to surgery in the future treatment of endovascular aneurysms.

Index terms: Aneurysm, intracranial; Aneurysm, embolization; Interventional instruments, coils

AJNR Am J Neuroradiol 17:1651–1657, October 1996

The treatment of intracranial aneurysms with preservation of the parent artery may be performed either by open surgical clipping or through an endovascular endosaccular technique (1); however, the endovascular approach has not yet proved to be as effective as surgery. Until recently, the endovascular approach to aneurysmal occlusion has been limited to balloon embolization (2), but the development of detachable coils has widened the alternatives for the endovascular therapeutic management of intracranial aneurysms. One recently described retractable coil system is the Guglielmi detachable coil (GDC; Target Therapeutics, Fremont, Calif) (3). The detachment mechanism of the GDC system works by means of an electrical current that induces detachment by electrolysis, which requires varying amounts of time. Another mechanical detachment system, the interlocking detachable coil (IDC) occlusion system (Target Therapeutics), now provides an immediate but still controllable coil detachment mechanism. We describe five intracranial aneurysms that were treated by IDCs with midterm angiographic follow-up results.

Subjects and Methods

Five patients were treated by means of endovascular endosaccular occlusion using IDCs. The IDCs are made of platinum, available in diameters of 2 to 8 mm and in lengths of 40 to 200 mm. The primary helix diameter is 0.015 inch in all coil sizes.

Three patients were male (31, 43, and 56 years old, respectively) and two patients were female (4 and 62 years old, respectively). The treated aneurysms were located at the basilar artery tip in two patients, the posterior inferior cerebellar artery (PICA) in one patient, and the internal carotid artery (ICA) in two patients. Three of the patients with aneurysms of the basilar artery and the PICA had subarachnoid hemorrhage. These patients had no neurologic deficit before the intervention. One of the two patients with an aneurysm of the ICA had bilateral third nerve palsy. This patient was 4 years old and had bilateral cavernous carotid artery aneurysms. The right ICA aneurysm was treated with preservation of the parent artery.

Received October 18, 1995; accepted after revision March 6, 1996.

From the Department of Radiology, Hacettepe University Hospital, Sihhiye Ankara, Turkey.

Address reprint requests to Isil Saatci, MD, Department of Radiology, Hacettepe University Hospital, Sihhiye Ankara 06100, Turkey.

AJNR 17:1651–1657, Oct 1996 0195-6108/96/1709–1651

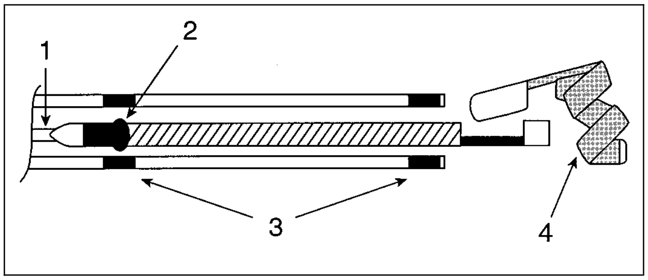

Fig 1. Schematic shows the IDC occlusion system. *1* indicates the coil pusher; *2*, the pusher marker; *3*, the catheter and its two radiopaque markers; and *4*, the occlusion coil. Since the pusher marker and the proximal marker on the distal end of the catheter are superimposed, the coil is detached.

Occlusion of the parent artery was performed for the left ICA aneurysm. The other patient with an aneurysm of the ICA was admitted for subarachnoid hemorrhage and had accompanying aneurysms of the anterior communicating artery and the middle cerebral artery. Surgical clipping of the anterior communicating and the middle cerebral artery aneurysms was successful, but the attempt to clip the ICA aneurysm failed. Surgical clipping had also been tried unsuccessfully in two patients who had basilar tip aneurysms. In the remaining patients (those with PICA and bilateral ICA aneurysms), endovascular treatment was performed with no previous surgical intervention in keeping with the patients' preferences after a full discussion of the alternatives. This new occlusion coil system was approved by the investigational committee of the Ministry of Health and the ethical board of our hospital.

The procedures were performed under general anesthesia. A 7F introducer sheath was placed into the right femoral artery. A 6F guiding catheter was used in all cases. A Tracker 18 catheter (Target Therapeutics) with two radiopaque tip markers was introduced coaxially. With the use of road mapping, the microcatheter was advanced over a 0.016-inch gold tip microglidewire (Terumo, Inc, Tokyo, Japan) until its tip was placed in the sac of the aneurysm. After controlling the position of the catheter in the sac by injecting a small amount of contrast material, we loaded the coil, which comes preattached to the pusher in an introducing tube, into the catheter. The coil and the coil pusher are interposed within the catheter by the help of the two interlocking cylinders so that the cylinder attached to the coil cannot travel beyond the cylinder attached to the coil pusher until fully ejected (Fig 1). There are two radiopaque markers at the distal end of the microcatheter and one on the distal of the pusher. The coil attached to the pusher may be advanced until the marker on the distal end of the pusher superimposes on the proximal marker of the microcatheter. When necessary, the coil can be easily retrieved before the two markers are superimposed, and may be pushed forward again. At the point of superimposition of the markers, the coil will be released with a slight rotational movement of the pusher with the help of the torque device. After detachment of the first coil, it may be difficult to see the coil-pusher junction of the second and subsequent coils within the mesh. Similar to the mechanism of the GDC system, the proximal radiopaque markers (outside the aneurysm) allow precise placement of the junction within the aneurysm even when the actual junction cannot be seen.

The patients were given 5000 IU of heparin, intravenously, when the coaxial system was introduced. A dose of 2500 IU was repeated every hour during the procedure. Intravenous heparin was continued with a total dose of 500 IU/kg of body weight for 24 hours during the first 3 days to avoid any thromboembolic complications. The patients were treated on admission with oral phenytoin for seizure prophylaxis.

Ultimate care was taken to fill the dome of the aneurysm first and to bridge the mesh of coils across the neck. Before the coils were released, their position, configuration, and filling of the aneurysm were controlled by contrast injection and fluoroscopy to ensure they did not impinge upon or protrude into the parent artery and/or into the adjacent arteries. Early detachment, resulting in coils stuck within the catheter, was not encountered. Our follow-up plan after treatment includes control angiograms at 3 months, 1 year, and 5 years.

Results

No neurologic deficit developed in any of the patients after the endovascular treatment. In four of the patients, control angiograms were obtained at 3 months and at 1 year. In the remaining patient, who had an aneurysm of the ICA, only a 3-month control angiogram was obtained.

In the patient with an aneurysm of the PICA, the aneurysmal sac was occluded with 12 coils (two were 8 mm in diameter and 20 cm in length; two were 7 mm, 10 cm; two were 5 mm, 8 cm; one was 4 mm, 12 cm; one was 4 mm, 4 cm; two were 3 mm, 6 cm; and two were 2 mm, 4 cm; total length, 112 cm). A control angiogram obtained in the first year revealed a small contrast filling in the neck (Fig 2). We decided that reintervention was unnecessary until the results of the 3-year follow-up angiographic examination are known.

In the 4-year-old patient with bilateral cavernous carotid artery aneurysms, the aneurysm of the left ICA was excluded after test occlusion of the parent artery. The right ICA aneurysm was occluded with nine coils (one was 8 mm in diameter and 20 cm in length; one was 7 mm, 20 cm; two were 5 mm, 15 cm; one was 4 mm, 12 cm; two were 3 mm, 10 cm; and two were 2 mm, 4 cm; total length, 110 cm) except for a minute contrast filling in the sac. The parent

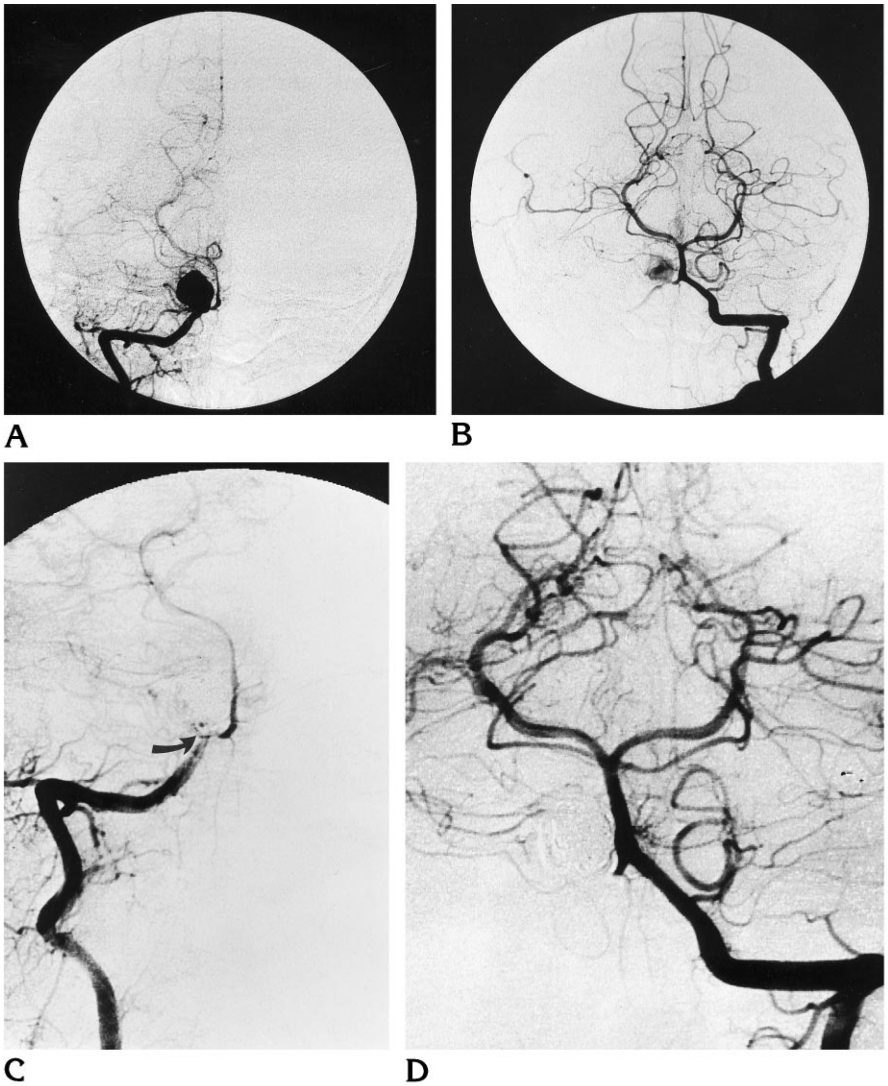

Fig 2. Aneurysm of the posterior inferior cerebellar artery (PICA).

Right (*A*) and left (*B*) anteroposterior vertebral angiograms before embolization show the aneurysm at the origin of the right PICA.

Right (*C*) and left (*D*) anteroposterior vertebral artery injections at 1-year follow-up reveal the occluded aneurysm with a small neck remnant (*curved arrow* in *C*) filling from the ipsilateral vertebral artery.

artery was preserved. The patient's bilateral third nerve palsy had completely resolved at the 3-month follow-up examination, and the 1-year control angiogram showed no further recanalization (Fig 3).

In one of the patients with a basilar tip aneurysm, the small sac was completely obliterated with three coils (one was 3 mm in diameter and 6 cm in length, and two were 2 mm in diameter and 4 cm in length; total length, 14 cm), and the 1-year control angiogram showed no recanalization (Fig 4).

In the second patient with a basilar tip aneurysm (Fig 5), the posterior cerebral arteries, arising from the wide neck of the aneurysm, started to fill not from the basilar artery but from the internal carotid arteries bilaterally, after occlusion of the aneurysmal sac with 10 coils (one was 8 mm in diameter and 20 cm in length; two were 8 mm, 10 cm; one was 6 mm, 20 cm; one was 5 mm, 15 cm; two were 4 mm, 12 cm; two were 3 mm, 10 cm; and one was 2 mm, 4 cm; total length, 123 cm) (Fig 5B and C). No neurologic symptoms attributable to bilateral occlusion of P1 segments and related perforators developed. The control study did not show an infarct. The lack of relevant symptoms were attributed to the fact that the posterior communicating artery, the P1 segment, the distal basilar artery, and the junction of the posterior communicating artery, P1 segment, and basilar artery are in unity during development, with a variable balance between their territories and perforating branches. The size of the P1 segment and the posterior communicating artery does not influence the territory of their perfora-

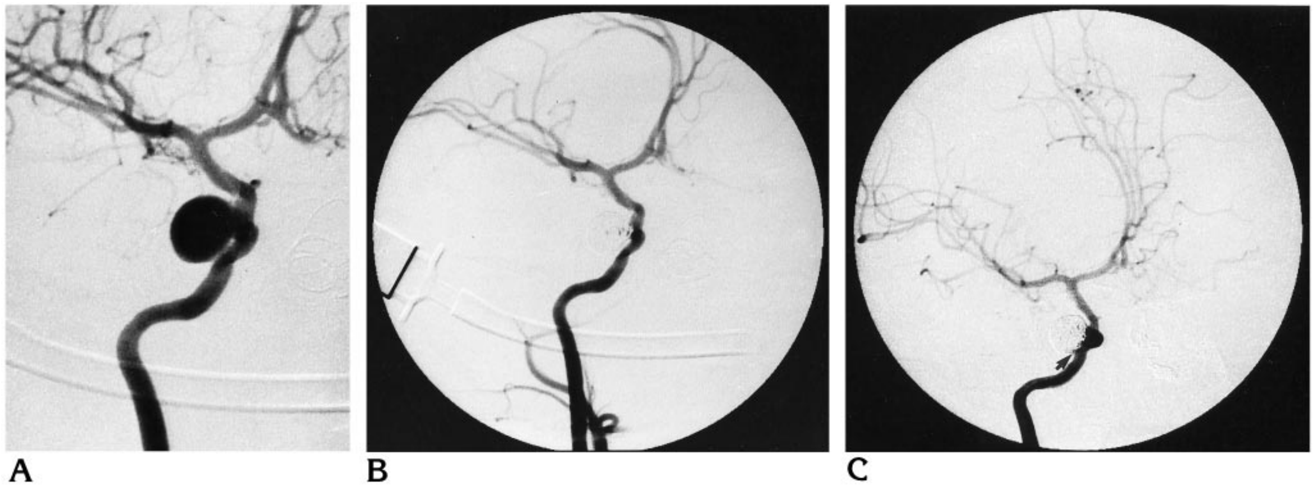

Fig 3. Aneurysm on the right internal carotid artery (ICA) in a 4-year-old patient.

A, Right internal carotid angiogram before embolization shows the right ICA aneurysm.

B, Angiogram obtained after embolization shows occlusion of the aneurysmal sac, with only minute contrast within the coil mesh.

C, Angiogram at 1-year follow-up shows no further recanalization. Note the superimposition of the curving ICA contour at the base of the aneurysm (*arrow*), which may lead to the false impression of a residual neck (also seen in *B*).

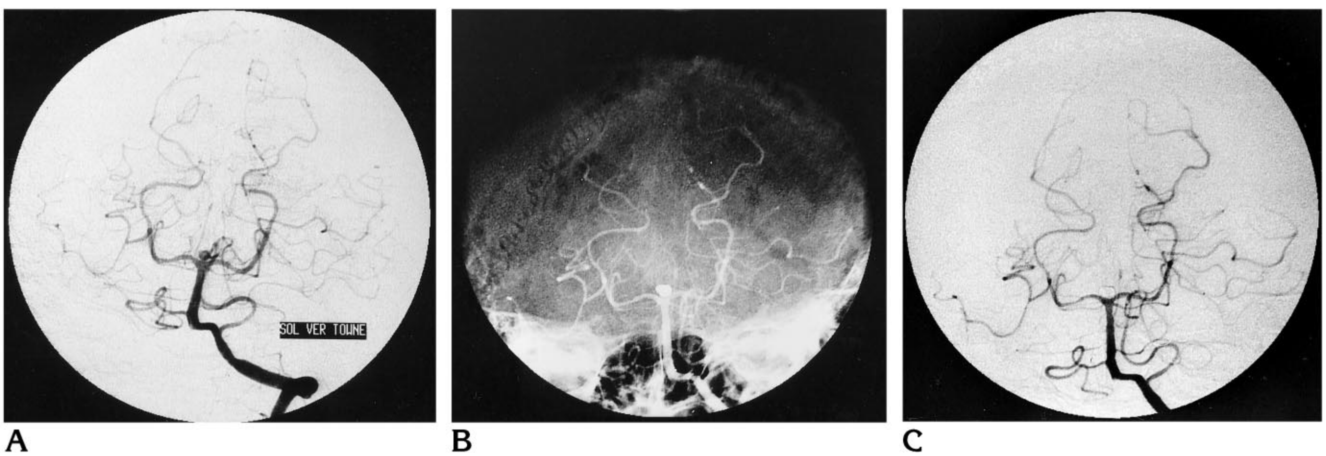

Fig 4. Small aneurysm of the basilar tip.

A, Left anteroposterior vertebral artery angiogram before embolization shows the aneurysm at the basilar tip.

At 1-year follow-up, nonsubtracted view (*B*) shows coil mesh and subtracted view (*C*) shows no recanalization.

tors. Although uncommon, it is also possible that no perforators originate from the P1 segment (4). The aneurysm remained occluded on the control angiograms at 3 months and 1 year (Fig 5D). This patient had an associated aneurysm of the anterior communicating artery, which was treated by surgical clipping, and another small aneurysm at the origin of the right superior cerebellar artery, which will be treated at a future time. (The patient is unwilling to have another intervention at present.)

In the other patient with a small, wide-necked aneurysm of the cavernous portion of the left ICA (who had undergone an unsuccessful clipping attempt), the aneurysmal sac could not be totally excluded, though bridging of the mesh of coils across the aneurysmal neck was achieved with five coils (1 was 6 mm in diameter and 10 cm in length; two were 4 mm, 12 cm; and two were 3 mm, 6 cm; total length, 46 cm). The 3-month control angiogram showed filling of the neck remnant. No further intervention was considered, since an attempt to occlude the residual neck carries the risk of possible coil protrusion into the parent artery through the 5-mm-wide neck. Further therapy will be planned according to the findings on the 1-year follow-up angiogram.

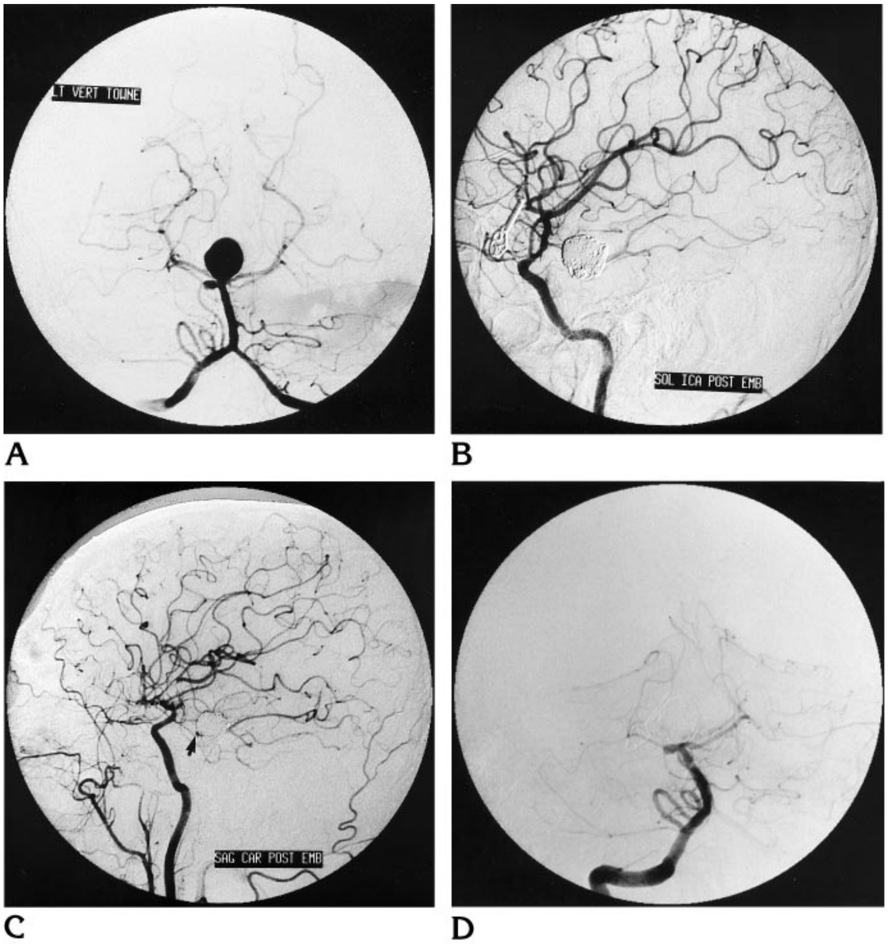

Fig 5. *A*, Anteroposterior vertebral angiogram before embolization shows aneurysms in the basilar tip and right superior cerebellar artery.

B, Lateral left carotid angiogram obtained immediately after treatment shows filling of the left posterior cerebral artery via the posterior communicating artery.

C, Lateral right carotid angiogram obtained immediately after treatment shows filling of the right posterior cerebral artery. Note the retrograde filling of the aneurysm at the origin of the right superior cerebellar artery (*arrow*).

D, Anteroposterior vertebral angiogram at 1-year follow-up reveals no recanalization of the basilar tip aneurysm. Note the slight filling of the left posterior cerebral artery with its origin superimposed on the coil mesh. (Surgical clip was used for treatment of an aneurysm of the anterior communicating artery.)

Discussion

The goal of treatment for an aneurysm is to isolate the aneurysm from the circulation; the parent artery may or may not be preserved. Although surgery is the proved method of treatment, the endovascular approach is an alternative, providing the following advantages over direct surgical clipping: craniotomy and brain manipulation are avoided; the medical condition of the patient does not affect the timing or performance of the procedure; and treatment may be implemented in cases in which direct clipping efforts have failed. Until recently, endovascular occlusion of aneurysms has been limited to balloon embolization (2, 5). However, at present, the use of balloons is confined to the treatment of parent artery occlusion, owing to certain drawbacks: the stress on the fragile wall of the aneurysm by the balloon may cause the aneurysm to rupture (5, 6); the risk of balloon rupture; the inability to navigate the balloon into a stable position; and the possibility of balloon migration after it is placed in the aneurysmal sac (2, 5, 7). Nonretrievable conventional coils became an alternative to balloons in the endosaccular occlusion of aneurysms (8); however, these coils cannot be withdrawn once they are released into an aneurysm or blood vessel. Therefore, the released coil may protrude into a parent vessel (8, 9) and cannot be repositioned or retracted when it is unstable in a blood vessel (10).

The latest development is the use of detachable coils, which offer a less traumatic and safer means to treat intracranial aneurysms. A retractable coil design, the GDC occlusion system, has been in use since 1990 with very promising results (3, 6, 11). The GDC system is based on the separation of the coil from the coil-pusher segment by means of electrolysis; that is, the uninsulated most distal portion of the stainless steel core wire dissolves following the direct application of an electrical current and releases the coil. Although initial placement of the coils is rapid (average, 1 to 2 minutes), the time it takes for coils to separate by electrolysis increases according to the number of coils placed (the more coils, the longer the time required for separation) (6). Softness, retrievability, and atraumatic detachment are the reported safety features of the GDCs (11). In addition, electrothrombosis, which takes place during the detachment of the coils by electrolysis, is thought to contribute to the process of complete aneurysmal occlusion (11). In a multicenter study in which aneurysms of the posterior circulation were treated with GDCs, Guglielmi et al (11) reported morbidity and mortality rates of 4.8% and 2.4%, respectively.

The mechanical detachable spirals (MDS-N, Balt, Montmorency, France) and the IDCs are the mechanical detachment systems available in the market. We know of two publications describing the IDCs (12, 13). Marks et al (12) tested the mechanical detachable coil designs developed by Target Therapeutics in an in vitro and animal model study. Their results proved the superiority of the interlocking cylinder design, the model used in the present study, which was eventually introduced on the market. They emphasized the immediate release feature of the mechanically detachable coil design and disputed the role of electrothrombosis provided by the GDC system in the occlusion of the aneurysmal sac. Since the endovascular coil procedures are generally performed with the use of systemic heparin to impede formation of blood clots at the time of placement, these researchers doubted whether there is an advantage to having thrombus form at the time of each coil placement.

In a recent study, Yoshimura and coworkers (13) presented their experience with IDCs in three patients with dural arteriovenous fistulas.

The IDCs are constructed from platinum. They recoil easily in the aneurysmal sac without displacing the tip of the microcatheter during the pushing action. Their radiopacity allows easy fluoroscopic control. It is always possible to retrieve a coil after partial ejection in case it is the wrong size or in an unstable position in the aneurysmal sac. Therefore, the mechanical detachment mechanism offers immediate but still controllable release, and does not require the waiting period necessary with the GDC system that may increase the risk of the procedure. This particular feature of the IDC system encouraged us to use the device in the treatment of aneurysms in the group of patients reported here.

The role of electrothrombosis provided by GDCs in the obliteration of an aneurysmal sac is still controversial, since it is not clear how much of the observed thrombosis is the result of electrothrombosis and how much is vascular stasis caused by the packing of coils into a vascular space (12). In our opinion, electrothrombosis probably contributes to the occlusion of the sac, resulting in the need for fewer coils, since thrombus formation, though reduced, is still stimulated by electrical current even under heparin infusion (14). On the other hand, the potential for inadvertent parent artery occlusion may be lower with the IDC coils, given the absence of electrothrombosis with that system. However, the GDC system has a wider variety of coil sizes, which may allow more accurate packing of the aneurysmal sac.

Although data regarding long-term results of endovascular coil occlusion are not yet available, and, therefore, comparison of its results with that of surgical clipping is not possible, we know that aneurysms treated with GDCs may regrow or recanalize (15). Since GDCs and IDCs are constructed from the same material, one may also expect some degree of recanalization in the aneurysms treated with IDCs. However, if recanalization is seen on control angiograms, the endovascular technique still offers the chance to re-treat any residual aneurysm. Larger series with long-term follow-up are needed to assess the recanalization rate of the aneurysms after endovascular coil occlusion with the use of both IDC and GDC systems. However, in comparing the results of endovascular treatment versus surgery, one should remember that most of the aneurysms treated endovascularly either have undergone previous unsuccessful surgical attempts or are high-risk surgical candidates because of their location and/or configuration, and this may result in a selection bias.

In conclusion, IDCs are soft and retrievable, and afford instantaneous coil release. In the future, they may be a fast and safe alternative for use in the endovascular treatment of aneurysms.

References

1. Higashida RT, Halbach VV, Hieshima G. Endovascular therapy of intracranial aneurysms. In: Vinuela F, Halbach VV, Dion JE, eds. *Interventional Neuroradiology: Endovascular Therapy of Central Nervous System*. New York, NY: Raven Press; 1992:87–106
2. Higashida RT, Halbach VV, Dowd CF, Barnwell SL, Hieshima GB. Intracranial aneurysms: interventional neurovascular treatment with detachable balloons: results in 215 cases. *Radiology* 1991; 178:663–670
3. Guglielmi G, Vinuela F, Dion JE, Duckwiler G. Electrothrombosis of saccular aneurysms via endovascular approach, 2: preliminary clinical experience. *J Neurosurg* 1991;75:8–14
4. Lasjaunias P, Berenstein A. *Surgical Neuroangiography*. Berlin: Springer-Verlag, 1990;3:170–180
5. Moret J. Endovascular treatment of berry aneurysms by endosaccular occlusion. *Acta Neurochir Suppl* 1991;53:48–49
6. Guglielmi G. Endovascular treatment of intracranial aneurysms. *Neuroimaging Clin North Am* 1992;2:269–278
7. Higashida RT, Halbach VV, Cahan CD, Hieshima GB, Konishi Y. Detachable balloon embolization therapy of posterior circulation intracranial aneurysms. *J Neurosurg* 1989;71:512–519
8. Casasco AE, Aymard A, Gobin P, et al. Selective endovascular treatment of 71 intracranial aneurysms with platinum coils. *J Neurosurg* 1993;79:3–10
9. Knuckey KW, Haas R, Jenkins R, Epstein MH. Thrombosis of difficult intracranial aneurysms by the endovascular placement of platinum: dacron microcoils. *J Neurosurg* 1992;77:43–50
10. Nancarrow PA, Fellows KE, Lock JE. Stability of coil emboli: an in vitro study. *Cardiovasc Intervent Radiol* 1987;10:226–229
11. Guglielmi G, Vinuela F, Duckwiler, G et al. Endovascular treatment of posterior circulation aneurysms by electrothrombosis using electrically detachable coils. *J Neurosurg* 1992;77:515–524
12. Marks MP, Chee H, Liddell RP, Steinberg GK, Panahian N, Lane B. A mechanically detachable coil for the treatment of aneurysms and occlusion of blood vessels. *AJNR Am J Neuroradiol* 1994;15: 821–827
13. Yoshimura S, Hashimoto N, Kazekawa K, Nishi S, Sampei K. Embolization of dural arteriovenous fistulas with interlocking detachable coils. *AJNR Am J Neuroradiol* 1995;16:322–324
14. Guglielmi G, Vinuela F, Sepetka I, Macellari V. Electrothrombosis of saccular aneurysms via endovascular approach, 1: electrochemical basis, technique, and experimental results. *J Neurosurg* 1991;75:1–7
15. Houdart E, Casasco A, George B, Cophignon J, Merland JJ. Our experience in therapeutic management of 159 intracranial aneurysms by GDC coils. *Neuroradiology* 1994;36(Suppl 1):S82

Please see the Commentary on page 1658 in this issue.