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Immediately Detachable Coil for Aneurysm Treatment

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Summary: We developed an endovascular coil that is instantly detached by high-frequency electrical current. By applying the electrical current, a polyvinyl alcohol junction between the coil and the delivery wire is disrupted by heat within a second. This detachment system was shown to be reliable in the treatment of experimental aneurysms.

Index terms: Aneurysm, therapeutic blockade; Interventional instruments, coils; Animal studies

Intrasaccular occlusion of cerebral aneurysms has been performed using detachable balloons and/or platinum microcoils. However, these procedures carry risks of regrowth of the residual aneurysmal sac, coil compaction, and coil dislocation during and after the procedure (1–4). With the introduction of the Guglielmi detachable coil, intrasaccular obliteration has become more promising, because the device is retrievable and is soft enough to adapt to irregular configurations of an aneurysm (5, 6). The Guglielmi detachable coil is detached within several minutes by application of a positive direct electrical current to electrolyze a stainless steel junction between the coil and delivery wire. With increasing numbers of detached coils in an aneurysm, however, detachment tends to be delayed. Because current application has to be continued until the coil is detached, electrothrombosis is uncontrollably produced. Prolongation of the whole procedure may increase the risk of thromboembolism from catheters and also affect the operators' concentration. To overcome these risks and inconvenience related to prolonged current application, we developed an endovascular coil that is immediately detachable by monopolar high-frequency electrical current.

Materials and Methods

Immediately Electrically Detachable Coil (IEDC)

This device has a polyvinyl alcohol (PVA) rod at the junction of a soft circular platinum coil and the delivery wire (Fig 1). The diameter of the PVA rod is 0.86 mm, and its length is between 0.5 and 1.0 mm. Polymerization degree of the PVA is 2000, and the PVA rod is disrupted when it is heated to 70°C. Total length of the device is between 173 and 190 cm, depending on coil length. Device diameter is 0.014 in, and "memorized" circle of the coil measures from 3 to 20 mm in diameter. The distal 4 cm of the delivery wire is made of platinum, and the other part is of stainless steel. The entire delivery wire is coated with polytef. A 2.7F microcatheter for the device has platinum markers on its tip and 4 cm proximal to the tip (IEDC and catheter: Kaneka Medix, Kanagawa, Japan). These twin markers are essential for knowing when the PVA junction is advanced beyond the catheter tip, as with the Guglielmi detachable coil (5, 6).

By applying monopolar high-frequency electrical current from the proximal end of the delivery wire, the PVA junction is disrupted by heat, and the coil is detached. Frequency of the current is 300 kHz (current generator: Kaneka Medix, Kanagawa, Japan), a commonly applied frequency in standard electrical surgical devices such as bipolar coagulator forceps and monopolar electrical knives. Power range of the generator is from 1 to 12 W, in increments of 1 W.

Preliminary Study

In a preliminary experiment in saline on the relationship between electrical power and detach time, the IEDC was not detached by 4 W or less, but was quickly detached without fail in 10 IEDCs by 5 W or more. With 5 W, heat measurement by a thermocouple at the junction showed 75°C. Mechanical strength of the PVA joint was examined by tensile test. Both ends of a 1-mm PVA rod were attached to the tips of 23-gauge needles. Tensile stress was exerted from the both ends with a traction speed of 100 mm/min. The test was repeated 10 times each for dried and wet PVA. Dry PVA rods were fractured at an average strength of 0.71 ± 0.079 kg (mean ± SD). In wet condition, as in the blood stream, the average tensil strength was 0.32 ± 0.053 kg (mean ± SD).

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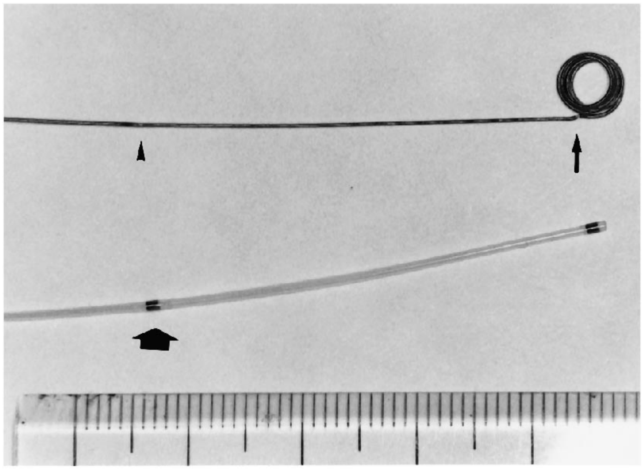

Fig 1. Distal portion of an IEDC (*upper*) and a microcatheter for the device (*lower*). The IEDC has a PVA rod at the junction of delivery wire and soft circular platinum coil (*small arrow*). The distal 4 cm of the delivery wire is made of platinum, whereas the proximal part is made of stainless steel wire. Their junction (*arrowhead*) is identifiable by fluoroscopic monitoring. The 2.7F microcatheter has twin markers, one at the tip and the other 4 cm proximal from the tip (*large arrow*).

Experimental Use with Canine Carotid Aneurysms

To examine the relationship between electrical power and detachment time in vivo and the accuracy of coil placement into aneurysmal sacs, IEDCs were used in experimentally created aneurysms.

Carotid aneurysms were surgically created in eight adult mongrel dogs (10 to 12 kg). In six dogs, bifurcation aneurysms were created by the method reported by Forrest and O'Reilly (7). The right common carotid artery was ligated and cut, and the distal part of the artery was anastomosed to the left common carotid artery in a partial end-to-side fashion with an 8-0 nylon suture. On this surgically created bifurcation, a venous pouch made of a left external jugular vein graft was sutured. In the other two dogs, a side wall aneurysm was created by our original method. The classic method of simply suturing a venous pouch to arterial wall often results in premature spontaneous thrombosis. In our method, a venous pouch was sutured as an aneurysmal dome on the side wall of the left common carotid artery after a circular arteriotomy was performed. Then, the right common carotid artery was ligated and cut, and the free end of the distal part anastomosed to the dome of the aneurysm. Transposition of the right carotid artery to the aneurysmal dome prevented premature spontaneous thrombosis of the aneurysm in five preliminary cases. Small neck aneurysms can be created by this method without spontaneous occlusion.

Seven to 10 days after the surgery, endovascular occlusion of the aneurysm was performed. Under general anesthesia, a 6F introducing catheter was positioned in the left common carotid artery using a transfemoral approach with 2500 U of heparin injected intravenously. After confirming aneurysm opacification by angiography, a 2.7F microcatheter with twin markers was advanced through the guiding catheter into the aneurysm. In the case of side wall aneurysms, the tip of the microcatheter was steamed and angled to the shape of a hockey stick. An IEDC with a circular diameter the same as the maximum diameter of the aneurysm first was delivered into the aneurysm. When the proximal end of the platinum portion of the delivery wire overlapped with the proximal marker of the catheter, monopolar high-frequency current (300 kHz) was applied to the proximal end of the wire to detach it. A stainless steel plate had been placed under the animal's back as an external ground electrode. Additional IEDCs of smaller circular diameter were added until the aneurysm was packed as completely as possible. All the coils used in the experiment were 10 cm long. In one dog, varying electrical power (from 4 to 6 W) was applied to determine suitable power. When the coil was not detached after a duration of 1 minute of current application, the electrical power was raised by 1 W.

Results

The results are shown in the Table. In dog 1, all the coils were immediately detached with 5 W or more, but not with 4 W—a similar result as seen in the experiments in saline. In this case, parent arteries were found to be narrowed by thrombi on postembolization angiograms, probably because of prolonged inadequate current application. This complication was not found in any other cases in which IEDCs were immediately detached. For eight aneurysms, 32 IEDCs were used altogether, and all of them were detached instantly with 5 W or more. The twin marker system was fully visible and useful with fluoroscopic monitoring. IEDCs were smoothly advanced and could be retrieved for repositioning. There was no premature detachment by external force or friction in the microcatheter. Complete packing was achieved as an immediate result in 5 cases (Fig 2). For aneurysms with broad necks (dog 1, 6, 8), coils could not be easily positioned within the aneurysmal sac, and therefore complete obliteration was not achieved in these three aneurysms. Narrowing or occlusion of parent arteries by the coil itself was not found in any case.

Discussion

Taki et al used a PVA junction for an electrically detachable balloon catheter (8), in which a balloon and a silicone catheter were connected by a PVA tube with two encircling electrodes made of small copper wire. The balloon was instantly detached by applying bipolar, high-

Early results of IEDC embolization

Dog	Type of Aneurysm	Aneurysm Size (Width × Length), mm	Width of Neck, mm	Number of IEDCs	Circular Diameter of IEDC, mm	Power of MHFEC* (300 kHz)	Time Required to Detach IEDC	% of Aneurysm Volume Packed (Just after Embolization)	Narrowing or Occlusion of Parent Artery
1	Bifurcation aneurysm	7.5 × 9	6	5	8	4 W	Not detached	90	Thrombus was noted in the parent artery
						5 W	1 s		
					6	4 W	Not detached		
						5 W	1 s		
					3	5 W	1 s		
					4	5 W	1 s		
					3	6 W	1 s		
2	Side wall aneurysm	6 × 6	4	2	5, 3	all 5 W	All 1 s	100	None
3	Side wall aneurysm	6 × 10	5	3	6, 6, 4	all 5 W	All 1 s	100	None
4	Bifurcation aneurysm	6 × 11	5	5	6, 5, 4, 3, 3	all 5 W	All 1 s	100	None
5	Bifurcation aneurysm	6.5 × 12	4.5	4	6, 5, 4, 3	all 5 W	All 1 s	100	Small intimal dissection by catheterization
6	Bifurcation aneurysm	8 × 12	7	7	8, 6, 6, 5, 4, 3, 3	all 5 W	All 1 s	85	None
7	Bifurcation aneurysm	6 × 7	4	2	7, 4	all 5 W	All 1 s	100	None
8	Bifurcation aneurysm	8 × 8	6	4	7, 5, 3, 3	all 5 W	All 1 s	90	None
Total				**32**					

*Monopolar high-frequency electrical current.

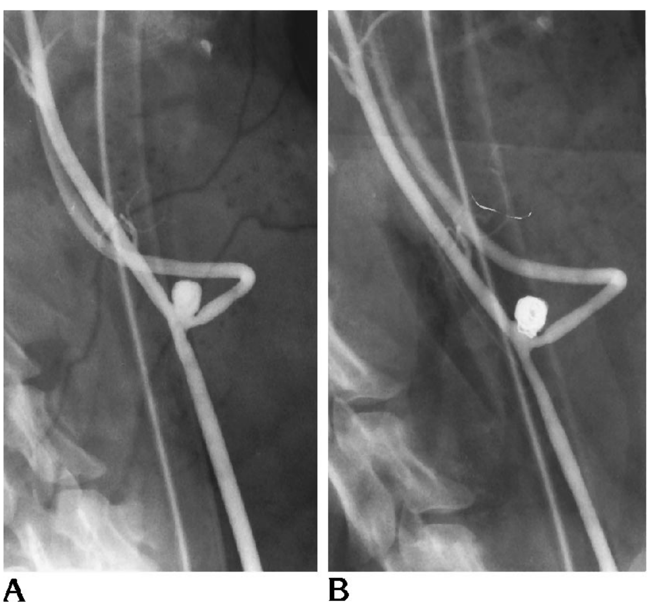

Fig 2. *A*, Preembolization angiogram of a surgically created bifurcation aneurysm in dog 7.

B, Postembolization angiogram immediately after almost complete packing of aneurysm with two IEDCs. There was no obstruction or narrowing of parent vessel by detached coils.

frequency electrical current without exerting external force. The IEDC has a similar detachable junction but without copper electrodes, because the delivery wire works as an electrode for monopolar current application. Because all of the 32 coils were detached within 1 second by 5 W of electrical power, detachment of the new device is very reliable, thus fulfilling the goal of this development. Thrombosis of parent arteries in dog 1 was probably caused by prolonged current application in an attempt to find a suitable electrical power. With 5 W, however, this complication never occurred because detachment occurs quickly.

For electrical surgical coagulators such as bipolar forceps and monopolar electrical knifes, high-frequency electrical currents of between 300 and 10 MHz are commonly used. In addition, more than 30 W of power is routinely applied in standard neurosurgical procedures. Therefore, applying 5 W of electrical current at 300 kHz for a very short duration should not cause any problems.

References

1. Higashida RT, Halbach VV, Barnwell SL, et al. Treatment of intracranial aneurysms with preservation of the parent vessel: results of percutaneous balloon embolization in 84 patients. *AJNR Am J Neuroradiol* 1990;11:633–640

2. Kwan ESK, Heilman CB, Shucart WA, Klucznik RP. Enlargement of basilar artery aneurysms following balloon occlusion: "water-hammer effect": report of two cases. *J Neurosurg* 1991;75:963–968
3. Kwan ESK, Heilman CB, Roth PA. Endovascular packing of carotid bifurcation aneurysm with polyester fiber-coated platinum coils in a rabbit model. *AJNR Am J Neuroradiol* 1993;14:323–333
4. Casasco AE, Aymard A, Gobin P, et al. Selective endovascular treatment of 71 intracranial aneurysm with platinum coils. *J Neurosurg* 1993;79:3–10
5. Guglielmi G, Vinuela F, Sepetka I, Macellari V. Electrothrombosis of saccular aneurysm via endovascular approach, I: electrochemical basis, technique, and experimental results. *J Neurosurg* 1991;75:1–7
6. Guglielmi G, Vinuela F, Dion J, Duckwiler G. Electrothrombosis of saccular aneurysm via endovascular approach, II: preliminary clinical experience. *J Neurosurg* 1991;75:8–14
7. Forrest MD, O'Reilly GV. Production of experimental aneurysms at a surgically created arterial bifurcation. *AJNR Am J Neuroradiol* 1989;10:400–402
8. Taki W, Handa H, Yamagata S, Yonekawa Y, Ikada Y, Iwata H. The releasable balloon technique with activated high frequency electrical current. *Surg Neurol* 1980;13:405–408