AJNR Am J Neuroradiol 19:566–569, March 1998

Embolization of Experimentally Created Aneurysms with a Laser-Activated Detachable Coil Device

Glen Geremia and Michael Haklin

Summary: Our experimental study in dogs suggests that laser-activated detachable coil devices show promise in the embolization of carotid aneurysms, allowing the interventionalist greater control than possible with nonretractable coil systems and permitting detachment of the coil from the wire in seconds.

Endovascular treatment of lesions throughout the body has become increasingly popular. Many devices and materials (balloons, coils, particles, glue, alcohol, etc) have been delivered to target lesions through an introducer catheter (1–4).

Coils are usually advanced through a catheter with an unattached pusher wire, and are deposited into the target lesion when they have completely extended beyond the catheter tip. A coil device with controlled detachment (the Guglielmi detachable coil, or GDC; Target Therapeutics, Fremont, Calif) is currently available that allows the practitioner to retract and reposition the coil even after it has extended beyond the catheter tip (5). Detachment occurs when the system is electrically activated.

We developed a controlled, detachable coil system that uses laser energy rather than electricity. Unlike the GDC, which requires several minutes for detachment of the coil from the wire, the laser system allows detachment in 1 to 2 seconds. We describe our experience with the laser-activated detachable coil system (US patent number 5 108 407; April 28, 1992) as tested in experimentally created aneurysms.

Methods

Adult mongrel dogs weighing 20 to 30 kg were anesthetized with sodium pentobarbital (Nembutal, 30 mg/kg IV), intubated endotracheally, and antiseptically prepped over the ventrolateral portion of the neck. The surgical procedure and handling of these dogs complied with guidelines established by our hospital's Institutional Animal Care and Use Committee. A 5- to 7-cm longitudinal incision was made in the neck between the common carotid artery and jugular vein; aneurysms were created in the carotid arteries using a modification of the technique described by German and Black (6) and by Geremia et al (7). The aneurysmal pouch, formed from a jugular vein segment, measured 1.5 × 0.6 cm, with an arteriotomy length of 0.5 cm.

The laser-coil units we used consisted of laser probes (Trimadyne, Santa Ana, Calif), heat-sensitive glue (Bostik, Middleton, Mass), and endovascular coils (Cook, Bloomington, Ind, and Target Therapeutics). Laser-coil units of different sizes were made. Laser probes with quartz fibers covered with silica and measuring 300 μm and 116 μm were used with coils of similar diameters. The larger coils (up to 0.038 inch) were produced by Cook, and the smaller coils (0.016 inch) by Target Therapeutics.

A metal tip was mechanically crimped onto the distal end of a laser fiber and served as the point of attachment for the coil, with the glue providing the bond (Fig 1). The glue is heat-sensitive and has a softening range of 75°C to 92°C. A thin film of heated glue was applied to the distal tip of the brass fitting. Immediately after the glue was applied, the coil was affixed to the tip, creating an adhesive bond that achieves about 50% of its strength after 1 minute, 75% after 1 hour, and 100% after 24 hours (Fig 2). We allowed the bond to seal for at least 24 hours. The bare coils were made of stainless steal or platinum. The laser probe and coil were united until the laser was activated and heated the metal tip, which subsequently melted the glue bond. Dissociation of the coil from the laser probe occurs when the probe is withdrawn simultaneously with laser activation (Fig 3).

Selective arteriography of the carotid arteries was performed via the transfemoral approach. An introducer catheter was placed near the aneurysmal orifice; the size of these catheters varied depending on the diameter of the laser coil selected for use in embolization. The coil was advanced beyond the distal open end of the catheter for placement into the aneurysmal pouch. If coil placement was suboptimal (eg, in the carotid artery lumen), it was withdrawn. The introducer catheter, laser-coil unit, or both could be repositioned. This maneuver could be performed several times until the coil was situated in the desired location (ie, in the aneurysmal pouch without extension into the carotid lumen). When the coil was in optimal position, the laser was activated. Three watts of power for 2 seconds was required for detachment of the coil from the laser probe. The laser beam heated the metal tip, which melted the glue bond, thereby separating the coil from the probe. Argon or Nd:YAG lasers were used as energy sources (Fig 4).

Results

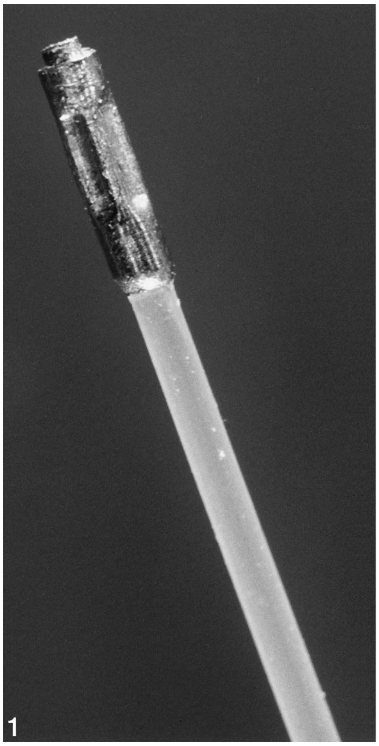
Nine of 10 aneurysms were embolized successfully. In one case, a coil prematurely detached during excessive torquing of the laser probe while the coil was engaged in the carotid artery; the remaining coils were successfully deployed without premature detachment. The specimens were removed 1 month after insertion of the coils. Gross pathologic examination of the specimens showed the coils to be embedded within fibrous reactive tissue; micropatho-

Received December 2, 1996; accepted after revision March 20, 1997.

The authors and their institution have entered into an exclusive licensing agreement with Trimadyne, Inc (Irvine, Calif) for a United States patent for the device described herein.

From the Departments of Diagnostic Radiology (G.G.) and Animal Research (M.H.), Rush-Presbyterian-St. Luke's Medical Center, Chicago, Ill.

Address reprint requests to Glen Geremia, MD, Rush-Presbyterian-St. Luke's Medical Center, 1653 W Congress Pkwy, Chicago, IL 60612.



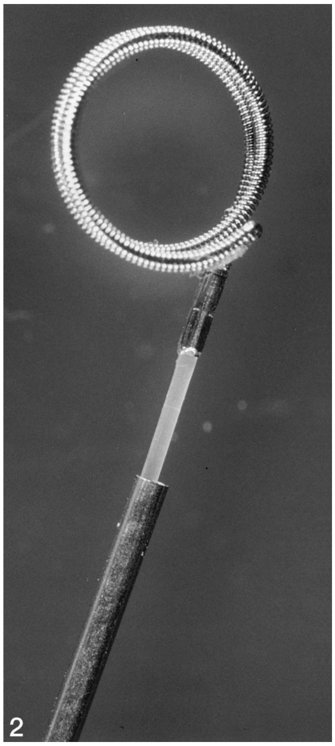


FIG 1. Laser probe. The laser fiber is produced by Trimadyne, Inc. The probe measures 300 μm in diameter. The distal tip of the probe was milled in our institution's machine shop. A brass tip (3 mm in length $\times$ 0.6 mm in diameter) was crimped onto the distal end of the probe. The distal portion of the tip measures 0.2 mm in length $\times$ 0.3 mm in diameter.

Fig 2. An assembled device with the stainless steel coil (0.033 inch) attached to the distal tip of the probe. The coil was affixed to the

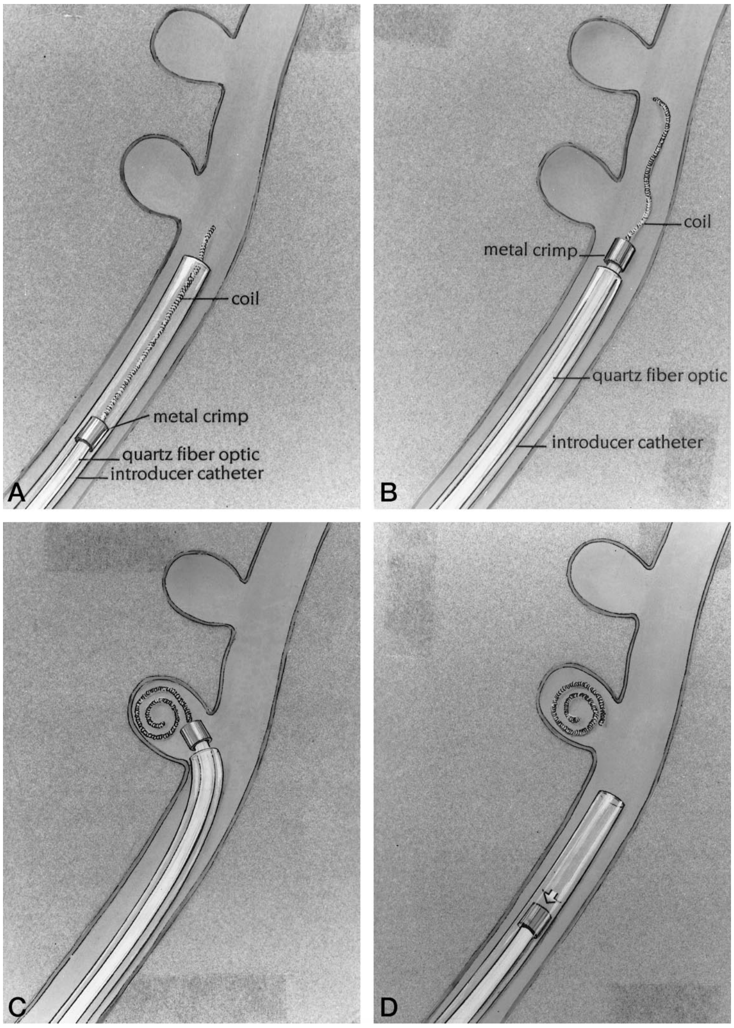


FIG 3. *A*, The laser coil device lies within the catheter. *B*, The coil extends into the carotid artery rather than lying within the aneurysm such that the coil would need to be partially withdrawn and repositioned. *C* and *D*, The coil is optimally placed within the aneurysm and the laser is activated, requiring about 3 W of power for approximately 2 seconds. The laser light heats the metal tip, which melts the glue bond, thus separating the coil from the laser probe. The probe is withdrawn.

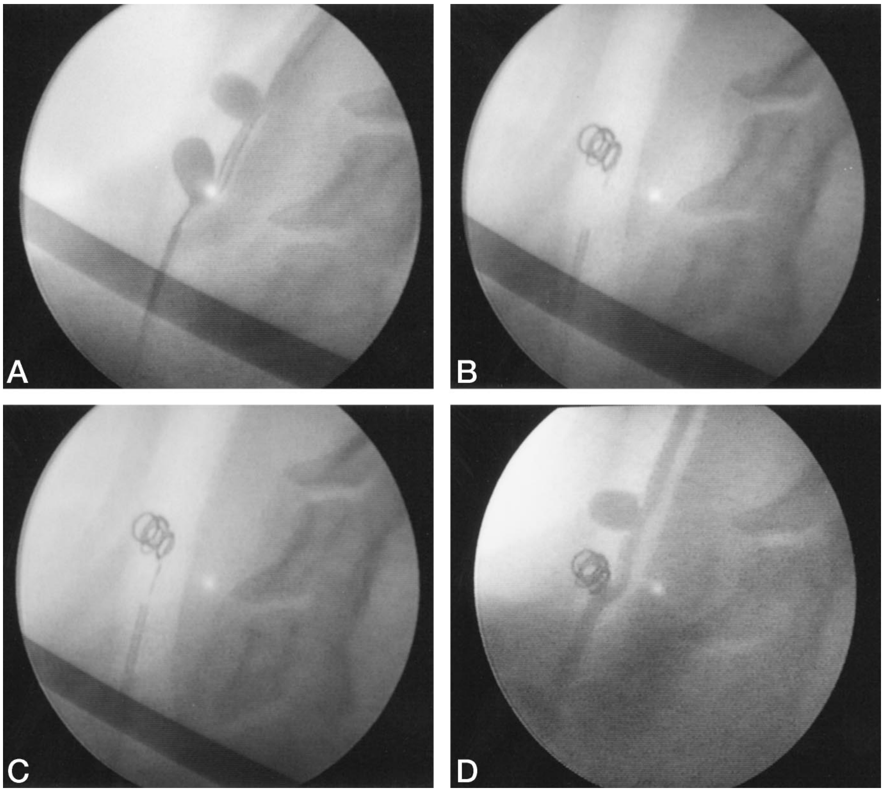


FIG 4. *A*, Arteriogram shows two saccular aneurysms extending off the carotid artery.
B, Prior to its detachment, the fifth coil is optimally positioned within the neck of the proximal carotid artery aneurysm.
C, The tip of the laser device is withdrawn after activation of the laser and separation of the coil.
D, Follow-up arteriogram shows the coils within the aneurysmal lumina. The last coil is optimally placed within the neck of the aneurysm without extension into the native carotid artery.

logic examination showed spindle-sheath fibroblasts within the lumina of the aneurysms (Fig 5).

Discussion

With traditional coil systems, the coil, once deployed, cannot be retrieved; thus, inadvertent placement is possible, which can have disastrous consequences. The GDC design uses an electrolytic process to dissolve a noninsulated portion of stainless steel core wire, with subsequent separation of the coil from the pusher wire in 4 to 12 minutes (5). The time for detachment increases as more coils are placed. The electric charge at the time of current application purportedly attracts negatively charged blood particles, causing electrothrombosis; but it is unclear how much of the observed thrombosis is the result of electrothrombosis or vascular stasis from packing of coils into a vascular space. It has been observed that aneurysmal thrombosis progresses after detachment with this coil system (8).

Recent reports describe mechanically detachable designs for coil systems, but these are neither widely available nor approved for use in this country (9). Although the mechanical system may be simpler, it does not allow retraction of the coil once it has been advanced completely beyond the tip of the catheter; however, this system has been shown to work well for aneurysms created in rabbits (9).

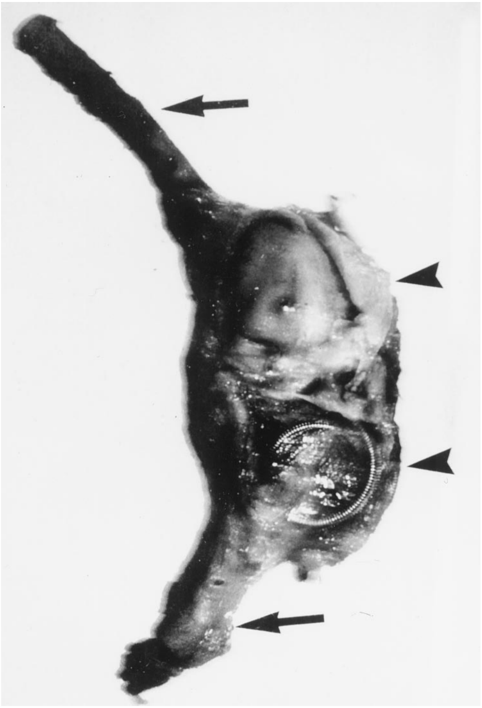


FIG 5. Gross specimen of a segment of a carotid artery including two aneurysms. The lateral wall of the more proximal aneurysm has been resected to observe the coil encased by granulation tissue and embedded within the aneurysm.

Laser catheter systems were also used in the treatment of rabbits to occlude 12 experimentally created berry aneurysms ranging in size from 4 × 3 mm to 8 × 6 mm, with patency of the adjacent arteries preserved (10). A small steel cap on the end of a laser fiber probe was fluoroscopically positioned within the aneurysm. The laser energy heated the metallic cap and caused a thermal tissue reaction within the aneurysm, which resulted in its eventual occlusion; the aneurysm and its contents contracted and firmly adhered to the steel cap. Once the aneurysmal occlusion had been established angiographically, the steel cap was detached from the laser fiber probe and left within the occluded aneurysm. A temperature-sensitive adhesive at the fiber tip softened at high temperatures, allowing detachment of the steel cap from the laser probe after laser activation. This system relies on laser-induced thermal energy to achieve thrombosis within the aneurysmal lumina. In contrast, our device requires coil deposition to promote thrombus formation and relies on laser energy for detachment of the coil.

Conclusion

A laser-activated detachable coil device was successfully used to embolize experimentally created aneurysms in mongrel dogs. The advantage of this system over current technology is the opportunity to detach the coil almost immediately after activation of the laser. Further experimentation and refinements in design are necessary before clinical trials in humans can be considered.

References

1. Debrun G, Lacour P, Caron JP, Hurth M, Comoy J, Keravel Y. **Inflatable and released balloon technique experimentation in dogs: application in man.** *Neuroradiology* 1975;9:267–271
2. Hieshima GB, Grinnel VS, Mehringer CM. **Detachable balloon for therapeutic transcatheter occlusions.** *Radiology* 1981;138:227
3. Lasjaunias P, Berenstein A. **Detachable balloons.** In: *Surgical Neuroangiography.* Berlin, Germany: Springer; 1987:13–17
4. Servinenko FA. **Balloon catheterization and occlusion of major cerebral vessels.** *J Neuroradiol* 1974;41:125–145
5. Guglielmi G, Vinuela F, Dion J, Duckwiler G. **Electrothrombosis of saccular aneurysms via endovascular approach, II: preliminary clinical experience.** *J Neurosurg* 1991;75:8–14
6. German WJ, Black SP. **Experimental production of carotid aneurysms.** *N Engl J Med* 1954;250:104–106
7. Geremia GK, Hoile RD, Haklin MF, Charletta DA. **Balloon embolization of experimentally created aneurysms: an animal training model.** *AJNR Am J Neuroradiol* 1990;11:659–662
8. Guglielmi G, Vinuela F, Dion J, Duckwiler G. **Electrothrombosis of saccular aneurysms via endovascular approach, I: electrochemical basis, technique, experimental results.** *J Neurosurg* 1991;75:1–7
9. 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
10. O'Reilly G, Forrest M, Schoene W, Clarke R. **Laser induced thermal occlusion of berry aneurysms: initial experimental results.** *Radiology* 1989;171:471–474