

Combined Use of Cellulose Acetate Polymer and Retrievable Platinum Coils for the Thrombosis of Cervical Carotid Aneurysms

Nobuyuki HIROTSUNE^{a*}, Kazushi KINUGASA^b, Shinya MANDAI^c, Koji TOKUNAGA^a, Akira HANDA^a, Sanami KAWADA^a and Takashi OHMOTO^a

^aDepartment of Neurological Surgery, Okayama University Medical School, Okayama 700-8558, Japan, ^bOkayama Rehabilitation Center for Traumatic Apallics, Okayama 700-0927, Japan and ^cDepartment of Neurological Surgery, Kagawa Prefectural Central Hospital, Kagawa 760-0017, Japan

Cellulose acetate polymer (CAP) solution is a new liquid embolic material, and it has been used clinically for the thrombosis of cerebral aneurysms. The purpose of the study was to test a method of aneurysm treatment. In an experimental model, retrievable interlocking detachable coils (IDCs) were used to create an intraaneurysmal frame or prop and then CAP was injected into 20 experimentally induced canine cervical aneurysms. Intraaneurysmal thrombosis was induced 1 week after aneurysm creation. Complete thrombosis was attempted in 12 aneurysms, and partial thrombosis was attempted in 4. Four other aneurysms served as controls. Follow-up angiography was performed for up to 8 weeks, and with the exception of 4 aneurysms, which were kept for a 2-year long-term follow-up study, the aneurysms were then harvested for histological examination. Thrombosis was successfully achieved in all cases except for 2 enlarged aneurysms that were initially partially thrombosed. No thromboembolism to distal vessels was observed. No compaction or shift of the CAP-IDC complex occurred even after 2 years. Histologically, CAP and IDCs conformed to the massive thrombotic complex without any fragmentation. By creating a frame or prop with retrievable microcoils, we were able to inject the CAP implies a comparison safely and precisely than has been previously reported. Our findings suggest that this method will be useful for the treatment of cerebral aneurysms.

Key words: experimentally induced aneurysm, cellulose acetate polymer (CAP), interlocking detachable coil (IDC),

endovascular technique

Endovascular procedures have gradually become an accepted alternative treatment for intracranial aneurysms. Recent developments in materials and techniques have improved the clinical efficacy and results obtained with such procedures. Mandai *et al.* have developed a new liquid embolic material, cellulose acetate polymer (CAP) solution (1), and Kinugasa *et al.* have used this material clinically to induce thrombosis in ruptured aneurysms in the acute stage (2-7). CAP solidifies and conforms to the contours of irregularly shaped aneurysms without increasing intraaneurysmal pressure, moreover, it does not induce compaction (1). However, caution is required as regards the possible distal migration of the material in the case of wide-necked aneurysms or where there is incomplete flow control (8, 9). If a frame or prop is initially created in an aneurysm, even a small number of retrievable microcoils can be used to block inflow into the aneurysm, and the liquid material can then be injected safely and precisely.

For the present study, we used interlocking detachable coils (IDC) that measured 0.015 inches in diameter (Target Therapeutics, San Jose, CA, USA). Such coils were the only available retrievable coils in Japan at the time the present study was performed. In this study, we evaluated the adjustability and efficacy of the combined use of CAP and IDCs. A long-term follow-up study was also conducted. The technical devices used in this method are described below.

* To whom correspondence should be addressed.

Materials and Methods

Twenty adult mongrel dogs, weighing 8 to 12 kg each, were used for this study. The dogs were anesthetized with intramuscular injections of ketamine HCl (15 mg/kg) and sodium pentobarbital (25 mg/kg) before the procedure was initiated. Further doses of pentobarbital were administered as necessary. Each surgical procedure was performed under sterile conditions. The dogs were not systemically heparinized. Experimental bifurcation or terminal aneurysms were created in the right common carotid artery using a microsurgical technique described by Forrest *et al.* (10) and Graves *et al.* (11). There were 12 bifurcation aneurysms and 8 terminal aneurysms. The experimental protocol was conducted according to the Guidelines of the Ethics Review Committee for Animal Experimentation of Okayama University Medical School.

Aneurysm Creation. An 8-cm midline incision was made in the dog's neck to expose the right and left common carotid arteries, and a 2-cm segment of the right external jugular vein was isolated and excised. This segment was cut to the appropriate configuration and placed in heparinized saline at room temperature. For the bifurcation aneurysms (Fig. 1A), the left common carotid artery was ligated at the proximal end of the exposure and divided. An edge of the vessel was cut from the medial

corner. A 6 to 7 mm-long elliptical arteriostomy was performed in the right carotid artery, and the left carotid artery was lifted over the trachea. A partial end-to-side anastomosis of the left carotid artery to the arteriostomy was performed using 8-0 nylon sutures, and the vein segment was then sutured to the arteriostomy. The free end of the vein segment was ligated with 3-0 silk thread. For the terminal aneurysms (Fig. 1B), the left common carotid artery was ligated proximally and divided. The right common carotid artery was clamped at the proximal and distal ends, and was divided 2-cm proximal to the distal clamp. An end-to-end anastomosis was created between the distal segments of the left and right carotid arteries, which resulted in the formation of a U-shaped tube. A 5-mm circular opening on both the superior and inferior surfaces at the base of the U-shaped left carotid artery was made. The proximal right common carotid artery was anastomosed end-to-side at the undersurface of the U-shaped left carotid artery, and a 2-cm segment of the excised jugular vein was anastomosed end-to-side on its superior surface with 8-10 sutures. The distal free end of the vein was ligated with 3-0 silk thread. The vascular clamps were then removed.

Thrombosis of Aneurysms. The composition of our thrombotic material, CAP solution, has been described in previous reports (1, 2). It is a mixture of

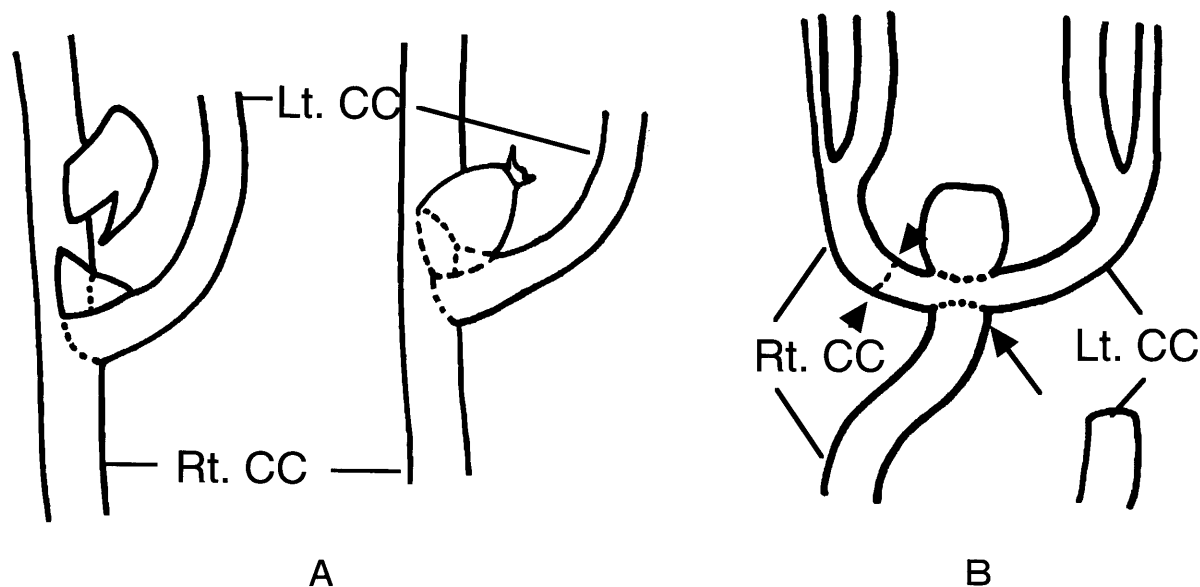


Fig. 1 Schemas of creating aneurysms. **A**, bifurcation model; **B**, terminal model. Rt. CC, right common carotid artery; Lt. CC, left common carotid artery. Arrowheads, end-to-end anastomosis of the right and left common carotid arteries; Arrow, end-to-side anastomosis of the right common carotid artery to the left common carotid artery.

250 mg cellulose acetate polymer, 3 ml dimethyl sulfoxide (DMSO) and 900 mg bismuth trioxide; the latter is used as a contrast medium.

One week after aneurysm creation, aneurysm patency was confirmed before treatment. CAP and IDCs were used for the direct thrombosis of each aneurysm, which was performed in 16 dogs. The remaining 4 dogs served as controls. A 6-French (Fr) double lumen balloon occlusion catheter was positioned in the right common carotid artery as a guiding catheter via the transfemoral route. A 4-Fr diagnostic catheter was also positioned into the right carotid artery. An angiogram was obtained before CAP thrombosis. The size of the aneurysm was measured in order to select a suitable coil size. In this experiment, we selected coils that were almost the same size as the width of the central portion of the aneurysm. To allow for accurate measurements that were also corrected for magnification, radiopaque concentric sizing balls 11 mm diameter were affixed to the front and back sides of the neck, the aneurysm was used to locate the middle point of the 2 balls. The average size of aneurysm was measured for scale. Flow control of the parent artery was attained by inflation of the occlusion balloon, if necessary. A Tracker-18 microcatheter (Target Therapeutics, San Jose, CA, USA) was introduced through the guiding

catheter, and the tip of the microcatheter was precisely positioned into the center of the aneurysmal lumen. IDCs were placed in the aneurysmal sac in order to form an intraaneurysmal frame or prop and to reduce inflow into the distal portion of the aneurysm (Fig. 2A and B). IDCs were inserted until we could confirm on angiography the stagnation of the contrast medium in the aneurysmal lumen. After the microcatheter was rinsed with a minimal amount of DMSO, CAP was slowly injected at the distal part of the aneurysmal dome via the same catheter under fluoroscopic visualization (Fig. 2C). The CAP solution solidified totally within a few minutes; however, the fraction that came into contact with blood solidified immediately. Angiography was repeated from the diagnostic catheter to determine whether or not further thrombosis was required. When thrombosis was no longer required, the microcatheter was withdrawn. In 12 cases, CAP was injected until nearly 100% thrombosis was obtained. Partial thrombosis (60-80%) was intentionally performed in 4 other cases.

Follow-up and Histological Examination.

Follow-up angiography was performed for all aneurysms immediately after thrombosis, and at time intervals of 1, 2, 4, and 8 weeks. Twelve of the 16 dogs were sacrificed 8 weeks after thrombosis. Aneurysms were harvested

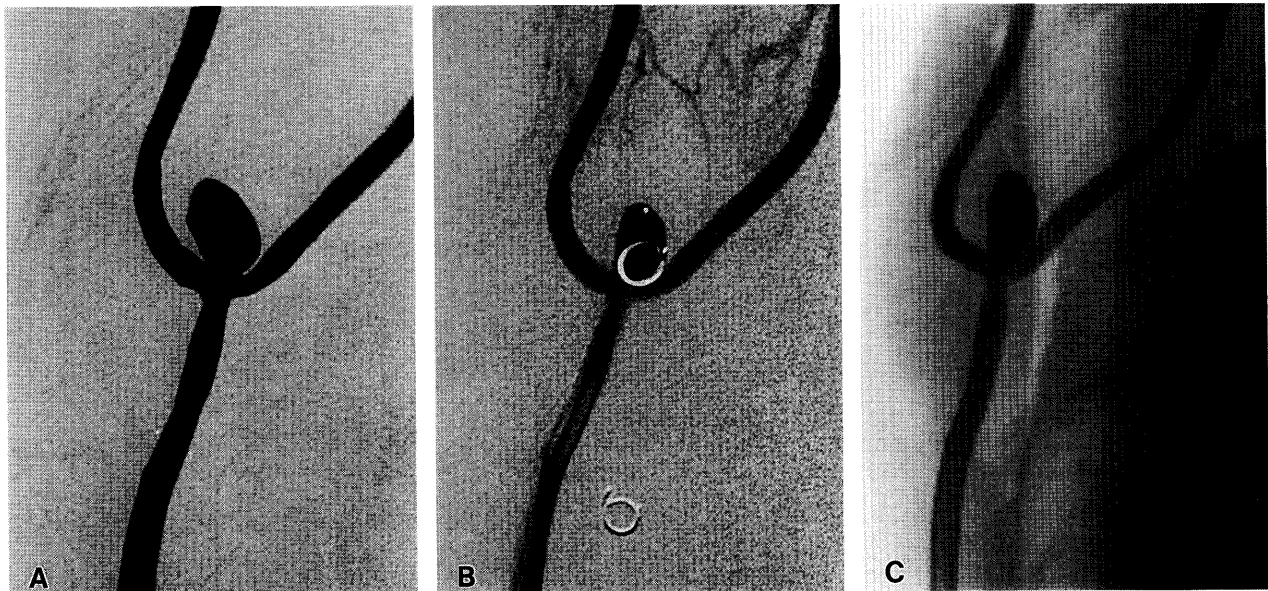


Fig. 2 Dog no. 11. **A**, right carotid angiogram obtained 1 week after aneurysm creation showing the terminal aneurysm patent; **B**, angiogram showing interlocking detachable coils (IDCs) positioned in the aneurysmal sac to block inflow into the distal portion of the aneurysm; **C**, angiogram of cellulose acetate polymer (CAP) injection under fluoroscopic visualization.

with their parent arteries for the histological observation. For the long-term follow-up of 4 cases, angiography was performed 2 years after thrombosis. The remaining 4 aneurysms were then harvested.

All harvested aneurysms, with their parent arteries, were fixed in a 10% solution of phosphate-buffered formaldehyde. After gross examination, aneurysms were resected near the neck portion. For the CAP-IDC complex specimens, sections were dehydrated and embedded in epoxy resin (methylmethacrylate). Transverse or axial sections 75 to 100 μm in thickness were obtained with a low-speed diamond saw. For the histological examination of the vasculature under light microscopy, parent arteries with the aneurysmal neck were sliced in longitudinal sections and stained with hematoxyline-eosin (HE) and factor VIII-related antigen.

Results

Angiography. Twenty aneurysms were successfully created, and the patency of these aneurysms was confirmed by carotid artery angiography 1 week later.

Angiographic results are summarized in Tables 1, 2 and 3. There were no complications in any of the cases, *i.e.*, there were no cases of aneurysm rupture, parent artery occlusion, or migration of CAP to the distal arteries.

All 4 control aneurysms exhibited slight ballooning or enlargement without spontaneous thrombosis.

Immediately after CAP thrombosis, 8 of 12 aneurysms in the group that underwent almost complete thrombosis had thrombosed nearly 100% by volume. The other 4 aneurysms had thrombosis of more than 90% by volume (Fig. 3A). In the latter 4 aneurysms, angiograms 1 week following thrombosis demonstrated

Table 1 Angiographic results depicting almost completely thrombosed aneurysms

Dog No.	Size of aneurysm (width \times length) (mm)	Used coils ¹⁾ (mm)	Volume of thrombosed		Angiographical results					Compaction
			CAP (ml)	Aneurysmal volume (%)	1 wk	2 wks	4 wks	8 wks	2 yrs	
1	6 \times 10	6 \times 100	0.25	> 90	100	→	→	→	→	(-)
2	6 \times 13	6 \times 100	0.31	> 90	100	→	→	→		(-)
3	8 \times 15	8 \times 150	0.68	> 90	100	→	→	→		(-)
4*	7 \times 11	7 \times 100	0.38	> 90	100	→	→	→	→	(-)
5	6 \times 8	6 \times 100	0.23	100	→	→	→	→		(-)
6	6 \times 10	6 \times 100	0.28	100	→	→	→	→		(-)
7	7 \times 13	7 \times 150	0.50	100	→	→	→	→		(-)
8	8 \times 15	8 \times 200	0.72	100	→	→	→	→	→	(-)
9*	6 \times 9	6 \times 100	0.26	100	→	→	→	→		(-)
10*	7 \times 10	7 \times 100	0.39	100	→	→	→	→		(-)
11*	8 \times 12	8 \times 200	0.60	100	→	→	→	→		(-)
12*	8 \times 15	8 \times 200	0.74	100	→	→	→	→	→	(-)

¹⁾, diameter of the primary coil helix \times total length of coils; *, terminal model; →, identical to the previous angiogram. CAP, cellulose acetate polymer.

Table 2 Angiographic results depicting partially thrombosed aneurysms

Dog No.	Size of aneurysm (width \times length) (mm)	Used coils ¹⁾ (mm)	Volume of thrombosed		Angiographical results				Compaction
			CAP (ml)	Aneurysmal volume (%)	1 wk	2 wks	4 wks	8 wks	
13	8 \times 13	8 \times 100	0.25	80	90	→	→	→	(-)
14*	6 \times 12	6 \times 100	0.31	80	→	→	→	→	(-)
15	8 \times 15	8 \times 150	0.68	70	SE	→	→	→	(-)
16	8 \times 14	8 \times 150	0.38	60	ME	→	→	→	(-)

¹⁾, diameter of the primary coil helix \times total length of coils; *, terminal model; →, identical to the previous angiogram; SE, slight enlargement; ME, moderate enlargement; CAP, cellulose acetate polymer.

nearly 100% thrombosis (Fig. 3B). Subsequently, the configuration of all aneurysms and CAP-IDC complexes exhibited no change until the animal was sacrificed. The angiographical results for terminal aneurysms did not differ significantly from those for bifurcation aneurysms (Fig. 4A and 4B). Angiograms of the 4 aneurysms maintained for 2 years following the after thrombotic procedure showed that the aneurysms had been completely eliminated from the parent artery circulation. They also revealed no recanalization of aneurysms, no parent artery stenosis (Figs. 3C and 4C), and no compaction of the CAP-IDC complex (Fig. 4D).

In the partial thrombosis group, the shapes of the remnant aneurysmal cavities were comparatively syringe-

like; there were no crescent-shaped crevices between the CAP-IDC complex and the aneurysmal sacs. Slight and moderate aneurysmal remnant ballooning was demonstrated in 2 cases within 1 week. In addition, a slightly enlarged aneurysm remained the same size until the last angiography, but without a shift in the position of the CAP-IDC complex (Fig. 5). The other 2 aneurysms did not enlarge. In one of the latter cases, the size of the remnant was slightly decreased 1 week following thrombosis (Fig. 6).

Histological results. Twelve of the 16 aneurysms were harvested with their parent arteries 8 weeks after thrombosis. The gross study revealed that CAP and IDC conformed to the massive complex without fragmen-

Table 3 Angiographic results depicting controls

Dog No.	Size of aneurysm (width × length) (mm)	Used coils (mm)	Volume of thrombosed		Angiographical results			
			CAP (ml)	Aneurysmal volume (%)	1 wk	2 wks	4 wks	8 wks
17	6 × 9	0	0	0	SE	→	→	→
18	8 × 10	0	0	0	SE	→	→	ME
19*	7 × 13	0	0	0	SE	→	→	→
20*	7 × 14	0	0	0	SE	ME	→	→

*, terminal model; →, identical to the previous angiogram; SE, slight enlargement; ME, moderate enlargement. CAP, cellulose acetate polymer.

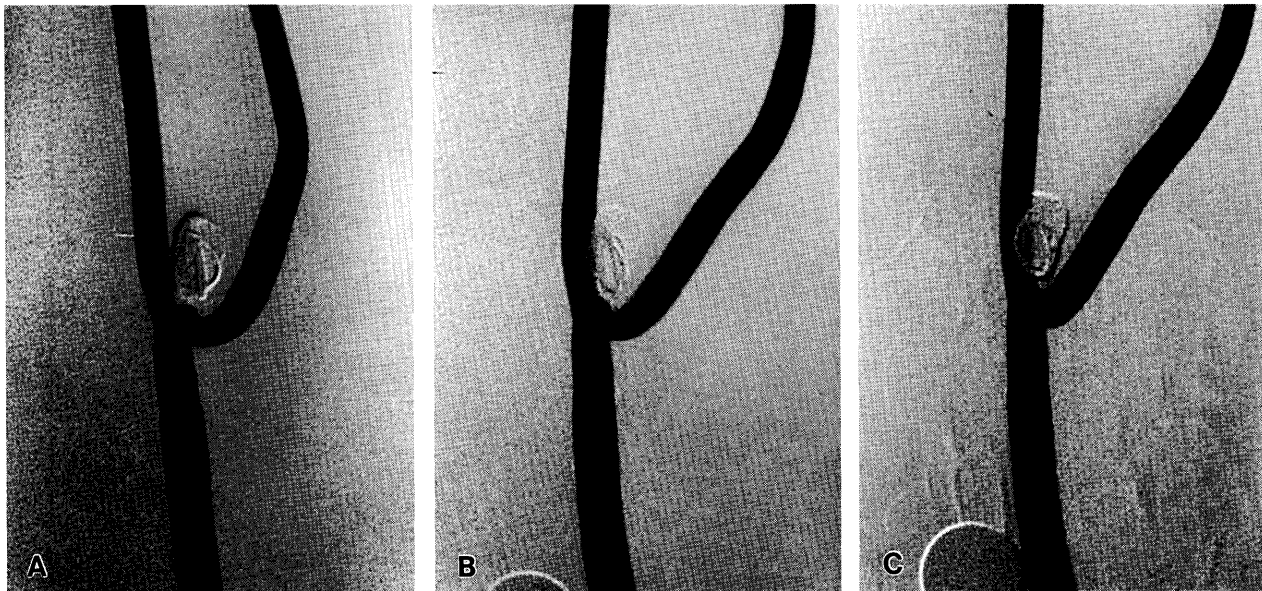


Fig. 3 Dog no. 1. **A**, immediate postthrombotic angiogram showing more than 90% thrombosis of the bifurcation aneurysm; **B**, angiogram 1 week after thrombosis, demonstrating nearly 100% thrombosis of the aneurysm; **C**, two-year follow-up angiogram demonstrating that the aneurysm was eliminated from the parent artery circulation.

tation, and new fibrous intima covered the luminal surfaces of the aneurysmal orifices (Fig. 7). On staining for factor VIII-related antigen, it was found that newly formed endothelial cells covered the aneurysmal orifice, and were smoothly continuous with those of the parent artery. These results are in good agreement with those of Sugiu *et al.* No inflammatory histological reaction was demon-

strated in the vessels. For 2 of the 4 partially thrombosed aneurysms (Nos. 13 and 14) the same findings as above were observed; however, the other 2 partially thrombosed aneurysms (Nos. 15 and 16) revealed clots between the aneurysmal lumen and the CAP-IDC complex, as was previously observed (13).

The 4 long-term follow-up aneurysms were entirely

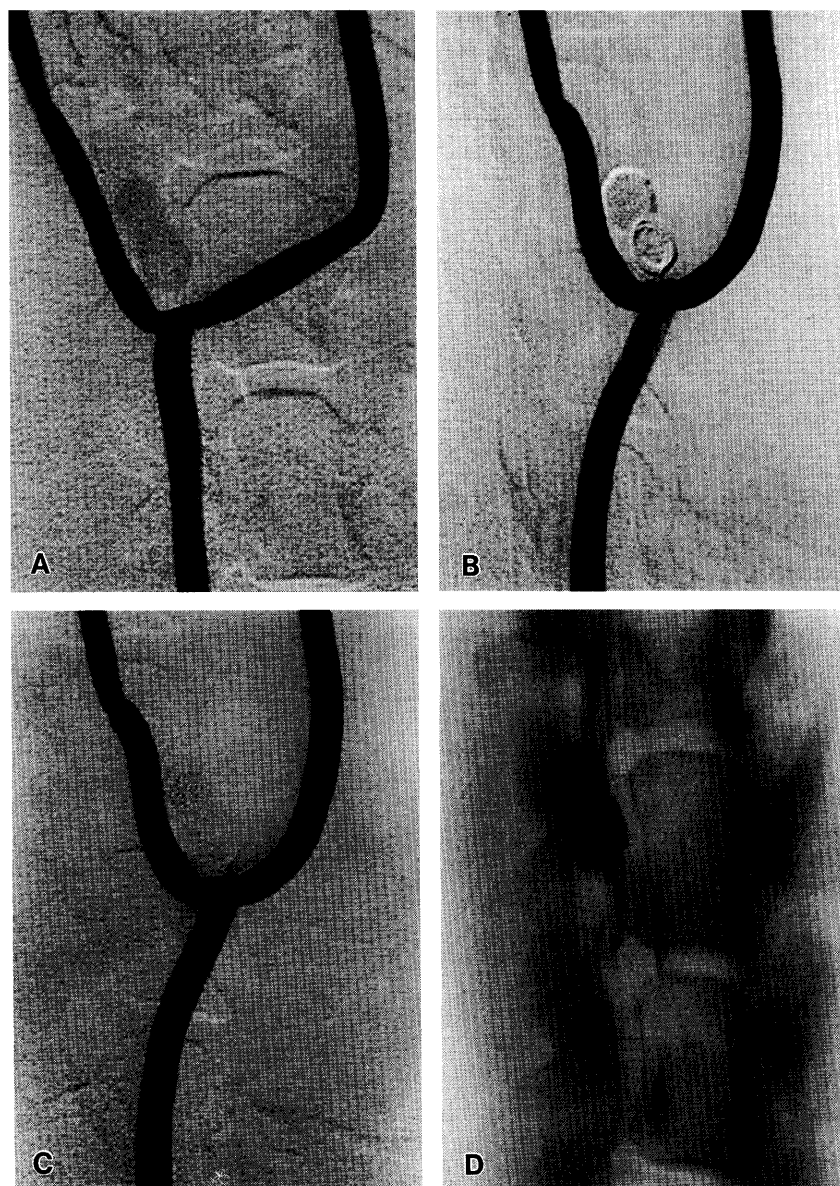


Fig. 4 Dog no. 12. **A**, angiogram immediately after thrombosis revealing nearly 100% thrombosis of the terminal aneurysm; **B**, angiogram obtained 8 weeks after thrombosis disclosing findings similar to (A); **C**, two-year follow-up angiogram revealing no recanalization of the aneurysm; **D**, X-ray photograph of CAP and IDC mass exhibiting no change in configuration. CAP; IDC, see legend to Fig. 2.

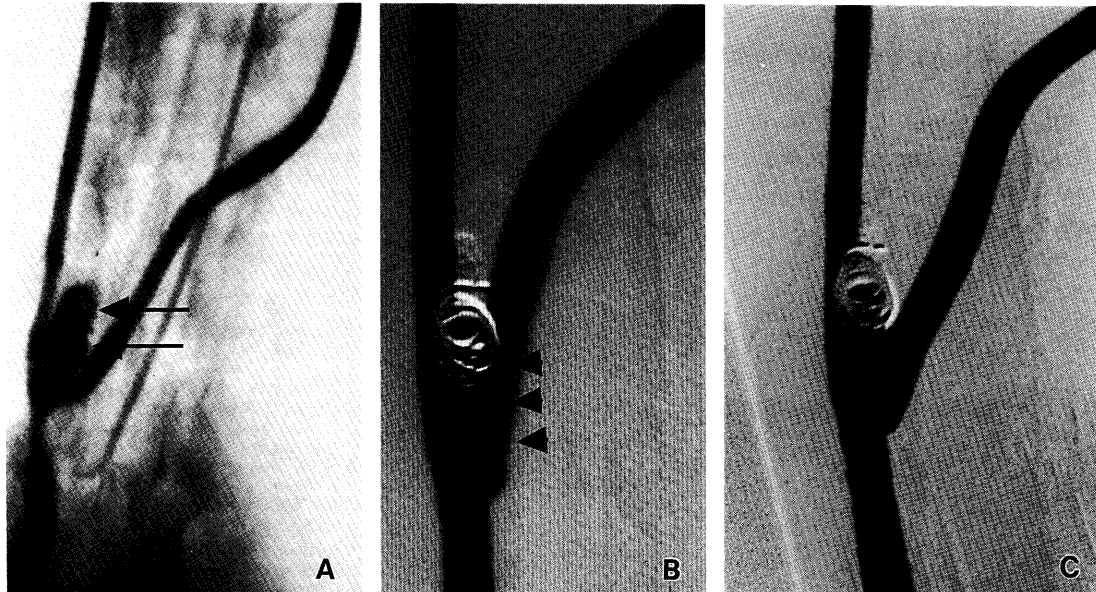


Fig. 5 Dog no. 16. **A**, immediate postocclusion angiogram showing 60% thrombosis of the aneurysm (arrows) without apparent crescent crevice; **B**, one week after thrombosis, angiogram disclosing the remnant space enlarged (arrowheads) without a shift of the CAP and IDC mass; **C**, angiogram 8 weeks after thrombosis is almost identical to that observed at 1 week. CAP; IDC, see legend to Fig. 2.

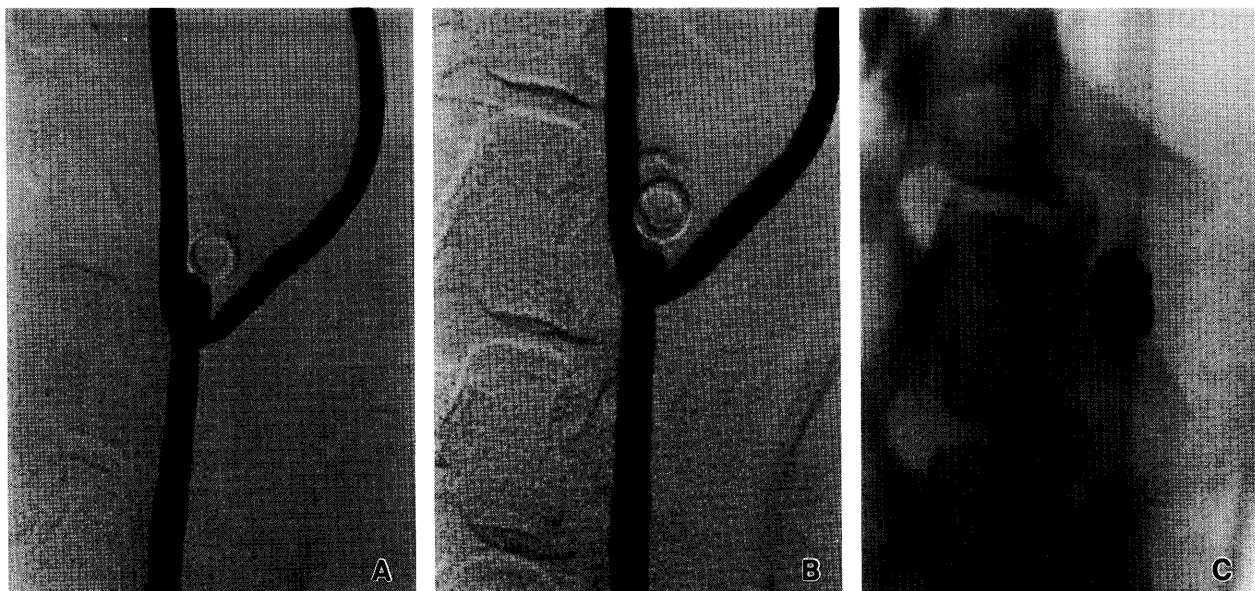


Fig. 6 Dog no. 13. **A**, angiogram immediately after thrombosis revealing almost 80% thrombosis; **B**, angiogram obtained 1 week after thrombosis demonstrating that the size of the remnant had slightly decreased; **C**, X-ray photograph of CAP and IDC mass exhibiting no change in configuration. CAP; IDC, see legend to Fig. 2.

excluded from the parent artery circulation. A thick layer containing collagen fibers and elastic fibers had developed between the CAP-IDC complex and the parent artery (Fig. 8). All aneurysms studied were completely filled with CAP and IDCs. There was, in particular, no space between the aneurysmal wall and the CAP-IDC complex; furthermore, CAP and IDC exhibited good compatibility (Fig. 9).



Fig. 7 Dog no. 10. Photograph of the sectioned specimen harvested 8 weeks after thrombosis, showing fibrous intima covering the luminal surface of the aneurysmal orifice (arrow).

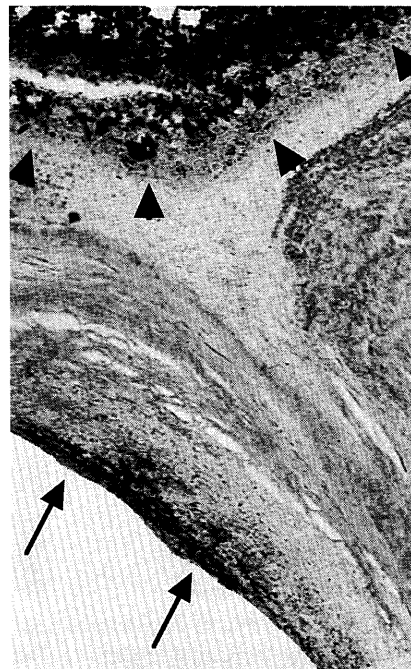


Fig. 8 Dog no. 4. Photomicrograph of the aneurysm with the parent arteries harvested 2 years after thrombosis and sectioned transversely; this section is similar to that designated by the arrow in Fig. 7. These findings demonstrate that the CAP-IDC complex (arrowheads) is covered with newly developed membrane containing endothelial cells on the surface (arrows), and collagen-like fibers and elastic fibers produced in the membrane (Factor VIII-related antigen stain; original magnification, $\times 200$). CAP; IDC, see legend to Fig. 2.

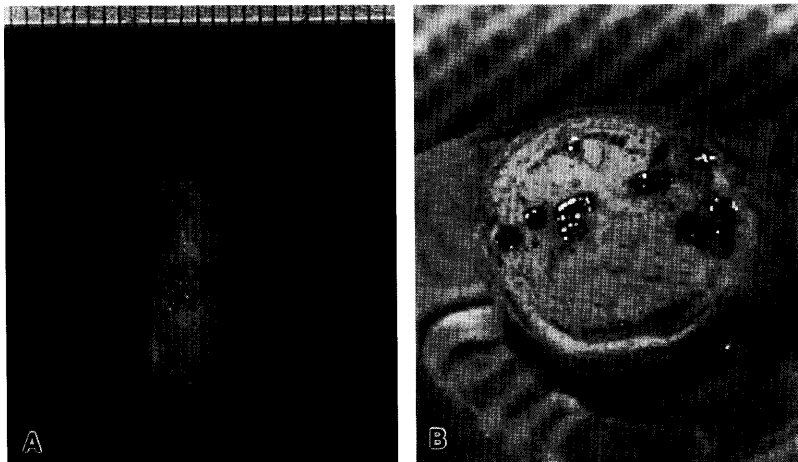


Fig. 9 Dog no. 2. **A**, photograph showing that the CAP and IDC conformed to a massive complex without any fragmentation; **B**, photograph of the axial section of the CAP-IDC complex embedded in epoxy resin (methylmethacrylate), demonstrating no space had developed between the aneurysmal wall and the CAP-IDC complex. CAP; IDC, see legend to Fig. 2.

Discussion

Endovascular surgery for intracranial aneurysms has gradually become an accepted alternative method of treatment, and recent developments in materials and techniques have improved the clinical results of such procedures. The selection of appropriate aneurysms for endovascular treatment appears to be one of the most important factors for the clinical outcome (14). Decisions concerning the best techniques or types of devices for treatment should be based on an understanding of each feature of the respective device.

Technical aspects. The technical aspects of combined use of CAP and IDC are presented briefly. For the coil stabilization, it is crucial to choose the most suitable coil size by measuring aneurysmal width. This technique requires that the chosen size is not associated pressure on the aneurysmal wall. The total length of the coils is necessary in order to reduce the stress of inflow on the aneurysmal lumen. If too many coils are required, it should be noted that the remaining aneurysmal lumen will be difficult to visualize with fluoroscopy. Before CAP injection, flow hemodynamics should be carefully confirmed by angiography with a guiding catheter or by aneurysmography with a microcatheter; furthermore, such procedures should be performed without increasing the intraaneurysmal pressure. Since CAP is slightly influenced by gravity, the apex of the aneurysm should be positioned downward, if possible. Aneurysms should be embolized with CAP, which forms a plane surface at the aneurysmal orifice without a crescent crevice remnant. If a crescent crevice does remain, further embolization should be attempted with CAP or coils (13). Cognard *et al.* (15) found that many berry aneurysms considered to be subtotally occluded at the end of the procedure were completely occluded a few months later, with delayed thrombosis of the neck remnant. Nevertheless, it remains unknown which of these remnants will result in subsequent thrombosis, regrowth, or rupture. In our study, we observed that the smaller remnants of aneurysms tended to attain delayed thrombosis.

In our recent clinical series, CAP thrombosis has resulted in a favorable clinical outcome. In particular, rebleeding from ruptured aneurysms was prevented. This method also allowed for the aggressive medical treatment of vasospasm with intrathecal tissue plasminogen activator administration and delayed surgery, if necessary (6, 7). However, this method does increase the potential risk,

namely, the distal migration of the CAP (2) and incomplete thrombosis from wide-necked aneurysms. In this study, we used retrievable IDCs in order to create an intraaneurysmal frame or prop and investigated the efficacy of the combined use of CAP and IDCs.

Embolic materials. The occlusive materials currently used in the endovascular treatment of aneurysms are balloons, coils, stents, and liquids.

Intraaneurysmal occlusion with detachable balloons is thought to be dangerous because of the prevalent geometric mismatch between the balloons and the aneurysmal wall. Some studies have shown that regrowth and rupture occur in a shorter period after procedures that involve the incomplete balloon occlusion of aneurysms (16). Use of the balloon technique has thus recently been limited (17, 18).

Coil embolization is an evolving method, and several microcoils have become available for clinical use (19–22). In particular, the Guglielmi detachable coil (GDC) has traditionally been used for intraaneurysmal occlusions. The risk of aneurysm rupture has been lower with the use of the GDC; hence, many clinical studies have supported the usefulness of the GDC for the endovascular occlusion of aneurysms (23–25). However, coils alone are rarely able to entirely fill an aneurysm cavity. Additional thrombus formation is required for the complete occlusion of the aneurysm. Preliminary studies have shown that a densely packed and completely treated aneurysm contains up to 40 % coil by volume (26). Spetzger *et al.* (27) found incomplete obliteration of all aneurysms on histopathological examination of 17 embolized experimentally induced aneurysms with the use of GDC or mechanically detachable coils. Endothelialization and intimal proliferation across the aneurysmal neck and the coils were not found in that study. Similar findings were observed in 2 human autopsy cases that exhibited no endothelialization across the GDC-embolized aneurysm neck (28). In experimental models, the thrombogenicity of the platinum coils was not sufficient to completely achieve complete thrombosis of aneurysms; moreover, poorly packed aneurysms have demonstrated a higher rate of recanalization and coil mass remodeling (20, 29). Although the dense packing of aneurysms improves the treatment results, the major disadvantage of coil embolization is probably coil compaction and recanalization of aneurysms. Uda *et al.* (30) reported finding recanalization in 5 of 14 acutely treated aneurysms due to coil compaction within 13 months of embolization. Even if complete occlusion was obtained,

recanalization was much more likely with large or giant aneurysms and also with wide-necked lesions (31, 32). A different coil system and new surface materials are therefore considered necessary for the successful endovascular treatment of human cerebral aneurysms with coils. In experimental models, collagen-filled coils, ion implantation and protein coating devices, laser-activated coil devices, and growth factor binding coils have all been shown to stimulate histological reactions such as local fibroblast proliferation and collagen production (29, 33-37).

The use of a stent or stents with coils has been reported by several authors in clinical and experimental series (38-41). Stent placement may not be possible for aneurysms that lie at the bifurcation of a vessel; however, stents can be used in the treatment of laterally projecting aneurysms in the carotid or vertebral arteries (42-44).

Mandai *et al.* developed a new liquid embolic material, cellulose acetate polymer solution, for the thrombosis of aneurysms (1); Kinugasa *et al.* used this liquid in a clinical series (2-7). Cellulose acetate polymer can be used to fill the irregularly-shaped aneurysm cavity entirely and it does not raise intraaneurysmal pressure (1). Histological analysis proved that newly formed endothelial cells and intimal fibrous proliferation covered the aneurysmal orifice within 2 weeks after CAP thrombosis in case of experimental aneurysms (12). If the embolic materials are covered by endothelial cells in the early stage of recovery, it might be possible to avoid embolic complications and regrowth of the aneurysm. An appropriate liquid embolic material would have to fulfill the following conditions, namely, that it has 1) an adjustive viscosity, 2) causes minimum chemical reactions with the aneurysmal wall, and 3) does not induce a change in volume. CAP satisfies all 3 of these conditions (1, 2, 12).

There remains a risk associated with the use of liquid material for the thrombosis of aneurysms. Distal migration or protrusion of the material can occur. Thrombosis induced by CAP alone is risky under conditions of insufficient flow control or in the case of a wide-necked aneurysm. To avoid such complications, several techniques and systems such as flow controls and protective balloons are used (45-47). If we inflate a neck plastic balloon during CAP injection, it is possible to fill the neck portion of the aneurysm more completely with CAP. In such cases, precautions should be taken to avoid thromboembolic phenomena and distal ischemic events. Szikora and associates (8) used protective stent implantations and

thereby prevented the distal migration of liquid polymer. Despite favorable results, stents are not always recommended for use because of their limited flexibility and also because of the complex anatomy of cerebral arterial bifurcation aneurysms and their tortuous parent arteries, as mentioned above. In this study, in order to inject CAP into aneurysms more safely and precisely, we used retrievable microcoils to create an intraaneurysmal frame or prop in cases of canine bifurcation and terminal aneurysms. We demonstrated the usefulness of the combined use of CAP and IDCs. Since GDCs have approximately the same components as IDCs, the combined use of CAP and GDCs can be useful in the treatment of aneurysms.

Teng and colleagues (48) treated 6 carotid aneurysms with an N-butyl-2-cyanoacrylate (NBCA) mixture injection for embolization after the placement of detachable balloons and/or microcoils. NBCA mixture is difficult to use for aneurysmal embolization because of its adhesive character and resolvability, which causes recanalization. The CAP-IDC complex revealed no change in the size of the aneurysms that were followed for 2 years.

In summary, the adaptability of the CAP-IDC complex appeared to be quite favorable, and it was not associated with compaction or recanalization. By creating a frame or prop in an aneurysm with retrievable microcoils, we could inject CAP more safely and precisely. The combined use of CAP and retrievable microcoils will provide a useful new technique in the endovascular treatment of cerebral aneurysms.

Acknowledgments. The authors wish to express their gratitude to Mr. Hideki Wakimoto for his help in preparing this manuscript.

References

1. Mandai S, Kinugasa K and Ohmoto T: Direct thrombosis of aneurysms with cellulose acetate polymer. Part I: Results of thrombosis in experimental aneurysms. *J Neurosurg* (1992) **77**, 497-500.
2. Kinugasa K, Mandai S, Terai Y, Kamata I, Sugiu K, Ohmoto T and Nishimoto A: Direct thrombosis of aneurysms with cellulose acetate polymer. Part II: Preliminary clinical experience. *J Neurosurg* (1992) **77**, 501-507.
3. Kinugasa K, Mandai S, Date I and Ohmoto T: Direct thrombosis of aneurysms. *J Neurosurg* (1993) **78**, 1007-1008. (Letter)
4. Kinugasa K, Mandai S, Tsuchida S, Sugiu K, Kamata I, Tokunaga K, Ohmoto T and Taguchi K: Cellulose acetate polymer thrombosis for the emergency treatment of aneurysms: Angiographic findings, clinical experience, and histopathological study. *Neurosurgery* (1994) **34**, 694-701.
5. Kinugasa K, Mandai S, Tsuchida S, Kamata I and Ohmoto T: Direct thrombosis of a pseudoaneurysm after obliteration of a carotid-cavernous fistula with cellulose acetate polymer: Technical case

- report. *Neurosurgery* (1994) **35**, 755-760.
6. Kinugasa K, Kamata I, Hirotsune N, Tokunaga K, Sugiu K, Handa A, Nakashima H, Ohmoto T, Mandai S and Matsumoto Y: Early treatment of subarachnoid hemorrhage after preventing rerupture of an aneurysm. *J Neurosurg* (1995) **83**, 34-41.
 7. Kinugasa K, Mandai S, Kamata I, Tokunaga K, Sugiu K, Handa A, Nakashima H and Ohmoto T: Prophylactic thrombosis to prevent new bleeding and to delay aneurysm surgery. *Neurosurgery* (1995) **36**, 661-667.
 8. Szikora I, Guterman LR, Standard SC, Wakhloo AK and Hopkins LN: Endovascular treatment of experimental aneurysms with liquid polymers: The protective potential of stents. *Neurosurgery* (1996) **38**, 339-347.
 9. Macdonald RL, Mojtahedi S, Johns L and Kowalczyk A: Randomized comparison of Guglielmi detachable coils and cellulose acetate polymer for treatment of aneurysms in dogs. *Stroke* (1998) **29**, 478-486.
 10. Forrest MD and O'Reilly GV: Production of experimental aneurysms at a surgically created arterial bifurcation. *AJNR Am J Neuroradiol* (1989) **10**, 400-402.
 11. Graves VB, Ahuja A, Strother CM and Rappe AH: Canine model of terminal arterial aneurysm. *AJNR Am J Neuroradiol* (1993) **14**, 801-803.
 12. Sugiu K, Kinugasa K, Mandai S, Tokunaga K and Ohmoto T: Direct thrombosis of experimental aneurysms with cellulose acetate polymer (CAP): Technical aspects, angiographic follow up, and histological study. *J Neurosurg* (1995) **83**, 531-538.
 13. Tokunaga K, Kinugasa K, Mandai S, Handa A, Hirotsune N and Ohmoto T: Partial thrombosis of canine carotid bifurcation aneurysms with cellulose acetate polymer. *Neurosurgery* (1998) **42**, 1135-1144.
 14. Bryan RN, Rigamonti D and Mathis JM: The treatment of acutely ruptured cerebral aneurysms: Endovascular therapy versus surgery. *AJNR Am J Neuroradiol* (1997) **18**, 1826-1830.
 15. Cognard C, Weill A, Castaing L, Ray A and Moret J: Intracranial berry aneurysms: Angiographic and clinical results after endovascular treatment. *Radiology* (1998) **206**, 499-510.
 16. Higashida RT, Halbach VV, Barnwell SL, Dowd C, Dormandy B, Bell J and Hieshima GB: 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.
 17. Fox AJ, Viñuela F, Pelz DM, Peerless SJ, Ferguson GG, Drake CG and Debrun G: Use of detachable balloons for proximal artery occlusion in the treatment of unclippable cerebral aneurysms. *J Neurosurg* (1987) **66**, 40-46.
 18. Higashida RT, Halbach VV, Dowd C, Barnwell SL, Dormandy B, Bell J and Hieshima GB: Endovascular detachable balloon embolization therapy of cavernous carotid artery aneurysms: Results in 87 cases. *J Neurosurg* (1990) **72**, 857-863.
 19. Guglielmi G, Viñuela F, Sepetka I and Macellari V: Electrothrombosis of saccular aneurysms via endovascular approach. Part I: Electrochemical basis, technique, and experimental results. *J Neurosurg* (1991) **75**, 1-7.
 20. Marks MP, Chee H, Liddell RP, Steinberg GK, Panahian N and Lane B: A mechanically detachable coil for the treatment of aneurysms and occlusion of blood vessels. *AJNR Am J Neuroradiol* (1994) **15**, 821-827.
 21. Byrne JV, Hope JK, Hubbard N and Morris JH: The nature of thrombosis induced by platinum and tungsten coils in saccular aneurysms. *AJNR Am J Neuroradiol* (1997) **18**, 29-33.
 22. Graves VB, Perl J, Lind, Strother CM, Wallace RC, Kesava PP and Masaryk TJ: Endovascular occlusion of the carotid or vertebral artery with temporary proximal flow arrest and microcoils: Clinical results. *AJNR Am J Neuroradiol* (1997) **18**, 1201-1206.
 23. Guglielmi G, Viñuela F, Dion J and Duckwiler G: Electrothrombosis of saccular aneurysms via endovascular approach. Part 2: Preliminary clinical experience. *J Neurosurg* (1991) **75**, 8-14.
 24. Viñuela F, Duckwiler G and Mawad M: Guglielmi detachable coil embolization of acute intracranial aneurysm: Perioperative anatomical and clinical outcome in 403 patients. *J Neurosurg* (1997) **86**, 475-482.
 25. Raymond J and Roy D: Safety and efficacy of endovascular treatment of acutely ruptured aneurysms. *Neurosurgery* (1997) **41**, 1235-1246.
 26. Halbach VV: The "current" status of aneurysm treatment? *AJNR Am J Neuroradiol* (1993) **14**, 799-800.
 27. Spetzger U, Reul J, Weis J, Bertalanffy H, Thron A and Gilsbach JM: Microsurgically produced bifurcation aneurysms in a rabbit model for endovascular coil embolization. *J Neurosurg* (1996) **85**, 488-495.
 28. Molyneux AJ, Ellison DW, Morris J and Byrne JV: Histological findings in giant aneurysms treated with Guglielmi detachable coils: Report of two cases with autopsy correlation. *J Neurosurg* (1995) **83**, 129-132.
 29. Szikora I, Wakhloo AK, Guterman LR, Chavis TD, Dawson RC IIIrd, Hergenrother RW, Twyford RH and Hopkins LN: Initial experience with collagen-filled Guglielmi detachable coils for endovascular treatment of experimental aneurysms. *AJNR Am J Neuroradiol* (1997) **18**, 667-672.
 30. Uda K, Goto K, Ogata N, Izumi N, Nagata S and Matsuno H: Embolization of cerebral aneurysms using Guglielmi detachable coils. Problems and treatment plans in the acute stage after subarachnoid hemorrhage and long-term efficiency. *Neurol Med Chir (Tokyo)* (1998) **38**, 143-154.
 31. Fernandez Zubillaga A, Guglielmi G, Viñuela F and Duckwiler GR: Endovascular occlusion of intracranial aneurysms with electrically detachable coils: Correlation of aneurysm neck size and treatment results. *AJNR Am J Neuroradiol* (1994) **15**, 815-820.
 32. Richling B, Gruber A, Bavinski G and Killer M: GDC-system embolization for brain aneurysms: Location and follow-up. *Acta Neurochir* (1995) **134**, 177-183.
 33. Dawson RC IIIrd, Shengelaia GG, Krisht AF and Bonner GD: Histologic effects of collagen-filled interlocking detachable coils in the ablation of experimental aneurysms in swine. *AJNR Am J Neuroradiol* (1996) **17**, 853-858.
 34. Murayama Y, Viñuela F, Suzuki Y, Do HM, Massoud TF, Guglielmi G, Ji C, Iwaki M, Kusakabe M, Kamio M and Abe T: Ion implantation and protein coating of detachable coils for endovascular treatment of cerebral aneurysms: Concepts and preliminary results in swine models. *Neurosurgery* (1997) **40**, 1233-1244.
 35. Geremia G and Haklin M: Embolization of experimentally created aneurysms with a laser-activated detachable coil device. *AJNR Am J Neuroradiol* (1998) **19**, 566-569.
 36. Kallmes DF, Williams AD, Cloft HJ, Lopes MB, Hankins GR and Helm GA: Platinum coil-mediated implantation of growth factor-secreting endovascular tissue grafts: An in vivo study. *Radiology* (1998) **207**, 519-523.
 37. Kallmes DF, Hankins GR, Borland MK, Cloft HJ, Jensen ME, Dion JE and Helm GA: Transforming growth factor-beta binds reversibly in vitro to Guglielmi detachable coils. *Intervent Neuroradiol* (1998) **4**, 21-26.
 38. Higashida RT, Smith W, Gress D, Urwin R, Dowd CF, Balousek PA and Halbach VV: Intravascular stent and endovascular coil placement for a ruptured fusiform aneurysm of the basilar artery: Case report and review of the literature. *J Neurosurg* (1997) **87**, 944-949.
 39. Geremia G, Haklin M and Brennecke L: Embolization of experimentally created aneurysms with intravascular stent devices. *AJNR Am J Neuroradiol* (1994) **15**, 1223-1231.
 40. Szikora I, Guterman LR, Wells KM and Hopkins LN: Combined use of

- stents and coils to treat experimental wide-necked carotid aneurysms: Preliminary results. *AJNR Am J Neuroradiol* (1994) **15**, 1091-1102.
41. Turjman F, Massoud TF, Ji C, Guglielmi G, Viñuela F and Robert J: Combined stent implantation and endosaccular coil placement for treatment of experimental wide-necked aneurysms: A feasibility study in swine. *AJNR Am J Neuroradiol* (1994) **15**, 1087-1090.
 42. Wakhloo AK, Lanzino G, Lieber BB and Hopkins LN: Stents for intracranial aneurysms: The beginning of a new endovascular era? *Neurosurgery* (1998) **43**, 377-379.
 43. Klein GE, Szolar DH, Raith J, Fruhwirth H, Pascher O and Hausegger KA: Posttraumatic extracranial aneurysm of the internal carotid artery: Combined endovascular treatment with coils and stents. *AJNR Am J Neuroradiol* (1997) **18**, 1261-1264.
 44. Sekhon LH, Morgan MK, Sorby W and Grinnell V: Combined endovascular stent implantation and endosaccular coil placement for the treatment of a wide-necked vertebral artery aneurysm: Technical case report. *Neurosurgery* (1998) **43**, 380-384.
 45. Moret J, Cognard C, Weill A, Castaing L and Rey A: The "remodeling technique" in the treatment of wide neck intracranial aneurysms: Angiographic results and clinical follow-up in 56 cases. *Interven Neuroradiol* (1997) **3**, 21-35.
 46. Mericle RA, Wakhloo AK, Rodriguez R, Guterman LR and Hopkins LN: Temporary balloon protection as an adjunct to endosaccular coiling of wide-necked cerebral aneurysms: Technical note. *Neurosurgery* (1997) **41**, 975-978.
 47. Levy DI and Ku A: Balloon-assisted coil placement in wide-necked aneurysms: Technical note. *J Neurosurg* (1997) **86**, 724-727.
 48. Teng MM, Chen CC, Lirng JF, Chen SS, Lee LS and Chang T: N-butyl-2-cyanoacrylate for embolisation of carotid aneurysm. *Neuroradiology* (1994) **36**, 144-147.
-
- Received October 6, 1998; accepted March 6, 2000.