Endovascular Treatment of Paraclinoid Aneurysms: Experience with 73 Patients

Hae Kwan Park, M.D.
Department of Neurosurgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, and Department of Neurosurgery, St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea

Michael Horowitz, M.D.
Departments of Neurosurgery and Radiology, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

Charles Jungreis, M.D.
Departments of Neurosurgery and Radiology, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

Amin Kassam, M.D.
Department of Neurosurgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

Chris Koebbe, M.D.
Department of Neurosurgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

Julie Genevro, R.N.
Department of Neurosurgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

Kim Dutton, R.N.
Department of Radiology, University of Texas Southwestern Medical Center at Dallas, Dallas, Texas

Phil Purdy, M.D.
Departments of Radiology and Neurosurgery, University of Texas Southwestern Medical Center at Dallas, Dallas, Texas

Reprint requests:
Michael Horowitz, M.D., Department of Neurosurgery, University of Pittsburgh Medical Center, 200 Lothrop Street, Suite B400, Pittsburgh, PA 15213-2582.
Email: horowitzmb@msx.upmc.edu

Received, November 1, 2002.
Accepted, March 11, 2003.

OBJECTIVE: Aneurysms arising from the internal carotid artery in close relation to the clinoid process have been called paraclinoid aneurysms. The surgical management of these aneurysms poses technical challenges, and such patients are frequently referred for endovascular treatment. We reviewed our experience with endovascular coil embolization of paraclinoid aneurysms to evaluate the safety and efficacy of this treatment modality.

METHODS: From December 1993 to May 2002, 70 patients underwent endovascular procedures with detachable coils for 73 paraclinoid aneurysms (8 ruptured, 65 unruptured) at the University of Pittsburgh Medical Center and the University of Texas Southwestern Medical Center. A retrospective review of the medical records, outpatient charts, and operative reports was performed. Angiographic outcome was determined at the end of each procedure and by review of follow-up angiograms. Clinical assessments and outcomes are reported according to the Glasgow Outcome Scale (GOS).

RESULTS: Immediate angiographic outcomes for 73 paraclinoid aneurysms demonstrated complete occlusion in 53 (72.6%), near-complete occlusion in 6 (8.2%), and partial occlusion in 14 (19.2%). Nine aneurysms required more than one coiling session to complete treatment; 8 of these aneurysms required two sessions and 1 required four, for a total of 84 endovascular procedures. Follow-up angiograms could be obtained in 49 patients with 52 paraclinoid aneurysms. During the follow-up period, 6 aneurysms demonstrating partial occlusion and 3 demonstrating near-complete occlusion showed spontaneous progression of thrombosis to complete occlusion. Twelve aneurysms initially demonstrating complete occlusion (5 aneurysms), near-complete occlusion (3 aneurysms), or partial occlusion (4 aneurysms) showed coil compaction requiring retreatment. Of these 12 aneurysms that demonstrated coil compaction, 3 were treated with surgery and 9 with coil repacking. The final angiographic outcomes, determined on the last available follow-up angiograms of 49 aneurysms, excluding 3 surgically clipped aneurysms, showed complete occlusion in 43 (87.8%), near-complete occlusion in 3 (6.1%), and partial occlusion in 3 (6.1%). The angiographic follow-up period ranged from 4 to 54 months (mean, 13.9 mo). Morbidity and mortality rates related to 84 endovascular procedures were 8.3 and 0%, respectively. There were no recurrent or new subarachnoid hemorrhages in 63 patients in whom clinical follow-up could be performed during a mean clinical follow-up period of 14.4 months. The final clinical outcomes demonstrated a GOS score of 5 (good recovery) in 56 patients (88.9%), a GOS score of 4 (moderate disability) in 2 (3.2%), and a GOS score of 3 (severe disability) in 1 (1.6%). Four patients (6.3%) died of unrelated causes. The average period of hospitalization was 17.8 days in patients with acutely ruptured aneurysms and 3.5 days in patients with unruptured or retreated aneurysms.

CONCLUSION: The results of this study indicate that endovascular treatment is a safe and effective therapeutic alternative in ruptured and unruptured paraclinoid aneurysms. The endovascular treatment may also confer a positive impact in terms of the length of hospital stay.

KEY WORDS: Aneurysm, Endovascular, Paraclinoid

Neurosurgery 53:14-24, 2003 DOI: 10.1227/01.NEU.0000068789.08955.1C www.neurosurgery-online.com

Aneurysms arising from the internal carotid artery (ICA) in proximity to the anterior clinoid process have been given various names. Many authors designate such aneurysms arising between the roof of the cavernous sinus and the origin of the posterior communicating artery as paraclinoid aneurysms (3, 6, 30).

The treatment of paraclinoid aneurysms is often more difficult than that of other anterior circulation lesions. Direct surgical treatment has been associated with an unusually high morbidity and mortality because such aneurysms often pose conceptual and technical problems with regard to acquisition of proximal control and safe intracranial exposure (17, 26, 27, 34, 40, 54). Moreover, these aneurysms are often large, posing additional difficulty in their surgical treatment (4, 30, 37). During the past 20 years, advances in microneurosurgical techniques and increasing anatomic knowledge have facilitated surgical approaches and greatly improved surgical outcomes with paraclinoid aneurysms (12, 19, 21, 27, 30, 39, 58, 61, 62). Nevertheless, successful treatment of paraclinoid aneurysms presents a continued neurosurgical challenge (4, 6, 12, 15, 16, 30, 43).

As the use of endovascular therapy for cerebral aneurysms has grown over the past few years, paraclinoid aneurysms are frequently referred for endovascular treatment (28, 31, 53, 59). In this study, we report our experience with endovascular embolization of paraclinoid aneurysms using detachable platinum coils.

PATIENTS AND METHODS

This study included aneurysms arising from the ICA between the roof of the cavernous sinus and the origin of the posterior communicating artery. Aneurysms arising from the distal cavernous ICA and projecting into the extracavernous intradural subarachnoid space were also included. All of these aneurysms were defined for our purposes as paraclinoid aneurysms.

Patient Population

From December 1993 to May 2002, 70 patients with 73 paraclinoid aneurysms (8 ruptured, 65 unruptured) were managed by endovascular embolization using electrolytically detachable platinum coils at the University of Pittsburgh Medical Center and the University of Texas Southwestern Medical Center. A retrospective review of the medical records, radiographic studies, and endovascular procedure reports was performed.

Clinical Analysis

Initial patient clinical status was assessed by use of the Hunt and Hess scale (35). To assess clinical outcome, the Glasgow Outcome Scale (GOS) score was recorded at discharge and at follow-up (*Table 1*) (36). Procedure-related morbidity was defined as a neurological deficit lasting more than 7 days that was attributable to the coil embolization procedure. If a death proved to be unrelated to the embolization procedure itself, the patient's clinical status was listed as an unrelated death.

Endovascular Technique

More than 95% of all procedures were performed with the patients under general anesthesia and with 3000 to 5000 U of systemic heparinization, including those procedures that were performed to treat recently ruptured aneurysms. Heparin was continued at 500 U/h for 12 to 18 hours after the procedure or was reversed at the end of the procedure with protamine sulfate, according to the surgeon's preference.

Usually, a 6-French Envoy guiding catheter (Cordis Endovascular, Miami Lakes, FL) and RapidTransit microcatheter (Cordis) were used for these procedures, although FasTracker 10 and 18 systems (Boston Scientific/Target, Fremont, CA), Prowler 10 and 18 systems (Cordis), and Jetstream 10 and 18 systems (MicroInterventional Systems, Sunnyvale, CA) were used occasionally.

TABLE 1. Clinical outcome: Glasgow Outcome Scale[a]

Score	Definition	Description
5	Good recovery	Resumption of normal activities even though there may be minor neurological or psychological deficits
4	Moderate disability (disabled but independent)	Patient is independent as far as daily life is concerned; the disabilities found include varying degrees of dysphasia, hemiparesis, or ataxia, as well as intellectual and memory deficits and personality changes
3	Severe disability (conscious but disabled)	Patient depends on others for daily support because of mental or physical disability or both
2	Vegetative survival	Patient exhibits no obvious cortical function
1	Dead	

[a] From, Jennett B, Bond M: Assessment of outcome after severe brain damage: A practical scale. **Lancet** 1:480–484, 1975 (36).

The guidewires included the Seeker (Boston Scientific/Target), QuickSilver (MicroInterventional Systems), and GlideWire (Terumo Co., Tokyo, Japan), sized for the microcatheter. All coils used, including the "soft" and three-dimensional coils, were Guglielmi detachable coils (GDCs) (Boston Scientific/Target) and Microsphere three-dimensional coils (Micrus Co., Mountainview, CA). When the remodeling technique (46) was performed, the Endeavor (Boston Scientific/Target) and the Solstice (MicroInterventional Systems) angioplasty balloons were used.

All coils were introduced into the aneurysm by use of simultaneous biplane imaging with and without roadmapping, depending on the patient. Coiling proceeded until no additional coils could be placed within the aneurysm, angiographically complete obliteration was achieved, or risk of occlusion of a normal arterial branch adjacent to the aneurysm was imminent. In some patients, systemic heparinization was reversed with protamine sulfate immediately after the procedure, whereas in others with potential risk of thromboembolic complications (wide-neck aneurysms or coil herniation into a parent artery), systemic heparinization was prolonged for 24 hours. After emerging from general anesthesia, the patient was transferred to the neurological intensive care unit for observation.

Description of Aneurysms

Aneurysm Subtype

Aneurysms were grouped into five anatomic categories according to the classification provided by Al-Rodhan et al. (3) (*Fig. 1*). Aneurysms arising from the posteromedial aspect of the clinoid segment of the ICA proximal to the origin of the ophthalmic artery were classified as carotid cave aneurysms. Aneurysms arising with a clear relation to the origin of the ophthalmic artery from the ICA and growing superomedially were classified as ophthalmic aneurysms. Aneurysms arising on the superior aspect of the ICA distal to the origin of the ophthalmic artery and proximal to the origin of the posterior communicating artery were classified as superior hypophyseal aneurysms. Aneurysms arising from the ventral surface of the ICA opposite the ophthalmic artery origin and projecting downward were classified as ventral paraclinoid aneurysms. Aneurysms arising from the distal cavernous ICA and projecting superiorly into the intradural extracavernous subarachnoid space were classified as transitional aneurysms.

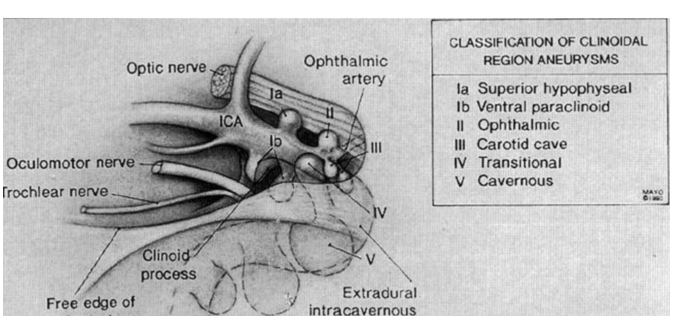

FIGURE 1. *Diagram of the proposed classification of paraclinoid aneurysms (from, Al-Rodhan NRF, Piepgras DG, Sundt TM Jr: Transitional cavernous aneurysms of the internal carotid artery.* ***Neurosurgery*** *33:993–998, 1993 [3]).*

Aneurysm Size

Aneurysm fundus and neck sizes were taken at the point of maximum width or length. Fundus sizes were considered small if they were up to 10 mm in size, large if 11 to 24 mm, and giant if 25 mm or greater. Neck size was considered narrow if 4 mm or less and wide if greater than 4 mm. Fundus-to-neck ratios were calculated and considered to be favorable if greater than 2 and unfavorable if 2 or less.

Embolization Evaluation

The degree of occlusion as determined by angiography was classified into three categories, as follows: complete occlusion when the sac and neck were densely packed in any projection, near-complete occlusion when the sac was occluded but there was suspicion of a neck remnant or there was an obvious small neck remnant less than 2 mm in size, and partial occlusion when there was loose packing and/or persistent opacification of the sac or neck remnant greater than 2 mm in size. Technical success was defined as the ability to superselectively catheterize and deploy more than one coil into the aneurysm.

Angiographic Follow-up

Follow-up angiograms were usually obtained 6 months and 1 year after embolization if complete or near-complete aneurysm occlusion was achieved. Patients with partial aneurysm occlusion had angiographic follow-up examinations 3 months after embolization. Additional follow-up angiography was performed in patients with a potential risk of coil compaction.

RESULTS

Patient Population

Seventy patients with 73 paraclinoid aneurysms were evaluated. Nine patients (13%) were men, and 61 patients (87%) were women. Patient ages ranged from 32 to 77 years (mean age, 53.6 yr). Reasons for selecting endovascular coil embolization as a therapeutic alternative were anticipated surgical difficulty or direct referral for embolization in 63 aneurysms, unsuccessful surgical clipping in 7 aneurysms, and poor neurological grade in 3 aneurysms.

Clinical Presentation

The clinical presentations of the patients are shown in *Table 2*. Eight patients (11.4%) presented with subarachnoid hemorrhage (SAH) from a ruptured paraclinoid aneurysm. These patients were treated during the acute phase after rupture. Among these patients, one was classified as Hunt and Hess Grade I, two as Grade II, two as Grade III, and three as Grade IV. Five patients (7.2%) presented with visual symptoms (vi-

TABLE 2. Clinical presentation of 70 patients with paraclinoid aneurysms

Clinical presentation	No. of patients (%)
Subarachnoid hemorrhage	8 (11.4%)
Visual symptom	5 (7.2%)
Incidental	57 (81.4%)

sual field defects) associated with aneurysm mass effect. Fifty-seven patients (81.4%) had incidental paraclinoid aneurysms. Among these 57 patients, 7 presented after attempted surgical clipping, 2 presented with an associated arteriovenous malformation, and 7 presented with an unrelated stroke.

Aneurysm Characteristics

Aneurysm Subtype

Aneurysms were classified into five anatomic subgroups. Seventeen aneurysms (23.3%) were carotid cave aneurysms, 18 (24.7%) were ophthalmic aneurysms, 26 (35.6%) were superior hypophyseal aneurysms, 10 (13.7%) were ventral paraclinoid aneurysms, and 2 (2.7%) were transitional aneurysms. Subtypes of ruptured and unruptured paraclinoid aneurysms are detailed in *Table 3*.

Aneurysm Size

Fundus sizes were small (≤10 mm) in 50 aneurysms (68.5%), large (11–24 mm) in 20 (27.4%), and giant (≥25 mm) in 3 (4.1%) (range, 3–28 mm). Fundus sizes of ruptured and unruptured paraclinoid aneurysms are described in *Table 4*. Fundus-to-neck ratios were favorable (>2) in 27 aneurysms (37%) and unfavorable (≤2) in 46 (63%) (*Table 5*). Forty-nine aneurysms (67.1%) had a narrow neck, and 24 (32.9%) had a wide neck (range, 1–8 mm).

TABLE 3. Subtype of ruptured and unruptured paraclinoid aneurysms

Subtype of aneurysm	No. of aneurysms		Total (%)
	Ruptured (n = 8)	Unruptured (n = 65)	
Carotid cave	1	16	17 (23.3)
Ophthalmic	2	16	18 (24.7)
Superior hypophyseal	4	22	26 (35.6)
Ventral paraclinoid	1	9	10 (13.7)
Transitional	0	2	2 (2.7)

TABLE 4. Fundus size of ruptured and unruptured paraclinoid aneurysms

Fundus size	No. of aneurysms		Total (%)
	Ruptured (n = 8)	Unruptured (n = 65)	
Small (≤10 mm)	3	47	50 (68.5%)
Large (11–24 mm)	3	17	20 (27.4%)
Giant (≥25 mm)	2	1	3 (4.1%)

Multiple Aneurysms

Twenty-four patients (34.3%) had multiple aneurysms. Two aneurysms were found in 18 patients each, three were found in 3 patients each, and four were found in 3 patients each. Nine of these patients had other aneurysms in a paraclinoid location.

Initial Degree of Occlusion

In 73 treated aneurysms, the immediate postprocedural angiogram showed complete occlusion in 53 aneurysms (72.6%) (40 of 50 small aneurysms, 12 of 20 large aneurysms, and 1 of 3 giant aneurysms), near-complete occlusion in 6 aneurysms (8.2%) (5 of 50 small aneurysms and 1 of 20 large aneurysms), and partial occlusion in 14 aneurysms (19.2%) (5 of 50 small aneurysms, 7 of 20 large aneurysms, and 2 of 3 giant aneurysms) (*Fig. 2*). There was no statistical difference in the initial occlusion rates according to the neck size ($P = 0.256$, χ^2 test) or the fundus-to-neck ratio ($P = 0.527$, χ^2 test) of the aneurysms.

Multiple and Ancillary Endovascular Procedures

Among 73 paraclinoid aneurysms managed with endovascular embolization, 9 required more than one session of endovascular treatment to complete treatment; 8 of these aneurysms required two sessions and 1 required four, for a total of 84 endovascular procedures, which included 16 procedures using the balloon remodeling technique.

Follow-up Degree of Occlusion

Follow-up cerebral angiograms could be obtained in 49 patients (70%) with 52 paraclinoid aneurysms. Follow-up angiograms could not be performed because of death from unrelated causes (3 patients), patient refusal (2 patients), old age/infirmity (3 patients), and loss to follow-up monitoring (7 patients). Six patients were waiting for their first follow-up angiography. Of these 21 patients whose follow-up angiograms were not available, the immediate postprocedural angiogram showed complete occlusion in 17 (81%) and partial occlusion in 4 (19%). Angiographic follow-up ranged from 4 to 54 months (mean, 13.9 mo). During the follow-up period, 6 aneurysms initially demonstrating partial occlusion and 3 aneurysms demonstrating near-complete occlusion showed

TABLE 5. Size and fundus-to-neck ratio of aneurysms

Fundus-to-neck ratio	Small (≤10 mm) (n = 50)	Large (11–24 mm) (n = 20)	Giant (≥25 mm) (n = 3)	Total (%)
Favorable (>2)	15	10	2	27 (37%)
Unfavorable (≤2)	35	10	1	46 (63%)

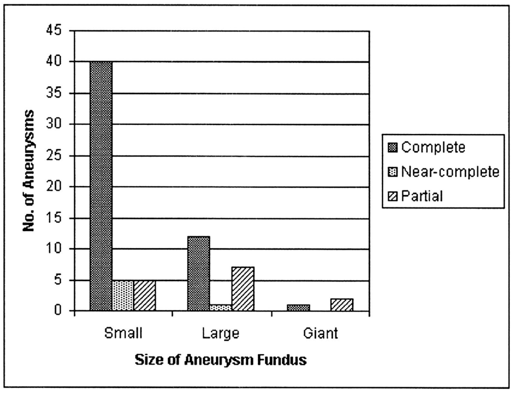

FIGURE 2. *Bar graph showing initial degree of occlusion based on aneurysm size. The number of aneurysms in each degree of occlusion immediately after embolization (n = 73) is shown.*

spontaneous progression to complete occlusion. Aneurysm recanalization attributable to coil compaction occurred in 12 aneurysms. Among these 12 aneurysms, 5 initially demonstrated complete occlusion, 3 demonstrated near-complete occlusion, and 4 demonstrated partial occlusion (*Table 6*). The initial size of these recanalized aneurysms was small in 6, large in 4, and giant in 2. Of these 12 aneurysms demonstrating coil compaction, 3 underwent surgical clipping, and the remaining 9 had repeated coiling. The final angiographic outcomes determined on the last available follow-up angiograms of 49 aneurysms, excluding 3 surgically clipped aneurysms, showed complete occlusion in 43 aneurysms (87.8%) (31 small, 10 large, and 2 giant), near-complete occlusion in 3 large aneurysms (6.1%), and partial occlusion in 3 aneurysms (6.1%) (2 small and 1 giant) (*Fig. 3*).

Procedural Complications

There were 10 immediate procedural complications (11.9%) among 84 procedures (*Table 7*). Eight of these occurred during initial embolization and 2 during reembolization. Two of 10 complications were associated with the remodeling technique. Two procedures (2.4%) were complicated by aneurysm rupture, once while the first coil was being positioned into a large

TABLE 6. Characteristics of aneurysms retreated (n = 12)

Aneurysm			Initial degree of occlusion	Follow-up degree of occlusion at time of retreatment	Time of retreatment after initial embolization (mo)	Retreatment	Final degree of occlusion after retreatment	Length of angiographic follow-up after initial embolization (mo)
Subtype	Size	Fundus-to-neck ratio						
Superior hypophyseal	Small	≤2	Complete	Partial	2	Clipping	Complete	4
Ventral paraclinoid	Small	≤2	Complete	Partial	6	Clipping	Complete	6
Carotid cave	Small	≤2	Complete	Partial	23	Coiling	Complete	35
Carotid cave	Small	≤2	Near-complete	Partial	35	Coiling	Partial	35
Carotid cave	Small	≤2	Near-complete	Partial	4	Coiling (remodeling)	Complete	13
Ophthalmic	Small	≤2	Partial	Partial	15	Clipping	Complete	23
Ophthalmic	Large	>2	Complete	Partial	7	Coiling	Complete	7
Ophthalmic	Large	>2	Near-complete	Partial	26	Coiling	Near-complete	26
Superior hypophyseal	Large	≤2	Partial	Partial	7	Coiling	Near-complete	43
Ophthalmic	Large	≤2	Partial	Partial	7	Coiling (remodeling)	Complete	20
Superior hypophyseal	Giant	>2	Complete	Partial	1, 3, 26	Coiling	Partial	26
Ophthalmic	Giant	>2	Partial	Partial	6	Coiling	Complete	6

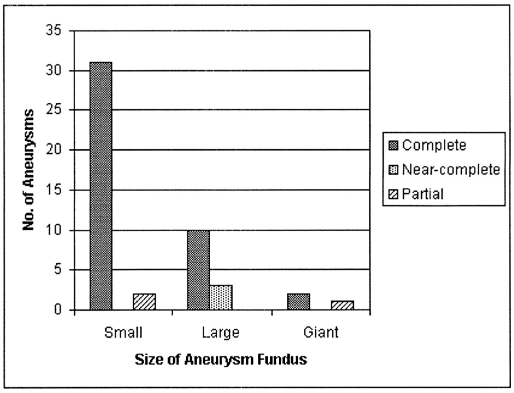

FIGURE 3. *Bar graph showing follow-up degree of occlusion based on aneurysm size. The number of aneurysms in each degree of occlusion after a follow-up period of at least 4 months after initial embolization (n = 49) is shown.*

ruptured SAH aneurysm and once after a partial embolization of a small unruptured SAH aneurysm. The first patient was treated with progressive coil deposition. This patient was asymptomatic on discharge. The second patient was treated via endovascular ICA sacrifice at the level of the aneurysm and eventually by distal surgical clipping. This individual was disabled at the time of discharge. Thromboembolic complications occurred in six procedures (7.1%), two of which were associated with the remodeling technique. Three were managed with local intra-arterial infusion of fibrinolytic or systemic administration of antiplatelet agents. Two patients experienced hemiparesis (caused by distal middle cerebral artery embolism), one homonymous quadrantanopsia (caused by distal embolism of fetal-type posterior cerebral artery), and one a small scotoma (caused by retinal artery embolism). Two patients experienced no neurological deficit. Two remaining procedures (2.4%) were complicated by an unexplained postembolization hemiparesis. Immediate cerebral angiography in both patients failed to demonstrate any stenotic or occlusive lesions. The rate of overall morbidity lasting more than 7 days was 8.3%. There was no procedure-related mortality.

Length of Hospital Stay

The average hospitalization period was 17.8 days in patients with acutely ruptured aneurysms and 3.5 days in patients with unruptured and recoiled aneurysms.

Immediate and Follow-up Clinical Outcome

Table 8 presents clinical outcomes at discharge and on follow-up with respect to clinical status at the time of treatment. All 70 patients were evaluated clinically before hospital discharge by use of the GOS. Of 62 patients without SAH, 59 (95.2%) were classified as having a GOS score of 5, 1 (1.6%) as a GOS score of 4, 1 (1.6%) as a GOS score of 3, and 1 (1.6%) as a GOS score of 2. Of 8 patients with SAH from ruptured paraclinoid aneurysms, 6 (75%) were classified as having a GOS score of 5 and 2 (25%) as a GOS score of 3. Of 6 patients with SAH classified as having a GOS score of 5, 1 patient

TABLE 7. Procedural complications and clinical outcomes in relation to location and size of aneurysm[a] (n = 10)

Complication	Aneurysm			Angiographic finding	Management	Clinical outcome
	Clinical presentation	Subtype	Size			
Rupture	Subarachnoid hemorrhage	Superior hypophyseal	Large	Minor leak of contrast	Progressive coiling	No sequelae
	Incidental	Superior hypophyseal	Small	Active leak of contrast	Progressive coiling and ICA sacrifice	Vegetative
Thromboembolic	Incidental	Superior hypophyseal	Large	Distal MCA occlusion	tPA (local)	Hemiparesis
	Incidental	Ophthalmic	Small	Thrombus on ICA and distal MCA occlusion[b]	Tirofiban (systemic)	Hemiparesis
	Recurrence	Ophthalmic	Large	P3 occlusion[b] (fetal PCA)		Homonymous quadrantanopsia
	Incidental	Superior hypophyseal	Small	Negative		Scotoma; retinal artery occlusion
	Incidental	Ophthalmic	Small	Ophthalmic artery occlusion		No sequelae
	Visual symptom	Ophthalmic	Large	Distal MCA occlusion	Abciximab (systemic)	No sequelae
Unexplained	Recurrence	Ophthalmic	Giant	Negative		Hemiparesis
	Subarachnoid hemorrhage	Superior hypophyseal	Large	Negative		Hemiparesis

[a] ICA, internal carotid artery; MCA, middle cerebral artery; P3, quadrigeminal segment of posterior cerebral artery; PCA, posterior cerebral artery; tPA, tissue plasminogen activator.
[b] Complications associated with the remodeling technique.

TABLE 8. Clinical outcomes at discharge and on follow-up with respect to clinical status at presentation

Clinical status (Hunt-Hess grade)	No. of patients in Glasgow Outcome Scale score									
	At discharge (n = 70)					On follow-up (mean, 14.4 mo) (n = 63)				
	5	4	3	2	1	5	4	3	2	1
Unruptured	59	1	1	1	0	50	2	0	0	3
I	1	0	0	0	0	1	0	0	0	0
II	2	0	0	0	0	2	0	0	0	0
III	2	0	0	0	0	2	0	0	0	0
IV	1	0	2	0	0	1	0	1	0	1
Total (%)	65 (92.9)	1 (1.4)	3 (4.3)	1 (1.4)	0 (0)	56 (88.9)	2 (3.2)	1 (1.6)	0 (0)	4 (6.3)

presented with Hunt and Hess Grade I, 2 patients Grade II, 2 patients Grade III, and 1 patient Grade IV at the time of initial embolization. Two patients with SAH classified as GOS 3 presented with Hunt and Hess Grade IV SAH.

Follow-up clinical outcomes were obtained in 63 (90%) of 70 patients. Seven patients lost to follow-up presented with unruptured aneurysms, and all were classified as having a GOS score of 5 at discharge. There was no case of recurrent or new SAH during the follow-up period, which varied from 4 to 54 months (mean, 14.4 mo). The GOS score was 5 for 56 patients (88.9%), 4 for 2 patients (3.2%), and 3 for 1 patient (1.6%). Four patients (6.3%) died of unrelated causes.

Five patients who presented with visual symptoms were all classified as having a GOS score of 5, and their symptoms showed no change at the time of discharge. Of these five patients, three experienced no change of their symptoms at 1-year clinical follow-up, and one had marked improvement in 6 months. One patient was lost to follow-up.

DISCUSSION

Paraclinoid aneurysms account for approximately 1.5 to 8% of all intracranial aneurysms (17, 27, 40, 44). Recent series, however, have reported a higher prevalence (11–20%) (12, 31, 53). This difference may reflect patient referral patterns and increasing detection of incidental lesions. Paraclinoid aneurysms are known to occur more commonly in women (6, 30, 31, 64). Patients with paraclinoid aneurysms are likely (21–64%) to have multiple lesions, particularly at sites such as the posterior communicating artery, the contralateral paraclinoid carotid artery, and the cavernous ICA segment (2, 12, 17, 27, 60, 62). A significant number of paraclinoid aneurysms are found incidentally (12, 30, 59), often because of the rupture of an associated lesion (12, 14). They frequently present with large size (4, 30, 37). Similar to previously published studies, in this study, 61 (87%) of the 70 patients were women. Twenty-four patients (34%) had additional aneurysms. Eight patients presented with SAH from ruptured paraclinoid aneurysms and 5 patients with visual symptoms attributable to their paraclinoid lesions. Fifty-seven patients (81.4%) were incidentally found to have paraclinoid aneurysms.

Definitions and Classifications

There have been many different definitions and classifications of aneurysms arising in proximity to the anterior clinoid process. Some authors have used the term *carotid-ophthalmic aneurysms* to describe all lesions arising from the ICA between the ophthalmic artery and posterior communicating artery (14, 17, 20, 27, 54, 60, 62). Many authors classified these aneurysms according to their anatomic relationship to the carotid artery, optic nerves, and chiasm (1, 2, 6, 12, 21, 30, 38, 49, 60, 62).

In this study, we included aneurysms arising from the ICA between the roof of the cavernous sinus and the origin of the posterior communicating artery. According to the recent anatomic segmentation of the ICA proposed by Bouthillier et al. (8), this portion of the ICA corresponds to the clinoid (C5) and the ophthalmic (C6) segments. Aneurysms arising on the distal cavernous ICA and projecting into the extracavernous intradural subarachnoid space were also included. All of these aneurysms were defined for our purposes as paraclinoid aneurysms.

Concerning the specific subclassification of paraclinoid aneurysms, we retained the classification proposed by Al-Rodhan et al. (3). In 1993, they provided a simplified classification for clinoidal region ICA aneurysms. Aneurysms arising distal to the origin of the ophthalmic artery and proximal to the origin of the posterior communicating artery were referred to as either superior hypophyseal aneurysms projecting superiorly or ventral paraclinoid aneurysms projecting posteroinferiorly. Aneurysms arising at the junction of the ophthalmic artery and the ICA were referred to as true ophthalmic aneurysms. Medial infraophthalmic and supracavernous aneurysms were designated carotid-cave aneurysms arising from the ICA in the clinoid space (carotid cave), which was named by Kobayashi et al. (38). They pointed out the similarity in the behavior of carotid cave aneurysms and ventral paraclinoid aneurysms, i.e., in terms of intradural neck location and occasional extension of their dome into the cavernous sinus. Aneurysms with necks arising from the cavernous ICA and domes projecting superiorly into the intradural extracavernous subarachnoid space were defined as transitional cavernous aneurysms.

Surgery

Early series reporting direct surgical treatment of paraclinoid aneurysms usually had mortality rates ranging from 20 to 60%. Good outcomes ranged from 40 to 71%, and the rate of successful clipping (neck occlusion) was 18 to 80% (17, 27, 34, 40, 54). As a result, some authors favored indirect therapy, such as common carotid artery ligation, cervical ICA ligation, ICA occlusion with a nondetachable or detachable balloon, or aneurysm trapping (22, 30, 34, 44, 58). When necessary, extracranial-intracranial arterial bypass has been performed in combination with surgical or endovascular occlusion of the ICA (5, 23, 29, 30, 32, 56–58). These indirect approaches, however, are associated with the risk of ischemic complications and do not always provide definitive treatment (23, 30, 32, 48, 56). With better understanding of aneurysm anatomy and improvements in surgical technique and instrumentation, several recent surgical series discussed below have shown favorable outcomes in patients treated with direct clipping and indicate that, whenever possible, direct clipping is the treatment of choice (12, 19, 21, 27, 30, 39, 58, 61, 62).

In 1994, Batjer et al. (6) reported their surgical series of 89 paraclinoid aneurysms. Temporary artery occlusion was used in 48 patients, permanent carotid artery occlusion in 4, and hypothermic circulatory arrest in 2. Outcome was good in 77 patients (86.5%), fair in 8 (9%), and poor in 3 (3%). One patient (1%) died. In 1997, Kumon et al. (42) reported their operative results in 15 patients with small, asymptomatic, unruptured carotid-ophthalmic artery aneurysms. Neck clipping was possible in 13 patients. Major complications were visual loss in 1 patient and visual field defect in 3 patients (26%). In 1998, Kattner et al. (37) reported surgical results in 29 patients with large and giant paraclinoid aneurysms. Twenty-eight lesions were clipped directly by use of Dolenc's combined epidural and subdural approach (14). Overall immediate surgical morbidity and mortality were assessed at 20 and 3.4%, respectively. In 1999, De Jesús et al. (13) described 35 paraclinoid ICA aneurysms. Satisfactory clipping was obtained in 32 lesions. The overall complication rate was 32%, with 16% permanent morbidity. They reported a 12% rate of postoperative complete or partial visual loss, 8% stroke rate, and 4% incidence of cranial nerve paresis.

Detachable Coil Embolization

Since the introduction of the GDC, endovascular treatment of intracranial aneurysms has been demonstrated to be feasible for both ruptured and unruptured lesions, with complication rates of less than 10% and delayed rerupture rates of 1 to 2% (7, 9–11, 18, 24, 25, 33, 41, 45, 47, 51, 55). Embolization of paraclinoid aneurysms with detachable coils seems to be a reasonable therapeutic option.

In 1996, Gurian et al. (28) presented their results for endovascular embolization of 11 superior hypophyseal aneurysms. They reported no technical or clinical complications related to embolization. Embolization was technically successful in 10 of 11 lesions. Complete obliteration was obtained in 5 lesions, whereas small residual necks remained in 4 aneurysms. One failure involved a large, wide-necked, semifusiform aneurysm. They reported no procedure-related complications or neurological deterioration. On angiographic follow-up (mean, 12.1 mo) of 7 aneurysms, recanalization occurred in 1 giant lesion. Nine patients for whom embolization was successful had good or excellent clinical outcomes. There was no clinical deterioration attributable to embolization. On the basis of their low procedural morbidity, the short length of the procedure, and the technical ease of catheterization, these authors concluded that GDC embolization of superior hypophyseal artery aneurysms is an excellent treatment alternative. In 1997, Roy et al. (53) reported the result of endovascular treatment of 28 ophthalmic segment aneurysms. Anatomic results were satisfactory in 25 aneurysms (89%). Complete occlusion was obtained in 14 (50%), and a small residual neck was left in 11 (39%). They reported 3 treatment failures. Treatment failed in 2 patients with giant aneurysms, and all 3 failures occurred in wide-necked (>4 mm) lesions. There was treatment-related permanent morbidity in one patient (3%) and no mortality. No bleeding occurred after treatment in either the nonruptured or the ruptured group (mean clinical follow-up was 23.5 and 25 mo, respectively). They proposed that endovascular treatment with GDCs was a safe and efficient alternative approach for ophthalmic segment aneurysms. In 2000, Thornton et al. (59) reported 61 paraclinoid aneurysms treated with endovascular coil embolization. The rate of major permanent deficits was 2.2%, and the mortality rate was 2.2%. They reported one rehemorrhage after endovascular coiling in a patient with a coagulopathy from liver metastasis. These authors concluded that the morbidity and mortality rates of their patients were equal to or better than those of published surgical series of similar aneurysms and recommended that an endovascular approach be given primary consideration in the treatment of paraclinoid aneurysms.

The final follow-up angiographic outcomes (mean follow-up, 13.9 mo) of 49 aneurysms in our study showed complete occlusion in 87.8%, near-complete occlusion in 6.1%, and partial occlusion in 6.1%. The final occlusion rate of aneurysms was clearly improved from primary angiographic results after retreatment. The primary complete occlusion rate of 72.6% had improved to 87.8% after retreatment. The overall procedure-related morbidity and mortality were 8.3 and 0%, respectively. The procedure-related morbidity and mortality observed in this series and those of previous authors indicate that treatment of paraclinoid aneurysms with detachable coils can be performed safely and effectively in most patients (28, 31, 53, 59).

With regard to initial occlusion rates of a total of 73 aneurysms treated, we found no statistically significant influence of neck sizes and fundus-to-neck ratios of aneurysms. In our series, the use of remodeling technique and newly designed coils seems to have allowed similar results to be obtained whatever the neck size or the fundus-to-neck ratio. Balloon-assisted remodeling technique was used in 16 of 84 procedures, and three-dimensional GDCs or Micrus spherical microcoils were used liberally. Of 73 paraclinoid aneurysms included in our series, 8 (11%) were treated between 1993 and 1996, and 65 (89%) were treated between 1997 and 2002. Of the first 8 aneurysms, 4 (50%) had favorable fundus-to-neck ratios. Five (62.5%) aneurysms were small, and 3 (37.5%) were large. Of the last 65 aneurysms, 23 (35.4%) had favorable fundus-to-neck ratios. Forty-five aneurysms (69.2%) were small, 17 (26.2%) were large, and 3 (4.6%) were giant. Initial degrees of occlusion of the first 8 aneurysms were complete in 6 (75%) and partial in 2 (25%). Those of the last 65 aneurysms were complete in 47 (72.3%), near-complete in 6 (9.2%), and partial in 12 (18.5%). A total of 8 procedures (2 for acutely ruptured aneurysms) were performed between 1993 and 1996, and 76 procedures (6 for acutely ruptured aneurysms) were performed between 1997 and 2002. There were 2 (25%) procedure-related complications during the first period and 8 (10.5%) during the last period. Two of 8 complications that occurred during the last period were related to retreatment procedures. Larger numbers of aneurysms were treated, and more aneurysms with unfavorable anatomic configuration were included after 1997 in this study. Even though more aneurysms with unfavorable anatomic configuration were included in the last experiences, initial degrees of occlusion were not significantly different between the two experiences. The procedure-related complication rate was higher during the first period. These results might be influenced by a combination of factors such as the use of newly designed coils, the introduction of new technique, and the physicians' learning curve. There was no subsequent bleeding from aneurysms after initial embolization during a mean clinical follow-up of 14.4 months.

From the results of this study and our review of the literature, it seems that the ability of endovascular treatment using detachable coils to secure aneurysms and achieve good outcomes is at least similar to that of surgical clipping. The comparison and discussion of these two treatments is complicated not only by the differing nature of the population characteristics but also by the presentation of variable outcome measures and morbidity and mortality rates. Comparison of the anatomic results obtained with surgery and with coils is difficult, because most surgical series do not mention the findings of postoperative control angiography (2, 6, 12, 20, 25, 27, 50, 54).

Hospital Stay

Roos et al. (52) investigated the current direct costs of modern management of patients with aneurysmal SAH in the first year after diagnosis. The major expense was the cost of hospital inpatient days, which accounted for two-thirds of the total costs. Of the diagnostic and therapeutic costs, 45% was a result of imaging and 42% a result of surgery or clipping. These costs can be reduced by decreasing the average length of stay, especially in the intensive care unit. Yundt et al. (63) retrospectively reviewed the clinical and hospital financial data of patients treated for nontraumatic SAH and unruptured cerebral aneurysms at their institution. The mean hospitalization period for all patients was 19.2 days, and that of patients with unruptured intracranial aneurysms was 10.9 days. In our series, the mean length of hospital stay of patients who underwent GDC embolization was 17.8 days for ruptured aneurysms and 3.5 days for unruptured aneurysms. This short hospitalization period may provide a significant benefit for patients' social activities and reduces the total direct medical costs generated by aneurysm patients.

CONCLUSION

Endovascular treatment is emerging as a promising alternative to surgical clipping in selected patients with intracranial aneurysms. The results of this study indicate that endovascular treatment is a safe and effective therapeutic alternative in ruptured and unruptured paraclinoid aneurysms. Endovascular treatment also confers a positive impact in terms of length of hospital stay, especially for unruptured lesions. The early experience with coil embolization for the treatment of intracranial aneurysms suggests that the procedural risks are fairly low, but the long-term effectiveness has not yet been proved. The proportion of patients with paraclinoid aneurysms who are best treated with endovascular coiling, alone or in combination with surgery, remains to be determined.

REFERENCES

1. Aldrich F: Anterior (dorsal) paraclinoid aneurysm: Case report. **Surg Neurol** 35:374–376, 1991.
2. Almeida GM, Shibata MK, Bianco E: Carotid-ophthalmic aneurysms. **Surg Neurol** 5:41–45, 1976.
3. Al-Rodhan NRF, Piepgras DG, Sundt TM Jr: Transitional cavernous aneurysms of the internal carotid artery. **Neurosurgery** 33:993–998, 1993.
4. Arnautovic KI, Al-Mefty O, Angtuaco E: A combined microsurgical skull-base and endovascular approach to giant and large paraclinoid aneurysms. **Surg Neurol** 50:504–520, 1998.
5. Barnett DW, Barrow DL, Joseph GJ: Combined extracranial-intracranial bypass and intraoperative balloon occlusion for the treatment of intracavernous and proximal carotid artery aneurysms. **Neurosurgery** 35:92–98, 1994.
6. Batjer HH, Kopitnik TA, Giller CA, Samson DS: Surgery for paraclinoidal carotid artery aneurysms. **J Neurosurg** 80:650–658, 1994.
7. Bavinzski G, Killer M, Gruber A, Reinprecht A, Gross CE, Richling B: Treatment of basilar artery bifurcation aneurysms by using Guglielmi detachable coils. **J Neurosurg** 90:843–852, 1999.
8. Bouthillier A, van Loveren HR, Keller JT: Segments of the internal carotid artery: A new classification. **Neurosurgery** 38:425–433, 1996.
9. Byrne JV, Sohn MJ, Molyneux AJ, Chir B: Five-year experience in using coil embolization for ruptured intracranial aneurysms. **J Neurosurg** 90:656–663, 1999.
10. Casasco AE, Aymard A, Gobin YP, Houdart E, Rogopoulos A, George B, Hodes JE, Cophignon J, Merland JJ: Selective endovascular treatment of 71 intracranial aneurysms with platinum coils. **J Neurosurg** 79:3–10, 1993.
11. Cognard C, Weill A, Spelle L, Piotin M, Castaings L, Rey A, Moret J: Long-term angiographic follow-up of 169 intracranial berry aneurysms occluded with detachable coils. **Radiology** 212:348–356, 1999.
12. Day AL: Aneurysms of the ophthalmic segment: A clinical anatomical analysis. **J Neurosurg** 72:677–691, 1990.

13. De Jesús O, Sekhar LN, Riedel CJ: Clinoid and paraclinoid aneurysms: Surgical anatomy, operative techniques, and outcome. **Surg Neurol** 51:477–488, 1999.
14. Dolenc VV: A combined epi- and subdural direct approach to carotid-ophthalmic artery aneurysms. **J Neurosurg** 62:667–672, 1985.
15. Dolenc VV: Carotid-ophthalmic aneurysms, in Carter LP, Spetzler RF (eds): *Neurovascular Surgery*. New York, McGraw-Hill, 1994, pp 673–686.
16. Drake CG, Peerless SJ, Fergusson GG: Hunterian proximal arterial occlusion for giant aneurysms of the carotid circulation. **J Neurosurg** 81:656–665, 1994.
17. Drake CG, Vanderlinden RG, Amacher AL: Carotid-ophthalmic aneurysms. **J Neurosurg** 29:24–31, 1968.
18. Eskridge JM, Song JK: Endovascular embolization of 150 basilar tip aneurysms with Guglielmi detachable coils. **J Neurosurg** 89:81–86, 1998.
19. Ferguson GG, Drake CG: Carotid-ophthalmic aneurysms: The surgical management of those cases presenting with compression of the optic nerves and chiasm alone. **Clin Neurosurg** 27:263–307, 1980.
20. Ferguson GG, Drake CG: Carotid-ophthalmic aneurysms: Visual abnormalities in 32 patients and the results of treatment. **Surg Neurol** 16:1–8, 1981.
21. Fox JL: Microsurgical treatment of ventral (paraclinoid) internal carotid artery aneurysms. **Neurosurgery** 22:32–39, 1988.
22. Fox AJ, Viñuela F, Pelz DM, Peerless SJ, Ferguson GG, Drake CG, DeBrun G: Use of detachable balloons for proximal artery occlusion in the treatment of unclippable cerebral aneurysms. **J Neurosurg** 66:40–46, 1987.
23. Gelber BR, Sundt TM Jr: Treatment of intracavernous and giant carotid aneurysms by combined internal carotid ligation and extra- to intracranial bypass. **J Neurosurg** 52:1–10, 1980.
24. Guglielmi G, Viñuela F, Dion J, Duckwiler G: Electrothrombosis of saccular aneurysms via endovascular approach. **J Neurosurg** 75:8–14, 1991.
25. Guglielmi G, Viñuela F, Duckwiler G, Dion J, Lylyk P, Berenstein A, Strother C, Graves V, Halbach V, Nichols D, Hopkins N, Ferguson R, Sepetka I: Endovascular treatment of posterior circulation aneurysms by electrothrombosis using electrically detachable coils. **J Neurosurg** 75:515–524, 1992.
26. Guidetti B, La Torre E: Carotid-ophthalmic aneurysms: A series of 16 cases treated by direct approach. **Acta Neurochir (Wien)** 22:289–304, 1970.
27. Guidetti B, La Torre E: Management of carotid-ophthalmic aneurysms. **J Neurosurg** 42:438–442, 1975.
28. Gurian JH, Viñuela F, Guglielmi G, Gobin YP, Duckwiler GR: Endovascular embolization of superior hypophyseal artery aneurysms. **Neurosurgery** 39: 1150–1154, 1996.
29. Hacein-Bey L, Connolly ES Jr, Duong H, Vang MC, Lazar RM, Marshall RS, Young WL, Solomon RA, Pile-Spellman J: Treatment of inoperable carotid aneurysms with endovascular carotid occlusion after extracranial-intracranial bypass surgery. **Neurosurgery** 41:1225–1231, 1997.
30. Heros RC, Nelson PB, Ojemann RG, Crowell RM, DeBrun G: Large and giant paraclinoid aneurysms: Surgical techniques, complications, and results. **Neurosurgery** 12:153–163, 1983.
31. Hoh BL, Carter BS, Budzik RF, Putman CM, Ogilvy CS: Results after surgical and endovascular treatment of paraclinoid aneurysms by a combined neurovascular team. **Neurosurgery** 48:78–90, 2001.
32. Hopkins LN, Grand W: Extracranial-intracranial arterial bypass in the treatment of aneurysms of the carotid and middle cerebral arteries. **Neurosurgery** 5:21–31, 1979.
33. Horowitz MB, Levy E, Kassam A, Purdy PD: Endovascular therapy for intracranial aneurysms: A historical and present status review. **Surg Neurol** 57:147–159, 2002.
34. Hosobuchi Y: Direct surgical treatment of giant intracranial aneurysms. **J Neurosurg** 51:743–756, 1979.
35. Hunt WE, Hess RM: Surgical risk as related to time of intervention in the repair of intracranial aneurysms. **J Neurosurg** 28:14–19, 1968.
36. Jennett B, Bond M: Assessment of outcome after severe brain damage: A practical scale. **Lancet** 1:480–484, 1975.
37. Kattner KA, Bailes J, Fukushima T: Direct surgical management of large bulbous and giant aneurysms involving the paraclinoid segment of the internal carotid artery: Report of 29 cases. **Surg Neurol** 49:471–480, 1998.
38. Kobayashi S, Kyoshima K, Gibo H, Hedge SA, Takemae T, Sugita K: Carotid cave aneurysms of the internal carotid artery. **J Neurosurg** 70:216–221, 1989.
39. Korosue K, Heros RC: "Subclinoid" carotid aneurysm with erosion of the anterior clinoid process and fatal intraoperative rupture. **Neurosurgery** 31:356–360, 1992.
40. Kothandaram P, Dawson BH, Kruyt RC: Carotid-ophthalmic aneurysms: A study of 19 patients. **J Neurosurg** 34:544–548, 1971.
41. Kuether TA, Nesbit GM, Barnwell SL: Clinical and angiographic outcomes, with treatment data, for patients with cerebral aneurysms treated with Guglielmi detachable coils. **Neurosurgery** 43:1016–1025, 1998.
42. Kumon Y, Sakaki S, Kohno K, Ohta S, Ohue S, Oka Y: Asymptomatic, unruptured carotid-ophthalmic artery aneurysms: Angiographic differentiation of each type, operative results, and indications. **Surg Neurol** 48:465–472, 1997.
43. Levy ML, Day JD, Giannotta SL: Giant aneurysms of the paraclinoid ophthalmic segment of the internal carotid artery: Intradural approaches, in Awad IA, Barrow DL (eds): *Giant Intracranial Aneurysms*. Park Ridge, AANS, 1995, pp 131–142.
44. Locksley HB: Natural history of subarachnoid hemorrhage, intracranial aneurysms and arteriovenous malformations: Based on 6368 cases in the cooperative study. **J Neurosurg** 25:219–239, 1966.
45. McDougall CG, Halbach VV, Dowd CF, Higashida RT, Larsen DW, Hieshima GB: Endovascular treatment of basilar tip aneurysms using electrolytically detachable coils. **J Neurosurg** 84:393–399, 1996.
46. Moret J, Cognard C, Weill A, Castaings L, Rey A: The "remodeling technique" in the treatment of wide neck intracranial aneurysms. **Intervent Neuroradiol** 3:21–35, 1997.
47. Murayama Y, Viñuela F, Duckwiler GR, Gobin YP, Guglielmi G: Embolization of incidental cerebral aneurysms by using the Guglielmi detachable coil system. **J Neurosurg** 90:207–214, 1999.
48. Nishioka H: Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage: Section VIII, Part 1—Results of the treatment of intracranial aneurysms by occlusion of the carotid artery in the neck. **J Neurosurg** 25:660–682, 1968.
49. Nutik S: Carotid paraclinoid aneurysms with intradural origin and intracavernous location. **J Neurosurg** 48:526–533, 1978.
50. Perneczky A, Knosp E, Vorkapic P, Czech T: Direct surgical approach to infraclinoid aneurysms. **Acta Neurochir (Wien)** 76:36–44, 1985.
51. Raymond J, Roy D: Safety and efficacy of endovascular treatment of acutely ruptured aneurysms. **Neurosurgery** 41:1235–1246, 1997.
52. Roos YB, Dijkgraaf MG, Albrecht KW, Beenen LF, Groen RJ, de Haan RJ, Vermeulen M: Direct costs of modern treatment of aneurysmal subarachnoid hemorrhage in the first year after diagnosis. **Stroke** 33:1595–1599, 2002.
53. Roy D, Raymond J, Bouthillier A, Bojanowski MW, Moumdjian R, L'Espérance G: Endovascular treatment of ophthalmic segment aneurysms with Guglielmi detachable coils. **AJNR Am J Neuroradiol** 18:1207–1215, 1997.
54. Sengupta RP, Gryspeerdt GL, Hankinson J: Carotid-ophthalmic aneurysms. **J Neurol Neurosurg Psychiatry** 39:837–853, 1976.
55. Solander S, Ulhoa A, Viñuela F, Duckwiler GR, Gobin YP, Martin NA, Frazee JG, Guglielmi G: Endovascular treatment of multiple intracranial aneurysms by using Guglielmi detachable coils. **J Neurosurg** 90:857–864, 1999.
56. Spetzler RF, Schuster H, Roski RA: Elective extracranial-intracranial arterial bypass in the treatment of inoperable giant aneurysms of the internal carotid artery. **J Neurosurg** 53:22–27, 1980.
57. Spetzler RF, Selman WR, Carter LP: Elective EC-IC bypass for unclippable intracranial aneurysms. **Neurol Res** 6:64–68, 1984.
58. Sundt TM Jr, Piepgras DG: Surgical approach to giant intracranial aneurysms: Operative experience with 80 cases. **J Neurosurg** 51:731–742, 1979.
59. Thornton J, Aletich VA, Debrun GM, Alazzaz A, Misra M, Charbel F, Ausman JI: Endovascular treatment of paraclinoid aneurysms. **Surg Neurol** 54:288–299, 2000.
60. Thurel C, Rey A, Thiébaut JB, Chai N, Houdart R: Carotido-ophthalmic aneurysms [in French]. **Neurochirurgie** 20:25–39, 1974.
61. Yaşargil MG, Fox JL: The microsurgical approach to intracranial aneurysms. **Surg Neurol** 3:7–14, 1975.
62. Yaşargil MG, Gasser JC, Hodosh RM, Rankin TV: Carotid-ophthalmic aneurysms: Direct microsurgical approach. **Surg Neurol** 8:155–165, 1977.
63. Yundt KD, Dacey RG Jr, Diringer MN: Hospital resource utilization in the treatment of cerebral aneurysms. **J Neurosurg** 85:403–409, 1996.
64. Zubillaga AF, Guglielmi G, Viñuela F, Duckwiler GR: Endovascular occlusion of intracranial aneurysms with electrolytically detachable coils: Correlation of aneurysm neck size and treatment results. **AJNR Am J Neuroradiol** 15:815–820, 1994.

COMMENTS

Park et al. describe their experience in treating 73 patients who underwent endosaccular procedures with detachable coils to treat 73 paraclinoid aneurysms at two institutions. It is interesting to note that the angiographic follow-up in these 73 paraclinoid aneurysms demonstrates complete occlusion in 72.6%, near occlusion in 8.2%, and partial inclusion in 20%. Nine aneurysms required more than one coiling session, which certainly does need to be taken into account with regard to additional morbidity during follow-up procedures, a point to which the authors allude. Quite interestingly, during the follow-up period, six aneurysms demonstrated partial occlusion and three showed near-complete occlusion. Both showed spontaneous progression of thrombosis to complete occlusion. The overall procedural and postoperative complication rate for 84 endovascular procedures was approximately 12% with 8.3% morbidity. Most important, there were recurrent subarachnoid hemorrhages and even aneurysms that were incompletely treated during a follow-up period of 14.4 months. The final clinical outcomes demonstrated a vascular outcome score and good recovery in 88.9% of patients, as well as appropriate reduction in morbidity depending on the grade of presentation. The authors' comment regarding cost-effectiveness and length of hospital stay is too premature. Certainly, up to this point, it may be cost-effective; however, if patients return for additional treatment, endocranial procedures, or transcranial surgery, the cost-effectiveness of the procedure will be mitigated because the financial impact of the reduction in length of stay is dissolved or eliminated. As the authors allude, paraclinoid lesions can be difficult from a surgical standpoint. The procedure that the authors describe certainly is an option when microsurgery may be problematic because of the anatomy of the lesion or the physiological age of the patient. As is always true of studies involving endosaccular occlusion, long-term follow-up will ultimately determine the usefulness of the procedure. The authors provide honest appraisal of their experience.

Robert H. Rosenwasser
Philadelphia, Pennsylvania

The authors present a retrospective review of their 9.5-year experience in treating 70 patients with "paraclinoid" aneurysms by performing endovascular coil embolization. Most patients had incidental unruptured aneurysms. Complete aneurysm occlusion was achieved in 73% of these patients initially and in 88% at follow-up, reflecting some occurrence of progressive intraaneurysmal thrombosis. Almost 90% of the patients had good clinical outcomes at follow-up.

The authors use a rather loose definition of *paraclinoid* and have included cavernous aneurysms projecting intradurally, as well as carotid-ophthalmic, superior hypophyseal, ventral paraclinoid, dorsal wall carotid, and transitional aneurysms in their analysis, making this a review of a large subset of anterior circulation aneurysms rather than the traditionally more narrow definition of paraclinoid aneurysms. This article adds more evidence to the literature suggesting that coil embolization of intracranial aneurysms is a safe and effective alternative to surgery and is associated with a shorter hospital stay and less financial burden than surgery.

Perry Ng
Sean Cullen
Randall T. Higashida
Interventional Neuroradiologists
San Francisco, California

A significant drawback of endovascular treatment of intracranial aneurysms is the occurrence of incomplete occlusion of the aneurysm at the time of the initial procedure. In most endovascular series, investigators have reported initial occlusion rates of approximately 50% (1–3). Although some incompletely coiled aneurysms are found to thrombose and occlude on the basis of follow-up angiography and initial incomplete aneurysm coiling may offer some protection against aneurysm rupture, improvements in initial occlusion rates are essential to further establish coiling as a valid alternative to surgical clipping. Recent improvements in coil design and advances in technique hold promise in this regard.

Park et al. report a series of 70 patients with paraclinoid aneurysms who underwent endovascular treatment with electrolytic detachable coils. The 8.3% overall morbidity rate (>7 d) with no deaths compares favorably with the results reported in other surgical series. Initial complete occlusion was achieved in 72.6% of the aneurysms in this series, and the final occlusion rate was 87.8% in average angiographic follow-up of 13.9 months. Sixty-three percent of the aneurysms had fundus-to-neck ratios greater than 2 mm and 32.9% had necks greater than 4 mm, indicating that aneurysm configurations previously thought to be unfavorable can be treated successfully by endovascular means. The authors accomplished these results by using balloon-assisted remodeling and three-dimensional, soft, and spherical coils when needed. These findings represent a considerable improvement in occlusion rates compared with the rates reported in most other series. We hope that improvement in aneurysm occlusion rates with the use of endovascular techniques will ultimately translate into improved, sustained protection against aneurysm growth and rupture.

Mark R. Harrigan
L. Nelson Hopkins
Buffalo, New York

1. Brilstra EH, Rinkel GJ, van der Graaf Y, van Rooij WJ, Algra A: Treatment of intracranial aneurysms by embolization with coils: A systematic review. **Stroke** 30:470–476, 1999
2. Ng P, Khangure MS, Phatouros CC, Bynevelt M, ApSimon H, McAuliffe W: Endovascular treatment of intracranial aneurysms with Guglielmi detachable coils: Analysis of midterm angiographic and clinical outcomes. **Stroke** 33: 210–217, 2002.
3. Roy D, Milot G, Raymond J: Endovascular treatment of unruptured aneurysms. **Stroke** 32:1998–2004, 2001.