ORIGINAL ARTICLE

Endovascular coiling versus neurosurgical clipping for ruptured intracranial aneurysms: significant benefits in clinical outcome and reduced consumption of hospital resources in Hong Kong Chinese patients

Simon CH Yu 余俊豪
George KC Wong 黃國柱
Jeffrey KT Wong 黃嘉德
WS Poon 潘偉生

Objectives Using specific selection criteria to determine whether endovascular coiling as compared to neurosurgical clipping is associated with significant benefits, in terms of 1-year clinical outcomes and consumption of hospital resources, for the treatment of ruptured intracranial aneurysms in Hong Kong Chinese patients.

Design Retrospective study.

Setting University teaching hospital, Hong Kong.

Patients Records of outcomes of 169 consecutive Chinese patients, who were treated with endovascular coiling (n=80) or surgical clipping (n=89), were reviewed. All patients were followed up clinically for a mean of 55 (standard deviation, 201) months and radiologically with sequential digital subtraction angiography at 6 and 18 months after treatment.

Results The mean ages of patients were 56 (standard deviation, 13) years for the coiling group, and 57 (standard deviation, 13) years for the clipping group (P=0.575). The median aneurysm size was 4 mm in both groups (P=0.898). The severity of subarachnoid haemorrhage in the two groups did not differ (P=0.619). The rate of death or permanent disability leading to dependency (Glasgow Outcome Scale, 1-3) at 1 year was significantly lower in the coiling group (12/80, 15%) as compared to the clipping group (30/89, 34%) [P=0.005], resulting in a risk reduction of 19% (95% confidence interval, 6-32%). There were significantly more frequent admissions into the intensive care unit in the clipping group (P<0.001); the median duration of intensive care unit stay was 2 days (vs 0 days in the coiling group). The incidence of subsequent treatment procedures for residual or recurrent aneurysm was more common in the coiling group (13/80 vs 3/89; P=0.004).

Conclusion Endovascular coiling as compared to neurosurgical clipping for treatment of patients with ruptured intracranial aneurysms is associated with significant benefits in terms of a reduced need for intensive care unit admissions and better general clinical outcomes in Hong Kong Chinese patients.

Key words
Aneurysm, ruptured; Cerebral arteries; Embolization, therapeutic; Intracranial aneurysm; Treatment outcome

Hong Kong Med J 2007;13:271-8

The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, Hong Kong:
Department of Diagnostic Radiology and Organ Imaging
SCH Yu, MD, FRCR
JKT Wong, FRCR
Department of Surgery
GKC Wong, FRCS (Edin)
WS Poon, FRCS (Edin)

Correspondence to: Dr SCH Yu
E-mail: simonyu@cuhk.edu.hk

Introduction

Endovascular coiling for the treatment of intracranial aneurysms has been developed for 15 years. Clinical reports of early results in the late 90s[1-13] as well as midterm outcomes[14-16] have shown the technique to be safe and effective. Thus, for the treatment of intracranial aneurysms this technique has become a well-recognised alternative to neurosurgical clipping. To date, there were only a few investigations comparing endovascular coiling to neurosurgical clipping, including a small study involving a single centre[12,13] and the International Subarachnoid Aneurysm Trial (ISAT).[17] However, other than in the latter trial, long-term clinical outcomes were not well-evaluated. Perhaps more relevant to Asian doctors and patients is the fact that small aneurysms (2-5 mm) constitute a major portion

選用血管內栓塞術還是顯微手術夾閉治療顱內動脈瘤：香港華裔患者的醫療結果以及醫院資源的節省

目的 以香港華裔病人為對象，按特定的挑選準則施行並比較治療顱內動脈瘤的兩種方法：血管內栓塞術和顯微手術夾閉，確定血管內栓塞術是否在一年內的療效以及醫院資源的耗用兩方面，都有明顯的好處。

設計 回顧研究。

安排 香港一所大學教學醫院。

患者 本研究共檢視連續169位患者病歷，當中80位採用血管內栓塞術，89位接受外科手術。所有患者的臨床隨訪期平均為55個月（標準差：201個月），並接受輻射檢查，在術後第6個月和第18個月進行數字減影血管造影。

結果 兩組患者中，栓塞術組平均年齡為56歲（標準差：13歲），夾閉組為57歲（標準差：13歲）[P=0.575]。腫瘤大小的中位數兩組均為4毫米(P=0.898)，蛛網膜下腔出血的嚴重程度無分別(P=0.619)。比較一年的死亡率以及因永久傷殘而須依賴別人（按格拉斯哥預後評分，1-3）的比率，栓塞術組（12/80，15%）明顯比夾閉組（30/89，34%）要低(P=0.005)，並減少死亡和依賴的可能性達19%（95%置信區間，6-32%）。夾閉組移送深切治療部的次數明顯較多(P<0.001)，留住期中位數為兩日，栓塞術組為零。因為有殘留或腫瘤復發而需再作治理的病例，栓塞術組(13/80)則比夾閉組(3/89)為多(P=0.004)。

結論 為香港華裔病人治療顱內動脈瘤時，血管內栓塞術的好處明顯比採用顯微手術夾閉的要多，不但減少深切治療的需要，同時醫療結果也較好。

(70%) of the clinical presentations (in Hong Kong Chinese patients at least),[16] which differs distinctly from what was observed in western populations.

The present study was conceived, with the realisation that in Hong Kong Chinese patients, the median size of ruptured aneurysms is 4 mm.[16] Using specific selection criteria, we aimed to determine whether treatment of intracranial aneurysms by endovascular coiling is associated with significant benefits (1-year clinical outcome and consumption of hospital resources) as compared to neurosurgical clipping.

Methods

Study methods

We retrospectively reviewed 169 consecutive patients who presented with ruptured intracranial saccular aneurysms during the period May 1995 to July 2001 inclusive. Eighty patients were treated with endovascular coiling and 89 by neurosurgical clipping. The results of the former patients have been previously reported together with those of 17 others with mass effect treated by the same method during the same period.[16] All patients were local Hong Kong Chinese and managed in a single medical centre. Being a retrospective study, patient parameters were retrieved from the hospital case records and included digital subtraction angiography (DSA). The selected study parameters were well-defined and quantifiable items were either standard clinical information entered in hospital case records or angiographic characteristics observed on DSA. The parameters included patient age and sex, aneurysm size, grading of subarachnoid haemorrhage according to the World Federation of Neurological Surgeons, degree of obliteration of the aneurysm as depicted on the initial and follow-up DSAs, incidence of serious peri-procedure complications, duration of hospital stay in the general ward and intensive care unit (ICU), the general clinical outcome at 1 year according to the Glasgow Outcome Scale (GOS) score, and the incidence of subsequent procedures for residual and recurrent aneurysms.

Treatment strategy

There were a total of 202 patients with clinically symptomatic aneurysms diagnosed during the study period. Five patients were treated conservatively without active intervention to the aneurysm, because they were moribund due to severe subarachnoid haemorrhage, or absent response to pain noted persistently for 48 hours after the haemorrhage. The decision as to whether or not to undertake surgery was made by neurosurgeons. Of the 197 patients treated surgically, 169 patients presented with a ruptured aneurysm with evidence of subarachnoid haemorrhage detected by computed tomography (CT) scan, another 28 presented with signs of mass effect. The selection of treatment modality was made jointly by an interventional neuroradiologist and a neurosurgeon based on two considerations: (1) if the aneurysm size was larger than 2 mm and the ratio of the sac-to-neck diameter was more than 1, endovascular coiling was preferred; or patients with smaller aneurysms or smaller sac-to-neck ratios, neurosurgical clipping was preferred; (2) patients with aneurysms located at the ophthalmic segment of internal carotid artery, the ophthalmic artery, or the vertebrobasilar system were preferentially treated by endovascular coiling, due to the more difficult neurosurgical access to these sites; whilst those with middle cerebral artery aneurysms were preferentially treated by clipping, due to relatively easy neurosurgical access. Based on these criteria, 80 patients with ruptured aneurysms were treated with endovascular coiling and 89 by neurosurgical clipping. Only the ruptured aneurysms of each patient (identified on DSA by their irregular contour and correlation with the distribution of subarachnoid blood) were treated.

Endovascular coiling procedure

All the endovascular treatment procedures were performed in the authors' institution, essentially by an interventional neuroradiologist assisted by a neurosurgeon. For the initial 62 patients, the endovascular treatment was undertaken by a single interventional neuroradiologist who had acquired 2 to 6 years of cumulative experience during the conduct of this study. The next 18 patients were treated by another interventional neuroradiologist, who had acquired 1 to 3 years of cumulative experience during the study period. A Philips V3000 DSA unit (Philips, BG Eindhoven, The Netherlands) was used in the treatment of the first 69 patients. A Philips BV5000 bi-plane DSA unit (Philips, BG Eindhoven, The Netherlands) was used for the last 11 patients.

Endovascular coiling was performed within a median of 3 days after clinical presentation, with all patients being put under general anaesthesia. The neck vessels were accessed with a 6-French guiding catheter introduced through a femoral artery. The aneurysms were catheterized with a FasTracker 18 or 10 microcatheter. Guglielmi detachable coils (GDCs, Boston Scientific Target, Fremont, US) were used for aneurysm occlusion. After deployment of the first GDC, each patient received a single intravenous 2000-3000 IU bolus of heparin and complete occlusion of the aneurysm was attempted. Initially, simple coils of GDC-18 (diameter, 0.018 inch) were used; later in the study, coils of two-dimensional GDC-18 (diameter, 0.018 inch), GDC-10 (diameter, 0.010 inch), and soft GDC were deployed.

Neurosurgical clipping procedure

Neurosurgical clipping was performed in the operating theatre under general anaesthesia, preferably by a neuro-anaesthetist. The procedures were performed by one of three neurosurgeons who had cumulative experience in neurosurgical clipping for 1 to 3 years, 5 to 8 years, and 3 to 6 years. Smooth induction was undertaken, with great emphasis on avoiding a hypertensive crisis. As far as possible, the intracranial pressure was stabilised before the operation. In some patients, a ventricular drain was inserted to drain the associated hydrocephalus. In patients with subarachnoid haemorrhages graded as good, the blood pressure was lowered to reduce the risk of intra-operative rupture and facilitate dissection. The head was positioned above heart level. Depending on the location of the aneurysm, an appropriate craniotomy approach was selected, which included: pterional (transsylvian approach), pterional-orbitozygomatic (transsylvian approach), frontal (inter-hemispheric approach), or retrosigmoid craniotomies. A Midarex high-speed drill was used for access and a Mayfield pin was used for fixation. Cervical exposure for proximal control of the internal carotid artery and intra-operative angiography were employed in selected cases. A ventricular catheter, if not inserted already, was inserted to aid brain decompression and for postoperative monitoring. The intradural procedure was performed using a Leica microscope and standard micro-instruments. The operation proceeded with arachnoid dissection, subarachnoid dissection, and aneurysm clipping with gentle brain retraction using a Greenberg retractor system. A temporary clip was sometimes used for intervals of 5 to 10 minutes to aid aneurysm dissection. All the patients were operated on within 3 days of their subarachnoid haemorrhage, with the exception of patients whose poor condition (due to diffuse brain oedema) warranted greater delay. The aneurysm was excluded from the parent trunks with a single or multiple aneurysm clips (Yasargil standard, Yasargil mini, Sundt-Kees or Sugita). Readjustment of surgical clips was performed when the parent trunk was compromised or the aneurysm was incompletely obliterated. Wrapping or trapping with extracranial-intracranial bypass was sometimes employed in complex cases (whenever clip reconstruction of the parent vessel was not feasible). The patient was then monitored in the ICU during the immediate postoperative period.

Assessment of aneurysm obliteration

Before the surgical procedure, the size of each aneurysm was measured by an interventional neuroradiologist, using electronic means, applied to the best DSA or CT angiography projection. Immediately after the coiling procedure in the coiling group, DSA was performed to assess the degree of aneurysm occlusion. Occlusion was classified as (a) total (100%) when the sac and neck were densely packed with no contrast material visible, (b) subtotal (95-99%) when the sac was occluded and an obvious small neck remnant was visible or when there was doubt about the presence of a neck remnant, or (c) incomplete (<95%) when loose packing and persistent opacification of the sac or the neck remnant were seen.[15] The degree of aneurysmal-occlusion was judged by the interventional neuroradiologist and the neurosurgeon undertaking the procedure, together with another independent neurosurgeon. Immediately following a clipping procedure, the degree of aneurysmal obliteration was assessed intra-operatively by the neurosurgeon and classified as total, subtotal, or incomplete. In the coiling group, a follow-up DSA was performed at 6 and 18 months

TABLE 1. Demographics, severity of subarachnoid haemorrhages, and aneurysmal characteristics of patients undergoing endovascular coiling and neurosurgical clipping

Characteristic	Coiling group, n=80	Clipping group, n=89	P value
Age (years)			0.575†
Mean (SD)	56 (13)	57 (13)	
Median (range)	56 (22-77)	59 (25-80)	
Male:female	32:48	33:56	0.697‡
Severity of subarachnoid haemorrhage* (grade)	n=77	n=88	0.619†
Median	1	2	
25th percentile	1	1	
75th percentile	3	3	
Minimum	1	1	
Maximum	5	5	
Aneurysm size (mm)			0.898†
Mean (SD)	4.85 (2.68)	4.89 (2.61)	
Median (range)	4 (2-16)	4 (2-16)	

* Graded according to the World Federation of Neurological Surgeons
† Kruskal Wallis test
‡ Chi squared test

after the procedure to assess any change in the status of the aneurysmal obliteration. For patients in the clipping group with favourable neurological recovery, a follow-up DSA was performed within 12 months of the procedure to confirm the status of the obliteration.

Outcome assessment

The patients were closely monitored by neurosurgeons before discharge from the hospital. Patients were then followed up at 1- to 6-month intervals in an out-patient clinic, where they were assessed by a neurosurgeon and an interventional neuroradiologist and follow-up DSA were reviewed. Clinical evaluation was based on the GOS—score 1 indicated death; score 2 indicated a vegetative state, with an unresponsive patient unable to interact with the environment; score 3 indicated a severe disability, with the patient able to follow commands but unable to live independently; score 4 indicated a mild disability, with the patient able to live independently, but unable to return to work or school; whilst score 5 implied a good recovery, with the patient able to return to work or school. The primary clinical outcome (or end-point) in this study was the GOS score 1 year after treatment. Mortality rates at 30 days, 6 months, and 12 months after the treatment procedure were also evaluated.

Subsequent treatment procedures

In the coiling group, repeated coiling using GDC was performed if the follow-up DSA revealed an enlarging residual or recurrent aneurysm with amenable morphology. For other such cases in which GDC coiling was considered inappropriate, coiling was not performed and surgical clipping was performed instead. The decision on the need for repeated treatment was made jointly by an interventional neuroradiologist and a neurosurgeon. When follow-up DSA showed the presence of a residual or recurrent aneurysm that was small and of static or slightly larger, no further treatment was offered, though the patient was further observed clinically and angiographically.

Statistical methods

The Chi squared test was used for sex incidence, the degree of occlusion of aneurysms, the rate of death and serious disability leading to dependency, and the incidence of repeated treatment procedures. The Kruskal Wallis test was used to analyse age, the grading of subarachnoid haemorrhage, aneurysm size, and the duration of stay in the ward and the ICU. Fisher's exact test was used to analyse the incidence of deaths and the Mann-Whitney test to assess age, the grading of subarachnoid haemorrhages, and the results of follow-up DSA.

Results

Details pertaining to demographics, severity of subarachnoid haemorrhages, and aneurysmal characteristics for patients undergoing coiling as opposed to clipping procedures are summarised in Table 1.

Aneurysm characteristics

The location of aneurysms in the respective groups is

TABLE 2. Location of ruptured intracranial aneurysms

Location	Coiling group, n=80	Clipping group, n=89
Internal carotid-ophthalmic	4	0
Internal carotid-terminus	2	5
Ophthalmic artery	4	0
Posterior communicating artery	22	21
Anterior communicating artery	25	24
Anterior cerebral artery—A1	1	0
Anterior cerebral artery—A2	1	4
Middle cerebral artery	7	29
Basilar tip	1	0
Posterior inferior cerebellar artery	1	2
Posterior cerebral artery	2	0
Superior cerebellar artery	3	0
Vertebral artery	6	1
Anterior choroidal artery	1	3

TABLE 3. Numbers of serious peri-procedural complications

Complication	Coiling group (8 complications)	Clipping group (36 complications)
Thromboembolism	2	0
Arterial spasm	3	2
Cerebral infarction with hemiparesis and aphasia	1	8
Chest infection	0	2
Third nerve palsy	0	2
Occlusion of branch of middle cerebral artery	0	1
Brain swelling	0	1
Brain abscess	0	1
Obstructive hydrocephalus	0	4
Cerebral haematoma	0	3
Hypertension	0	1
Deep vein thrombosis	0	2
Sepsis	2	1
Generalised tonic-clonic convulsion	0	3
Cardiac arrhythmia	0	3
Peptic ulcer with or without perforation	0	2

shown in Table 2. There were more patients with middle cerebral artery aneurysms in the clipping group than in the coiling group (33 versus 9%), whereas there were more patients with vertebrobasilar aneurysms (16% vs 3%) and ophthalmic segment/ophthalmic artery aneurysms (10% vs 0%) in the coiling group than in the clipping group.

Clinical outcome

Serious peri-procedural complications are shown in Table 3. Clinical outcomes of the patients at 1 year after treatment assessed according to the GOS are shown in Table 4. The rate of death or permanent disability leading to dependency (GOS 1-3) was significantly lower in the coiling group (12/80, 15%) than in the clipping group (30/89, 34%; P=0.005), with a corresponding risk reduction of 19% (95% confidence interval, 6-32%). During the first week after the procedures, one patient in the coiling group died as did five in the clipping group. By the first month after the procedures, one patient in the coiling group and

TABLE 4. Clinical outcome 1-year post-procedure

Glasgow Outcome Scale score	Coiling group, n=80	Clipping group, n=89
1: Dead	3	9
2: Vegetative state	2	8
3: Severe disability, live dependently	7	13
4: Severe disability, live independently	8	14
5: Good recovery	60	45

TABLE 5. Duration of hospital stay

Hospital stay	Coiling group, n=72	Clipping group, n=88	P value*
Intensive care unit stay (days)			
Median	0	2	<0.001
25th percentile	0	1	
75th percentile	2	6	
Minimum	0	0	
Maximum	19	51	
General ward stay (days)			
Median	13	14	0.947
25th percentile	10	10	
75th percentile	23	23	
Minimum	6	1	
Maximum	120	104	

* Kruskal Wallis test

six in the clipping group had died (P=0.447).

Hospitalisation

The durations of hospital stay in general wards and the ICU are summarised in Table 5. There was no statistically significant difference between the groups for the duration of stay in general wards (P=0.947) but the difference was statistically significant in terms of ICU duration of stay (P<0.001).

Degree of aneurysm obliteration and subsequent treatment

As assessed by immediate post-treatment angiography, in the coiling group, total occlusion of the aneurysm was achieved in 67 (84%) patients, subtotal occlusion in four (5%), and incomplete occlusion in nine (11%). In the clipping group, the corresponding figures were 75 (84%), 10 (11%), and four (4%). There was no statistically significant difference in the degree of aneurysmal obliteration between the groups (P=0.100). In the coiling group, follow-up DSAs at 6 and 18 months were performed in 56 patients, and showed persistent complete occlusion of the aneurysms in 46 (82%) patients, unchanged size of the residual aneurysm in six (11%), and an increase in the size of the residual aneurysm in four (7%). In the clipping group, follow-up DSAs within 12 months were performed in 44 patients, and revealed persistent complete occlusion of the aneurysms in 38 (86%) patients, unchanged size of the residual aneurysm in four (9%), and development of mycotic aneurysms in two (5%). There was no significant difference in the findings at follow-up DSA between the coiling and clipping groups (P=0.08). In the coiling group, a subsequent treatment procedure was performed for residual or recurrent aneurysms in 13 patients, of which five were GDC coiling procedures and eight involved clipping. In the clipping group, three subsequent procedures were performed, all entailing GDC coiling. There was a significant difference in the number of such subsequent procedures performed between the two groups (P=0.004). Direct comparison was not undertaken due to differences in the timing and frequency of follow-up angiography.

Discussion

The ISAT[17] has shown favourable early results from endovascular coiling of ruptured aneurysms as compared to neurosurgical clipping; the risk reduction for dependency or death being 6.9% at 1 year. The present study aimed to evaluate the difference between these procedures (both performed according to specific selection criteria), in terms of 1-year clinical outcome and consumption of hospital resources. Moreover, all the patients were Hong Kong Chinese, in whom the median size of the ruptured aneurysms was 4 mm,[16] which is quite different from that reported in western populations. In the present study, endovascular coiling as a treatment for ruptured aneurysm was significantly safer than neurosurgical clipping; there being a much lower incidence of serious complication. Patients treated with endovascular coiling were significantly more independent postoperatively and did not utilise as much intensive care. The clinical outcome of patients who received endovascular coiling was significantly better 1 year after treatment, of which the findings concurred with results in the western populations reported in the ISAT.[17]

Subsequent longer-term follow-up in the

present study showed that a significantly higher proportion of patients treated by endovascular coiling underwent repeated treatment procedures for enlarging residual or recurrent aneurysms. Whereas, once an aneurysm is properly clipped at its neck, the chance of aneurysmal recanalisation and re-growth at the neck is extremely low, minimising the need for repeated treatment. Whilst a higher re-treatment rate is to be expected in the coiling group, Yu et al[16] suggested another contributory factor among Chinese patients, namely progressive recanalisation of the aneurysm neck and compaction of GDC in the sac. Although the benefit of a relatively safe coiling procedure must be balanced against the drawbacks of a higher chance of repeated procedures for aneurysm recurrence, it should be appreciated that the latter are elective procedures and therefore safer. Moreover, techniques and technologies for endovascular coiling have evolved in recent years and enabled tight packing of aneurysms even in unfavourable conditions involving a wide-neck. Such procedures now have optimised functional results involving embolisation coils as aneurysm occluders.[18-20] The techniques employed in the present study were basic and the aneurysms might not have been tightly packed when the body-to-neck ratio was 1:1, thus resulting in aneurysmal recanalisation and coil compaction in a recanalisation-prone patient population. Arguably therefore, the full potential of endovascular coiling has not been exemplified in the present study.

As mentioned in the Methods section, the selection of treatment modality in the present study was based on considerations of size, configuration, and location of the aneurysms. Such selection considerations explain the discrepancy in the incidence of aneurysm location in our two groups (Table 2) and could also contribute to the more frequent re-treatment rate in the coiling group. Thus, certain locations (the ophthalmic segment of internal carotid artery and the ophthalmic artery) are known to be associated with a higher chance of aneurysm recurrence.[21-23] The selection criteria for the two procedures also led to more middle cerebral artery aneurysms being included in the clipping group, and more vertebrobasilar aneurysms being included in the coiling group.

Since the present study was not a randomised controlled trial, there was no intention to evaluate the efficacy and safety of the two treatment modalities. Rather, our purpose was to determine whether there might be a significant benefit in introducing endovascular coiling (as compared to neurosurgical clipping) for the clinical management of selected patients with ruptured intracranial aneurysms presenting to a regional hospital in Hong Kong. Due to the differing constraints on the specific requirements in terms of aneurysmal morphology and location for coiling as opposed to clipping procedures, the authors adopted the above-mentioned selective treatment strategy. For these reasons, direct comparison of outcomes associated with the two procedures is not strictly valid.

In conclusion, the introduction of endovascular coiling as a treatment modality for the clinical management of Hong Kong Chinese patients with ruptured intracranial aneurysms is associated with significant benefits as compared to neurosurgical clipping, both in terms of a reduced need for intensive care and better clinical outcomes.

References

1. Collice M, D'Aliberti G, Arena O, et al. Multidisciplinary (surgical and endovascular) approach to intracranial aneurysms. J Neurosurg Sci 1998;42(1 Suppl 1):131S-140S.
2. Leber KA, Klein GE, Trummer M, Eder HG. Intracranial aneurysms: a review of endovascular and surgical treatment in 248 patients. Minim Invasive Neurosurg 1998;41:81-5.
3. Lot G, Houdart E, Cophignon J, Casasco A, George B. Combined management of intracranial aneurysms by surgical and endovascular treatment. Modalities and results from a series of 395 cases. Acta Neurochir (Wien) 1999;141:557-62.
4. Lempert TE, Malek AM, Halbach VV, et al. Endovascular treatment of ruptured posterior circulation cerebral aneurysms. Clinical and angiographic outcomes. Stroke 2000;31:100-10.
5. Solander S, Ulhoa A, Vinuela F, et al. Endovascular treatment of multiple intracranial aneurysms by using Guglielmi detachable coils. J Neurosurg 1999;90:857-64.
6. Yamaura I, Tani E, Yokota M, et al. Endovascular treatment of ruptured dissecting aneurysms aimed at occlusion of the dissected site by using Guglielmi detachable coils. J Neurosurg 1999;90:853-6.
7. Byrne JV, Sohn MJ, Molyneux AJ, Chir B. Five-year experience in using coil embolization for ruptured intracranial aneurysms: outcomes and incidence of late rebleeding. J Neurosurg 1999;90:656-63.
8. Debrun GM, Aletich VA, Kehrli P, Misra M, Ausman JI, Charbel F. Selection of cerebral aneurysms for treatment using Guglielmi detachable coils: the preliminary University of Illinois at Chicago experience. Neurosurgery 1998;43:1281-97.
9. Gruber DP, Zimmerman GA, Tomsick TA, van Loveren HR, Link MJ, Tew JM Jr. A comparison between endovascular and surgical management of basilar artery apex aneurysms. J Neurosurg 1999;90:868-74.
10. Steiger HJ, Medele R, Bruckmann H, Schroth G, Reulen HJ. Interdisciplinary management results in 100 patients with ruptured and unruptured posterior circulation aneurysms. Acta Neurochir (Wien) 1999;141:359-67.
11. Turjman F, Massoud TF, Sayre J, Vinuela F. Predictors of

aneurysmal occlusion in the period immediately after endovascular treatment with detachable coils: a multivariate analysis. AJNR Am J Neuroradiol 1998;19:1645-51.
12. Vanninen R, Koivisto T, Saari T, Hernesniemi J, Vapalahti M. Ruptured intracranial aneurysms: acute endovascular treatment with electrolytically detachable coils—a prospective randomized study. Radiology 1999;211:325-36.
13. Koivisto T, Vanninen R, Hurskainen H, Saari T, Hernesniemi J, Vapalahti M. Outcomes of early endovascular versus surgical treatment of ruptured cerebral aneurysms. A prospective randomized study. Stroke 2000;31:2369-77.
14. Vinuela F, Duckwiler G, Mawad M. Guglielmi detachable coil embolization of acute intracranial aneurysm: perioperative anatomical and clinical outcome in 403 patients. J Neurosurg 1997;86:475-82.
15. Cognard C, Weill A, Castaings L, Rey A, Moret J. Intracranial berry aneurysms: angiographic and clinical results after endovascular treatment. Radiology 1998;206:499-510.
16. Yu SC, Chan MS, Boet R, Wong JK, Lam JM, Poon WS. Intracranial aneurysms treated with Guglielmi detachable coil: midterm clinical and radiological outcome in 97 consecutive Hong Kong Chinese patients. AJNR Am J Neuroradiol 2004;25:307-13.
17. Molyneux A, Kerr R, Stratton I, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. Lancet 2002;360:1267-74.
18. Nelson PK, Levy DI. Balloon-assisted coil embolization of wide-necked aneurysms of the internal carotid artery: medium-term angiographic and clinical follow-up in 22 patients. AJNR Am J Neuroradiol 2001;22:19-26.
19. Henkes H, Bose A, Felber S, Miloslavski E, Berg-Dammer E, Kuhre D. Endovascular coil occlusion of intracranial aneurysms assisted by a novel self-expandable nitinol microstent (Neuroform). Interventional Neuroradiology 2002;8:107-19.
20. Fessler RD, Ringer AJ, Qureshi AI, Guterman LR, Hopkins LN. Intracranial stent placement to trap an extruded coil during endovascular aneurysm treatment: technical note. Neurosurgery 2000;46:248-53.
21. De Jesus O, Sekhar LN, Riedel CJ. Clinoid and paraclinoid aneurysms: surgical anatomy, operative techniques, and outcome. Surg Neurol 1999;51:477-88.
22. 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 2001;48:78-90.
23. Roy D, Raymond J, Bouthillier A, Bojanowski MW, Moumdjian R, L'Esperance G. Endovascular treatment of ophthalmic segment aneurysms with Guglielmi detachable coils. AJNR Am J Neuroradiol 1997;18:1207-15.