

Intracranial Aneurysms Treated with Guglielmi Detachable Coils: Midterm Clinical and Radiological Outcome in 97 Consecutive Chinese Patients in Hong Kong

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BACKGROUND AND PURPOSE: Use of Guglielmi detachable coils (GDCs) has proved to be a promising endovascular treatment for intracranial aneurysms. This study aimed to evaluate midterm clinical and radiologic outcomes of this treatment in Hong Kong Chinese patients, 68% of whom had small aneurysms (≤ 5 mm).

METHODS: We included 97 consecutive patients in whom GDCs were placed with curative intent. The patients presented with subarachnoid hemorrhage ($n = 80$) or mass effect ($n = 17$). The aneurysms measured $5 \text{ cm} \pm 2.8 \text{ mm}$; 68% were ≤ 5 mm. All patients were followed up clinically for an average of 54.5 ± 20.9 months and radiologically with sequential digital subtraction angiography at 6 and 18 months.

RESULTS: Total occlusion of the aneurysm was successfully achieved in 71.1% of patients after the initial treatment and in 82.5% after subsequent treatments. The retreatment rate was 17.5%. Procedure-related complication and mortality rates were 11.3% and 0%, respectively. The overall mortality was 5%, including mortality due to treatment failure in 1%. Neurologic outcomes were excellent in 77% of patients. Improved neurologic status, unchanged status, and deteriorated status was noted in 61.5%, 22%, and 16.5% of patients, respectively, at the end of the follow-up period. Intrinsic differences existed between Chinese and Western patients regarding the size of the aneurysm at presentation, periprocedural complications, and progression patterns of anatomic outcomes.

CONCLUSION: Endovascular coiling with GDCs is a reasonably effective and safe treatment for intracranial aneurysms in this group of Hong Kong Chinese patients, with favorable clinical and radiologic outcomes.

Thirteen years have elapsed since the first endovascular procedure with the Guglielmi detachable coil (GDC) was performed for the treatment of saccular intracranial aneurysms. The technique has proved to be promising its early results (1–11) and midterm outcomes (12, 13). In a randomized European-US trial comparing neurosurgical clipping (1070 cases) with GDC treatment (1073 cases) for ruptured intracranial aneurysms, short-term outcomes in terms of disability-free survival at 1 year were significantly better with GDCs, though the long-term risk of bleeding

from the treated aneurysm may be somewhat higher with coiling (14). However, we have observed in our Chinese patients that small aneurysms (2–5 mm) constitute a major portion of clinically presenting aneurysms. The efficacy of GDC treatment in such patients remains to be determined. This prospective study aimed to evaluate the midterm clinical and radiologic outcomes in 97 consecutive Chinese patients in Hong Kong, nearly 70% of whom had aneurysms sized 2–5 mm.

Methods

Patient Demographics

We included 97 consecutive patients in whom intracranial saccular aneurysms were treated with endovascular GDCs during the period from May 1995 to July 2001. All patients were local Hong Kong Chinese patients from a single medical center. They included 39 men and 58 women, with an average age of $56.8 \text{ years} \pm 12.9$, (median, 58 years; range, 22–80 years).

Received May 14, 2003; accepted after revision July 29.

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TABLE 1: Size of aneurysms

Size mm	No. of Aneurysms Treated with GDCs	No. of Aneurysms Treated at the Authors' Institution	No. of Aneurysms Treated at Three Major Institutions in Hong Kong
≤5	66 (68)	138 (70.1)	170 (63.4)
6–10	26 (27)	50 (25.4)	72 (26.9)
11–15	4 (4)	8 (4)	12 (4.5)
>15	1 (1)	1 (0.5)	14 (5.2)
Total	97 (100)	197 (100)	268 (100)

Note.—Numbers in parentheses are percentages.

Eighty patients presented with subarachnoid hemorrhage (SAH), and 17 presented with mass effect. The severity of SAH, as categorized by the World Federation of Neurologic Surgeons was grade I in 46 patients, grade II in 12 patients, grade III in five patients, grade IV in 11 patients, and grade V in six patients. In 77 patients, the presenting aneurysm was the only aneurysm. An additional incidental aneurysm was present in 10 patients. Seven patients had two additional aneurysms, and three patients had three additional aneurysms.

Aneurysm Characteristics

Only the presenting aneurysm was treated in each patient. The size of each aneurysm was measured with digital subtraction angiography (DSA). They ranged from 2 to 16 mm, with a median of 4 mm and an average of 5 mm \pm 2.8 mm. More than two-thirds of the aneurysms (68%) were 2–5 mm (Table 1). An interventional neuroradiologist (M.S.Y.C. or S.C.H.Y.) measured the aneurysms by electronic means on the best DSA projections. The size of all 197 clinically presenting aneurysms diagnosed and treated with clipping or GDC treatment in our center during the same period was also analyzed. The proportion of small aneurysms <5 mm in the whole group of 197 was 70.1% (Table 1), consistent with that observed in the GDC treated group. The ratio of aneurysmal sac to neck diameters was always \geq 1. About three-quarters (75.3%) of the aneurysms were located at the internal carotid artery (49.5%) or the anterior communicating artery (25.8%). The locations in the internal carotid artery were specifically the posterior communicating artery ($n = 29$), the ophthalmic artery ($n = 12$), the cavernous segment ($n = 4$), the supraclinoid segment ($n = 2$), and the anterior choroidal artery ($n = 1$). Locations of the other 24.7% of the aneurysms included the middle cerebral artery ($n = 7$), the vertebral artery ($n = 6$), the posterior cerebral artery ($n = 3$), the superior cerebellar artery ($n = 3$), the anterior cerebral artery ($n = 2$), the basilar artery ($n = 2$), and the posterior inferior cerebellar artery ($n = 1$).

Treatment Strategy

Clinically symptomatic aneurysms were diagnosed in 202 patients during the study period. The aneurysms were not treated in five because of a moribund patient condition due to severe SAH. Endovascular treatment was the treatment of priority in our center. The criteria used to select patients for endovascular treatment were an aneurysm \geq 2 mm, and a ratio of aneurysm-sac diameter to aneurysm-neck diameter of \geq 1. The presenting aneurysms of 97 patients fulfilled these two criteria, and all were treated with GDC embolization. One hundred patients were treated with surgical clipping.

Neurosurgeons made the decision to treat the patients. An interventional neuroradiologist (M.S.Y.C. or S.C.H.Y.) and a neurosurgeon (W.S.P., J.M.K.L., or R.B.) jointly selected the treatment technique. In Hong Kong, asymptomatic patients are not evaluated with imaging studies such as CT angiography, MR angiography, or DSA as a standard practice. Therefore,

incidental or asymptomatic aneurysms are rarely discovered for treatment.

Endovascular Procedure

All endovascular procedures were performed at the authors' institution, essentially by an interventional neuroradiologist (M.S.Y.C. or S.C.H.Y.), with the assistance of a neurosurgeon (W.S.P., J.M.K.L., or R.B.). The endovascular treatment for the initial 73 patients was performed by a senior interventional neuroradiologist who had 2–6 years of cumulative experience in interventional neuroradiology during the study period. The subsequent 24 patients were treated by another interventional neuroradiologist who had 1–3 years of cumulative experience in interventional neuroradiology. A Philips V3000 DSA unit (Philips Medical Systems, Best, the Netherlands) was used in the treatment of the first 86 patients. A Philips BV5000 bi-plane DSA unit (Philips Medical Systems) was used for the last 11 patients.

The procedure of GDC embolization was performed within a median of 4 days after clinical presentation, with the patient under general anesthesia. In all patients, the neck vessels were accessed with a 6F guiding catheter introduced through a femoral arterial approach. The aneurysms were catheterized with a FasTracker 18 or 10 microcatheter (Target Therapeutics, Fremont, CA). After deployment of the first GDC, the patients received a single intravenous bolus of 2000–3000 IU of heparin. Complete occlusion of the aneurysm was attempted in each case. The number of GDCs used for each aneurysm varied from 1 to 12, with a median of 4 and an average of 4.4 \pm 2.7. A total of 428 coils were used. The length of the GDC used for each aneurysm ranged from 4 to 270 mm, with a median of 24 mm and an average of 45 \pm 55 mm. The total length of the coils was 4362 mm.

Immediately after the procedure, DSA was performed to assess the degree of aneurysm occlusion, which was classified as follows: total occlusion (100%) when the sac and neck were densely packed with no contrast material visible, as subtotal occlusion (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 as incomplete occlusion (<95%) when loose packing and persistent opacification of the sac or the neck remnant were seen (13). The interventional neuroradiologist and neurosurgeon who took part in the treatment procedure judged the degree of occlusion together with an independently observing neurosurgeon (W.S.P., J.M.K.L., or R.B.).

Outcome Assessment

The neurosurgeons closely monitored the patients before their discharge home from the hospital. After discharge, the patients were followed up at 1- to 6-month intervals in an outpatient clinic where they underwent clinical assessment by a neurosurgeon and an interventional neuroradiologist. Follow-up DSA images were also reviewed by the neurosurgeon and the interventional radiologist together. Clinical evaluation was based on the Glasgow Outcome Scale (GOS). A score of 1 indicated good recovery without neurologic deficit, 2 indicated moderate disability (The patient was independent but disabled.), 3 indicated severe disability (The patient needed the assistance of another person for some activities of daily living.), 4 indicated a vegetative state, and 5 indicated death. The clinical outcome of patients included in the outcome analysis was represented by the GOS score at the latest clinical visit at 15–89 months (average, 54.5 months \pm 20.9) after GDC treatment. The change in neurologic status from before GDC treatment to the latest follow up visit was graded as improved, unchanged, or deteriorated. Change in neurologic status was also observed before and after subsequent treatment following the first GDC treatment.

Sequential follow-up DSA was performed in all patients at 6 and 18 months after GDC embolization to observe for recurrence or progression of the treated aneurysms. Subsequent treatment was performed with surgical clipping when follow-up DSA revealed an enlarging residual or recurrent aneurysm with a morphology amenable to clipping for cases in which GDC coiling was considered less preferable (15–17). For other cases of enlarging residual or recurrent aneurysms, a repeat GDC treatment was performed (18–23). An interventional neuroradiologist (M.S.Y.C. or S.C.H.Y.) and a neurosurgeon (W.S.P., J.M.K.L., or R.B.) jointly made the decision for retreatment. When follow-up DSA showed a residual or recurrent aneurysm that was small and that had static or slight marginal growth, no further treatment was offered, and the patient was observed clinically and angiographically.

Results

Periprocedural Complications

Procedure-related complications occurred in 11 cases (11.3%). All of these complications occurred in patients with an aneurysm not bigger than 5 mm. Periprocedural rupture of the aneurysm occurred in seven patients; all of these cases occurred during coil packing, and none resulted in mortality during the follow-up period. Subsequent clinical follow-up showed a GOS score of 1 in two patients, 3 in two patients, and 4 in three patients. Thromboembolism occurred in two patients, both of whom recovered completely with a GOS score of 1. Of three cases of arterial spasm, one was associated with periprocedural aneurysmal rupture. Another patient with procedure-related arterial spasm initially presented with high-grade SAH and a poor Glasgow coma scale (GCS) score and subsequently died of sepsis. The remaining patient with vasospasm made a full recovery, with a GOS score of 1. None of the procedure-related complications led directly to a fatal outcome.

Immediately following the procedure, 34 (35%) of 97 patients were monitored in the intensive care unit for an average of 1.79 days \pm 3.8. The average duration of hospital stay was 19.1 days \pm 18.9; the median was 13 days.

Mortality and Clinical Outcomes

Five patients died during the follow-up period. There was no procedure-related mortality. The only treatment-related death was due to rupture of an incompletely occluded aneurysm that had been static in size on follow-up DSA and not treated further. An improvement in neurologic status had been observed in this patient after the initial GDC treatment. The rupture occurred at 18 months after GDC treatment. Therefore, the mortality rate due to treatment failure was 1%. The other four deaths were due to rupture of a second incidental aneurysm at 5 months after GDC treatment for an aneurysm that presented with mass effect in one patient or due to sepsis in the other three patients who presented with high-grade SAH and a poor GCS score. GDC treatment was technically successful in these three patients, with the aneurysms totally occluded. One patient had two episodes of ischemic stroke at 2 years and at 3 years after

TABLE 2: Change in neurologic status by clinical presentation

Clinical Presentation	Change in Neurologic Status		
	Improved	Unchanged	Deteriorated
Mass Effect	9	6	1
SAH I	25	12	7
SAH II	7	1	4
SAH III	3	0	2
SAH IV	9	1	1
SAH V	3	0	0
Total	56	20	15

GDC treatment. With these six patients excluded, the clinical outcomes of the other 91 patients (94%), were a GOS score of 1 in 70 patients (77%), 3 in nine patients (10%), and 4 in 12 patients (13%). As compared before GDC treatment, neurologic status improved in 56 patients (61.5%), was unchanged in 20 patients (22%), and deteriorated in 15 patients (16.5%). The change in neurologic status in relation to clinical presentation is shown in Table 2.

Angiographic Outcome and Subsequent Treatment

Immediate postprocedural DSA showed total aneurysmal occlusion in 80 (82.5%) of 97 cases, subtotal occlusion in six cases (6.2%), and incomplete occlusion in 11 cases (11.3%). Of the 80 patients with initial total occlusion, three were lost to follow-up because of high-grade SAH and poor GCS and subsequently death from sepsis. Of the other 77 aneurysms, 67 (87%) remained completely occluded, as shown on the two sequential follow-up DSA studies. A recurrent aneurysm occurred in the other 13 aneurysms (16.3%), of which five were treated with surgical clipping and four with repeat GDC. Two of the four remaining recurrent aneurysms were static in size, and the other two increased only slightly; therefore, no subsequent treatment was offered in these four cases. Of the six aneurysms with initial subtotal occlusion, one became completely occluded, as shown on the sequential follow-up DSA, and three were static in size. The two remaining aneurysms were treated with surgical clipping. Of the 11 aneurysms that were incompletely occluded initially, six were treated with surgical clipping, one became completely occluded subsequently, and four were static in size. At the end of the follow-up period, 67 (69.1%) of 97 aneurysms became totally occluded after one GDC treatment, including the two aneurysms that were subtotally and incompletely occluded initially but that became totally occluded later.

A total of 17 subsequent procedures were performed (retreatment rate, 17.5%); nine involved clipping, and eight, coiling with GDCs. Six of the nine clipped aneurysms and five of the eight coiled aneurysms became completely occluded on follow-up DSA. Therefore, aneurysms in 80 of the 97 patients were totally occluded at the end of the follow-up period after the initial and subsequent treatment, for

TABLE 3: Outcomes by aneurysm size

A: Radiologic and clinical outcome						
Aneurysm Size, mm	Occlusion			Glasgow Outcome Scale		
	Total	Subtotal	Incomplete	1	2	3 or 4
≤5	58/66 (88)	0	8/66 (12)	49/64 (76.6)	0	15/64 (23.4)
>5	22/31 (71)	6/31 (19)	3/31 (10)	21/27 (77.8)	0	6/27 (22.2)

B: Periprocedural complication, mortality, and subsequent procedure rates					
Aneurysm Size, mm	Complication			Mortality Rate	Subsequent Procedure
	Rupture	Thromboembolism	Vasospasm		
≤5	7/66 (10.6)	2/66 (3)	2/66 (3)	2/66 (3)	11/66 (16.6)
>5	0	0	0	3/31 (9.7)	6/31 (19.3)

TABLE 4: Clinical and radiologic outcome analysis by presentation and SAH severity

	Complication Rate	Mortality Rate	Glasgow Outcome Score				Occlusion			Subsequent Procedure
			1	2	3	4	Total	Subtotal	Incomplete	
Presentation										
SAH	10/80 (12.5)	4/80 (5)	55/75 (73.3)	0	9/75 (12)	11/75 (14.7)	67/80 (83.8)	4/80 (5)	9/80 (11.2)	15/80 (18.75)
Mass effect	1/17 (5.9)	1/17 (5.9)	15/16 (93.7)	0	0	1/16 (6.3)	13/17 (76.5)	2/17 (11.75)	2/17 (11.75)	4/17 (23.5)
SAH severity										
I	3/46 (6.5)	1/46 (2.2)	35/44 (79.5)	0	4/44 (9.1)	5/44 (11.4)	40/46 (86.9)	1/46 (2.1)	5/46 (11)	7/46 (15.2)
II	2/12 (16.7)	0	7/12 (58.3)	0	2/12 (16.7)	3/12 (25)	8/12 (66.7)	3/12 (25)	1/12 (8.3)	2/12 (16.7)
III	3/5 (60)	0	3/5 (60)	0	1/5 (20)	1/5 (20)	4/5 (80)	0	1/5 (20)	1/5 (20)
IV	1/11 (9.1)	0	8/11 (72.7)	0	1/11 (9.1)	2/11 (18.2)	10/11 (90.9)	0	1/11 (9.1)	2/11 (18.2)
V	2/6 (33.3)	3/6 (50)	2/3 (66.7)	0	1/3 (33.3)	0	5/6 (83.3)	0	1/6 (16.7)	0

Note.—Numbers in parentheses are percentages.

a success rate of 82.5%. There was no change in neurologic status in five of the nine patients subsequently treated with clipping and in all eight patients treated with GDCs. The other four patients treated with clipping had an improved neurologic status.

Discussion

Characteristics of Aneurysm

In our group of 197 Chinese patients treated in our center, a high proportion (70.1%) of the presenting aneurysms consisted of small aneurysms 2–5 mm (Table 1). Of the 97 patients treated with GDC embolization, most (68%) presented with aneurysms ≤5 mm (Table 1).

In a 3-year period, 266 Chinese patients in Hong Kong presenting with SAH and were in three major local hospitals, including the authors' hospital, which provide care to most patients with SAH in Hong Kong. In these patients, who are supposedly representative of the Chinese population in Hong Kong, 170 (63.4%) of 266 aneurysms were ≤5 mm (Table 1). Such a high proportion of small aneurysm (≤5 mm) is consistent with the findings in the authors' patient group. There is no statistically significant difference among the three proportions: 66 of 97, 138 of 197, and 170 of 268 ($P = .3086$, chi-square test).

On the basis of these observations, we postulate that Chinese patients in Hong Kong tend to present with intracranial aneurysms at an earlier stage and

therefore a smaller size due to unknown intervening factors.

Outcome Analysis by Size of Aneurysm

We analyzed the clinical and radiologic outcome of small aneurysms, as well as the procedure-related complications, mortality rates, and the need for subsequent procedures with respect to the size of aneurysms (Table 3). A high success rate of total occlusion was achieved in aneurysms ≤5 mm (58 of 66). This success rate was significantly higher than that achieved in aneurysms >5 mm (22 of 31) (Table 3). ($P = .0422$, Fisher exact test). There was no significant difference in the clinical outcomes for aneurysms smaller or larger than 5 mm. A GOS score of 1 was observed in more than three-quarters of the cases in both groups (Table 3) ($P = .5660$, Fisher exact test).

In our group of patients, the size of the aneurysm appeared to be an important factor affecting the occurrence of periprocedural complications. All 11 cases with complications occurred in patients with aneurysms ≤5 mm, and no complication occurred during the treatment of larger aneurysms (Table 3). This difference is proved to be statistically significant ($P = .0108$, Fisher exact test). Larger aneurysms did not pose a higher risk of mortality in our patients. The overall mortality rate was not significantly higher in aneurysms >5 mm (three of 31 vs two of 66, Table 3) ($P = .1845$, Fisher exact test). The size of the aneurysm did not affect the need for subsequent treatment. About the same proportion

of patients required a subsequent treatment (11 of 66 vs six of 31, Table 3) ($P = .4756$, Fisher exact test).

Periprocedural Complications

In the present study, periprocedural complications were more common in patients with SAH than those with mass effect, with a rate of 12.5% (10 of 80 patients) and 5.9% (one of 17 patients), respectively (Table 4). However, this difference was not statistically significant ($P = .3867$, Fisher exact test). There was no definite association between the complication rate and the severity of SAH (Table 4).

Perforation or rupture of the aneurysmal sac is said to be a rare complication (24), but it was the most common perioperative complication in this series (7%). Rupture occurred in one case with mass effect. All cases of rupture in the present series occurred in aneurysms ≤ 5 mm. In six cases, the procedure was performed for an aneurysm occurring with SAH. In two cases, the procedure was performed 1 day after SAH, and in two other cases, 2 and 4 days after SAH. All six were treated within 2 weeks after SAH. Such rupture is reported more common in recently ruptured aneurysms than in other settings (24). All seven of our patients with a periprocedural rupture survived, and two had made an excellent recovery with a GOS score of 1.

Thromboembolic events has been the most common periprocedural complication and is, by far, the most important cause of permanent morbidity following GDC treatment in the Western population (13, 24). Heparin has been administered to achieve an activated clotting time 4–6 times greater than normal, with the additional intravenous administration of aspirin and the postprocedural administration of heparin for 48 hours and low-molecular-weight heparin for 1 week. However, intraprocedural thrombosis has been observed in 27 patients (11%), with seven patients having permanent neurologic deficits and 10 having postprocedural thrombosis within 1 week (13). In a report by Pelz et al, the occurrence rate of symptomatic thromboembolic events was 27.5%, and the stroke rate was 15.5%, with permanent deficits in 3.4% (24). In the present series, a single intravenous 2000- to 3000-IU bolus of heparin was given to each patient after the first GDC was deployed to achieve an activated clotting time of 1.5–2 times greater than normal, with low-molecular-weight heparin given for 48 hours after the procedure. Periprocedural thrombosis occurred in two patients (2%), who had fully recovered from the event with a clinical outcome with a GOS score 1. Our patients with thrombotic complications were not treated with thrombolytic therapy because of a concern about subsequent bleeding complications (25, 26). Vasospasms were managed with intraarterial papaverine (27, 28).

Mortality and Clinical Outcomes

In this study, the overall mortality was 5%. The mortality rate due to post-treatment bleeding was 1%, and the complication-related mortality rate

TABLE 5: Radiologic outcome by a detailed breakdown of aneurysm size

Aneurysm Size, mm	No of Aneurysms	Degree of Occlusion		
		Total	Subtotal	Incomplete
2–3	30	27 (90)	0	3 (10)
>3–5	36	31 (86.1)	0	5 (13.9)
>5–8	18	13 (72.2)	3 (16.7)	2 (11.1)
>8	13	9 (69.2)	3 (23.1)	1 (7.7)

Note.—Numbers in parentheses are percentages.

was 0%. The overall mortality rates were comparable in patients presenting with SAH and in those presenting with mass effect, namely, four of 80 and one of 17, respectively (Table 4). The difference was not statistically significant ($P = .6270$, Fisher exact test). The overall mortality rate was significantly higher in patients presenting with grade V SAH than in those with grade I SAH (three of six vs one of 46, Table 4) (Fisher exact test, $P = .0035$).

In the present series, 70 patients had a good clinical recovery after GDC treatment, without neurologic deficits, giving a outcome rate of 72% for a GOS score of 1 in the group of 97 patients. If the 17 patients (17.5%) with poor-grade (IV–V) SAH were excluded, the outcome rate for a GOS score of 1 would have been 87.5%. The proportion of favorable clinical outcomes appeared to be higher in patients presenting with mass effect than in those presenting with SAH, ie, 15 of 16 versus 55 of 75 (Table 4); however, this difference is not statistically significant ($P = .0677$, Fisher exact test). The outcome rate for a GOS score of 1 was slightly higher in patients with SAH grade I and more or less the same in patients with SAH of other grades (Table 4). The difference in the outcome rate for a GOS score of 1 among the five SAH grades was not statistically significant ($P = .6282$, chi-square test).

Angiographic Outcomes

As mentioned earlier, a higher success rate of total occlusion was achieved in aneurysms < 5 mm (87.9%) than those > 5 mm (70.9%) (Tables 3, 5). Our results were best in aneurysms sized 2–3 mm. Dense packing had been the goal of GDC treatment. The endpoint of total occlusion was when the aneurysm was densely packed and further coiling was not possible, with DSA showing no visible contrast material in the sac and neck. With these criteria, total occlusion was achieved in 80 patients (82.5%). The compactness of packing was reflected in the average number of 4.4 ± 2.7 coils, the average coil length of 45 ± 55 mm for each aneurysm, and a total of 428 coils used. However, the rate of aneurysm recurrence in the group with total occlusion was high (16.2%). Delayed thrombosis of the neck remnant in the initially subtotally occluded aneurysm meant that total occlusion occurred uncommonly (16.7% of cases, Table 6). The high recurrence rate and low delayed-thrombosis rate in our series is contrary to what that observed by

TABLE 6: Radiologic outcome and subsequent treatment

Follow-Up DSA	Complete Occlusion	Static Growth	Slight Growth	Subsequent Clipping	Subsequent GDC Treatment
Recurrent aneurysm (<i>n</i> = 13)	0	2 (15.4)	2 (15.4)	5 (38.4)	4 (30.8)
Residual after subtotal occlusion (<i>n</i> = 6)	1 (16.7)	3 (50)	0	2 (33.3)	0
Residual after incomplete occlusion (<i>n</i> = 11)	1 (9.1)	4 (36.4)	0	6 (54.5)	0

Note.—Numbers in parentheses are percentages.

Cognard et al (13). In their series, the total occlusion rate rose from 55% to 76% in 160 cases followed up for few months, and the subtotal occlusion rate decreased from 40% to 16%. Conversion of subtotal occlusion to total occlusion due to delayed thrombosis of a neck remnant occurred in at least 34 (53%) of 64 cases. We noticed a tendency for aneurysm recurrence due to progressive recanalization of the aneurysm neck and progressive compaction of GDCs in the sac.

Limitations

In this article, we report our experience in treating aneurysms with GDC embolization in a group of Chinese patients. Only patients who had an aneurysms with a ratio of aneurysm-sac diameter to neck diameter of ≥ 1 were selected for treatment (29). The remodeling technique was not applied in this series (30). We did not compare results in our patients with findings in Western populations in previous reports because there is a basic difference between the two groups regarding the size of aneurysms, the criteria for selecting aneurysms for GDC treatment, the additional techniques involved in the embolization procedures, the timing of follow-up angiographic assessment, and the criteria for clinical assessment.

Conclusion

Endovascular treatment of intracranial aneurysm with GDC embolization appeared to be reasonably effective and safe for our group of Hong Kong Chinese patients. Success and complication rates were promising. Small aneurysms ≤ 5 mm seemed to constitute most (68%–70%) presenting intracranial aneurysms in Chinese patients in Hong Kong.

Acknowledgments

The authors wish to thank Mr Clinton Wong for his technical support during the procedures of GDC embolization and Miss Mi Lau for her effort in preparing the manuscript. The authors would also like to thank Dr K. M. Cheng for providing the data on the size of ruptured aneurysms at Queen Elizabeth Hospital and Queen Mary Hospital in Hong Kong.

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