Treatment of Recurrent Intracranial Aneurysms After Neck Clipping: Novel Classification Scheme and Management Strategies

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BACKGROUND: Recurrent aneurysms after initial clipping have been discussed as an important issue in the surgical management of aneurysm.

OBJECTIVE: To report our experience with recurrent cerebral aneurysms after neck clipping and to discuss classification and recommended management.

METHODS: Aneurysm treatments from a single institution over a 20-year period were retrospectively reviewed. Twenty-three recurrent aneurysms in 23 patients were managed during the study period. Recurrent aneurysms were classified using the concepts of closure line and closure plane, as follows. *Type 1:* neck situated in an almost different site from the previous clip. *Type 2:* existing closure plane and reconstructive closure plane are almost the same. *Type 3:* existing closure plane and reconstructive closure plane cross *(type 3a)*; in rare cases, the existing closure line is sufficiently distant from the neck *(type 3b)*. *Type 4:* no reconstructive closure line is identifiable.

RESULTS: Nine patients presented with subarachnoid hemorrhage at recurrence. The mean interval to recurrence was 15.0 years. Management comprised clipping with elective subsequent old-clip removal (n = 7), clipping with preceding old-clip removal (n = 2), bypass occlusion (n = 1), coating (n = 1), combined surgery (n = 1), endovascular surgery (n = 4), and observation (n = 3). Therapeutic intervention was not indicated in 4 patients. Types 3a and 4 required more complex surgical procedures or coil embolization. Procedural complications were observed in 2 patients.

CONCLUSION: A small but definite propensity toward recurrence after neck clipping exists, and most recurrent aneurysms require some form of retreatment. The novel classification scheme may provide conceptual clarity and therapeutic guidance for decision making.

KEY WORDS: Aneurysm, Clipping, Recurrence, Retreatment, Recurrent aneurysm
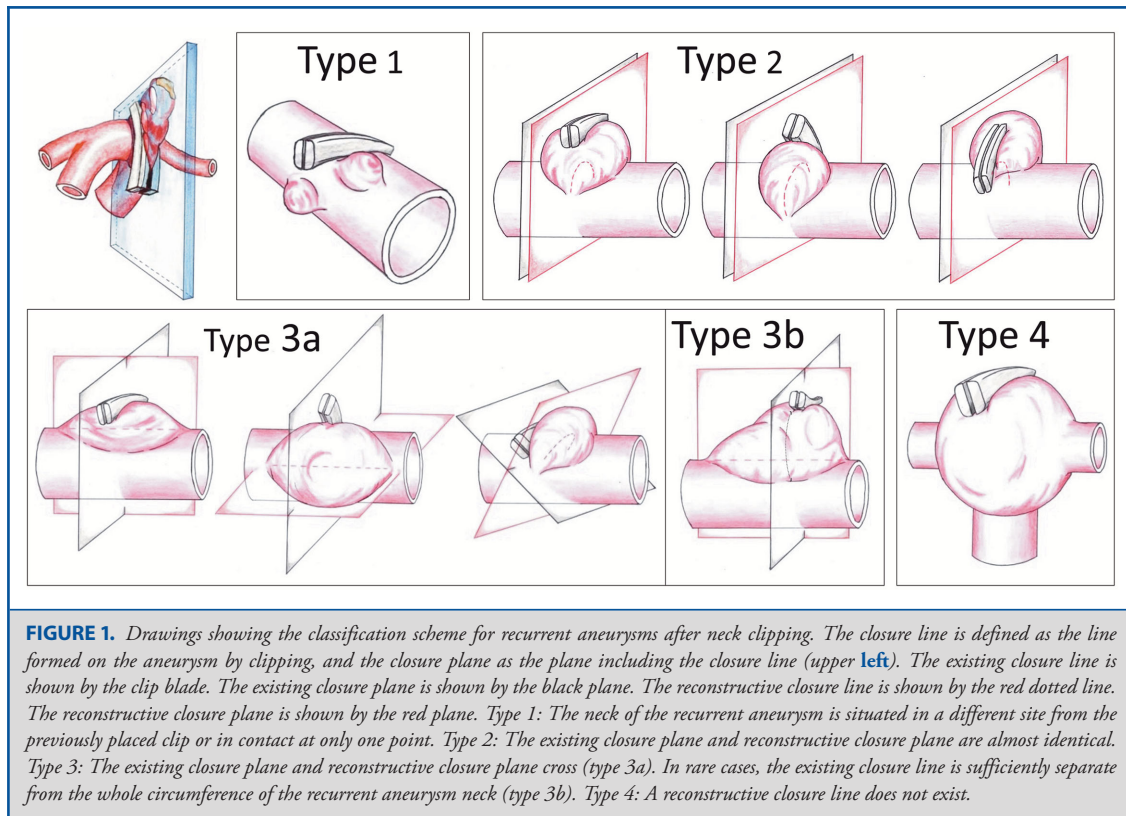
The main goal in the treatment of cerebral aneurysm is complete obliteration of the aneurismal sac and neck. Surgical clipping is a useful option for achieving this goal, but aneurysm recurrence after initial clipping remains an important issue. The frequency of aneurysm recurrence after complete clipping is difficult to determine, but has been reported as about 0.02% to 0.52% annually.[1-3]

ABBREVIATIONS: CT, computed tomography; **MRA,** magnetic resonance angiography; **SAH,** subarachnoid hemorrhage

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To date, surgical clipping, endovascular coil embolization, combined surgery, and other methods have been applied for the treatment of lesions.[2,4-19] Surgical treatment for recurrence of a previously clipped aneurysm is one of the most difficult procedures in aneurysm surgery.[2,4,7,8] Such surgery is not only technically difficult due to issues such as surgical-site adhesions, but also difficult in terms of decision making. We describe our experience with recurrent aneurysms after neck clipping, and discuss the management of this entity. Analysis of the anatomical characteristics of recurrent aneurysms led to a novel classification scheme, with type-specific management recommendations for this diverse and potentially treacherous collection of aneurysms.

FIGURE 1. *Drawings showing the classification scheme for recurrent aneurysms after neck clipping. The closure line is defined as the line formed on the aneurysm by clipping, and the closure plane as the plane including the closure line (upper* **left***). The existing closure line is shown by the clip blade. The existing closure plane is shown by the black plane. The reconstructive closure line is shown by the red dotted line. The reconstructive closure plane is shown by the red plane. Type 1: The neck of the recurrent aneurysm is situated in a different site from the previously placed clip or in contact at only one point. Type 2: The existing closure plane and reconstructive closure plane are almost identical. Type 3: The existing closure plane and reconstructive closure plane cross (type 3a). In rare cases, the existing closure line is sufficiently separate from the whole circumference of the recurrent aneurysm neck (type 3b). Type 4: A reconstructive closure line does not exist.*

METHODS

Patients and Data Collection

We retrospectively reviewed all patients diagnosed with cerebral aneurysms at our institution between April 1995 and March 2016. During this period, a total of 1818 patients with cerebral aneurysms underwent open surgery in our institution. Intraoperative microvascular Doppler ultrasonography was routinely used to evaluate successful aneurysm obliteration, and intraoperative indocyanine green video angiography was added after June 2011. Follow-up diagnosis of aneurysm for patients who underwent surgical clipping, which has been described elsewhere,[20] was based on images obtained using digital-subtraction angiography or 3-dimensional computed tomography (CT) angiography at least once within 6 months of the initial treatment. Magnetic resonance angiography (MRA) was performed every 12 months thereafter until 2 years after surgery. Patients were also repeatedly examined with 3-dimensional CT angiography or MRA every 1 to 5 years. During the study period, we identified 23 patients with 23 recurrent aneurysms after neck clipping. Recurrent aneurysm was defined as regrowth of an aneurysm after neck clipping or rupture of a remnant after neck clipping. Remnants that were not either regrown or ruptured were excluded. The clinical charts, reports, images, and surgical videos of all 23 inpatients were reviewed. All recurrent aneurysms were morphologically evaluated by 3-dimensional rotational angiography or 3-dimensional CT angiography, with the exception of 2 aneurysms (cases 22 and 23) with severe subarachnoid hemorrhage (SAH) at rebleeding.

The study protocol was approved by our Institutional Review Board for Human Research.

Classification of Recurrence

We classified recurrent aneurysms after neck clipping into 4 different types including 2 subtypes, using the concepts of the closure line and closure plane (Figure 1). Ishikawa et al[21] defined the closure line as the line on the aneurysm caused by clipping, and demonstrated that the ideal closure line on each aneurysm can be identified to eliminate the aneurysm as far as possible. This concept can be theoretically comprehended and accepted by most neurosurgeons, since clipping refers to the task of converting the aneurismal orifice as a 3-dimensional curved sphere into a 2-dimensional curved line. To allow for the ideal closure line, an appropriate direction for insertion of the clip applicator is required. As Nakayama[22] defined the concept, the closure plane is that plane in which the ideal closure line is included. In most cases, the ideal closure line is curved, so the only ideal closure plane is defined for the particular aneurysm according to the ideal closure line. This study defined the existing closure line as the line on the recurrent aneurysm caused by the old clip, and the existing closure plane as the plane in which the existing closure line was included. We also defined the reconstructive closure line as the ideal closure line on the recurrent aneurysm, and the reconstructive closure plane as the plane in which the reconstructive closure line is included.

Type 1: The neck of the recurrent saccular aneurysm is situated in a different site from the previously placed clip, or in contact at only one
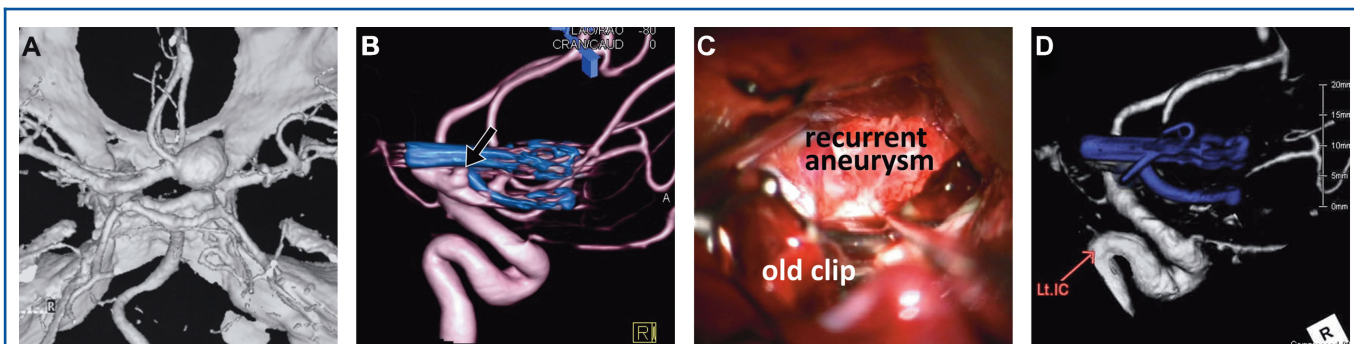
FIGURE 2. *Images showing type 1 recurrent aneurysm (case 1). A 79-year-old man who had undergone clipping of an unruptured large anterior communicating artery aneurysm 14 years earlier presented with SAH and recurrent aneurysm. The neck of the recurrent aneurysm was in contact with the previously placed clips at only 1 point. He was treated by clipping without removal of the old clips.* **A,** *Three-dimensional CT angiography before initial clipping.* **B,** *Three-dimensional rotational angiography at recurrence (recurrent aneurysm shown by the arrow).* **C,** *Intraoperative photograph immediately before additional clipping.* **D,** *Three-dimensional CT angiography after second clipping.*
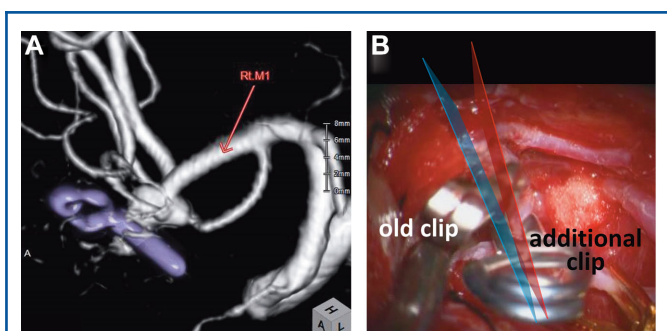

FIGURE 3. *Images showing type 2 recurrent aneurysm (case 5). A 54-year-old woman who had undergone clipping of a ruptured right middle cerebral artery aneurysm 26 years earlier was incidentally diagnosed with recurrence. The reconstructive closure plane was almost the same as the existing closure plane. She was treated by clipping with removal of the old clip just after completion of new neck clipping.* **A,** *Three-dimensional CT angiography at recurrence.* **B,** *Intraoperative photograph immediately after additional clipping (existing closure plane shown by blue plane, reconstructive closure plane shown by red plane).*

point (Figures 1 and 2). This aneurysm is just like a de novo aneurysm originating from the same location and growing in different directions from the previous aneurysm. The reconstructive closure line is variable and free from influence of the existing closure line, so the old clip does not prevent new neck clipping.

Type 2: In this type of recurrent aneurysm, the existing closure plane and reconstructive closure plane are almost the same (Figures 1 and 3). Additional clipping to the old clip is likely to completely secure this type of aneurysm neck.

Type 3 (types 3a and b): When the existing closure plane and reconstructive closure plane are crossed, typically when almost perpendicular (type 3a; Figures 1 and 4), the old clip disturbs ideal additional clipping. However, in rare cases the existing closure line is sufficiently distant from the whole circumference of the recurrent aneurysm neck (type 3b; Figures 1 and 5). The old clip of this exceptional-type aneurysm has some small influence on ideal additional clipping.

Type 4: In this type of recurrent aneurysm, we cannot identify the reconstructive closure line (Figures 1 and 6). This type of aneurysm is often large or huge, and frequently involves parent arteries or perforating arteries.

The supplemental video demonstrates the intraoperative findings of those illustrative cases (**Video, Supplemental Digital Content**).

RESULTS

Patients and Aneurysms Characteristics

Patients and aneurysms characteristics are summarized in Table. Ten patients (cases 2, 5, 7, 8, 13, 14, 17, 18, 20, and 22) had initially been treated with microsurgical clip obliteration at another institution. Among the 13 aneurysms initially treated at our institution, 9 had been clipped completely and 4 (30.7%, cases 1, 6, 11, and 16) had been clipped with small remnants at initial treatment. Mean age at recurrence was 65 ± 13 years. The mean interval between first clip obliteration and recurrence was 15.0 ± 8.5 years. Five aneurysms recurred in less than 10 years. Among these, 3 aneurysms recurred within 2 years. Thirteen aneurysms recurred in 10 to 19 years, and 6 aneurysms after more than 20 years. In the course of observation after the diagnosis of regrowth, 2 recurrent aneurysms (cases 8 and 17) progressed and rebled, and the patients were subsequently transferred to our institution. The intervals between diagnosis of regrowth and rebleeding were 6 years and 1 year, respectively. One patient (case 5) had been diagnosed with fibromuscular dysplasia, and that pre-existing pathology might have contributed to the recurrence. Mean maximum diameter of the recurrence was 10.6 ± 6.4 mm.

The most common type of recurrent aneurysm was type 3 (n = 10; 47.6%), with type 3b (n = 2) representing 20% of these. The second most frequent type was type 2 (n = 6; 28.6%), followed by type 4 (n = 3; 14.3%) and type 1 (n = 2; 9.5%). Both type 1 aneurysms, 2 type 2 aneurysms (33.3%), 3 type 3 aneurysms
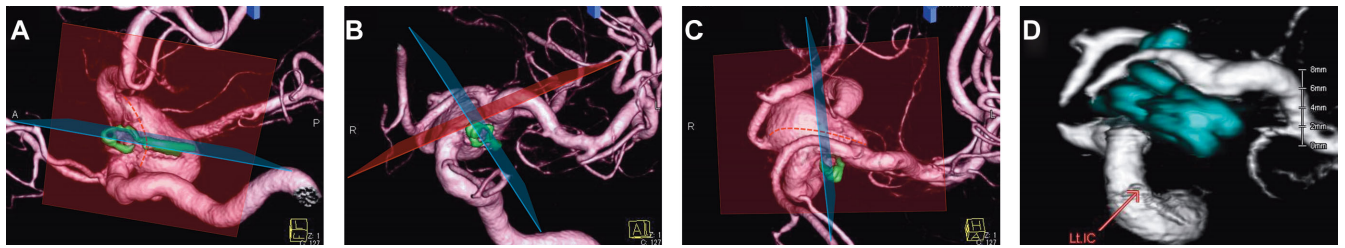
FIGURE 4. *Type 3a recurrent aneurysm (case 7). A 74-year-old woman who had undergone clipping of a ruptured left internal carotid-posterior communicating artery aneurysm 13 years earlier was incidentally diagnosed with recurrence. The existing and reconstructive closure planes crossed perpendicularly. She was treated by clipping with suction decompression and removal of the old clip just before completion of new neck clipping. A-C, Three-dimensional rotational angiography at recurrence (existing closure plane shown by blue plane, reconstructive closure line shown by red dotted line, and reconstructive closure plane shown by red plane). D, Three-dimensional CT angiography after second clipping.*
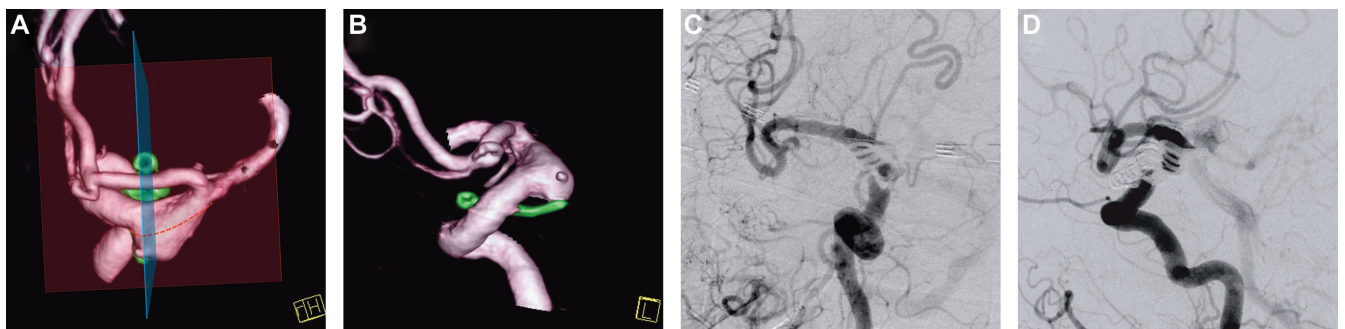

FIGURE 5. *Type 3b recurrent aneurysm (case 13). An 82-year-old woman who had undergone clipping of a ruptured right internal carotid-posterior communicating artery aneurysm 30 years earlier presented with SAH and recurrent aneurysm. The existing and reconstructive closure planes crossed, and the existing closure line was sufficiently separate from the whole circumference of the recurrent aneurysm neck. She was treated by clipping with removal of the old clip just after complete new neck clipping. A and B, Three-dimensional rotational angiography at recurrence (existing closure plane shown by blue plane, reconstructive closure line shown by red dotted line, and reconstructive closure plane shown by red plane). C and D, Digital-subtraction angiography (common carotid artery injection, anteroposterior and lateral views, respectively) after second clipping.*

(30%), and no type 4 aneurysms resulted in subsequent SAH. Mean post-treatment interval was 14.5 years for type 1 recurrences, 19.0 years for type 2 recurrences, 16.6 years for type 3 recurrences, and 4.2 years for type 4 recurrences. Mean size was 3.8 mm for type 1, 10.3 mm for type 2, 9.5 mm for type 3 (type 3a, 9.1 mm; type 3b, 11.0 mm), and 17.7 mm for type 4. Our 4 small remnants recurred as 1 each of types 1, 2, 3, and 4.

Management and Outcomes

Therapeutic intervention was not indicated in 3 patients because of the severity of SAH, and in 1 patient because of poor general condition. Eleven patients underwent open surgery, 1 patient underwent combined open and endovascular surgery, and 4 patients underwent endovascular surgery. Three recurrent aneurysms in the remaining 3 patients have been under observation without enlargement or rupture over relatively short follow-up periods (case 11, 9 months; case 15, 18 months; case 16, 6 months).

Two recurrent aneurysms were clipped with removal of the old clip just before the new neck clipping, termed "clipping with preceding old-clip removal," which is a difficult and stressful maneuver for surgeons. Four aneurysms were clipped without removal of the old clip, and 3 aneurysms were clipped with removal of the old clip just after the new neck clipping. These are collectively termed "clipping with elective subsequent old-clip removal." One giant recurrent aneurysm was treated by aneurysm occlusion with bypass surgery, and one recurrent aneurysm with a hard atherosclerotic wall was treated by the coating procedure. All these aneurysms were approached through the same old craniotomy, and the old clip was released from surrounding adhesions. In 5 patients, application of temporary clips (cases 1, 2, 5, 6, and 13) or the suction decompression method (case 7) was used. Outcomes of 4 patients were deteriorated. Surgical complications were observed in 1 patient (case 2), as cerebral infarction due to temporary occlusion. Outcomes were deteriorated in 2 patients (cases 6 and 13) due to damage from
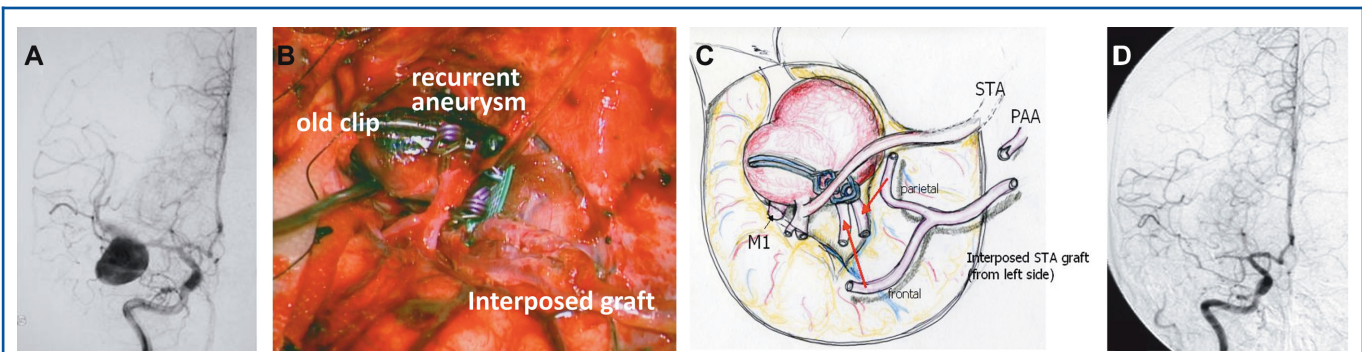
FIGURE 6. *Type 4 recurrent aneurysm (case 14). A 24-year-old woman who had undergone clipping of an unruptured right middle cerebral artery aneurysm 6 months earlier was diagnosed with recurrence during a regular check-up. The recurrent aneurysm was huge and involved the parent arteries. She was treated by EC-IC bypass and trapping of the aneurysm. A, Digital-subtraction angiography (internal carotid artery injection, anteroposterior view) at recurrence. B, Intraoperative photograph. C, Surgeon's drawing of the intraoperative situation (STA, superficial temporal artery; PAA, posterior auricular artery). D, Digital-subtraction angiography (internal carotid artery injection, anteroposterior view) after second operation.*

TABLE. Summary of 23 Recurrent Aneurysms Previously Treated With Microsurgical Clip Obliteration Identified in 23 Patients

Patient no.	Age/sex	Aneurysm location	Initial SAH	Rebleed (WFNS)	Interval (years)	Recurrence size (mm)	Treatment modality	Type	mRS on last follow-up
1	79/M	AcomA	−	+(II)	14	3	Clipping (without old-clip removal)	1	1
2	70/F	ICA-PcomA	+	−	18	15	Clipping (without old-clip removal)	2	3
3	52/M	MCA	−	−	6	4.5	Clipping (without old-clip removal)	2	0
4	59/F	AcomA	+	−	30	4	Clipping (with subsequent old-clip removal)	2	0
5	54/F	MCA	+	−	26	8	Clipping (with subsequent old-clip removal)	2	0
6	77/F	MCA	−	+(III)	11	8	Clipping (with preceding old-clip removal)	2	4
7	74/F	ICA-PcomA	+	−	13	15	Clipping (with preceding old-clip removal)	3a	1
8	70/F	ICA-PcomA	+	+(III)	17	14	Combined open and endovascular surgery	3a	6
9	56/F	ICA-ophthA	+	−	24	6	Coating	3a	0
10	67/M	MCA	−	−	15	7	Coil embolization (as alternative treatment)	3a	0
11	43/M	ACA	+	−	2	3.6	Observation	3a	0
12	69/F	ICA-PcomA	+	−	15	7	Clipping (without old-clip removal)	3b	0
13	82/F	ICA-PcomA	+	+(III)	30	15	Clipping (with subsequent old-clip removal)	3b	2
14	24/F	MCA	−	−	0.5	27	Bypass and trapping	4	0
15	77/F	ICA terminus	+	−	2	16	Observation	4	0
16	76/M	MCA	+	−	10	10	Observation	4	0
17	66/M	ICA-PcomA	+	+(I)	15	4.5	Coil embolization (as first-line treatment)	1	0
18	68/M	MCA	+	−	23	12	Coil embolization (as first-line treatment)	3a	6
19	61/M	MCA	−	+(IV)	12	11	Coil embolization (as first-line treatment)	3a	5
20	69/F	ICA-PcomA	+	+(V)	23	22	Conservative	2	6
21	72/M	MCA	−	−	15	4	Conservative	3a	5
22	73/M	AcomA	+	+(V)	15	NA	Conservative	NA	6
23	70/M	ICA-PcomA	−	+(V)	9	NA	Conservative	NA	6

ACA, anterior cerebral artery; AcomA, anterior communicating artery; F, female; ICA, internal carotid artery; M, male; MCA, middle cerebral artery; mRS, modified Rankin scale; ophthA, ophthalmic artery; PcomA, posterior communicating artery; SAH, subarachnoid hemorrhage; WFNS, World Federation of Neurological Surgeons Subarachnoid Hemorrhage Grading system

SAH, and in 1 patient (case 7) due to postoperative cardiogenic cerebral embolism.

The orifice of the large fusiform recurrent aneurysm was not completely closed by neck clipping alone because of an inability to remove the old clip in 1 case (case 8), so that patient underwent subsequent coil embolization. Cerebral infarctions due to the procedures and cerebral vasospasm were the cause of the death for this patient.

Endovascular surgery was selected as first-line treatment in 3 patients, because the recurrent aneurysms had narrow neck

orifices. One patient chose endovascular surgery as an alternative treatment because of the risks inherent in clipping surgery requiring old-clip removal. In coil embolization for the second treatment, complete occlusion was achieved in 1 patient (case 19), and a neck remnant was observed in the remaining 3 patients. No procedural complications occurred during or after coil embolization. One patient (case 18) required 3 additional coil embolizations, and then suddenly died outside of hospital. Outcomes for 1 patient (case 19) were deteriorated due to damage from SAH.

Type of Recurrence and Treatment Modalities

Relationships between the classification of recurrence and treatment modality were assessed. In this assessment (cases 1-16), 4 aneurysms without any indication for therapeutic intervention and 3 aneurysms treated by endovascular surgery as first-line treatment were excluded. Most type 1, 2, and 3b aneurysms were treated with neck clipping with elective subsequent old-clip removal, and only one type 2 aneurysm required preceding old-clip removal, not for new neck clipping itself, but for development of the surgical site. In contrast, type 3a aneurysms were treated with various procedures other than clipping with elective subsequent old-clip removal. Type 4 aneurysms were treated by aneurysm occlusion with bypass surgery or follow-up examination.

Patient management, type of recurrence, and outcomes are also summarized in Table. In summary, type 3a and 4 aneurysms required treatment with more complex surgical procedures or coil embolization.

DISCUSSION

Overview

Cerebral aneurysms can recur from residual necks,[1,3,6,7,23,24] and can even arise from apparently perfectly clipped aneurysms.[1-3,7,24] However, few data are available regarding the long-term angiographic follow-up of successfully treated aneurysms with neck clipping. David et al[1] reported an annual regrowth rate of 0.52% for completely clipped aneurysms in a series of 135 patients followed for 4.4 years. In another study with a mean follow-up of 9 years, Tsutsumi et al[3] reported an annual incidence of 0.26% in a series of 125 patients. In a recent case series of 9 recurrent intracranial aneurysms after successful neck clipping from a single center, the incidence was concluded to be approximately 0.02% per year, and aneurysms recurred after a mean of 13.3 years.[2] Surgical treatment for recurrence of a previously clipped aneurysm is one of the most difficult procedures in aneurysm surgery. Distinct technical difficulties are seen for adhesiotomy of the surgical site and removal of previously placed clips.[2,4,7,8] Furthermore, specific difficulties are encountered in decision making: whether appropriate treatment can be achieved with reclipping alone; if so, whether preceding removal of the old clip is needed; if not, whether treatment with bypass surgery is warranted; and so on. Less invasive endovascular
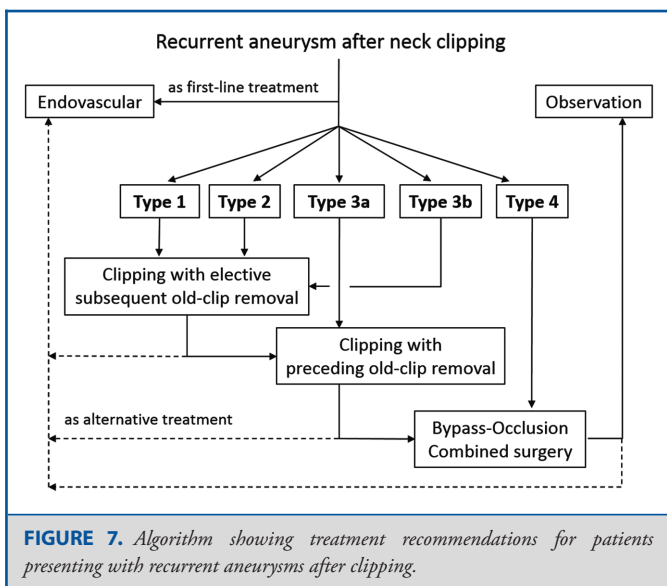
coil embolization is also considered in all recurrent aneurysms as first-line or alternative treatment methods. In addition, combined open and endovascular surgery was recently developed, and has been considered for some recurrent aneurysms. These various treatment methods have been taken into account,[5] but no systematic management strategy for recurrent aneurysms has been established.

Our Experience

This paper described our experience based on 23 recurrent aneurysms after neck clipping, and introduced a novel classification scheme using the concepts of the closure line and closure plane. Sindou et al[25] classified aneurysmal remnants into 5 grades: grade I, less than 50% of neck size; grade II, more than 50% of neck size; grade III, residual lobe of a multilobulated sac; grade IV, residual sac less than 75% of aneurysmal size; and grade V, residual sac more than 75% of aneurysmal size. They reported that only the group with residual neck and sac (grades III, IV, and V) were amenable to re-operation for complementary clipping. In our own cases, we encountered 4 recurrences resulting from grade I aneurysmal remnants. No definitive relationship was evident between our novel classification of recurrence and other characteristics of recurrent aneurysms, such as aneurysm location, rebleeding, recurrence interval, and size. However, type 1 aneurysms were smaller than the other types and both rebled. In the shorter interval from initial treatment, type 4 aneurysms became noticeably larger than the other types. These findings imply that some specificity may exist in the etiologies of type 1/type 4 recurrences. Only 2 procedural complications were seen in which we assumed the complexity of the procedure had contributed. Further studies with more cases are thus required in the future to discuss the influence of factors such as time to recurrence, aneurysmal location, size, and our classification on procedural complications. Nevertheless, as expected, a certain relationship between the novel classification and treatment management was confirmed.

Management Strategies

We then developed an algorithm showing the flow of treatment recommendations for patients with recurrent aneurysm after neck clipping (Figure 7). To begin with, we inspected whether endovascular coil embolization can represent a first-line treatment. Re-operation for a recurrent aneurysm is usually more difficult, so endovascular coil embolization naturally became the alternative treatment modality. A number of case reports and small case series have confirmed the feasibility and safety of this treatment strategy in the management of residual or recurrent aneurysms after surgical clipping.[10-18] Despite none of the studies reporting procedure-related complications, no large-scale studies have been conducted, and long-term follow-up data are unavailable. Rabinstein and Nichols[19] reported that endovascular coiling for residual or recurrent aneurysms resulted in complete occlusion in 17 of 21 cases (81%). However, most recurrent aneurysms have a complex morphology and wide neck orifice, and some cases treated for

FIGURE 7. *Algorithm showing treatment recommendations for patients presenting with recurrent aneurysms after clipping.*

near-complete occlusion remain at risk of recurrence. Endovascular coil embolization is therefore rarely selected as first-line treatment in recurrent aneurysms after surgical clipping. We then divided the other recurrent aneurysms according to the novel classification scheme. Type 1, 2, and 3 aneurysms can be treated with clipping. Orifices of type 1 and 2 aneurysms are highly likely to be closed by clipping without preceding old-clip removal. Type 3b aneurysms also have a chance to be treated using the same procedure. In these type 1, 2, and 3b aneurysms, the old clip may be removed, if necessary, after the new neck clipping. This treatment is referred to as clipping with elective subsequent old-clip removal. Unfavorable conditions in aneurysmal location or size may move our decision on to the next step in the sequence. In contrast, type 3a aneurysms treated with clipping inevitably require preceding old-clip removal. When the old clip cannot be removed in type 3a aneurysms for reasons such as unfavorable conditions in aneurysmal location or size, procedures other than clipping should be considered. Against type 4 aneurysms, clipping is never effective, so we consider intricate procedures such as aneurysm occlusion with bypass surgery or combined open and endovascular surgery. In some cases of this type, we have no option but to perform conservative management. At each step of this algorithm, application of endovascular techniques as an alternative treatment is also considered based on patient characteristics. Recently, 2 large recurrent aneurysms treated with flow-diverting stents were reported.[9] Further evolution of endovascular techniques is expected, including stent-assisted coiling and flow-diverting stents, particularly with treacherous recurrent aneurysms such as types 3a and 4.

Versus Other Classification Schemes

Spiotta et al[26] categorized 26 recurrent aneurysms from 2 institutions into 3 types: type I, proximal to the clip; type II, distal

to the clip; and type III, lateral to the clip. That report implied that recurrent aneurysms result solely from incorrect placements. However, no data support this contention. In addition, they did not even consider the relationship of that categorization to management strategy and outcomes. Furthermore, our series included some recurrent aneurysms belonging to none of their categories. After all, their categorization was simple and easy to understand, but not particularly practical in clinical settings. el-Beltagy et al[2] reported 9 recurrent aneurysms after primary completion of clipping, and 3 types according to the relationship of the new aneurysm neck to the old clip: type A, part of the old clip occupies the newly formed aneurysm neck; type B, old clip located far from the aneurysm neck; and type C, location of the old clip independent of the recurrent aneurysm neck. They speculated that the old clip has to be removed in type A, removal is not always necessary in type B, and the old clip does not prevent new clipping in type C. The direction and purpose of their classification has a few points in common with our novel classification. However, their classification was not free of ambiguity, and their report never evaluated the relationship between classification and management. In fact, their speculations about the relationship, as noted by the authors, suggested too many potential exceptions, being neither discriminative nor systematic.

Follow-up and Limitations

Unfortunately, the present report could not derive a rate of aneurysm recurrence after clipping, because the study defined a numerator but not a denominator. Without prospective long-term follow-up of clipped aneurysms over a broad population, the true rate of recurrence will remain unknown. The true etiology of aneurysm recurrence after complete neck clipping also remains unclear. However, a small but definite propensity toward recurrence clearly exists, and most recurrent aneurysms require some form of retreatment. Based on our experience with 23 patients, our follow-up protocol appears reasonable, and long follow-up exceeding 10 years is required for young, healthy patients. Particularly in patients with neck remnant or pre-existing diseases associated with cerebral aneurysms, more frequent follow-up may be necessary. Our novel classification is free of ambiguity and our algorithm is systematic and extremely practical for both pre- and intraoperative decision making. Although the appropriateness of our classification and algorithm needs to be evaluated in further studies with larger groups, we believe that this classification and accompanying algorithm will be theoretically comprehended and accepted by most neurosurgeons. Further studies are needed to evaluate the effects of management strategies using our classification on the outcomes for recurrent aneurysm.

CONCLUSION

This report described our experience with 23 recurrent aneurysms after neck clipping. We discriminatively classified recurrent aneurysms into 4 different types, including 2 subtypes, using the concept of the closure line and closure plane. The

type-specific management strategy was systematic and practical for decision making.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

Decision for treatment of recurrent intracranial aneurysm after microsurgical neck clipping and choice of its most appropriate modality are always difficult. This is particularly true when the parent artery at the level of the neck insertion has a dysplasic wall, which was apparently frequent in the authors' presented cases, as well as in our experience and in most of the literature series. Such a condition entails similar difficulties and dangerousness to treat as for so-called blister aneurysms, due to fragility of the arterial wall.

Perhaps, the weakness of the presented work is that endovascular treatments, which are more and more commonly used, have not been considered enough.

Regardless, the novel classification of the authors will significantly help for defining strategy and designing best surgical or endovascular approach.

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Some of the most challenging surgical cases in neurosurgery are previously treated aneurysms. There are many hazards that abound: scar tissue, adherent surgical planes, friability of cortex and vessels, and dealing with the prior clip placement, which can reduce ideal visibility for trajectory of clip placement.

In this thoughtful review of their experience dealing with previously microsurgically treated aneurysms, the authors provide a 20-year follow-up, treatment strategies, and a classification system that can aid neurosurgeons with their decision algorithm. In the manuscript, the frequency of recurrent subarachnoid hemorrhage in previously surgically treated aneurysms necessitated prompt surgical intervention. The authors are to be commended on developing a paradigm for treatment: a parallel closure line, which incorporates the previous clipping. This developing an optimal strategy is necessary but not always attainable. By providing long-term follow-up and a detailed evaluation of their experience, the authors provide neurosurgeons further literature for strategy in surgical

management of these aneurysms. Unfortunately, in every surgical case, there is a what we "want" versus what we can "get" that limits treatment.

The rapid advent of endovascular devices, such as flow diversion, brings even more promise of treating these treacherous lesions, but may not always provide a perfect solution due to the complexity of branching patterns and need to preserve collaterals and distal vasculature. Overall, the authors add to the body of literature in treating previously clipped aneurysms and should be commended for providing an open surgical strategy. Endovascular avenues should also be explored as future treatment strategies evolve.

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The authors report a 20-year experience of 23 recurrent aneurysms (in 23 patients) out of a total of 1818 patients treated with open surgery at their institution. The recurrences are classified into 4 different types and 2 subtypes. The average interval between clipping and recurrence was 15 years. Not surprisingly, given the small number of recurrent aneurysms, the authors were not able to establish a correlation between the type of aneurysmal remnant, and aneurysm location, size, or hemorrhagic presentation. This report has several valuable findings, including that of a low recurrence rate after aneurysm clipping, which is consistent with the rest of the literature on this topic.

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