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Surgical Treatment of Very Small Aneurysms: Cotton-Assisted Clipping

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Abstract

Objective: Very small Intracranial Aneurysms (VSIAs) are challenging to treat because aneurysm tearing and clip slippage can occur during neurosurgical clipping. In this study, we introduce and share our experience with cotton-assisted clipping of VSIAs.

Materials and Methods: We retrospectively analyzed the data of 20 patients with 24 VSIAs treated with cotton-assisted clipping between February 2008 and December 2014 in the Neurosurgery Departments of the First Affiliated Hospital, Soochow University and Taizhou People's Hospital. During surgery, 2 aneurysm necks were torn. To treat the tears, we wrapped rectangular cotton pads around the parental arteries at the site of rupture. The remaining 22 aneurysms were clipped after being wrapped in cotton pads.

Results: The 2 aneurysm ruptures were successfully repaired with cotton-assisted clipping. In the remaining 22 aneurysms, no cases of aneurysm clip slippage or aneurysm rupture occurred. Patients were followed up on average for 59.0 months (range, 30-113 months). Of the 20 patients, the 16 patients with preoperative Hunt-Hess grades of 1 to 3 recovered well after the surgery (Glasgow Outcome Scale [GOS] score, 5). Of the 4 patients with Hunt-Hess grades of 4 to 5.3 had a good recovery (GOS scores, 4-5), and 1 patient died of heart disease 6 months after being discharged from the hospital; this patient had a GOS score of 4 at the time of discharge.

Conclusion: Cotton-assisted clipping could prevent aneurysm clip slipping and aneurysm rupture and facilitate the repair of aneurysm neck tears. This technique is a useful alternative therapy for VSIAs.

Keywords: Clipping; Cotton pads; Treatment outcome; Very small aneurysm

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Abbreviations

BBA: Blood Blister like Aneurysm; CT: Computed Tomography; CTA: Computed Tomographic Angiography; DSA: Digital Subtraction Angiography; EC-IC: Extracranial–Intracranial; GOS: Glasgow Outcomes Scale; ICA: Internal Carotid Artery; MCA: Middle Cerebral Artery; NBBA: Non-Blood Blister like Aneurysm; SAH: Sub Arachnoid Hemorrhage; VSIA: Very Small Intracranial Aneurysm

Introduction

A Very Small Intracranial Aneurysm (VSIA) is defined as an intracranial aneurysm no wider than 4 mm [1-4]. Currently, the main treatments for VSIAs are endovascular coiling and neurosurgical clipping. The endovascular treatment of VSIAs is challenging due to the technical difficulties of packing the coil in a small space [5-7].

The neurosurgical clipping of aneurysms is also difficult to accomplish. If the aneurysm neck is too small, there is very little space for the aneurysm clip, which can easily slide off and tear the aneurysm neck. Moreover, direct clipping can lead to stenosis and occlusion of the parent artery, resulting in ischemic insult.

To resolve these difficulties, we use a cotton-assisted surgical clipping method to treat patients with VSIAs. In the present study, we describe our experience with this clipping technique in which a cotton pad is applied as a bolster around the aneurysm neck or body to prevent aneurysmal tears. This technique yielded satisfactory outcomes in our patients and reduced the risk of clip slipping,

aneurysm neck rupture, and vascular stenosis or occlusion. Moreover, the cotton-assisted clipping technique has the potential to reinforce "unclippable" aneurysmal segments or small remnants of aneurysm necks between the parent vessel and the base of the clip [3,8].

Materials and Methods

Patients

Between February 2008 and December 2014, a total of 473 patients underwent surgical treatment for aneurysms in the Neurosurgery Departments of the First Affiliated Hospital of Soochow University and Taizhou People's Hospital. Of these, 20 patients (4%) with 24 VSIAs were treated using the cotton-assisted clipping technique and were included in this retrospective study. The patient's legally authorized representative provided written informed consent for the patient's information and images to be included in this report. The study was approved by the Ethics and Review Committee of the First Affiliated Hospital of Soochow University.

The inclusion criteria were as follows: 1) VSIA (maximum aneurysm diameter ≤ 4 mm) observed on Computed Tomography (CT), and 2) in cases of multiple aneurysms, a VSIA was responsible for the Sub Arachnoid Hemorrhage (SAH). The exclusion criteria were 1) lost to follow-up and 2) SAH combined with other serious chronic diseases (e.g., diabetes mellitus, hypertension, and hepatico-renal insufficiency).

Clinical and imaging data

We collected the patients' clinical and imaging data. The severity of SAH was classified using the Hunt-Hess scale, which is a 5-point scale that classifies SAH from grades 1 to 5, with greater grades indicating greater severity and therefore lower survival. Preoperative complete cerebral 3-dimensional rotational angiography was performed on a monoplane system in all patients, and preoperative Computed Tomographic Angiography (CTA) was performed in 19 patients. One patient directly underwent craniotomy surgery without any preoperative angiographic examination due to cerebral herniation (patient #13, Table 1). Postoperatively, CTA, magnetic resonance angiography, and/or Digital Subtraction Angiography (DSA) were used to confirm the absence of bleeding or recurrence.

Operation and follow up

In all 20 patients, surgical clipping of the aneurysm was performed *via* the pterional approach with the patient under general anesthesia. After the operation, all patients were given general supportive treatment and care in the neurosurgical department and were followed up by telephone (5 patients), letter (2 patients), and clinical visits (13 patients) for 3 months after being discharged from the hospital. Postoperative outcomes were classified using the Glasgow

Table 1: Clinical data of 20 patients with very small intracranial aneurysms treated using cotton-assisted clipping.

No.	Sex/Age, Years	Onset Date, y/m/d	Symptoms	Physical Signs	Side/Location	Diameter, mm	H-H Grade	Treatment of Aneurysm
1	F/50	2008.01.08 (113 m)	SAH	MR, no deficit	L-OphAAn	3	2	RACP + clipping
2	M/52	2008.02.13 (112 m)	SAH	SMR, no deficit	R-OphAAn	3.4	1	RACP + clipping
3	M/45	2008.06.21 (108 m)	SAH + IPH	MR, no deficit	R-MCAM1An	3.5	2	Clipping
4	F/55	2008.12.20 (102 m)	SAH	SMR, no deficit	L-AchAn	2.5	1	Clipping
					L-ICAAn	3		Clipping
5	M/48	2009.07.22 (95 m)	SAH	SMR, no deficit	R-ACAAn	2.5	1	Clipping
6	M/67	2009.11.13 (91 m)	SAH	SMR, no deficit	R-ICAPCAAn	3.5	1	Clipping
7	F/49	2011.09.20 (69 m)	SAH + IPH	MR, no deficit	R-OphAAn	3.1	2	RACP + clipping
8	F/55	2012.08.12 (58 m)	SAH	MR no deficit	R-ACAAn	3	2	Clipping
9	M/58	2013.03.05 (51 m)	No SAH	O	L-OphAAn	3	1	Clipping
10	M/49	2013.06.23 (48 m)	SAH	MR, no deficit	L-ACAAn	2.3	2	Clipping
11	M/59	2013.11.19 (43 m)	SAH	Stupor, MH	R-ACAAn	2.5	4	Clipping
12	M/51	2014.05.27 (37 m)	SAH	MR, no deficit	L-OphAAn	2.4	1	Clipping
13	F/60	2014.05.29 (37 m)	SAH + IPH	Stupor, MH	R-ICA-PCAAn	3.2	4	Clipping
					R-ICAAn	2.2		Clipping
					L-MCA M1An	2.8		Clipping
					L-ICAAn	3		Clipping
14	F/50	2014.07.21 (35 m)	SAH	MR	L-ACAAn	3.4	2	Clipping
15	F/67	2014.08.06 (34 m)	SAH	SMR	R-ICA-PCAAn	2.5	1	Clipping
16	F/72	2014.08.26 (34 m)	SAH + IPH	Coma, decerebration	L-MCAM$_1$An	3.8	5	Clipping
17	M/51	2014.10.06 (32 m)	SAH	MR, no deficit	L-OphAAn	2.5	1	RACP + clipping
18	M/45	2014.11.28 (31 m)	SAH	MR, no deficit	L-ACA$_{1-2}$An	3	2	Clipping
19	M/25	2014.12.22 (30 m)	IS	O	L-OphAAn	2.5	1	RACP + clipping
20	M/53	2014.12.23 (30 m)	SAH + IPH	Coma, decerebration	R-ACAAn	2	5	Clipping

H-H grade: Hunt–Hess grade; F: Female; SAH: Subarachnoid Hemorrhage; MR: Muscle Rigidity; L: Left; OphA: Ophthalmic Artery; An: Aneurysm; RACP: Removal of Anterior Clinoid Process; M: Male; SMR: Slight Muscle Rigidity; R: Right; IPH: Intraparenchymal Hemorrhage; MCAM1: M1 segment of the Middle Communicating Artery; AchA: Anterior choroidal Artery; ICA: Internal Carotid Artery; ACA: Anterior Communicating Artery; PCA: Posterior Communicating Artery; MH: Moderate Hemiparesis; MCA: Middle Cerebral Artery; ACA1–2: Segments 1 and 2 of the ACA; IS: Ischemic Stroke; O: No SAH

Outcomes Scale (GOS), with scores of 4 or 5 indicating favorable outcomes and scores of 1 to 3 indicating unfavorable outcomes.

Results

Clinical characteristics

Of the 20 study patients, 12 were men and 8 were women. Their average age was 53.5 years (range, 25-72 years). Only 1 patient had a non-ruptured aneurysm and presented with paroxysmal dizziness. The remaining 19 patients had ruptured aneurysms with headache, nausea, and vomiting. These verity of SAH was classified using the Hunt-Hess scale as follows: Grade 1, 9 patients; grade 2, 7 patients; grade 4, 2 patients; and grade 5, 2 patients (Table 1).

Imaging findings

In 1 patient (#19), preoperative CT examination of the head showed a mild cerebral infarction (Table 1), and CTA then incidentally revealed an aneurysm in the left Internal Carotid Artery (ICA) – ophthalmic artery segment. In the other patients, preoperative CT of the head revealed SAH with hematoma (8 patients) or imaging suggestive of SAH (10 patients). Patient #13 directly underwent craniotomy without angiographic examination due to cerebral herniation. After the operation, aright ICA–posterior cerebral artery aneurysm and aright ICA aneurysm were detected using DSA (Table 1). In addition, during surgery to remove the hematoma, a left Middle Cerebral Artery (MCA) aneurysm was found and clipped.

Preoperative DSA revealed a total of 24 VSIAs in 20 patients (patient #4 with 2 aneurysms, and patient #13 with 4 aneurysms, (Table 1)). Of these 24 aneurysms, 11 were involved the carotid artery and ophthalmic artery, 3 involved the anterior choroidal artery, 4 involved the MCA, and 6 involved the ACA (Table 1). Of these 24 aneurysms, 3 were non–blood blister–like aneurysms (NBBAs; patient #9, #12 and #19, Table 1), and the other 21 were Blood Blister like Aneurysms (BBAs).

Surgical outcomes

During the course of clipping, re-rupture occurred in 2 ruptured aneurysms (patients #2 and #3, Table 1) involving the ICA and the MCA. Because the aneurysms were very small and the tear in each case extended to the parental artery, the ruptured site was repaired using a piece of rectangular cotton wrapping (Figure 1, 2). In the case of other 2 aneurysms, the aneurysm clips slipped off during the clipping procedure; the clips were secured with a cotton wrap, and clipping was performed with no re-slipping. In the remaining 20 aneurysms, clipping was performed after wrapping the aneurysm neck or body with cotton. Turbulent blood flow through the aneurysm neck was observed through the aneurysm wall in 8 aneurysms. After successful wrapping with cotton and clipping, no cases experienced clip slippage or aneurysm rupture (Figure 3). In 5 cases of ICA–ophthalmic artery aneurysm, the anterior clinoid process was first removed, and then clipping was conducted after the aneurysm or parental artery wrapping with cotton (Figure 4). In 1 patient, the aneurysm was clipped using 2 fenestrated clips after the 2 free ends of the cotton pad were placed on the aneurysm body (Figure 5).

All operations were successful with no operative mortality or fever due to cotton-related infection. The duration of follow-up ranged from 30 to 113 months (average, 59.0 months). Of the 20 patients, 16 patients with Hunt-Hess grades of 1 to 2 recovered well (GOS score, 5). Of the 4 patients with Hunt-Hess grades of 4 to 5.3 patients had a good recovery (GOS scores, 4-5), and 1 patient died of heart disease 6 months after being discharged from the hospital (patient #15, GOS score 4 at the time of discharge; Table 2).

Discussion

The neurosurgical clipping of VSIAs is a challenging procedure, as the aneurysm can rupture or the aneurysm clip can slip during the clipping procedure. The use of cotton-assisted aneurysm clipping can effectively prevent aneurysm rupture and decrease the risk of clip slippage, thereby improving operative safety. In our study, cotton wraps were used in the 3 conditions described in the following subsections.

Repair of aneurysm neck rupture

The most dangerous complication of aneurysm clipping is rupture of the aneurysm neck, particularly when the aneurysm involves the ICA. This is difficult to treat because hypotensive shock rapidly sets in. Most such patients will die or enter a vegetative state due to large

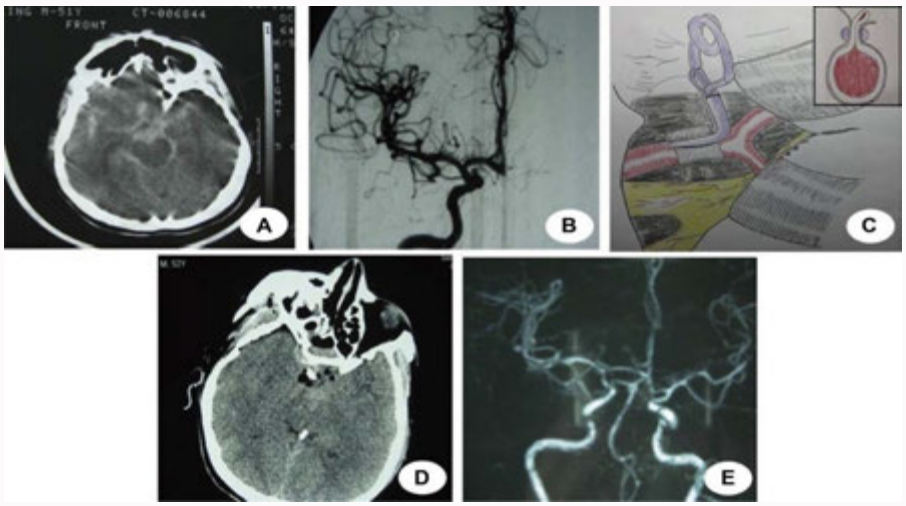

Figure 1: Patient #2: A 52-year-old man. (A) A Computed Tomography (CT) scan of the head revealed subarachnoid hemorrhage. (B) Digital subtraction angiography showed a right internal carotid aneurysm. (C) Diagram showing the tearing of the aneurysm neck during the process of aneurysm clipping. A small piece of cotton pad was used to wrap the tear in the internal carotid artery, and an aneurysm clip was used to secure the 2 ends of the cotton pad. (D) Postoperative CT scan at 48 h showing no bleeding or infarction in the surgical area. (E) CT angiography before discharge revealed the disappearance of the right internal carotid aneurysm.

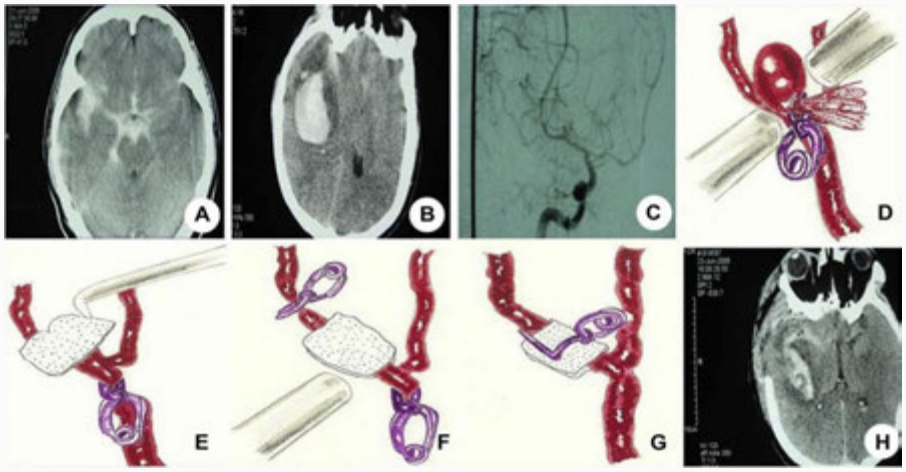

Figure 2: Patient #3: A 70-year-old man. (A and B) A Computed Tomography (CT) scan of the head revealed a right subarachnoid hemorrhage and a right temporal lobe intracranial hematoma. (C) Digital subtraction angiography showed a right middle cerebral artery aneurysm. (D) The aneurysm neck was torn during the process of aneurysm clipping. (E–G) A cotton pad was used to wrap the tear in the middle cerebral artery. The proximal end of the parental artery was temporarily clipped, and the soft tissue under the parental artery was isolated. A cotton pa was placed below the parental artery, and its 2 ends were folded to fix the aneurysm clip. The cotton pad was tightly packed around the tear in the aneurysm neck. (H) CT scans taken on postoperative day 2 showed small amounts of residual intracranial hematoma, but no cerebral infarction.

Figure 3: Patient #13: A 60-year-old woman. (A) A Computed Tomography (CT) scan of the head revealed subarachnoid hemorrhage. (B) Digital Subtraction Angiography (DSA) showed a right internal carotid artery–posterior communicating artery aneurysm. (C) Three-dimensional DSA showed 2 aneurysms in the right internal carotid artery. (D–F) The neck or the body of the aneurysm was wrapped with a cotton pad and clipped by aneurysm clips. (G and H) Postoperative DSA confirmed the disappearance of the aneurysm and unobstructed blood flow in the parental artery.

cerebral infarction. In our study, patient #2 (Table 1) presented with SAH in February 2008. DSA showed a dorsal aneurysm of the ICA beneath the right anterior clinoid process. Because of the thinness of the aneurysm wall, the aneurysm neck ruptured and caused bleeding during the clipping procedure.

A number of techniques for the control of unexpected intraoperative hemorrhage have been applied but with no success, including the application of a large-bore suction cannula over the bleeding site, and blocking of the aneurismal rent through proximal temporary occlusion with an aneurysmal clip, absorbable gelatin sponge, or muscle. The ICA proximal and distal to the aneurysm was only temporarily blocked. In our study, a 5 mm × 12 mm cotton pad was wrapped around the artery at the rupture site. The diameter of the artery was consistent with the size of the cotton pad. An aneurysm clip was placed on the overlapping ends of the cotton pad after confirming that there was no evidence of arterial narrowing. Bleeding did not recur after the clip was removed. The patient regained consciousness and had full activity of all limbs after the surgery. Postsurgical CTA showed that the aneurysm had disappeared, and normal blood flow had been reestablished (Figure 1). Another patient with an MCA aneurysm was treated using the same method with the satisfactory outcomes (Figure 2). Previously, some studies used a dura mater graft rather than a cotton pad to wrap the parental artery after aneurysm rupture [9,10]. However, compared with the dura mater, cotton pads are more stable, more flexible, and stronger, and their rough surface due to staggered fibers promotes the aggregation of red blood cells and platelets, which is conducive to the repair of a ruptured aneurysm. Suture is a good method for the repair of a vessel tear and maintains blood flow in the parent artery. However, in the case of a tear at the neck of an aneurysm, the integrity of the vessel wall is poor, and suturing is often either impossible or may lead to further tearing. The Sundt-clip graft (Codman, Raynham, Massachusetts, USA) is a vessel-encircling clip used to repair defects in the wall of

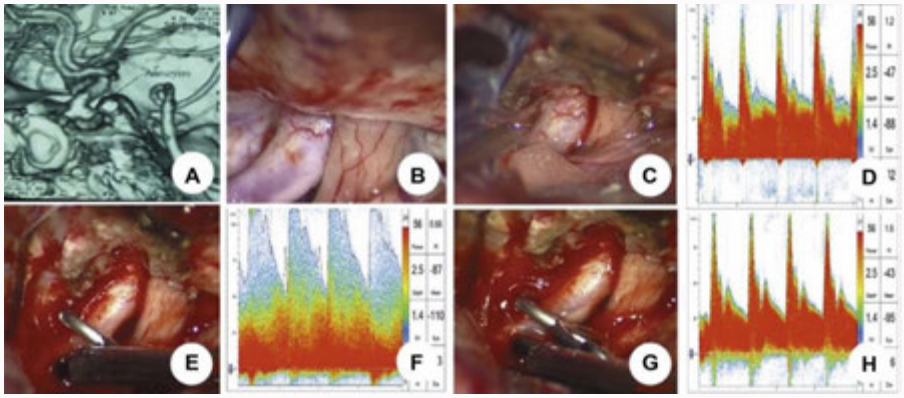

Figure 4: Patient #19: A 25-year-old man. (A) Computed tomography angiography scan of the head showed a left internal carotid paraclinoid aneurysm. (B) During the operation, internal carotid artery bulging was seen next to the clinoid process and indicated the upper edge of th aneurysm. (C and D) After the partial removal of the anterior clinoid process, the aneurysm was exposed. Blood flow was tested using Transcranial Doppler (TCD). (E and F) After the cotton pad was wrapped around the aneurysm body, the aneurysm was clipped with a ring clip. TCD suggested stenosis of the parental artery. (G and H) After the aneurysm clip was adjusted, blood flow was preserved.

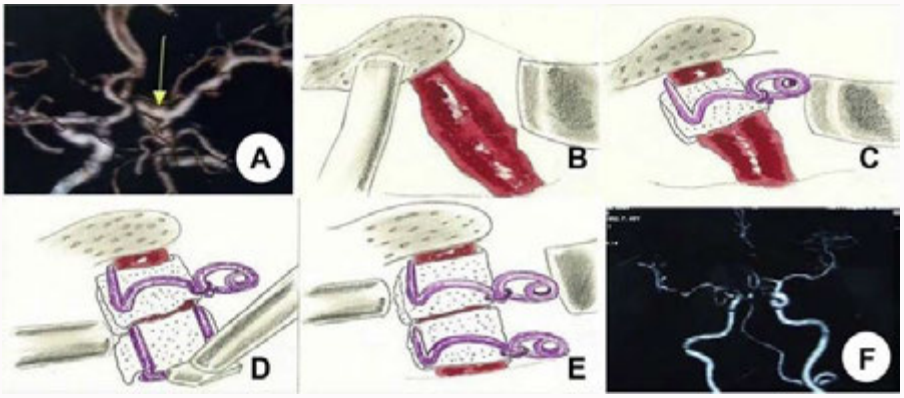

Figure 5: Patient #7: A 49-year-old woman. (A) Magnetic resonance angiography of the brain revealed a right internal carotid artery paraclinoid aneurysm. (B–E) After partial removal of the anterior clinoid process, the aneurysm was wrapped with a cotton pad, and the ends of the cotton pad were put together underneath the parental artery and secured by an aneurysm clip. (F) At discharge, computed tomography angiography showed the disappearance of the aneurysm and unobstructed blood flow in the parental artery.

Table 2: Postoperative outcomes in the 20 study patients.

Hunt–Hess Scale Pre-operation		Favorable (GOS, 4–5 score)		Unfavorable (GOS, 1–3 score)			Rebleeding and Recurrence
		5	4	3	2	1	
1	9	9 (45.0)	0 (000)	0 (0)	0 (0)	0 (000)	0
2	7	7 (35.0)	0 (000)	0 (0)	0 (0)	0 (000)	0
3	0	0 (0.00)	0 (000)	0 (0)	0 (0)	0 (000)	0
4	2	1 (5.00)	1 (5.00)	0 (0)	0 (0)	0 (000)	0
5	2	1 (5.00)	0 (000)	0 (0)	0 (0)	1 (5.00)	0

Values are shown as number of patients (percentage)

the blood vessel, but this clip has several disadvantages. The clip graft is difficult to maneuver and to apply precisely with preservation of adjacent branches or a perforator. Although the clip-graft is available in various sizes, it is sometimes impossible to find the precise size that accommodates the damaged segments of the vessel while preserving adjacent perforator-bearing segments. If the vessel defect to be repaired is a tear at the neck of the aneurysm, the encircling clip graft must include the dome of the aneurysm. The additional tissue within the clip graft can occlude the lumen of the parent vessel. Permanent trapping poses the risk of ischemic complications, and intraoperative assessment of collateral flow is difficult. Generally, the surgeon may not have prepared for an Extra Cranial–Intracranial bypass (EC-IC) bypass, and ischemic injury may occur during construction of the bypass. Furthermore, if the trapped segment harbors a perforator, the bypass will not protect against ischemia in the region of the perforator [9,10].

VSIA clipping technique

The rupture of VSIAs is not uncommon [9-11]. VSIAs can be categorized into 2 types: BBAs and NBBAs. Both types are challenges for neurosurgeons from the aspect of surgery or interventional treatment. To some extent, interventional therapy is more difficult than craniotomy [9-12]. Although the feasibility and risks of endovascular treatment for VSIAs have recently been reported in

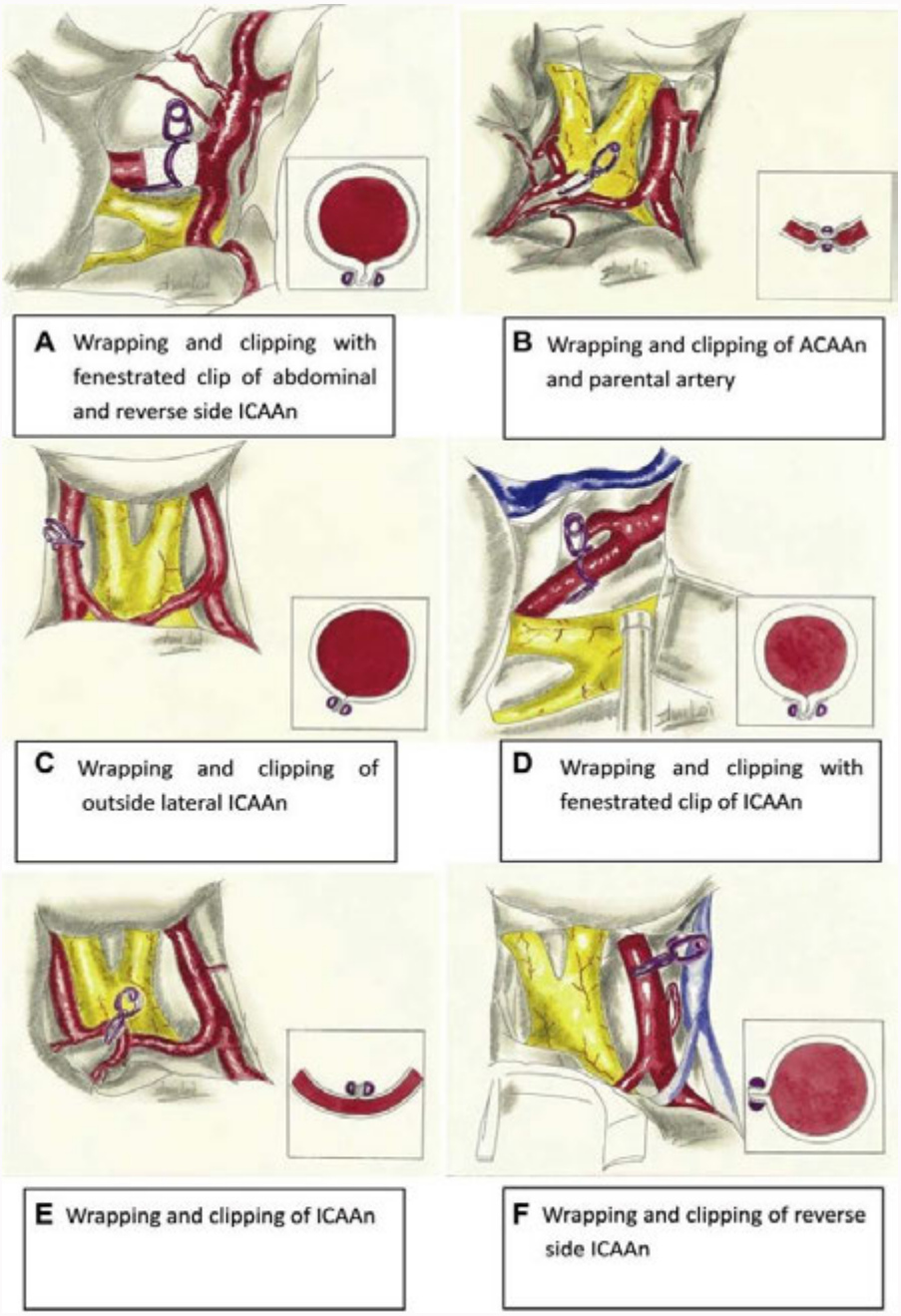

Figure 6: Differences in wrapping methods based on location of the aneurysm. (A) Patient #7, (B) patient #10, (C) patient #12, (D) patient #13, (E) patient #14, and (F) patient #15.

the literatures [13,14], the risks associated with surgical clipping have not been well identified. Aneurysm size is an important factor in the interventional therapy of ruptured and bleeding aneurysms, and VSIAs are more prone to rupture and cause bleeding during treatment [15-18]. Surgical clipping of BBAs is more likely to be complicated by rupture, whereas surgical clipping of NBBAs is more likely to be complicated by slipping. Multiple clipping increases the risk of aneurysm rupture.

There are many ways to treat VSIAs, such as wrapping the aneurysm, suturing the parental artery, wrapping and clipping the aneurysm, aneurysm isolation, and EC-IC bypass [18-20]. However, these methods have limitations: Aneurysm recurrence after aneurysm wrapping; parental artery suturing resulting in arterial stenosis; and an EC-IC bypass transforming a single operation into 2 separate operations and increasing the complexity of the procedure.

In our report, the first 2 patients developing rupture after the aneurysms were clipped. Although the ruptures were satisfactorily resolved after using a cotton pad to wrap the parental artery, aneurysm rupture during aneurysm clipping surgery is not avoidable. For subsequent patients, we preemptively used a cotton pad to wrap the aneurysm body or neck and then performed aneurysm clipping, which could prevent slipping of the aneurysm clip in the case of NBBAs and the rupture of BBAs during surgery. The rough surface of the cotton pad increases resistance, which prevents slipping of the

aneurysm clip. In addition, the support the cotton pad reduces the chances of aneurysm wall damage. Both types of aneurysms can be safely clipped with satisfactory surgical results.

Wrapping methods differ based on aneurysm location

In the case of a VSA of the ICA, if the aneurysm is located lateral or dorsal to the ICA, the cotton pad is wrapped around the aneurysm neck or body, and the aneurysm is clipped using a common, micro, straight, or curved clip (Figure 6). If the aneurysm is located on the ventral side, it is difficult to use a cotton pad to wrap the aneurysm. Alternatively, a rectangular piece of cotton pad can be used to wrap the parental artery. The 2 ends of the cotton pad are placed on the body of the aneurysm, and aneurysm clipping is performed with a fenestrated clip. Generally, the cross-aneurysm clip is more likely to cause parental artery stenosis than straight or curved aneurysm clips [11]. Therefore, when using fenestrated aneurysm clips, the diameter of the parental artery must be consistent before and after clipping. The diameter of the blood vessel within the fenestrated clip should be consistent with that of the proximal and distal parental artery segments to prevent parental artery stenosis. If necessary, microvascular Doppler monitoring should be used [21].

Conclusion

In conclusion, the microsurgical treatment of VSIAs is difficult because it is easy to cause tears during the clipping of BBAs, and the clips are easy to slip during the clipping of NBBAs. Cotton pad-assisted VSIA clipping can reduce the risk of aneurysm tears and aneurysm clip slipping and significantly improve surgical safety.

Queries and Answers

Query: If there are any drug dosages in your article, please verify them and indicate that you have done so by initialing this query

Answer: No Question.

Query: As per journal style, only 1 corresponding author is allowed. Please choose one author to whom correspondence should be addressed.

Answer: No Question.

Query: Please confirm we have supplied the correct manufacturer and location for Sundt-clip graft.

Answer: No Question.

Query: Have we correctly interpreted the following funding source(s) and country names you cited in your article: National Science Foundation of China, China?

Answer: Yes

Query: Kindly provide explanation for arrow in legend of Figure 5a.

Answer: No Question.

Query: In Table 1, in the third column, Onset Date, does “m” indicate months? If so, please spell out per style.

Answer: Yes, months

Query: In Patient 4 of Table 1, should the H-H grade read 1 or 2 (II)? Please clarify.

Answer: 2

Query: Please confirm that given names and surnames have been identified correctly and are presented in the desired order and please carefully verify the spelling of all authors’ names.

Answer: Yes

Query: Please confirm that you have obtained written consent from any patients that are identifiable from images or videos in your manuscript.

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Query: Please confirm that all x-rays, ultrasound images, pathology slides or laparoscopic images in your article have been anonymized – i.e., patient names or other identifying details have been removed or hidden.

Answer: Yes.

Acknowledgement

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