Retrograde Suction Decompression for Clip Occlusion of Internal Carotid Artery Communicating Segment Aneurysms

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■ BACKGROUND: **Retrograde suction decompression (RSD) can achieve proximal parent vessel control, improve aneurysm neck visualization, and allow parent vessel reconstruction for direct clipping of internal carotid artery (ICA) aneurysms. The aim of the present study was to describe the technique and surgical results of RSD for direct clipping of ICA communicating segment (C1) aneurysms.**

■ METHODS: **The clinical data and treatment summaries of 20 patients who underwent RSD-assisted clipping of ICA C1 aneurysms were retrospectively reviewed. Pre- and postoperative three- or four-dimensional computed tomography angiograms, postoperative magnetic resonance images, surgical notes, operative complications, and outcomes were assessed.**

■ RESULTS: **All patients except one harbored unruptured C1 aneurysms. Extracranial-intracranial graft bypass using the radial artery was performed in five patients. Fifteen patients required temporary clipping of the posterior communicating artery for further reduction of blood back-flow into the aneurysm. All aneurysms were successfully clipped and postoperative three- or four-dimensional computed tomography angiography revealed no major branch occlusion or residual aneurysm. At the 6-month follow-up examination, 19 patients had a good outcome and 1 patient had poor outcome associated with anterior choroidal artery ischemia. No death had occurred at 6-month follow-up examination.**

■ CONCLUSIONS: **The RSD technique is a useful procedure to achieve proximal vascular control, to soften and shrinkage the aneurysm sac, and to provide a wide and clean operative field allowing safe clip placement. The RSD technique requires special attention to the relationship between the perforators and the aneurysm, and close cooperation between the surgeon and the assistant.**

INTRODUCTION

Aneurysms arising from the internal carotid artery (ICA) are common and usually located at the communicating segment of the ICA (C1).[1,2] These C1 aneurysms frequently involve the origin of the posterior communicating artery (PcomA) and anterior choroidal artery (AchA). In addition, some C1 aneurysms tend to adhere to the surrounding structures such as the AchA, anterior thalamoperforating artery (ATPA), oculomotor nerve, and the dura of the skull base. Proximal temporary clipping is often used to reduce the transmural pressure into the parent vessel and to soften the aneurysm sac. In some circumstances, the aneurysm remains tense after proximal and distal temporary clipping of the ICA, leading to difficulties for permanent clip placement, such as clip slipping or occlusion of the parent artery and perforators.

The suction decompression technique using direct aneurysmal puncture into giant aneurysms was introduced in 1981.[3] Batjer

Key words
- Cerebral aneurysm
- Clipping
- Internal carotid artery
- Retrograde suction decompression

Abbreviations and Acronyms
AchA: Anterior choroidal artery
ATPA: Anterior thalamoperforating artery
C1: Communicating segment of the internal carotid artery
C2: Ophthalmic segment of the internal carotid artery
C3: Clinoid segment of the internal carotid artery
CCA: Common carotid artery
3D-CT: Three-dimensional computed tomography
4D-CT: Four-dimensional computed tomography
ECA: External carotid artery
ICA: Internal carotid artery
MCA: Middle cerebral artery
mRS: Modified Rankin Scale
PcomA: Posterior communicating artery
RA: Radial artery
RSD: Retrograde suction decompression
STA: Superficial temporary artery

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and Samson[4] in 1990 and Tamaki et al.[5] in 1991 described the surgical retrograde suction decompression (RSD) technique as an alternative to achieve proximal vascular control of the parent vessel, to improve the visualization of the aneurysm neck, and to reconstruct the parent vessel without occluding important perforators.[1,4-12] Subsequently, the adoption of less invasive procedures has led to the use of the endovascular suction decompression technique as an option to surgical exposure; however, it carries a higher risk of ICA dissection.[1,6-9,12] The surgical RSD technique has been applied mainly for large or giant aneurysms located in the ophthalmic (C2)/clinoid (C3) segment of the ICA, and less often for C1 aneurysms.[13] Previous case series of RSD-assisted clipping focused mainly on C2/C3 aneurysms or failed to show the results of RSD-assisted clipping for C1 aneurysms.[6,7]

The present study analyzed 20 consecutive patients with C1 aneurysms treated through direct microsurgical clipping assisted by RSD to provide proximal control of the parent vessel to evaluate the surgical technique and feasibility of RSD for direct clipping of C1 aneurysms.

METHODS

Study Cohort

This study retrospectively analyzed 338 patients with ICA aneurysms treated at our institution between April 2012 and March 2015. This study excluded the 157 patients with C2/3 aneurysms, 21 patients with C4 aneurysms, and 140 patients who underwent only clipping, clipping with bypass, or trapping with bypass without RSD for C1 aneurysms. Finally, this study included only 20 patients who underwent RSD-assisted direct microsurgical clipping of C1 aneurysms. The study protocol was approved by the institutional ethics committee.

Clinical and Radiological Data

The clinical charts and treatment summaries of the 20 patients were analyzed retrospectively to identify associated comorbidities and preoperative clinical status. Each patient underwent preoperative three- and four-dimensional computed tomography (3D-CT and 4D-CT) angiography to assess parent vessel characteristics (e.g., presence of calcifications, diameter), aneurysm characteristics (e.g., shape, wall features, neck diameter, size), relationships between the aneurysm and vessel branches, and bony structures to determine the best surgical strategy. 4D-CT angiography was performed if 3D-CT angiography failed to demonstrate the AchA or ATPA (Figure 1). We do not routinely perform preoperative digital subtraction angiography for intracranial aneurysms at our institution.

Outcome

All patients underwent direct surgical treatment of the C1 aneurysm. Clinical outcome according to the modified Rankin Scale (mRS) was assessed by a neurosurgeon immediately after surgery and at 6 months follow-up. Outcome was classified according to the mRS score as *good* (0–2) or *poor* (3–6). 3D- or 4D-CT angiography and magnetic resonance imaging were performed after the surgical procedure to evaluate acute complications, patency of the parent vessel, and aneurysm occlusion.

Surgical Strategy

The indications to perform surgical RSD were based on adhesion of the aneurysm dome or neck, or both, to the PcomA, ATPA, and AchA in preoperative studies, regardless of the size of the aneurysm. The first intention to treat C1 aneurysms was direct clipping if possible. However, C1 aneurysms with complex anatomy (perforators arising from the aneurysm sac, presence of calcifications) and large/giant size were considered unclippable and were treated by trapping and bypass. The bypass indications were based on the complexity of the aneurysm (size, projection, and relationship between the aneurysm and vessel branches).

The patients were divided into two groups according to the surgical strategy. Group 1 included patients with aneurysm clipping requiring short temporary parent vessel occlusion time (<10 min) and who underwent only RSD-assisted clipping. Group 2 included patients with aneurysm clipping requiring long temporary parent vessel occlusion time (≥10 min) and who underwent RSD-assisted clipping and superficial temporary artery (STA)-middle cerebral artery (MCA) bypass, external carotid artery (ECA)-radial artery (RA)-M2 bypass, or both.

Surgical Technique: RSD-Assisted Clipping and Bypass

Figure 2 shows a schematic drawing of the RSD technique. The patient was positioned supine with the head rotated 45 degrees to the opposite side. Intraoperative transcranial motor-evoked potentials and somatosensory-evoked potentials were monitored. The first step corresponded to neck dissection under the operating microscope, followed by identification and exposure of the common carotid artery (CCA), ICA, ECA, and superior thyroid artery. Next, multiple vessel loops were placed around the CCA, ICA, and ECA. If necessary, STA-MCA bypass and/or ECA-RA-M2 bypass was performed before approaching the aneurysm.[13]

All patients underwent an anterior temporal approach as described previously.[14,15] After preliminary exposure of the aneurysm, the RSD technique was initiated. In Group 1 (patients without ECA-RA-M2 bypass), the superior thyroid artery was incised, and a polyvinyl chloride catheter (Atom indwelling feeding tube for infants, 5 Fr; Atom Medical, Tokyo, Japan) was introduced into the ICA through the superior thyroid artery (Figure 3A).[5] In Group 2 (patients with ECA-RA-M2 bypass), the ICA was punctured with a 18-gauge indwelling needle (Figure 3B). After these preparations, temporary clamps and clips were placed on the CCA and the ECA, followed by clamps on the intracranial ICA (C1 segment) distal to the aneurysm neck (Figure 4A, B), or on the A1 and M1. In patients with a large PcomA, a temporary clip was applied to reduce blood back-flow into the aneurysm (Figure 4C). Subsequently, blood was gently aspirated through a tube or needle introduced into the cervical ICA, resulting in aneurysm collapse and enabling the surgeon to complete aneurysm dissection and clipping with preservation of the PcomA, ATPA, and AchA (Figure 4D–F). The occlusion time was limited to 10 minutes per attempt in patients without bypass to prevent cerebral ischemia; therefore, RSD was staged in some cases. After aneurysm clipping, the temporary clamps and clips were removed. Finally, micro-Doppler ultrasonography and indocyanine green videoangiography were used to confirm successful clipping and patency of the parent vessel.

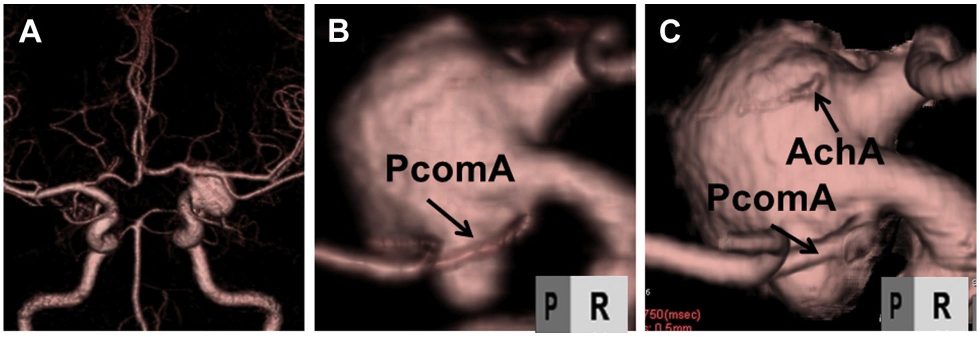

Figure 1. Representative preoperative computed tomography angiograms (Case 8). Three-dimensional computed tomography angiograms from the (**A**) anteroposterior view and (**B**) posterolateral view show a large left C1 aneurysm (18 mm in diameter). Note that the anterior choroidal artery (AchA) is not visible. (**C**) Four-dimensional computed tomography angiogram (posterolateral view) revealing that the AchA originates from the aneurysm dome. PcomA, posterior communicating artery.

RESULTS

Preoperative Clinical Data and Aneurysm Characteristics

Nineteen patients had unruptured aneurysms, and 1 patient had a ruptured aneurysm presenting with Hunt and Hess grade 2. Fifteen of the unruptured aneurysms were incidental findings, whereas 2 manifested as preoperative visual deficits, 2 as chronic headaches, and 1 with vertigo. All aneurysms were saccular without side predominance (10 right versus 10 left). The aneurysm size was medium (7—14 mm) for 11 aneurysms, large (14—21 mm) for 7 aneurysms, and giant (>21 mm) for 2 aneurysms. Table 1 summarizes the clinical data and aneurysm characteristics.

Surgical Treatment and RSD

Group 1 included 16 patients treated with RSD and assisted clipping, and Group 2 included 4 patients requiring additional ECA-RA-M2 bypass. Extradural anterior clinoidectomy was performed in 6 patients because of the large size of the aneurysm. Distal temporary clipping was performed at the C1 and PcomA in 13 patients, only C1 in 3 patients, A1, M1, and PcomA in 2 patients, and A1 and M1 in 2 patients. The total occlusion time ranged from 283 to 1126 seconds (mean, 595.3 seconds).

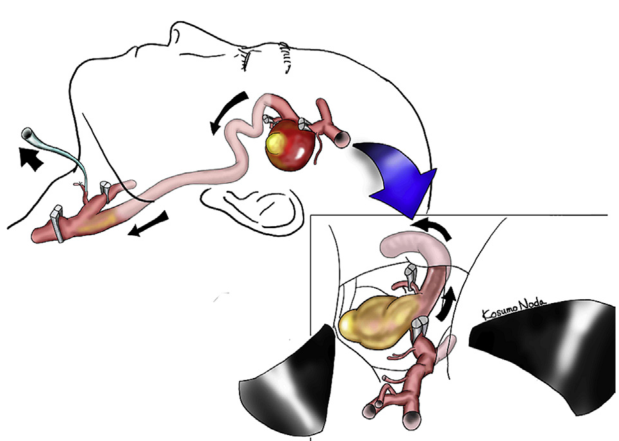

Figure 2. The retrograde suction decompression technique for a C1 aneurysm.

Clinical and Radiological Outcomes

All aneurysms were successfully treated, and postoperative images demonstrated complete occlusion of the aneurysm and patency of the parent vessel. Postoperative radiologic ischemic events compromising the ATPA or AchA territories appeared in 7 patients (Figure 5). Of these patients, 3 had transient neurologic deficits that had completely resolved by the last follow-up examination, and 2 patients (patients 1 and 13) had permanent neurologic deficits characterized by hemiparesis, memory disturbances, and mild aphasia. Nineteen patients had good outcome, and 1 patient had poor outcome associated with AchA ischemia (patient 13) with no surgical mortality at the 6-month follow-up examination.

DISCUSSION

Advantages of RSD Technique for C1 Aneurysms

In our series, surgical RSD-assisted clipping allowed for successful surgical management of C1 aneurysms, as previously reported.[6,7] Treatment of C1 aneurysms can be hindered by large aneurysm size, arachnoid adhesions of the aneurysm dome or neck to the surrounding neurovascular structures (PcomA, ATPA, AchA, the oculomotor nerve, and the dura of skull base), or the presence of calcifications on the proximal ICA. The RSD technique provides proximal vascular control of the ICA, and allows softening and shrinking of the aneurysm sac by continuous suction, thus improving the surgical view and visualization of the aneurysm neck and its surrounding structures, and allowing the neurosurgeon to place the permanent clips safely and correctly.[6] Previously, the surgical RSD technique has been applied mainly for large or giant aneurysms. However, treatment of medium-sized aneurysms that are attached to the PcomA, ATPA, or AchA may benefit from this technique to achieve direct clipping and final occlusion

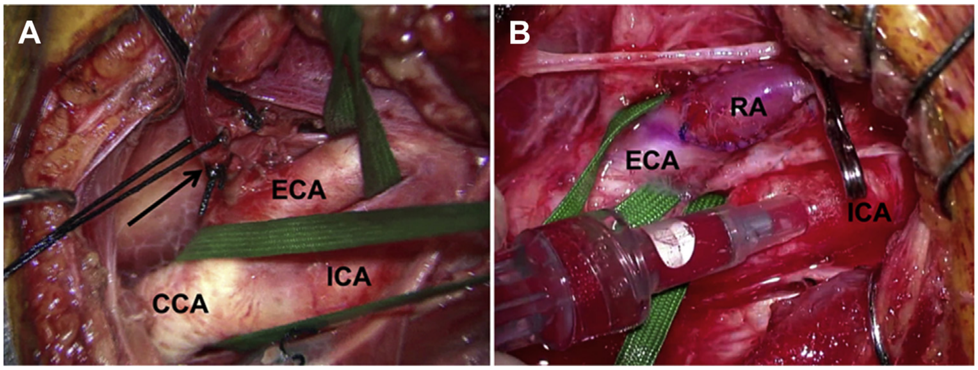

Figure 3. Representative intraoperative photographs (cervical procedure). (**A**) Case without external carotid artery (ECA)-radial artery (RA)-M2 bypass. The superior thyroid artery (*arrow*) is incised, and a polyvinyl chloride catheter is introduced into the internal carotid artery (ICA) through the superior thyroid artery. (**B**) Case with ECA-RA-M2 bypass. The ICA is punctured with an 18-gauge indwelling needle after the bypass procedure. CCA, common carotid artery.

of the aneurysm. Our present study demonstrates that surgical dissection of the neck carries a relatively low risk of permanent morbidity.

Surgical Nuances

The treatment indications for incidental medium-sized C1 aneurysms are based on the risk factors, such as smoking, female sex,

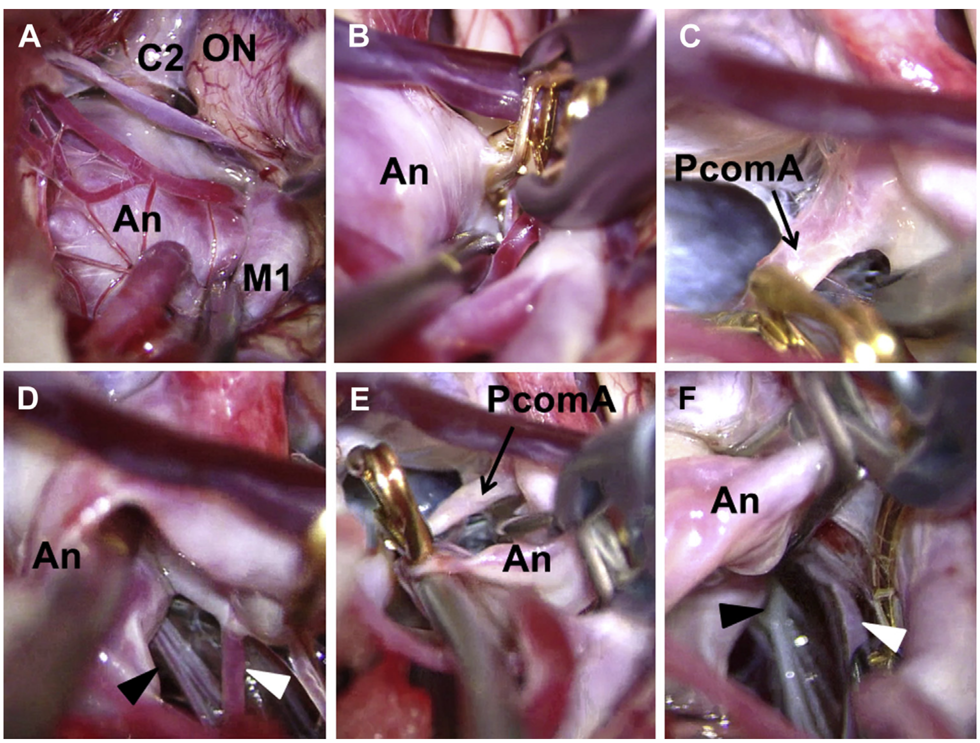

Figure 4. Representative intraoperative photographs (intracranial procedure). (**A** and **B**) After temporary clamps and clips are placed on the common carotid artery and the external carotid artery, the intracranial internal carotid artery (C1 segment) distal to the aneurysm neck is clamped. (**C**) The posterior communicating artery (PcomA) is clamped to reduce blood back-flow into the aneurysm. (**D**–**F**) Subsequently, blood is gently aspirated through a tube, resulting in aneurysm collapse and enabling the surgeon to complete aneurysm dissection and clipping with preservation of the PcomA, anterior thalamoperforating artery (*black arrowhead*), and anterior choroidal artery (AchA; *white arrowhead*). An, aneurysm; C2, ophthalmic segment of the internal carotid artery; ON, optic nerve.

Table 1. Summary of Clinical Data

Case No.	Age (years)	Sex	Unruptured or Ruptured	Side	Size (mm)	Additional Procedure	Fetal PcomA Type	Site of Catheter Insertion	Site of Distal Temporary Clip	Total Occlusion Time for Neck Clippings (seconds)	Complication	Postoperative MRI Findings	mRS
1	70	Female	Unruptured	Left	20.0	Anterior clinoidectomy, STA-MCA bypass, STA-P2 bypass, ECA-RA-M2 bypass	Yes	Cervical ICA	C1, PcomA	684	Mild aphasia, paresis, ONP	ATPA infarction	2
2	73	Female	Unruptured	Right	11.0	—	Yes	Superior thyroid artery	C1, PcomA	506	—	ATPA infarction	0
3	75	Female	Unruptured	Right	16.8	—	Yes	Superior thyroid artery	C1, PcomA	283	—	No lesion	0
4	81	Female	Unruptured	Left	10.6	—	No	Superior thyroid artery	A1, M1	605	Myocardial infarction	No lesion	1
5	71	Female	Unruptured	Right	17.8	Anterior clinoidectomy, STA-MCA bypass, ECA-RA-M2 bypass	Yes	Cervical ICA	A1, M1, PcomA	820	—	ATPA infarction	0
6	71	Female	Unruptured	Right	14.9	—	No	Superior thyroid artery	C1, PcomA	814	—	No lesion	0
7	65	Female	Unruptured	Left	10.4	—	No	Superior thyroid artery	A1, M1	363	—	No lesion	0
8	54	Female	Unruptured	Left	18.0	—	No	Superior thyroid artery	C1, PcomA	430	—	No lesion	0
9	82	Female	Unruptured	Right	14.1	—	Yes	Superior thyroid artery	A1, M1, PcomA	452	—	No lesion	0
10	73	Female	Unruptured	Left	10.7	—	Yes	Superior thyroid artery	C1, PcomA	444	—	No lesion	0
11	85	Female	Unruptured	Left	12.5	—	Yes	Superior thyroid artery	C1, PcomA	448	—	No lesion	0
12	53	Female	Unruptured	Right	18.0	Anterior clinoidectomy	No	Superior thyroid artery	C1, PcomA	430	—	No lesion	0
13	76	Female	Unruptured	Right	24.1	Anterior clinoidectomy, STA-MCA bypass, ECA-RA-M2 bypass	No	Cervical ICA	C1, PcomA	1126	Paresis, memory disturbance	AchA infarction	3
14	71	Male	Unruptured	Right	8.6	—	No	Superior thyroid artery	C1, PcomA	528	—	No lesion	0
15	52	Female	Ruptured (Hunt and Hess grade 2)	Left	9.6	STA-MCA bypass	Yes	Superior thyroid artery	C1, PcomA	864	—	No lesion	0
16	70	Female	Unruptured	Right	8.7	—	No	Superior thyroid artery	C1	361	—	No lesion	0
17	62	Female	Unruptured	Left	38.0	Anterior clinoidectomy, STA-MCA bypass, ECA-RA-M2 bypass	No	Cervical ICA	C1	894	Transient memory disturbance	ATPA infarction	1
18	69	Male	Unruptured	Left	12.7	Anterior clinoidectomy, STA-MCA bypass	Yes	Superior thyroid artery	C1, PcomA	960	—	No lesion	0
19	66	Male	Unruptured	Left	11.5	—	Yes	Superior thyroid artery	C1, PcomA	520	Transient memory disturbance	ATPA infarction	1
20	75	Female	Unruptured	Right	11.1	—	No	Superior thyroid artery	C1	373	Transient paresis	ATPA infarction	1

A1, A1 segment of anterior cerebral artery; AchA, anterior choroidal artery; ATPA, anterior thalamoperforating artery; C1, communicating segment of internal carotid artery; ECA, external carotid artery; ICA, internal carotid artery; M1, M1 segment of middle cerebral artery; M2, M2 segment of middle cerebral artery; MCA, middle cerebral artery; MRI, magnetic resonance imaging; mRS, modified Rankin Scale; ONP, oculomotor nerve palsy; P2, P2 segment of posterior cerebral artery; PcomA, posterior communicating artery; RA, radial artery; STA, superficial temporal artery.

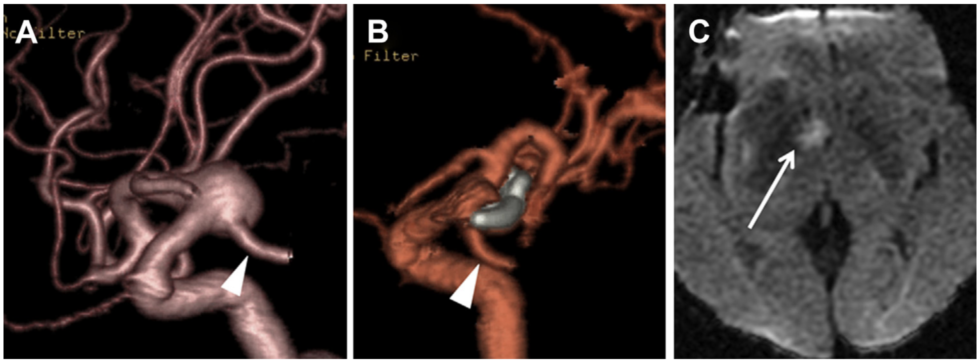

Figure 5. Representative preoperative three-dimensional computed tomography (3D-CT) angiograms and postoperative magnetic resonance images in a patient who developed postoperative cerebral ischemia (patient 2). (**A**) Preoperative 3D-CT angiogram (anteromedial view) showing a right internal carotid-posterior communicating artery (*arrowhead*) aneurysm (11 mm in size). (**B**) Postoperative 3D-CT angiogram (posteromedial view) showing complete occlusion of the aneurysm with preservation of the PcomA (*arrowhead*). (**C**) Postoperative diffusion-weighted magnetic resonance image showing a small right infarction (*arrow*) in the territory of the right anterior thalamoperforating artery.

high blood pressure, and familial history of intracranial aneurysms, and the findings of the Unruptured Cerebral Aneurysm Study in Japan demonstrating that ICA-PcomA aneurysms are more likely to rupture, leading to recommendation for treatment (clipping or coiling).[16]

Careful study of preoperative images is important for the planning of surgery for C1 aneurysms. The relationship between the aneurysm and the ipsilateral PcomA should be carefully considered, as 15 of 20 cases in our series required temporary occlusion of the PcomA to reduce retrograde blood flow into the aneurysm sac. In addition, the occlusion period should be limited to 10 minutes per attempt to decrease the risk of cerebral ischemia. RSD can provide a wide operative field to prevent inadvertent injury of small perforators, which tend to be located behind the aneurysm in most cases. We have routinely used the anterior temporal approach to provide a wide operative field in the retrocarotid space in cases of C1 aneurysms.[15,17,18] We recommend taking precautions, including complete hemostasis before further steps, to avoid blood obscuring the surgical field. Furthermore, the surgeon and the assistant must closely synchronize their actions to shorten the occlusion time when using the RSD technique.

Clinical Outcome and Complications

Good outcomes for RSD-assisted clipping of C1 aneurysms were previously reported in 79% to 83% of patients[6,7] similar to our results that demonstrated good outcomes in 95% of cases. RSD-assisted clipping of large or giant C2/C3 aneurysms has been associated with visual neurologic deficits.[10] In contrast, our study showed no visual worsening after RSD-assisted clipping.

In our series, postoperative ischemic lesions were mostly asymptomatic or transient, and relatively common in the territories of the AchA and ATPA, and mostly related to the size (large or giant) of the C1 aneurysm; however, this is unsurprising because the reported postoperative morbidity rate for large or giant C1 aneurysms is 36%–67% of cases.[19,20] Theoretically, in cases of strong attachments and adherences to the perforators, careful dissection of the aneurysm dome after gentle suction of the aneurysm through the RSD may be helpful to decrease the rate of perforator injury and consequently reduce the rate of ischemic events. However, our study did not assess this aspect. Further large, case-controlled or randomized controlled studies may be required to determine whether the RSD technique can prevent postoperative ischemia in the territory of small perforators.

Bypass Procedures for Large or Giant Aneurysms

Revascularization procedures or bypass techniques are useful to prevent cerebral ischemia caused by prolonged temporary occlusion during clipping of large or giant aneurysms.[21,22] This is especially the case with complex aneurysms, in which clipping may require prolonged temporary or permanent occlusion of the parent vessel.[23] In our series, none of the patients developed bypass-related complications.

Limitations

This study has certain limitations. First, this was a retrospective case series of C1 aneurysms treated using RSD-assisted clipping. Second, the decision making for the necessity of bypass was based mainly on aneurysm complexity and institutional experience.

CONCLUSIONS

The RSD technique is a useful procedure to achieve proximal vascular control, to soften and shrinkage the aneurysm sac, and to provide a wide and clean operative field allowing safe clip placement. The RSD technique requires special attention to the relationship between the perforators and the aneurysm, and close cooperation between the surgeon and the assistant.

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