Surgical Strategies for Ruptured Complex Aneurysms Using Skull Base Technique and Revascularization Surgeries

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Abstract

Object: Surgical clipping of paraclinoid aneurysm, thrombosed large aneurysm, and/or vertebral-basilar dissecting aneurysms can be very difficult and has relatively high morbidity. We describe our experience using skull base and bypass technique and discuss the advantages and its pitfalls. **Patients and Methods:** We retrospectively reviewed medical charts of 22 consecutive patients with complex aneurysmal lesions underwent skull base and/or bypass techniques between March 2012 and April 2017. **Results:** There were 5 patients with paraclinoid or internal carotid artery (ICA) aneurysm underwent modified extradural temporopolar approach with mini-peeling of the dura propria with suction decompression, 3 patients with ICA aneurysm underwent intradural anterior clinoidectomy, 12 patients with vertebral dissecting aneurysm through transcondylar fossa approach (6 patients underwent occipital artery-posterior inferior cerebellar artery [OA-PICA] bypass), 1 patients with vertebral artery dissection underwent superficial temporal artery-superior cerebellar artery and OA-PICA bypass through posterior transpetrosal approach, 1 patient with arteriovenous fistula at the ventral side of the craniovertebral junction through extremely far lateral approach. Surgical outcome was good recovery in 10 patients, moderate disability in 4, severe disability in 4, vegetative state in 2, and dead is 2 patients. The favorable outcome was 63.6%, and poor outcome was 36.4%, which showed poor grade subarachnoid hemorrhagic patients. No patient suffered any complication related to re-rupture and/or incomplete clipping. **Conclusion:** Skull base technique, which can create a wide and shallow operative space, allowed us to improve surgical outcome and to reduce the risk of intraoperative neurovascular injury for surgical treatment of deeply located complex aneurysms.

Keywords: *Giant aneurysm, ruptured aneurysm, skull base, subarachnoid hemorrhage*

Introduction

Surgical clipping of paraclinoid aneurysm, thrombosed large aneurysm, and/or vertebral-basilar dissecting aneurysms can be very difficult and has relatively high morbidity.[1-4] Intravascular treatment for ruptured complex aneurysms, which are difficult to cope with simple clipping technique, seems to have contributed to improve the clinical outcome including minimization of invasiveness and treatment time. On the other hand, there is a problem with curability such as highly recurrence rate.[5-8] In addition, there seems to be exist the aneurysms inappropriate for endovascular treatment. Therefore, it will be necessary to deal with various surgical treatment strategies, while making full use of the skull base and/or revascularization technique.[9-11] We herein present our own experienced cases using skull base and/or revascularization technique and describe the surgical tips on it.

Patients and Methods

Patient characteristics

This retrospective analysis included 22 consecutive patients underwent skull base and/or bypass technique for ruptured complex aneurysms at the National Defense Medical College Hospital between March 2012 and April 2017. Medical charts, radiological findings, surgical techniques, complications, and clinical results were retrospectively reviewed.

Preoperative evaluation

Three-dimensional computed tomography angiography (3DCTA) and/or digital subtraction angiography (DSA) are essential to investigate the cross flow through the anterior and/or posterior communicating arteries, the height of the bifurcation of the carotid artery with or without the carotid artery stenosis, or the size of the bilateral

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Access this article online

Website: www.asianjns.org

DOI: 10.4103/ajns.AJNS_176_18

Quick Response Code:

How to cite this article: Otani N, Wada K, Toyooka T, Takeuchi S, Tomiyama A, Mori K. Surgical strategies for ruptured complex aneurysms using skull base technique and revascularization surgeries. Asian J Neurosurg 2018;13:1165-70.

vertebral artery (VA) for the paraclinoid and vertebra-basilar aneurysms. The anterior clinoid process (ACP) size, shape, pneumatization, and relationship with the sphenoid or ethmoid sinus were assessed on bone CT scans for safe clinoidectomy.

Surgical technique and methods

If necessary, the radial artery, the superficial temporal artery (STA), or the occipital artery (OA) were secured for preparing the revascularization procedures. Intraoperative motor evoked potential was routinely performed for safe surgical procedures. Three-head fixation by carbonated Mayfield-Kees head clamp was used for performing intraoperative DSA. Indocyanine green (ICG) videoangiography and/or microvascular Doppler ultrasonography were regularly used to assess blood flow of the parent and branch vessels.

Extradural anterior clinoidectomy combined with suction decompression for paraclinoid aneurysms

Just before positioning in the surgical posture, lumbar spinal drainage was instituted to ensure adequate brain relaxation to obtain full exposure of the epidural space in the extradural surgical procedure and to avoid postoperative cerebrospinal fluid (CSF) leakage. After induction of general anesthesia, the patient is placed in the supine position, and the head is rotated 30 degrees away from the operative side. The neck is slightly extended to facilitate exposure of the cervical carotid artery. A semicoronal skin incision is performed followed by interfascial dissection. A standard frontotemporal craniotomy is performed up to the supraorbital notch, and the temporal squama is rongeured out until the floor of the middle cranial fossa is exposed. If the orbitozygomatic approach is needed, the orbitozygomatic bar is removed as in the two-piece fashion. The lesser wing of the sphenoid is flattened until the meningo-orbital band is exposed. The superior orbital fissure is skeletonized to expose the junction between the dura propria and the periosteal dura. Peeling of the dura propria from the lateral wall of the cavernous sinus continues until the ACP is epidurally exposed. The optic canal is then widely opened using a micro-punch to avoid heat injury. After removal of the ACP, the clinoid segment (C3) of the internal carotid artery (ICA) can be seen. The remainder of the optic strut can be completely removed to provide space for the clip blade in cases of paraclinoid aneurysm. The dura mater is opened along the Sylvian fissure and continued inferomedially to the level of the optic nerve. An incision from the falciform ligament to the optic sheath helps to mobilize the optic nerve. The tentorial edge is incised from the anterior petroclinoid ligament, and the temporal lobe can be retracted posteriorly over the dura mater. An additional incision is made across the distal dural ring to expose and identify the origin of the ophthalmic artery and to mobilize the ICA. Such incisions of the falciform ligament and distal dural ring will facilitate movement of the optic nerve and ICA.

Simultaneously, the cervical common carotid artery (CCA), ICA, and external carotid artery (ECA) are routinely exposed for proximal control, suction decompression (SD), intraoperative angiography, and high-flow bypass if necessary [Figure 1]. The CCA is punctured using a 20 gauge plastic needle just before SD. After the 3000–5000 U heparinization, the CCA and ECA are clamped. Moreover, then, the aneurysm is temporary trapped by putting a temporal clip on the intracranial ICA distal to the aneurysm neck with special attention to spare the AchoA. Blood is aspirated through the catheter introduced into the cervical ICA, resulting in collapse of the aneurysm and therefore enabling the surgeon to complete dissection and neck clipping [Figure 1: arrow indicated]. The occlusion time can be limited to within 5 min even if there are no obvious changes occur in electrophysiological monitoring. The retrograde SD was repeated after the declamping the arteries for the duration of the longer than each occlusion time. These procedures can be repeated until confirming the complete clipping. Intraoperative DSA through the catheter placed in the cervical ICA confirmed the complete clipping without stenosis of the parent artery. Complete hemostasis at the puncture site is achieved by suturing.

Posterolateral skull base approach including far lateral, transcondylar fossa, transcondylar approach for vertebral basilar aneurysms including dissecting aneurysm

A three-quarter prone position is used. The ipsilateral mastoid process becomes the highest point in the operating field. An inverted U-shaped skin incision is made beginning in the cervical midline over the C4 process. It extends to the inion, course laterally along the superior nuchal line to the mastoid bone, and finish inferiorly to the mastoid tip. If necessary to require the condylectomy, skin incision was further extended to the cervical region. OA was routinely secured, and the suboccipital muscles were peeled away layer by layer. The suboccipital craniotomy is extended unilaterally from the foramen magnum in the midline, up to the level of the transverse sinus, and then back around the foramen

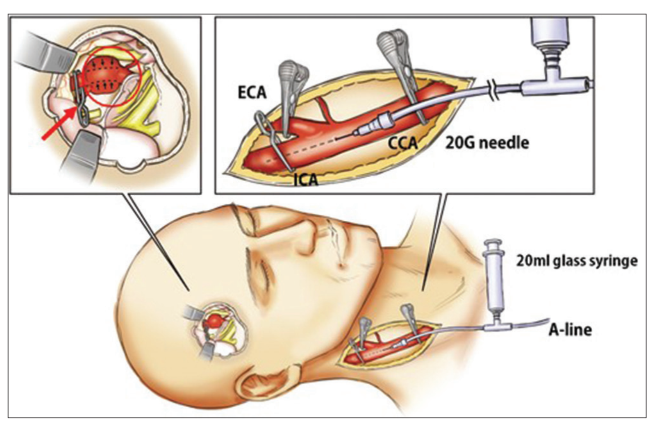

Figure 1: Schematic illustrations showing the modified extradural temporopolar approach combined with suction decompression for paraclinoid aneurysms

magnum. In the case of the VA aneurysms located laterally in lower third of the clivus, this standard suboccipital craniotomy can be appropriate. However, the aneurysmal lesions located medially and/or higher than the lower third of the clivus requires transcondylar fossa and/or transcondylar approach. The arch of the C1 is removed with the drill and the extracranial VA was secured. The dural penetrating portion of the VA was recognized. The supracondylar area of the suboccipital bone is removed (far lateral approach), and the sigmoid-magnum triangle is adequately removed, condylar emissary vein is cauterized, and condylar fossa is fully exposed and removed (transcondylar fossa approach). In addition, the joint surface of the occipital and C1 condyle is exposed, and posteromedial two-thirds of the occipital condyle is removed until the hypoglossal canal can be recognized (transcondylar approach). A semicircular dural incision is made from the cervical dura to the lateral edge of the craniotomy. The VA is secured intradurally. After securing the inferior cranial nerve and the origin of posterior inferior cerebellar artery (PICA), the lesion site can be recognized. If

Table 1: Clinical characteristics of patients with ruptured aneurysms who underwent skull base and/or bypass techniques between March 2012 and April 2017

No.	Age (yrs)	/	Sex	Symptom	H & K grade	Site	Size (mm)	Surgical approach	Surgical procedures	Surgical outcome GOS
1	69	/	F	SAH	II	paraclinoid	20	modified EDTPA	suction decompression	GR
2	61	/	F	SAH	II	paraclinoid	7	modified EDTPA	suction decompression	GR
3	75	/	F	SAH	IV	paraclinoid	15	modified EDTPA	suction decompression	VS
4	68	/	F	SAH	II	IC-ancho	6	modified EDTPA		GR
5	63	/	F	SAH	II	IC-ancho	5	modified EDTPA		GR
6	56	/	F	SAH	II	IC-Pcom	8	intradural ACP drilling		GR
7	63	/	F	SAH	II	IC-Pcom	7	intradural ACP drilling		GR
8	71	/	F	SAH	II	distal Pcom	15	intradural ACP drilling		GR
9	58	/	M	SAH	V	VA dissection		trans-condylar fossa	trapping	SD
10	39	/	M	SAH	II	distal PICA dissection		trans-condylar fossa	OA-PICA bypass + trapping	MD
11	77	/	F	SAH	IV	distal PICA dissection		trans-condylar fossa	OA-PICA bypass + trapping	VS
12	56	/	M	SAH	IV	VA dissection		trans-condylar fossa	proximal occlusion	MD
13	65	/	M	SAH	IV	VA-basilar dissection		combined trans-petrosal	OA-PICA + STA-SCA bypass	SD
14	58	/	M	SAH	V	bil. VA dissection		trans-condylar fossa	OA-PICA bypass	D
15	73	/	M	SAH	V	VA dissection		trans-condylar fossa	direct clipping	SD
16	53	/	M	SAH	V	VA dissection		trans-condylar fossa	proximal occlusion	D
17	51	/	M	SAH	IV	VA dissection		trans-condylar fossa	trapping	GR
18	72	/	F	SAH	III	VA dissection		trans-condylar fossa	proximal occlusion	GR
19	47	/	M	SAH	V	VA dissection		trans-condylar fossa	proximal occlusion	SD
20	38	/	M	SAH	II	VA dissection		trans-condylar fossa	OA-PICA bypass + proxymal occlusion	GR
21	51	/	F	SAH	V	VA dissection		trans-condylar fossa	OA-PICA bypass + proxymal occlusion	MD
22	70	/	M	SAH	II	cervical AVF		extremely far lateral	trapping	MD

M: male, F: female, SAH: subarachnoid hemorrhage, Pcom: posterior communicating artery, VA: vertebral artery, EDTPA: extradural temporopolar approach, ACP: anterior clinoid process, PICA: posterior inferior cerebellar artery, AVF; arteriovenous fistula, OA: occipital artery, SCA: superior cerebellar artery, GR: good recovery, MD: moderate disability, SD: severe disability, VS: vegetative state, D: death necessary, OA-PICA bypass and/or STA-superior cerebellar artery (STA-SCA) bypass are performed. The temporary clip is applied to the proximal part of the VA. The aneurysmal lesion can be safely dissected. After securing the distal site of the lesion, aneurysmal clipping or trapping was performed, and ICG videoangiography enables us to confirm the patency of the parent artery, and/or complete clipping.

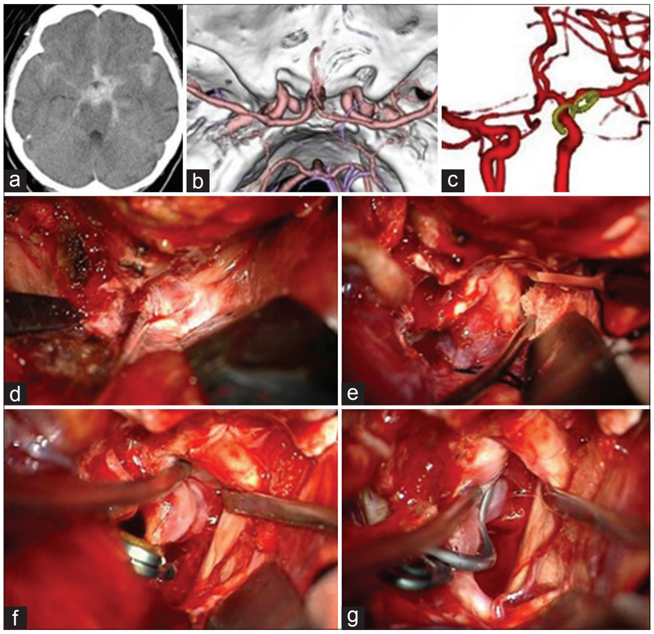

Figure 2: Case 2: (a and b) Preoperative three-dimensional computed tomography angiography showed the cause of hemorrhage due to ruptured a ruptured carotid cave aneurysm on the left. Emergent direct clipping through a modified extradural temporopolar approach combine with suction decompression was performed (d-g). Postoperative three-dimensional computed tomography angiography showing that complete clipping was done (c)

Results

The clinical course of all 22 cases is summarized in Table 1. The average age was 60.6 years old (38–77), 11 males and 11 females. In all cases, the initial symptom was subarachnoid hemorrhagic (SAH), underwent extradural temporopolar approach (ETA) with SD for paraclinoid aneurysms in 5 cases, intradural anterior clinoidectomy for IC aneurysm in 3 cases, transcondylar fossa approach for VA dissecting aneurysms in 12 cases including OA-PICA bypass in 6 cases, posterior transpetrosal approach combined with STA-SCA bypass in 1, and extremely far lateral approach for spinal dural AV-shunt in 1 case. In all cases, complete hemostasis can be performed, there was no recurrent and re-bleeding. Clinical outcome at discharge was 10 cases of GR, 4 cases of MD (63.6% of the favorable group), 4 cases of SD, 2 cases of VS, and 2 cases of death (36.4% of poor prognosis group). All patients with poor prognosis were Grades IV and V patients.

Case presentations

Case 2

A 61-year-old female suffered from sudden-onset headache and transient loss of consciousness. A plain head CT on admission showed massive SAH (H and K Grade II) [Figure 2a]. 3DCTA on admission

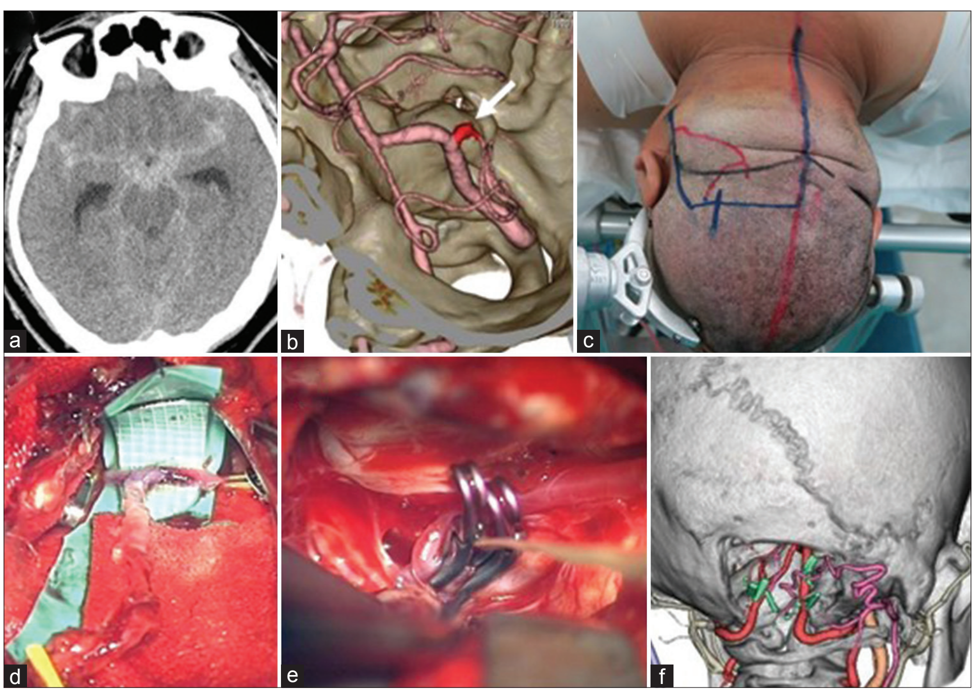

Figure 3: Case 10: (a and b: white arrow) Preoperative three-dimensional computed tomography angiography showing a ruptured distal posterior inferior cerebellar artery dissecting aneurysm on the right. (c-e) Emergent occipital artery-posterior inferior cerebellar artery bypass and trapping of the distal posterior inferior cerebellar artery dissecting lesion through the transcondylar fossa approach were performed. (f) Postoperative three-dimensional computed tomography angiography showing good bypass graft patency

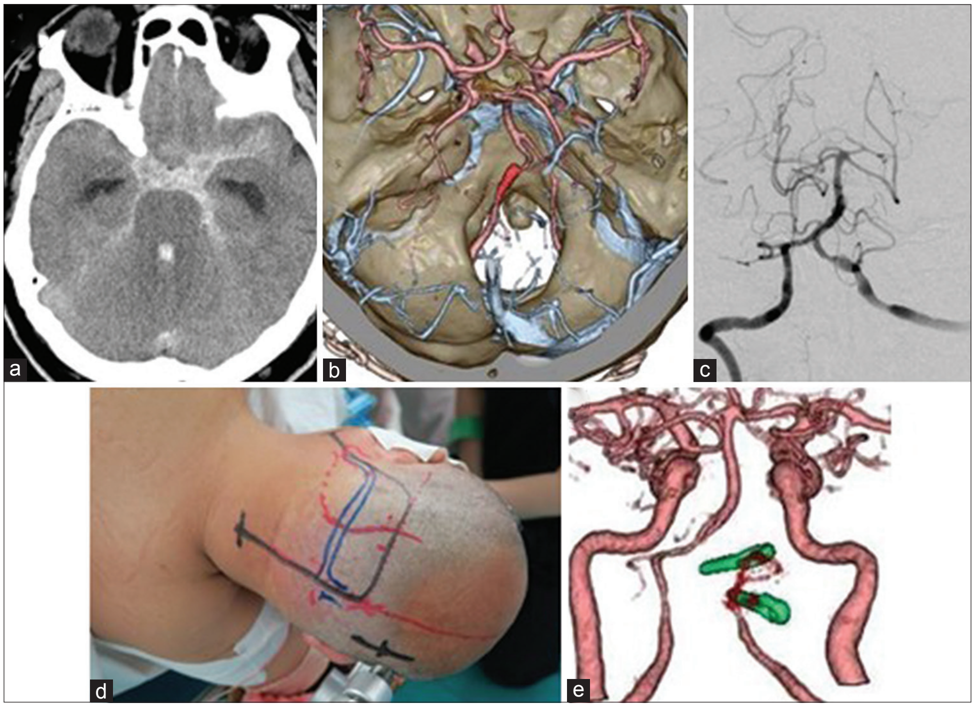

Figure 4: Case 9: (a and b) Preoperative three-dimensional computed tomography angiography showing a ruptured vertebral artery dissecting aneurysm on the left. (c) The dissecting lesion was located in the mid-sagittal position at just distal from the posterior inferior cerebellar artery bifurcation. (d) Emergent vertebral artery trapping through the transcondylar fossa approach was performed (e)

showed the cause of hemorrhage due to ruptured left carotid cave aneurysm [Figure 2b]. On the same day, emergent direct clipping was performed through an extradural tempolopolar approach [Figure 2d-g]. SAH around the aneurysm was so thick, and rupture point was confirmed. Complete clipping was done [Figure 2c]. Postoperative course was uneventful.

Case 10

A 39-year-old male suffered SAH (H and K grade II) [Figure 3a]. 3DCTA on admission showed the cause of hemorrhage due to ruptured dissecting aneurysm at the periphery of right PICA [Figure 3b, white arrow indicated]. On the same day, emergent trapping of the PICA lesions with OA-PICA bypass was performed through a transcondylar fossa approach [Figure 3c-e]. Complete clipping was done. The patency of the bypass and/or parent artery flow were confirmed. There was no appearance of the new cerebral infarction [Figure 3f]. There was no conscious disorder and he was discharged for rehabilitation purpose.

Case 9

A 58-year-old male suffered SAH (H and K Grade V) [Figure 4a]. 3DCTA on admission showed the cause of hemorrhage due to ruptured dissecting aneurysm at the left side [Figure 4b]. The lesion is confined to the VA on the peripheral side of the PICA bifurcation, which showed nondominant flow side [Figure 4c]. On the same day, emergent trapping of the VA lesions was performed through a transcondylar fossa approach [Figure 4d]. The patency of the bypass and/or parent artery flow were confirmed. There was no appearance of the new cerebral infarction [Figure 4e]. There was no conscious disorder and he was discharged for rehabilitation purpose.

Discussion

Surgical clipping of paraclinoid aneurysms, thrombosed large aneurysms, and/or vertebral-basilar dissecting aneurysms can be very difficult and has relatively high morbidity. Skull base technique, which can create a wide and shallow operative space, allowed us to improve surgical outcome and to reduce the risk of intraoperative neurovascular injury for surgical treatment of deeply located complex aneurysms. The present study showed our surgical results and presented the operative nuances.

When doing direct clipping for large paraclinoid aneurysms, confirming the whole aneurysm and adequate anterior clinoidectomy will be required to secure the proximal internal carotid artery. In addition, there were any cases in difficulty to perform the proximal flow control due to severe arteriosclerosis and to dissect severe adhesion with the perforators and surrounding structures. In addition, an angioplastic clipping technique will be required due to aneurysmal wide neck. Consequently, it will be essential to reduce the aneurysmal internal pressure to complete safe and reliable clipping procedure. Therefore, we usually use the modified ETA combined with SD for these lesions.[12,13]

In 1990, Batjer and Samson[14] described the therapeutic strategy for large paraclinoidal aneurysm using these methods. Along with the development of surgical techniques and instruments in endovascular therapy, SD method with introducing a catheter into the ICA by the Seldinger method has also been reported.[15,16] However, this method does not complement surgical procedures such as anterior clinoidectomy and securing carotid arteries. There are additionally some problems of embolic complications due to indwelling of the catheter in the blood vessel over a long period, and installation and loading into the surgical site of the intraoperative DSA device may become complicated.

The advantage of this method seems to be that before epidural anterior clinoidectomy, carotid artery securing against intraoperative rupture in advance, intermittent interruption of the ICA can be repeated, its possibility to confirm the patency of the parent artery and the presence or absence of residual aneurysm by intraoperative DSA, and if necessary, it will be possible to promptly move to aneurysmal trapping and high-flow bypass without changing the operative field. On the other hand, the disadvantage of this method seems to be that CSF leakage, sphenoparietal sinus injury during peeling of the lateral cavernous sinus, various cranial nerve injury, and hemostasis of the venous bleeding from the cavernous sinus.

It will be important to secure a wide and shallow operative view from the inferior-lateral side with an adequate deleting of the supracondylar area for ruptured VA aneurysm including dissecting aneurysms. In addition, deleting condylar fossa or condyle bone enables us to secure the operative field from the lower lateral outside. On the head fixation, we have to pay attention to fully expose the articular joint surface formed by occipital condyle and C1 condyle due to bending the head slightly. It is necessary to evaluate the operative procedures and necessity of revascularization (OA-PICA, STA-SCA, and STA-posterior cerebral artery), considering the site of the lesion including the distance from the midline and the height from the craniovertebral junction, and the relationship with the PICA bifurcation.

Conclusion

We presented surgical strategy and outcome in our hospital for ruptured complex aneurysm, which is hard to treat with normal clipping surgery. Brain swelling is strong in the acute phase of SAH, an adequate and sufficient removal of the skull base bone enable us to reduce the cerebral contusion caused by brain retraction and to secure a wide operative field. In addition, an improvement of the clinical outcome can be expected using various modalities such as SD and revascularization.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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