Presigmoid Approach to Vertebrobasilar Artery Aneurysms: A Series of 31 Patients and Review of the Literature

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■ OBJECTIVE: **The presigmoid approach can be used to treat vertebrobasilar artery aneurysms when circumstances require more operative exposure. High morbidity and mortality in these cases have been reported. In this study, we describe our modified presigmoid approach for vertebrobasilar artery aneurysms and our clinical results.**

■ METHODS: **This series includes patients with vertebrobasilar aneurysms clipped via the modified presigmoid approach at the Department of Neurosurgery at Helsinki University Hospital from 1998 to 2014. Data were collected from the operating record books, patients' medical records, and a radiologic database server.**

■ RESULTS: **Thirty-three presigmoid procedures of 31 patients were performed to treat 34 aneurysms (14 ruptured, 20 unruptured). The aneurysms had a mean distance from the posterior clinoid process to the aneurysm neck of 12.2 mm (range, 0—26.6 mm). A favorable outcome was achieved in 21 patients (64%). A favorable outcome was achieved in 74% of unruptured and good-grade patients, whereas favorable outcome was achieved in only 36% of poor-grade patients. Complete or near-complete occlusion was achieved in 79%. Larger aneurysms, fusiform morphology, and anterior dome projection had lower occlusion rates.**

■ CONCLUSIONS: **We have described our experiences of using the presigmoid approach to treat vertebrobasilar aneurysms. The clinical and radiographic results are acceptable given the complex location and configuration of the treated aneurysms. Unfavorable outcomes are related to the poor admission Hunt and Hess grade, aneurysm morphology, and aneurysm size.**

INTRODUCTION

The presigmoid approach (also referred to as the posterior transpetrosal approach or combined suprainfratentorial approach) is considered one of the most complex procedures in microneurosurgery. This approach was originally introduced as a surgical route to treat the ventral brainstem and clival tumors but it has also been applied to posterior circulation aneurysms that were not feasible for standard pterional, subtemporal, or retrosigmoid approaches.[1] In the early years of skull-base surgery, this procedure was performed through the infratentorial corridor, sacrificing the sigmoid sinus and labyrinth. This approach resulted in hearing loss and complications related to venous hypertension.[2,3] Hakuba et al.[4,5] later introduced a modification of a combined partial labyrinthectomy and petrous apicectomy to treat retrochiasmatic craniopharyngiomas and clival meningiomas. This technique avoided sacrifice of the sigmoid sinus with improved hearing outcomes and fewer complications related to venous insufficiency.

Recently, many less invasive variations of the presigmoid approach have been described, including retrolabyrinthine, transcrusal, minimum combined transpetrosal, and partial superoposterior petrosectomy.[6-12] However, the presigmoid approach still carries a relatively high morbidity (62%) and

Key words
- Angioplasty
- Aortic arch reconstruction
- Arterial occlusive disease
- Intracranial stenting
- Mechanical thrombolysis
- Stroke

Abbreviations and Acronyms
BA: Basilar artery
CSF: Cerebrospinal fluid
GOS: Glasgow Outcome Score
PCP: Posterior clinoid process
SPS: Superior petrosal sinus

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mortality (9%).[10,11] After the publication of the ISAT (International Subarachnoid Aneurysm Trial) and ISUIA (International Study of Unruptured Intracranial Aneurysms) trials reporting competitive results of endovascular therapy for aneurysm treatment, endovascular therapy has become more common in general and especially for treating posterior circulation aneurysms.[13-15] Nonetheless, not all vertebrobasilar aneurysms can be treated well by endovascular means. Some drawbacks of the endovascular treatment of cerebral aneurysms in either clinical or radiologic evaluation have been reported.[16-19] In certain cases, microsurgery still has a role in treating posterior circulation aneurysms.

In this study, we review our experience in using a modified presigmoid approach to treat vertebrobasilar aneurysms and to correlate the preoperative clinical and radiologic characteristics to patient outcomes.

METHODS

This retrospective review includes a consecutive series of patients with vertebrobasilar aneurysm treated by our modified presigmoid approach at the Department of Neurosurgery at Helsinki University Central Hospital (catchment area of 1.8 million inhabitants) between 1998 and 2014. Data were collected from the operating record books, patients' medical records, and a radiologic database server.

Patient Data

Our review included 3492 patients with 4677 intracranial aneurysms. From this population, 601 aneurysms were located in the vertebrobasilar system. A microsurgical procedure was performed for 421 aneurysms, endovascular therapy in 66 aneurysms, and conservative management in 114. The cases managed conservatively were mainly because of poor clinical condition at presentation for ruptured cases or small aneurysm size (< 3 mm) in unruptured cases indicating a lower risk for rupture.

Clinical Data

Preoperative clinical condition was assessed using the Hunt and Hess score.[20] The outcome after surgery was assessed using the modified Rankin Scale with classification into 3 categories: favorable if the condition is similar to the preoperative condition or with minor neurologic signs that did not disturb their life activities including walking satisfactorily (Glasgow Outcome Score [GOS] 4—5); unfavorable if the condition is worse postoperatively with moderate to severe neurologic deficit (GOS 2—3); and death (GOS 1).

Radiologic Measurement

Radiologic data for the study were obtained from the available computed tomography angiography and digital subtraction angiography images. Radiologic images were analyzed both in 2 and 3 dimensions using the GE Centricity RA 600 software (GE Medical Systems, Milwaukee, Wisconsin, USA) and the IMPAX software version 5.3 (Agfa, Mortsel, Belgium). The aneurysm characteristics for statistical analysis included the size of aneurysm dome and neck, vertical distance from the aneurysm neck to the posterior clinoid process (PCP), the lateralization of the aneurysm neck or parent artery with respect to the clivus, direction of aneurysm dome projection, and postoperative angiographic occlusion of the aneurysm. Patients with incomplete radiologic data were excluded from this study. Aneurysm size was categorized as: very small, <3 mm; small, 3—6 mm; medium, 7—13 mm; large, 14—24 mm; or giant, ≥25 mm. The radiologic evaluation of aneurysm occlusion was performed on the first postoperative day and divided into 3 categories: complete occlusion, near-complete occlusion (any signs of neck remnant), and incomplete occlusion (fundus remnant).

Operative Technique and Methods

Although the details of the presigmoid approach have been described elsewhere, below we review our modifications of this approach (Figure 1).[21]

Patient Position and Cerebrospinal Fluid Drainage. The patient is placed in the park bench position with the mastoid process as the highest point. The upper shoulder is carefully retracted caudally and backward with tape to increase the surgeon's working space. Lumbar cerebrospinal fluid (CSF) drainage (50 mL) helps to provide a slack brain before the dural opening and this action facilitates the subtemporal route to the interpeduncular cistern.

Skin Incision And Craniotomy. The 1-layer horseshoe incision forming musculocutaneous flap is performed from a point about 1 cm anterior and superior of the root of the zygoma, arching posterosuperiorly 2—3 cm over the ear and stopping 2 cm posterior to the occipitomastoid suture. This myocutaneous flap is retracted frontocaudally and fixated with several Sugita spring-hook retractors to expose the temporal and occipital-retrosigmoid area. The craniotomy is made to expose the dura of the middle fossa and lateral suboccipital area. An extradural dissection is performed to expose the subtemporal dural and the upper part of the sinodural angle.

Temporal Bone Drilling. Drilling is performed under high magnification of the operating microscope. The base of the squamous part of the temporal bone is drilled first to support an adequate supratentorial surgical corridor with minimal retraction of the temporal lobe. Drilling the posterosuperior mastoid part of the temporal bone increases the exposure of the sinodural angle, which has been exposed after the craniotomy. This angle or the presigmoid dura is exposed as necessary and drilling stops at the level of the anthrum without compromising the structures of the middle or inner ear. During this procedure, gradual and cautious detachment of the dura mater from the inner surface of the petrous-mastoid temporal bone is important to prevent damage to the sigmoid sinus. The transverse and sigmoid sinuses are left intact. The postoperative result of the temporal bone drilling can be seen in Figure 2.

Dural Opening and Cutting of the Tentorium. The dura mater is opened in a J shape that involves the subtemporal and presigmoid areas. The first opening is a horizontal incision of the subtemporal dura mater that extends posteriorly toward the sinodural angle. The second opening is a vertical incision of the presigmoid dura mater. These 2 dural openings are connected by dividing the superior petrosal sinus (SPS). The tentorium is cut to the incisura just posterior to the insertion of the fourth nerve into the tentorial edge. The mobilized anterior flap of the tentorium is folded anteriorly and fixed to the anterior tentorium with small aneurysm clips (Figure 1).

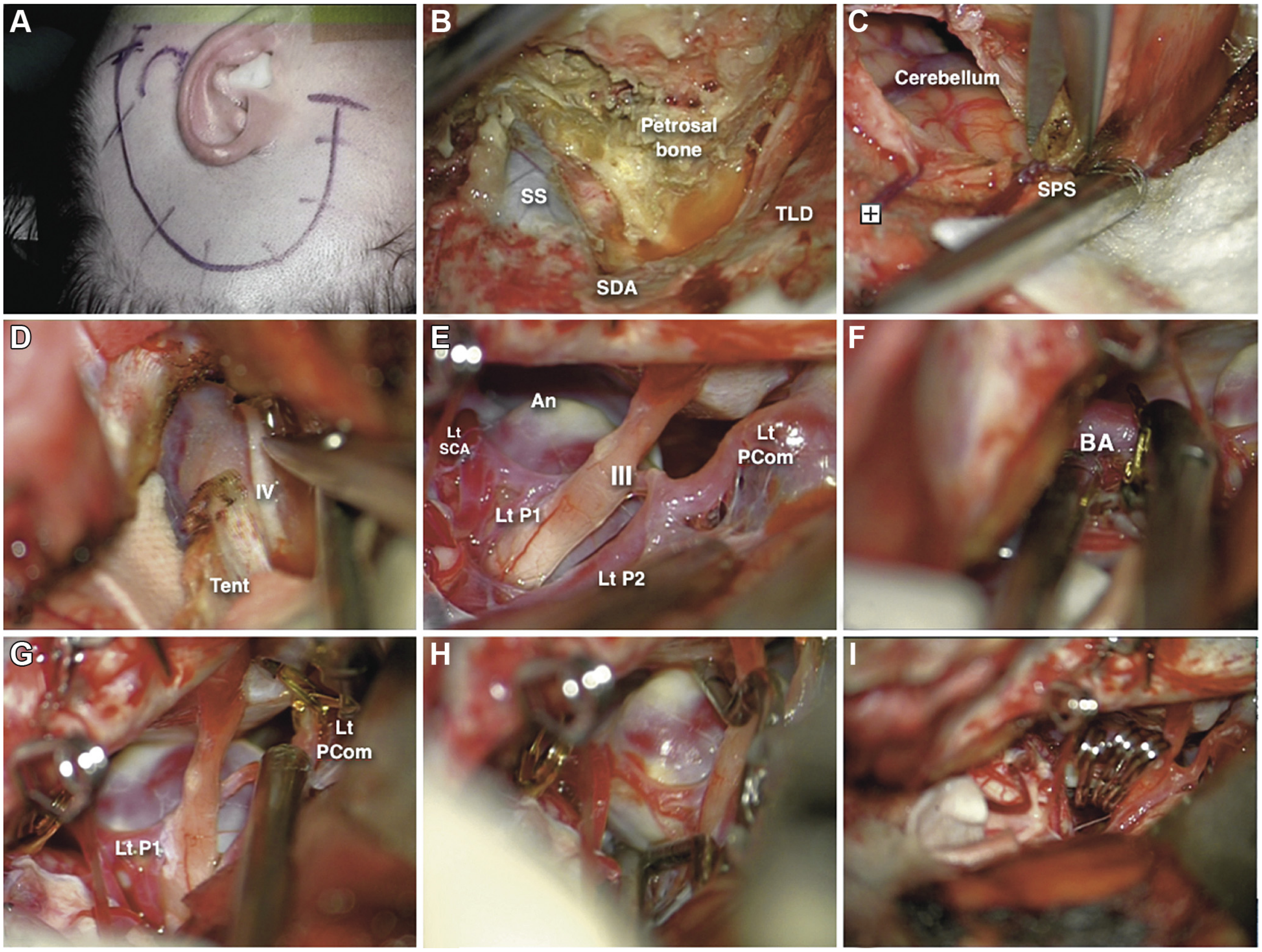

Figure 1. Steps of the presigmoid approach to clip a basilar tip aneurysm. (**A**) Skin incision marking. (**B**) The exposure after the craniotomy and temporal bone drilling. (**C**) Opening the dura mater and cutting the superior petrosal sinus (SPS). (**D**) The tentorium (Tent) is cut toward its edge with preservation of the fourth nerve. (**E**) Aneurysm exposure with its surrounding neurovascular anatomy. (**F**) Proximal temporary clip of basilar artery (BA). (**G**) Distal temporary clip of left posterior communicating artery (Lt PCom). (**H**) Neck clip application. (**I**) Definitive tandem clip application. III, oculomotor nerve; IV, trochlear nerve; An, aneurysm; Lt P1, left posterior cerebral artery segment 1; Lt P2: left posterior cerebral artery segment 2; Lt SCA, left superior cerebellar artery; SDA, sinodural angle; SPS, superior petrosal sinus; SS, sigmoid sinus; TLD, temporal lobe dura.

Closing. The closure for this approach is of the utmost importance to avoid postoperative CSF leakage and infection. The dura mater is closed in a watertight fashion and if necessary reinforced by dural sealants. Any open mastoid air cells are identified and sealed with a pedicle of the temporal muscle flap. This flap promotes the granulation between the muscle and the air-cell mucosa that closes the defect. Bone, soft tissue, and skin closure should be performed in layers under high magnification of the operating microscope.

RESULTS

From 1998 to 2014, the senior author (J.H.) performed 36 presigmoid approaches to operate on 37 vertebrobasilar aneurysms in 34 patients. Three patients were excluded because of incomplete radiologic data for the analysis, leaving 31 patients with 33 procedures on 34 vertebrobasilar aneurysms. Two of the patients came from outside Finland but could be followed up postoperatively.

General Characteristics of the Patients

The male/female ratio was 1:1 (16 men and 17 women) with a mean age of 47.9 years (range, 28–68 years). Three of 31 patients had 2 basilar artery aneurysms. Two of these patients required bilateral approaches because of the different origin and projections of the basilar artery aneurysms. Twenty aneurysms (59%) were ruptured with a median Hunt and Hess score of 3 (Table 1). The mean duration of surgery from skin incision to skin closure was 189 minutes (range, 70–257 minutes).

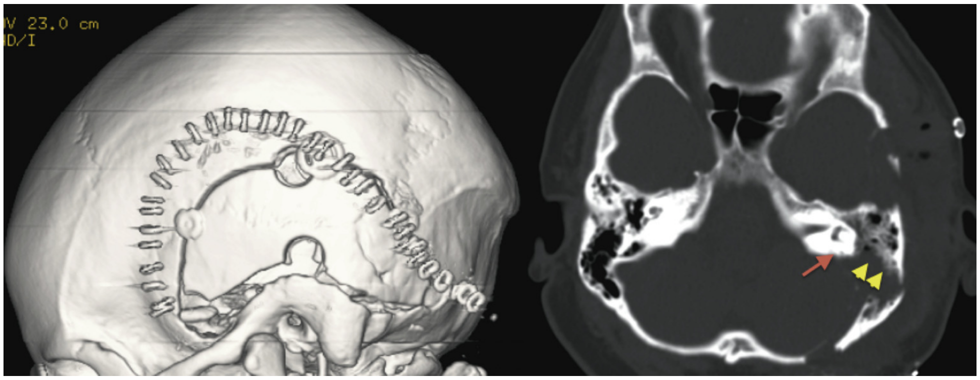

Figure 2. The postoperative computed tomographic bone reconstruction showed the area of craniotomy and temporal bone drilling. The minimal bone drilling allows the surgery to be faster and safer (*yellow arrows*). Red arrow, the inner ear structures that were left intact.

General Aneurysm Characteristics

Aneurysm Morphology. The aneurysms were saccular in 29 cases (85%), fusiform in 4 cases (12%), and dissecting in 1 case (3%). The mean aneurysm dome size was 9.8 mm (range, 2.6–38.4 mm). The mean aneurysm neck size for saccular and dissecting aneurysms was 5.5 mm, with a mean dome/neck ratio of 1.6. Most aneurysms were small and medium-sized, accounting for 17 (35%) and 10 (29%) cases, respectively (Table 1).

Table 1. Clinical Characteristics of 33 Procedures Using the Presigmoid Approach in Our Series

Description	Value
Age (years), mean (range)	47.9 (28–68)
Sex	
Male	16 (49)
Female	17 (51)
Preoperative Hunt and Hess grade	
0	14 (43)
1	6 (18)
2	3 (9)
3	6 (18)
4	3 (9)
5	1 (3)
Operation duration (skin to skin) (minutes), mean (range)	189 (70–257)
Approach side	
Right side	24 (73)
Left side	9 (27)
Postoperative outcome	
Favorable	21 (64)
Unfavorable	7 (21)
Dead	5 (15)

Values are number (%) unless otherwise indicated.

Aneurysm Location. The most common site of the aneurysm was the basilar trunk, accounting for 14 aneurysms (41%). In decreasing order of frequency, the remaining aneurysms were located at the basilar bifurcation, basilar-superior cerebellar artery, basilar-anterior inferior cerebellar artery, vertebrobasilar junction, and distal vertebral artery (Table 2 and Figure 3). The mean distance from the PCP to the proximal neck of the aneurysm was 12.2 mm (range, 0–26.6 mm). The lateralization of the aneurysm proximal neck was as follows: 26 midline aneurysms (76%), 5 right sided (15%), and 3 left sided (9%). The presigmoid approach was performed from the right side in 24 procedures (73%) and from the left side in 9 procedures (27%). Aneurysms at the midline were approached from the right side in 21 patients (81%) and from the left side in 5 patients (19%).

Radiographic Outcome

A complete or near-complete aneurysm occlusion was achieved in 27 cases (79%). The mean aneurysm size for aneurysms with complete occlusion, neck remnant, and fundus remnant was 7.8 mm, 9.9 mm, and 16.7 mm, respectively. Several other factors were also found to predict fundus remnants including fusiform morphology (75%), vertebrobasilar junction location (50%), and anterior dome projection (50%) (Table 3 and Figure 4).

Clinical Outcome

Clinical outcome was evaluated with a mean follow-up of 6.2 months (range, 1–30 months). The median GOS in this series was 4. Postoperative CSF leak was seen in 2 cases (6%); one of them also developed a postoperative wound infection. The CSF leaks were transient and healed with spinal drainage and antibiotics. A favorable outcome was achieved in 21 patients (64%). A favorable outcome was more common in unruptured cases (71%) compared

Table 2. Patient's General Outcome According to the Clinical and Radiologic Factors

Description	Favorable	Unfavorable	Dead	Total
Age (years), mean (range) (n = 33)	47.5 (30–68)	47.6 (28–62)	50 (36–65)	
Hunt and Hess score (n = 33)				
Good grade (0–2)	17 (74)	5 (22)	1 (4)	23 (68)
Poor grade (3–5)	4 (36)	2 (28)	4 (36)	10 (32)
Aneurysm morphology (n = 34)				
Saccular	19 (66)	7 (24)	3 (10)	29 (85)
Fusiform	2 (50)	1 (25)	1 (25)	4 (12)
Dissecting	0 (0)	0 (0)	1 (100)	1 (3)
Neck size (mm), mean (range) (n = 30)	4.3 (1.7–12.8)	8.2 (2.4–20.4)	5.4 (4.8–6.1)	
Dome size (mm), mean (range) (n = 34)	8.9 (2.6–38.4)	14.8 (5.5–28.6)	5.8 (2.6–7.3)	
Very small (<3 mm)	4 (80)	0 (0)	1 (20)	5 (15)
Small (3–7 mm)	9 (75)	1 (8)	2 (17)	12 (35)
Medium (7–14 mm)	5 (50)	3 (30)	2 (20)	10 (29)
Large (14–24 mm)	2 (50)	2 (50)	0 (0)	4 (12)
Giant (>24 mm)	1 (33)	2 (67)		3 (9)
Distance from the tip of posterior clinoid process to the proximal aneurysm distance	13 (0–26.6)	12 (5.6–26.4)	8.6 (4.4–15.1)	
Aneurysm origin (n = 34)				
Basilar bifurcation	6 (55)	3 (27)	2 (18)	11 (32)
Basilar-superior cerebellar artery	2 (50)	2 (50)	0 (0)	4 (12)
Basilar trunk	9 (64)	2 (14)	3 (21)	14 (41)
Basilar-anterior inferior cerebellar artery	2 (100)	0 (0)	0 (0)	2 (6)
Vertebrobasilar junction	1 (50)	1 (50)	0 (0)	2 (6)
Distal vertebral	1 (100)	0 (0)	0 (0)	1 (3)
Dome projection (n = 34)				
Superior	3 (43)	2 (29)	2 (29)	7 (20)
Posterior	4 (57)	3 (43)	0 (0)	7 (20)
Anterior	3 (50)	2 (33)	1 (17)	6 (18)
Right	7 (70)	1 (10)	2 (20)	10 (30)
Left	4 (100)	0 (0)	0 (0)	4 (12)

Values are number (%) unless otherwise indicated.

with ruptured cases (58%). An unfavorable outcome occurred in 7 patients (36%) and 5 patients died (15%) (Table 2). Four of the mortalities (80%) had poor Hunt and Hess grade on admission. The only unruptured case that had a fatal outcome was a patient with Ehlers-Danlos syndrome with a medium-sized basilar trunk aneurysm. This patient experienced an intraoperative rupture because the arterial wall was fragile. The situation was successfully managed, Indocyanine green angiography showed well-contrasted filling of the basilar artery and perforators, but severe basilar artery vasoconstriction occurred postoperatively, with subsequent postoperative brainstem stroke resulting in death.

Postoperative permanent cranial nerve deficit was seen in 5 patients (16%) (Table 4). Three patients developed cranial nerve VII and VIII palsy, 1 patient developed an abducens palsy, and 1 patient developed cranial nerve III and IV palsy. Transient cranial nerve deficit occurred in 13 patients (39%). Six of them (46%) had multiple cranial nerve deficits. Diplopia associated with abducens nerve palsy was the most common transient postoperative cranial nerve deficit and was seen in 10 patients (32%). Hemiparesis occurred in 8 patients, with 7 (88%) patients recovering to normal motor function.

DISCUSSION

The presigmoid approach for treating vertebrobasilar aneurysms is used in a selective manner.[33,34] A current literature review of the

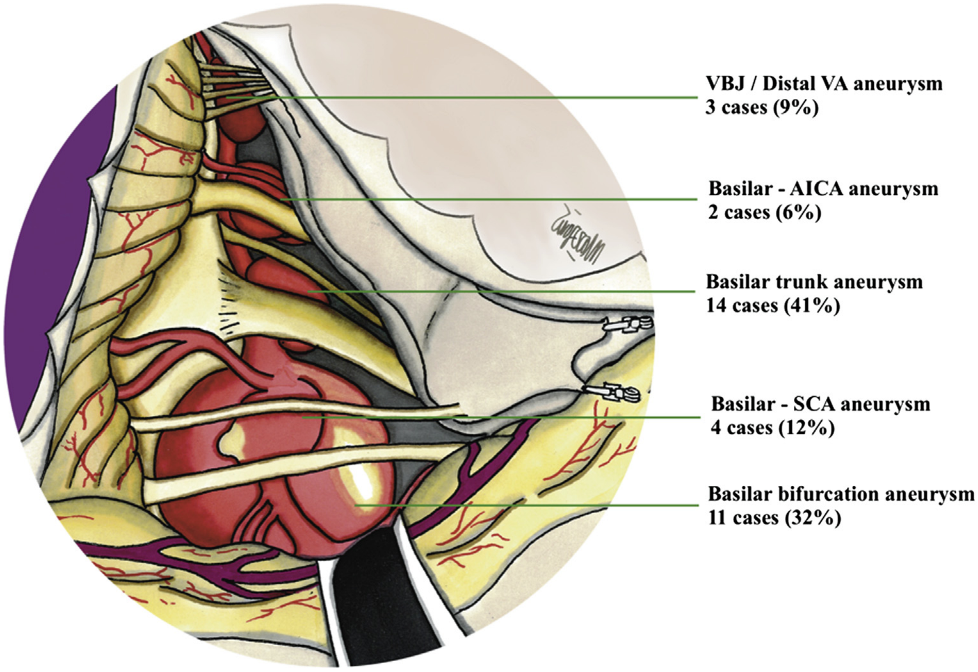

Figure 3. The location of basilar artery aneurysms that were clipped using our modified presigmoid approach. AICA, anterior inferior cerebellar artery; SCA, superior cerebellar artery; VA, vertebral artery; VBJ, vertebrobasilar junction.

posterior transpetrosal approach to aneurysms in the posterior circulation found reports of only 34 patients published in the last 20 years.[10] Our series comprises 33 procedures in 31 patients, making it the largest series to date; moreover, all the consecutive cases were treated by a single surgeon (J.H.) in a single center. No patient was lost to follow-up.

In the present series, we showed a simplified classic posterior petrosal/presigmoid approach with a tailored petrosal bone drilling. This approach modification was invented by the senior author (J.H.). In most cases, we do not need to drill the petrosal bone extensively and usually stop before reaching the semicircular canals. For this more limited bony removal to still provide the necessary exposure, cooperation with the neuroanesthetist to maintain a slack brain and the use of very high magnification during surgery are required.[35] With this strategy, surgical times are limited to approximately 3 hours. Only 2 patients (6%) developed postoperative CSF leakage, which was treated without surgical intervention. These findings are interesting because the literature reports a CSF leak rate of 21%.[10] We believe the technique of a tailored bone drilling and closing the opened air cells with a temporalis muscle pedicle are keys to the prevention for CSF leakage.

Until now, many surgical approaches have been proposed for reaching retroclival basilar artery aneurysms, including anterolateral, lateral, or posterolateral routes.[6,33,36,37] The anterolateral route (eg, pterional, orbitozygomatic, pretemporal, and their modifications) gives a relatively shorter working distance to reach the region.[38] The main disadvantage of this approach is the limited access to the lower segment of the basilar artery, even after the removal of the PCP and petrous apex.[39-42] The lateral route consists of a subtemporal approach and its extensions.[43-46] This approach for basilar aneurysms was introduced and popularized by Charles Drake and continues to be used regularly by the senior author (J.H.).[44,47] Additional removal of the petrosal apex, which was popularized by Kawase et al.,[45] allows surgeons to reach basilar aneurysms up to 18 mm below the sellar floor.[48]

The posterolateral route (eg, presigmoid, retrosigmoid, and their modifications) gives a relatively longer working distance, but it exposes lesions at almost all segments of the basilar artery. The presigmoid approach with opening of the dura over the petrous temporal bone, subtemporal dura, and sectioning of the tentorium creates a supratentorial and infratentorial corridor for exposure of the vertebrobasilar system.[1,3,4,12] The disadvantage of the presigmoid approach is its complexity, resulting in a longer operative duration and higher risk of injuring venous structures, cranial nerves, and the vestibulocochlear system. In some specific situations in which the patient has a petrosal or sphenopetrosal venous system, sacrifice of the SPS and cutting the tentorium are not safe. Hafez et al.[49] recommended freeing the SPS from its groove to the Meckel cave and cutting the tentorium below the SPS. In our experience, if the patient has such a venous system group, the senior author (J.H.) works from the supratentorial and

Table 3. The Aneurysm Occlusion Rate Characteristics

Description	Complete (number) (%)	Near-Complete (number) (%)	Incomplete (number) (%)
Aneurysm presentation			
Unruptured	6 (43)	3 (21)	5 (36)
Ruptured	17 (85)	1 (5)	2 (10)
Aneurysm morphology			
Saccular	21 (72)	4 (14)	4 (14)
Fusiform	1 (25)	0 (0)	3 (75)
Dissecting	1 (100)	0 (0)	0 (0)
Posterior clinoid process to aneurysm distance	11.4 (0—26.6)	12.9 (8.2—16.8)	15.4 (0—26.4)
Neck size (mm), mean (range)*	5.0 (1.7—20.4)	7.1 (4.7—12.8)	5.9 (2.6—9.5)
Aneurysm origin			
Basilar bifurcation	7 (64)	2 (18)	2 (18)
Basilar-superior cerebellar artery	4 (100)	0 (0)	0 (0)
Basilar trunk	8 (57)	2 (14)	4 (29)
Basilar-anterior inferior cerebellar artery	2 (100)	0 (0)	0 (0)
Vertebrobasilar junction	1 (50)	0 (0)	1 (50)
Distal vertebral	1 (100)	0 (0)	0 (0)
Dome size (mm), mean (range)	7.8 (2.6—28.6)	9.9 (7—13.4)	16.7 (6.4—38.4)
Very small (<3 mm)	5 (100)	0 (0)	0 (0)
Small (3—7 mm)	11 (92)	0 (0)	1 (8)
Medium (7—14 mm)	4 (40)	4 (40)	2 (20)
Large (14—24 mm)	2 (50)	0 (0)	2 (50)
Giant (>24 mm)	1 (33)	0 (0)	2 (67)
Dome projection			
Superior	6 (86)	0 (0)	1 (14)
Posterior	4 (57)	1 (14)	2 (28)
Anterior	3 (50)	0 (0)	3 (50)
Right	7 (70)	2 (20)	1 (10)
Left	3 (75)	1 (25)	0 (0)

Values are number (%) unless otherwise indicated.
*Fusiform aneurysms were not included in this analysis.

infratentorial corridor, cutting only the edge of the tentorium to increase the exposure.

Previous literature emphasizes the level of the aneurysm neck relative to the bony structures (such as the PCP or floor of the sellae turcica) for selection of surgical approaches.[37,48] Aziz et al.[48] proposed using the presigmoid approach if the aneurysm is located more than 18 mm below the floor of the sellae turcica. In the present series, the aneurysms treated with a presigmoid approach had an average distance, being 12.2 mm below the PCP, placing most aneurysms well above the cutoff point proposed by Aziz et al. We prefer to use the distance of aneurysms from the PCP to determine surgical approaches because this structure is encountered in surgery, whereas the floor of the sellae turcica is only radiographically identified.

Surgical Outcomes and Complications

Even when taking into account the unselected nature of the series, the results are comparable with the existing literature (Table 4).[10] The incidence of permanent postoperative cranial nerve injury and hemiparesis occurred in 16% and 3.2%, respectively. The death rates were highly related to the poor Hunt and Hess scale on admission.[10] In addition, we believe that the learning curve led to for lower morbidity at the end of the series.

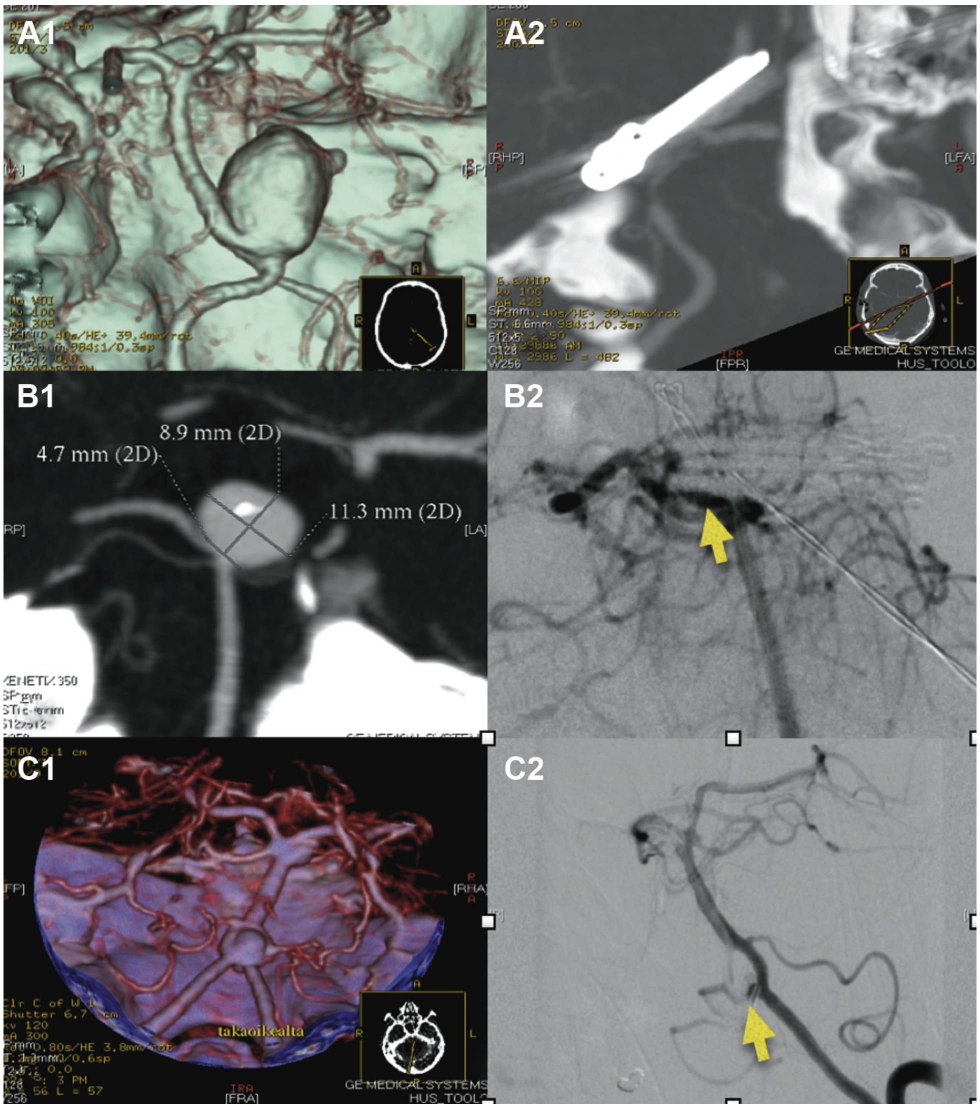

Figure 4. (**A1**, **A2**) Pre- and postoperative result of complete clipping of a large proximal basilar trunk aneurysm. (**B1**, **B2**) Pre- and postoperative result of the neck residual of the medium-sized basilar tip aneurysm; some part of the neck remnant is still seen on the postoperative angiogram (*yellow arrow*). (**C1**, **C2**). Pre- and postoperative image of both basilar-superior cerebellar artery and fenestrated vertebrobasilar junction aneurysm. The basilar-superior cerebellar artery aneurysm is completely clipped, but there is a small neck and fundus remnant of the fenestrated vertebrobasilar junction aneurysm (*yellow arrow*).

Clip occlusion rates of the aneurysms were evaluated by postoperative computed tomography angiography or digital subtraction angiography. For saccular aneurysms, the rate for complete occlusion was 71% (nontitanium clips cause artifact, making full estimation of neck remnants challenging). This finding is consistent with the finding of Kivisaari et al. in 2004,[50] who reported a 74% rate of occlusion for vertebrobasilar saccular aneurysms operated by the senior author (J.H.). These investigators also considered the aneurysm location, small gap, and size of the aneurysms as reasons for the postclipping aneurysm remnants, which were consistent with our findings.

Endovascular and Microsurgery Perspective

With endovascular therapy using natural routes, one can avoid extensive skull-base approaches and cranial nerve deficits, which

Table 4. The Multiauthor Review of Presigmoid Approach Experience for Vertebrobasilar Aneurysm (Adapted from Gross et al.[10])

Reference	Number of Cases	Cerebrospinal Fluid Leak, n (%)	Permanent Cranial Nerve Deficit, n (%)	Mortality
Solomon et al., 1991[22]	1	0	0	0
Spetzler et al., 1992[11]	2	1 (50)	0	0
King et al., 1993[23]	4	0	1 (25)	0
Origitano et al., 1993[24]	2	0	1 (50)	0
Collice et al., 1997[25]	5	0	1 (20)	1 (20)
Day et al., 1997[6]	1	0	0	0
Arai et al., 1998[26]	1	0	1 (100)	0
Motoyama et al., 2000[27]	1	0	0	0
Seifert and Stolke, 2003[28]	15	6 (40)	1 (7)	1 (7)
Evans et al., 2004[29]	1	0	0	1 (100)
Hamel et al., 2005[30]	1	1 (100)	0	0
Bambakidis et al., 2009[31]	1	1	0	0
Higa et al., 2009[32]	1	0	0	0
Present study	33	2 (6)	5 (16)	5 (15)

are the downside of microsurgical approaches. However, endovascular procedures also carry risks of complications in cases of vertebrobasilar aneurysms. Even with the rapid development of the technology, complications with endovascular approaches, including thromboembolic complications, aneurysm recanalization, intraprocedural hemorrhage, in-stent stenosis, jailed perforators, and formation of pseudoaneurysms, have been reported, and long-term follow-up of the patients is lacking.[16,18,19,51-53] A recent study on flow-diverting stents for posterior circulation aneurysms[54] showed a mortality of 12.3% and permanent neurologic deficit of 11% with mean follow-up time of 9.5 months. For more complex cases, such as fusiform vertebrobasilar aneurysms, the procedural morbidity and mortality after endovascular treatment have been reported at 29% and 57%, respectively.[55] The role of microneurosurgery in many vertebrobasilar aneurysm cases is still essential, not only because of the technical means but also because of the reality that many people cannot access high-priced endovascular procedures. To maintain a high-level performance in microneurosurgery, it should be performed in high-volume centers. Therefore, centralization of the service is the best strategy to achieve acceptable outcomes.

CONCLUSIONS

We have described our experiences of using a modified presigmoid approach to treat vertebrobasilar aneurysms by a single experienced neurosurgeon. The overall results are still acceptable when accounting for the complex location and configuration of the aneurysm. Unfavorable patient outcomes were related to poor preadmission Hunt and Hess grade, aneurysm morphology, and aneurysm size.

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