Simple Lateral Suboccipital Approach and Modification for Vertebral Artery Aneurysms: A Study of 52 Cases Over 10 Years

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■ INTRODUCTION: **Complex skull base approaches are frequently used to treat intracranial vertebral artery (VA) and proximal posterior inferior cerebellar artery (PICA) aneurysms. These complex procedures are associated with higher risk of neurovascular injury. Hence, a less-invasive surgical approach is needed to improve the efficacy and safety of treatment.**

■ METHODS: **A retrospective analysis was conducted on clinical and radiologic data from surgeries in which simple lateral suboccipital and "lateral-enough" approaches were used to clip VA aneurysms in the Department of Neurosurgery at Helsinki University Central Hospital from 2000 to 2009.**

■ RESULTS: **Fifty-two VA or PICA aneurysms were treated using the simple lateral suboccipital approach. Sixteen patients (31%) presented with an unruptured aneurysm, 21 patients (40%) with World Federation of Neurosurgical Societies (WFNS) grade 1—3, and 15 patients (29%) with World Federation of Neurosurgical Societies grade 4—5. The aneurysms were saccular in 48 cases (92%), dissecting in 3 cases (6%), and fusiform in 1 case (2%). The most common aneurysm location was the VA-PICA junction (81%). The mean final modified Rankin Scale score was 2, and in unruptured cases, all patients had favorable clinical outcomes. The main causes of unfavorable outcome were poor preoperative clinical grade ($P = 0.002$), preoperative intraventricular hemorrhage ($P = 0.008$), postoperative hydrocephalus ($P = 0.003$), brain infarction ($P = 0.005$), and postoperative pneumonia ($P < 0.001$).**

■ CONCLUSIONS: **We describe a 10-year experience using a simple lateral suboccipital approach and its modification by the senior author (J.H.) to treat VA and proximal PICA aneurysms. Unfavorable outcome was related to the poor preoperative clinical grade, preoperative intraventricular hemorrhage, and postoperative pneumonia.**

INTRODUCTION

Vertebral artery (VA) aneurysms account for approximately 3% of all intracranial aneurysms and 10%—15% of aneurysms in the vertebrobasilar system.[1-5] Treatment of VA aneurysms can be difficult because of the relationship of the VA with the brainstem, tortuosity, and proximity to lower cranial nerves. The lateral suboccipital approach was classically used to treat these aneurysms.[6-9]

Because of the long working distance and narrow working corridor, more extensive skull base procedures have been used (e.g., far-lateral, transcondylar, paracondylar, juxtacondylar, supracondylar, transjugular, or extreme lateral approach).[10-26] The goal of these skull base approaches is to remove the bony anatomy lateral to the foramen magnum (i.e., occipital condyle and jugular tubercle), allowing for a larger working corridor.[16,27,28] However, more extensive skull base approaches are associated with

Key words
- Aneurysm clipping
- Lateral suboccipital approach
- Vertebral artery aneurysm

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
CT: Computed tomography
IAR: Intraoperative aneurysm rupture
IVH: Intraventricular hemorrhage
LCNP: Lower cranial nerve palsy
LOS: Length of stay
mRS: Modified Rankin Scale
PICA: Posterior inferior cerebellar artery
VA: Vertebral artery
WFNS: World Federation of Neurosurgical Societies

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Citation: World Neurosurg. (2017) 108:336-346.
https://doi.org/10.1016/j.wneu.2017.09.014

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

increased surgical time and carry potential complications of neurovascular injury and craniocervical instability.[27]

The improvement of neuroanesthetic techniques along with the advancement in microsurgical equipment may reduce the need of these extensive surgical approaches. In this study, we assess the efficacy of a simple lateral suboccipital approach and its modification used by the senior author (J.H.) to treat VA aneurysms.

METHODS

A retrospective analysis was conducted on clinical and radiologic data from surgeries in which simple lateral suboccipital and "lateral-enough" approaches were used to clip VA aneurysms in the Department of Neurosurgery at Helsinki University Central Hospital from 2000 to 2009. The preoperative and postoperative radiologic examination and analyses were mostly based on computed tomography (CT) and CT angiography. Digital subtraction angiography was used if there was uncertainty in initial diagnosis or in evaluation of the operative result. This study was approved by the research ethics committee of Helsinki University Central Hospital.

Patient Data

We reviewed 601 patients with posterior circulation aneurysms. In these patients, microsurgery was performed in 421 aneurysms, endovascular therapy in 66 aneurysms, and conservative management in 114 aneurysms. The lateral suboccipital approach was performed on 52 aneurysms in 51 patients.

Clinical Data

Preoperative clinical condition for ruptured aneurysms was assessed using the World Federation of Neurosurgical Societies (WFNS) score (good, 1–3; poor, 4–5). The outcome after surgery was assessed using the modified Rankin Scale (mRS) score at discharge and at final follow-up. Outcomes were classified as favorable (mRS score 0–3), unfavorable (mRS score 4–5), or death (mRS score 6).

Radiologic Measurement

Preoperative and postoperative radiologic data for the study were obtained from CT angiography and digital subtraction angiography. Radiologic images were analyzed both in 2 dimensions and in 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 1) aneurysm dome size, 2) neck size, and 3) postoperative angiographic occlusion. Aneurysm dome 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 degree of occlusion was categorized as complete occlusion (100%), near-complete/neck remnant (>90%), partial occlusion (80%–90%), incomplete occlusion (<80%), and treatment failure (unable to clip aneurysm).

Statistical Analysis

The continuous data are expressed as means with ranges in parentheses and tested with the Student *t* test and analysis of variance. Categorical variables are presented as percentages and are analyzed using a χ^2 test. A P value less than 0.05 was considered significant. Statistical analysis was performed using SPSS software for Macintosh (version 22.0 [IBM Corp., Armonk, New York, USA]).

Operative Technique and Methods

Patient Positioning. For the lateral suboccipital approach,[29] the patient is placed in the lateral park bench position with the head elevated 20 cm above the heart level. The upper body is rotated slightly (5°–10°) anteriorly and the upper shoulder is heavily retracted caudally and posteriorly. The head is positioned 1) flexed slightly; 2) tilted contralaterally; and 3) slightly rotated toward the floor, with the mastoid tip becoming the highest point. A lumbar drain is placed to release 50 mL of cerebrospinal fluid (CSF).

Skin Incision and Craniotomy. A vertical linear skin incision is placed 2 cm behind the mastoid process centered over the transverse sigmoid junction (Figure 1). A curved self-retaining

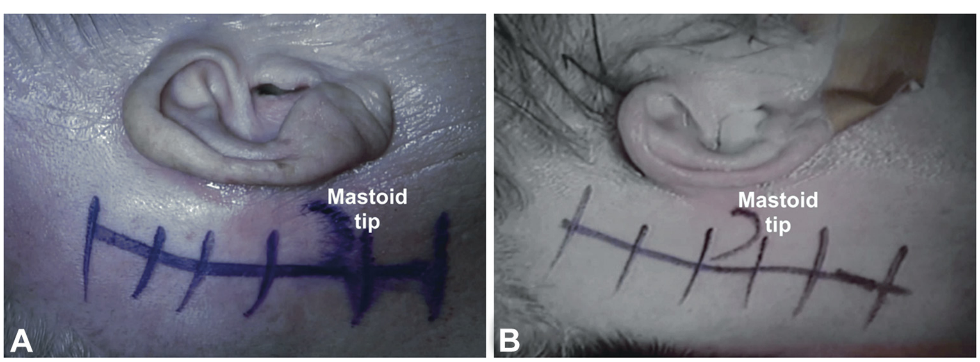

Figure 1. (**A**) Skin incision for simple lateral suboccipital approach for higher positioned vertebral/posterior inferior cerebellar artery aneurysm. (**B**) Skin incision for lateral-enough approach for lower positioned aneurysm.

retractor is placed from the cranial side of the incision. The subcutaneous fat and muscles are split along the linear incision with electrocautery to the occipital bone. Subperiosteal dissection is continued to expose the occipital bone.

One burr hole is placed at the posterior aspect of the exposed occipital bone. An osteotome with a footplate is used to create a 2-cm to 3-cm bone flap. The mastoid bone is drilled to expose the posterior border of the sigmoid sinus. If the VA aneurysm is located low (<10 mm above the foramen magnum), the craniotomy is extended medial and inferiorly to open the lateral foramen magnum (lateral-enough approach) (Figures 1 and 2).

Aneurysm Identification, Dissection, and Occlusion. After dural opening, the cisterna magna is opened to release more CSF. The cerebellomedullary space is subsequently entered anteriorly and dissection is continued into the lateral medullary space. The cranial part of the 11th cranial nerve and proximal intradural VA are encountered first. Following the course of the VA distally, the ninth and tenth cranial nerves as well as the anterior and lateral medullary segments of the posterior inferior cerebellar artery (PICA) are seen. A good viewing angle, sharp dissection, and fine movement under high magnification are mandatory to perform safe aneurysm dissection (Figure 3). If the jugular tubercle obstructs the surgical view, rotating the patient's head contralaterally and elevating the table to look under the jugular tubercle often solves this problem.

After proximal and distal sides of the parent artery are identified, a straight temporary clip is placed on the VA proximal to the aneurysm. A pilot clip is placed on the aneurysm parallel to the distal VA direction. The aneurysm dome is dissected to confirm a good clip position across the neck with preservation of the PICA. The temporary clip is removed and the aneurysm and vessels are evaluated with Doppler ultrasonography and indocyanine green video angiography. A papaverin-soaked Surgicel (Ethicon) ball is then applied to alleviate any surgically induced vasospasm. The surgical wound was closed under high magnification.[30]

RESULTS

From 2000 to 2009, the senior author (J.H.) performed the lateral suboccipital approach and modified lateral-enough approach to operate on 51 patients with 52 cases of VA and proximal PICA aneurysms.

General Characteristics of the Patients

The clinical characteristics in this series are shown in Table 1. Sixteen patients (31%) presented with an unruptured aneurysm, 21 patients (40%) were good grade, and 15 patients (29%) were poor grade. The female/male ratio was 2.6:1. The mean age was 58.7 years (range, 32–80 years). One patient had 2 aneurysms on opposite sides clipped at different times.

General Aneurysm Characteristics

Aneurysm Characteristics. The aneurysms were saccular in 48 cases (92%), dissecting in 3 cases (6%), and fusiform in 1 case (2%). The mean aneurysm dome size was 6.8 mm (range, 2–21 mm). The mean aneurysm neck size for saccular and dissecting aneurysms was 4 mm. The small and medium-sized groups comprised most of our cases, accounting for 28 (54%) and 13 (25%) cases, respectively.

Aneurysm Location. The most common aneurysm location was the VA-PICA junction (81%). The remaining aneurysm locations in

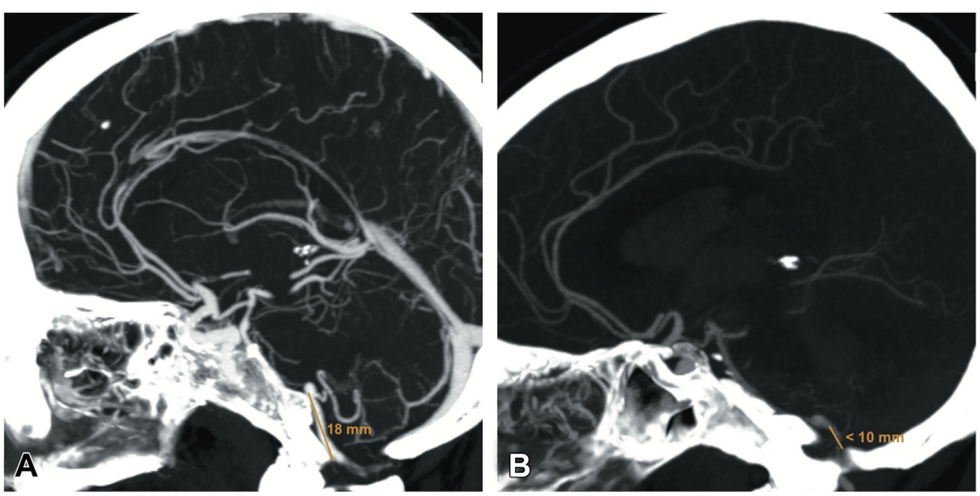

Figure 2. The location of vertebral–posterior inferior cerebellar artery aneurysms determines the surgical approach. (**A**) If the aneurysm is located more than 10 mm above the foramen magnum, a simple lateral suboccipital approach (tic craniotomy) is enough to access the aneurysm neck. (**B**) If the aneurysm is located less than 10 mm above the foramen magnum, a modification of the simple lateral suboccipital approach (lateral-enough approach) is recommended.

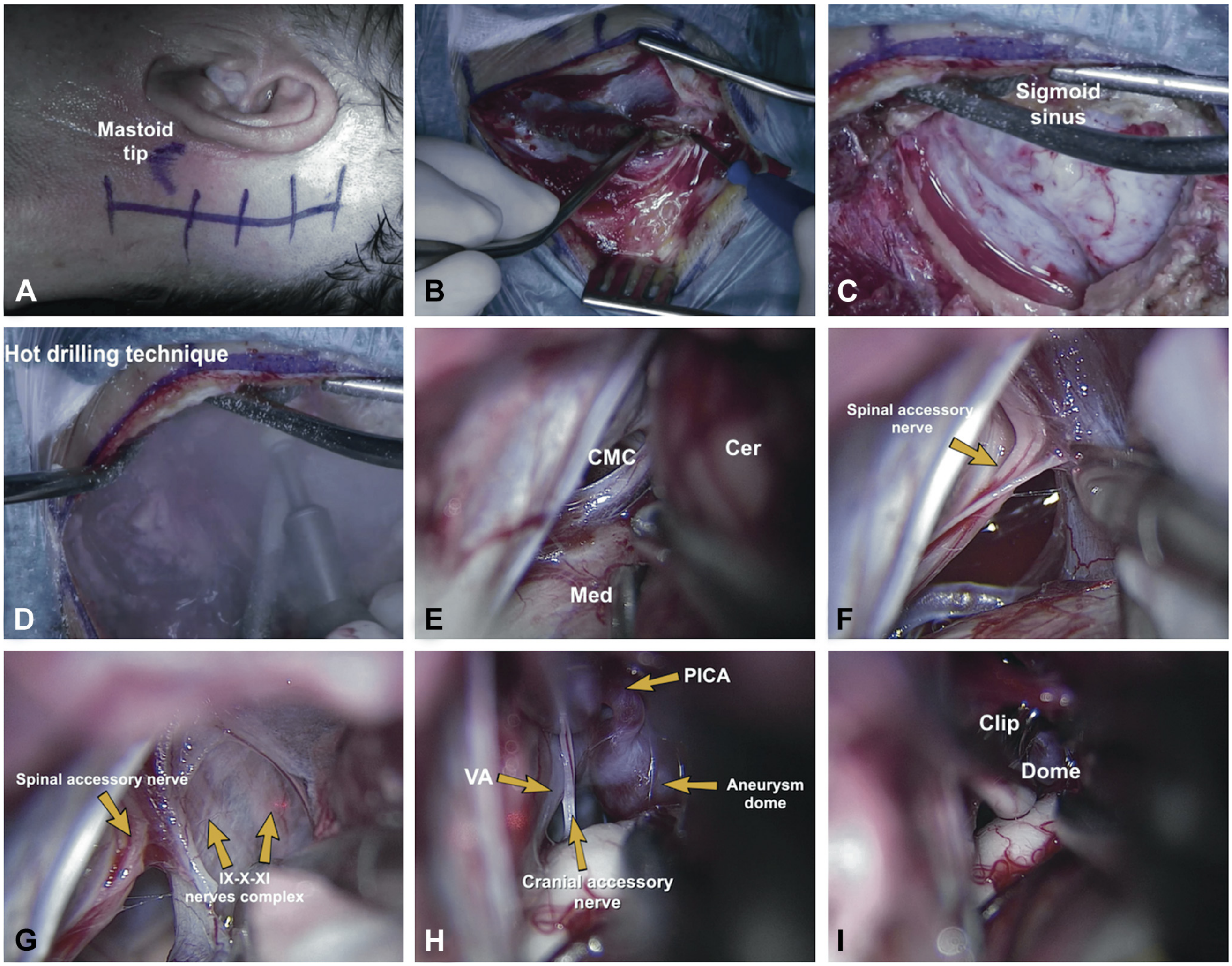

Figure 3. Steps of the simple lateral suboccipital approach to clip a vertebral—posterior inferior cerebellar artery (PICA) junction aneurysm. The senior author (J.H.) usually performs the whole procedure starting from skin incision under microscope. (**A**) Skin incision marking. (**B**) Soft tissue dissection, which is meticulously performed using monopolar cauterization under high magnification. (**C**) The exposure of a small craniotomy flap (usually a 2-cm to 3-cm bone flap is enough). (**D**) Hot drilling technique to control the bleeding from the bone and to increase the retrosigmoid exposure. (**E**) Opening the cerebellomedullary cistern (CMC) to release the cerebrospinal fluid and to gain access to proximal control. (**F**) Sharp dissection of the arachnoid bands around the neurovascular structures. (**G**) Identification of cranial nerves 9—11 complex; the aneurysm was located just medial and anterior to the complex. (**H**) Vertebral—posterior inferior cerebellar artery junction aneurysm was nicely exposed and accessed from a space between the spinal accessory nerve and cranial nerves 9—11 complex. (**I**) Definitive clip application to the aneurysm neck, preserving a good flow of vertebral and posterior inferior cerebellar artery. Cer, cerebellum, Med, medulla oblongata.

decreasing order of frequency were the vertebral trunk, proximal PICA, and vertebrobasilar junction (Table 1). Nineteen cases were right sided (37%) and 33 were left sided (63%).

Clinical Outcome

Patients' outcomes were evaluated with an average follow-up of 3.5 months (0—18 months). The mean discharge mRS score was 3.2 and the mean final mRS score was 2. A favorable clinical outcome in the final follow-up was found in 38 patients (73%). The rate of favorable outcome in the unruptured group was 100%. Preoperative clinical grade was significantly related to the final clinical outcome ($P = 0.002$). All 16 unruptured patients had a favorable outcome with mean final mRS score of 0.94. In ruptured cases, good grade and poor grade had favorable outcomes of 71% and 47%, respectively. Other factors associated with unfavorable clinical outcome were preoperative intraventricular hemorrhage (IVH) ($P = 0.008$), postoperative hydrocephalus ($P = 0.003$), brain infarction ($P = 0.005$), and postoperative pneumonia ($P < 0.001$) (Table 2).

IVH and Postoperative Hydrocephalus. Thirty-two patients presented with IVH. Ventriculostomy was performed in 13 patients (41%)

Table 1. Clinical Characteristic of 52 Patients in Our Series

Description	Unruptured (n = 16)	Good Grade (n = 21)	Poor Grade (n=15)
Age, years (n = 52), mean (range)	55.6 (34—77)	62.1 (42—80)	57.3 (32—77)
Gender (n = 52)			
Male	3 (19)	6 (29)	5 (33)
Female	13 (81)	15 (71)	10 (67)
Aneurysm morphology			
Saccular (n = 48)	15 (94)	20 (95)	13 (87)
Fusiform (n = 1)	1 (6)	0 (0)	0 (0)
Dissecting (n = 3)	0 (0)	1 (5)	2 (13)
Mean aneurysm size, mm (range)	7.3 (2—21)	6.1 (2 17)	7.2 (2—17)
Aneurysm location			
Vertebral artery—PICA	13 (81)	16 (76)	13 (87)
Proximal PICA	1 (6)	1 (5)	0 (0)
Vertebral trunk	2 (13)	3 (14)	2 (13)
Vertebrobasilar junction	0 (0)	1 (5)	0 (0)
Operative time (skin-to-skin) (minutes)	89.9 (30—169)	96.3 (40—189)	99.7 (50—179)
Hospital length of stay (days)	12 (4—62)	17 (5—46)	21 (2—59)
Immediate occlusion grade (n = 44)			
Complete	11 (92)	17 (89)	12 (92)
Neck remnant (near complete)	1 (8)	2 (11)	0 (0)
Incomplete	0 (0)	0 (0)	1 (8)
Final occlusion grade (mean follow-up, 3.5 months) (n = 44)			
Complete	11 (92)	17 (89)	12 (92)
Neck remnant (near complete)	1 (8)	2 (11)	0 (0)
Incomplete	0 (0)	0 (0)	1 (8)

Values are number (%) except where indicated otherwise.
PICA, posterior inferior cerebellar artery.

with IVH and 6 patients with ventriculostomy needed shunting. Postoperative hydrocephalus was found in 15 of 36 ruptured patients (42%) and all had preoperative IVH. Preoperative IVH showed was strongly associated with unfavorable outcomes (41% vs. 5%; P = 0.008; Table 2).

Perioperative Complications

Postoperative Pneumonia. Postoperative pneumonia occurred in 23 patients (44%) and 48% of patients with pneumonia had an unfavorable outcome at discharge mRS score (P < 0.001) (Table 3). Poor preoperative clinical grade (P = 0.009), IVH (P = 0.026), and postoperative hydrocephalus (P = 0.004) were related to the incidence of postoperative pneumonia (Table 4). In subgroup analysis of good-grade patients, postoperative pneumonia was associated with unfavorable outcomes (P = 0.029). Lower cranial nerve palsy (LCNP) was not found as a significant factor in the development of pneumonia (P = 0.465).

Vasospasm, Brain Infarction, and Parent Artery Occlusion Times. Symptomatic vasospasm was found in 5 patients (10%). All cases were treated with medical management (i.e., no endovascular treatment) and 4 patients recovered with favorable outcome. Brain infarction occurred in 10 patients (19%). Six patients (60%) with infarction had an unfavorable outcome. No decompressive craniectomy as a result of cerebellar infarction was necessary. The only factor associated with brain infarction was a longer duration of parent artery occlusion (mean occlusion times of 17.6 minutes vs. 5.5 minutes; P = 0.006). Overall, parent artery occlusion times did not predict clinical outcome (favorable outcomes 5.9 minutes vs. unfavorable outcomes 11.6 minutes; P = 0.137). However, poor-grade patients with favorable outcomes had a lower mean occlusion time (2.5 minutes) compared with poor-grade patients with unfavorable outcomes (13.5 minutes; P = 0.011).

Postoperative LCNP. A total of 20 patients (39%) had LCNP postoperatively. Of these 20 patients, 5 had LCNP preoperatively and 15

Table 2. Factors Related to Patient's Outcome

Description	Favorable	Unfavorable	Dead	*P* Value
Age, years (n = 52), mean (range)	56.6 (32–79)	64.8 (49–80)	62 (47–77)	0.112*
Gender				
Male	7 (50)	6 (43)	1 (7)	0.075†
Female	31 (82)	6 (16)	1 (2)	
Preoperative World Federation of Neurosurgical Societies grade (n = 52)				
Unruptured (n = 16)	16 (100)	0 (0)	0 (0)	0.002†
Good grade (1–3) (n = 21)	15 (71)	6 (29)	0 (0)	
Poor grade (4–5) (n = 15)	7 (47)	6 (40)	2 (13)	
Preoperative intraventricular hemorrhage (n=52)				
Yes	19 (59)	11 (34)	2 (6)	0.008†
No	19 (95)	1 (5)	0 (0)	
Postoperative HCP (n = 52)				
Yes	7 (44)	7 (44)	2 (22)	0.003†
No	31 (86)	5 (14)	0 (0)	
Postoperative lower cranial nerve palsy (n = 52)				
No	23 (72)	7 (22)	2 (6)	0.245†
Transient	10 (91)	1 (9)	0 (0)	
Permanent	5 (56)	4 (44)	0 (0)	
Postoperative pneumonia (n = 52)				
Yes	12 (52)	11 (48)	0 (0)	<0.001†
No	26 (90)	1 (3)	2 (7)	
Brain infarction				
Yes	4 (40)	4 (40)	2 (20)	0.005†
No	34 (83)	7 (17)	0	
Aneurysm related				
Mean aneurysm size, mm (range)	6.2 (2–21)	7.8 (3–17)	12 (7–17)	0.137*

Values are number (%) except where indicated otherwise.
HCP, hydrocephalus.
*Analysis of variance.
†χ^2.

(29%) developed LCNP postoperatively. Of the 15 patients with newly developed postoperative LCNP, 9 had complete resolution of symptoms (mean follow-up, 3.5 months). Six patients (11.5%) had permanent LCNP, 4 of whom had mild symptoms and 2 of whom had severe symptoms of dysphagia and needed tracheostomy. The only factor that determined LCNP was aneurysm dome size (Table 5). Permanent LCNP, transient LCNP, and no LCNP were found in mean aneurysm dome sizes of 10.6 mm, 6.7 mm, and 5.8 mm, respectively (P = 0.021) (Table 5).

Surgical Time, Intraoperative Aneurysm Rupture, and Other Complications. Mean surgical time was 95 minutes (range, 30–189 minutes). Intraoperative aneurysm rupture (IAR) occurred in 14 patients (27%) and mostly occurred in ruptured cases (93%). In the 14 patients experiencing IAR, 5 (36%) had an unfavorable outcome. Unfavorable outcomes in IAR cases (36%) was not statically higher than in cases without IAR (18%, P = 0.297). No postoperative CSF leak or wound infection was reported in our series. More information on perioperative complications is available in Table 3.

Endovascular to Microsurgery Switching

In this series, we found 4 patients (8%) who initially underwent attempted endovascular embolization before requiring microsurgery. The causes of endovascular treatment failure were access failure in 1 patient, incomplete occlusion (<80%) in 1 patient, and intraprocedural aneurysm rupture in 2 patients. After

Table 3. Perioperative Complications

Description	Unruptured, n (%)	Good Grade, n (%)	Poor Grade, n (%)
Intraprocedural aneurysm rupture (n = 14)	1 (7)	9 (64)	4 (29)
Brain infarction (n = 10)	2 (20)	3 (30)	5 (50)
Postoperative lower cranial nerve palsy (n = 15)			
Temporary	3 (33)	2 (22)	4 (44)
Permanent	2 (33)	2 (33)	2 (33)
Vasospasm	0 (0)	2 (40)	3 (60)
Wound infection	0 (0)	0 (0)	0 (0)
Cerebrospinal fluid leakage	0 (0)	0 (0)	0 (0)
Postoperative pneumonia (n = 23)	3 (13)	9 (39)	11 (48)

Table 4. Causes and Impacts of Postoperative Pneumonia

Variables	Pneumonia	No Pneumonia	*P* Value
Age, years (n = 52), mean (range)	59.7 (32—80)	57.9 (34—79)	0.591*
Gender (n = 52)			
Female	14 (61)	24 (83)	0.073†
Male	9 (39)	5 (17)	
Preoperative World Federation of Neurosurgical Societies grade (n = 52)	9 (39)	5 (17)	
Unruptured	3 (13)	13 (45)	0.009†
Good grade	9 (39)	12 (41)	
Poor grade	11 (48)	4 (14)	
Preoperative intraventricular hemorrhage (n = 52)			
Yes	18 (78)	14 (48)	0.026†
No	5 (22)	15 (52)	
Postoperative lower cranial nerve palsy (n = 52)			
No	12 (52)	20 (69)	0.465†
Transient	6 (26)	5 (17)	
Permanent	5 (22)	4 (14)	
Postoperative HCP (n = 52)			
Yes	12 (75)	11 (31)	0.004†
No	4 (25)	25 (69)	
Discharge modified Rankin Scale score (n = 52)			
Favorable outcome	12 (52)	26 (90)	<0.001†
Unfavorable outcome	11 (48)	1 (3)	
Death	0 (0)	2 (7)	
Hospital length of stay (days) (n = 52), mean (range)	23.7 (5—62)	11.3 (2—28)	<0.001*

Values are number (%) except where indicated otherwise.
HCP, hydrocephalus.
*Student *t* test.
†χ^2.

Table 5. Lower Cranial Nerves Palsy Incidence in Our Series

Variables	No Lower Cranial Nerve Palsy	Transient	Permanent	*P* Value
Age (years), mean (range)	57.5 (32—79)	56.2 (34—76)	66.1 (49—80)	0.125*
Sex				
Male	8 (25)	3 (27)	3 (33)	0.886†
Female	24 (75)	8 (73)	6 (67)	
World Federation of Neurosurgical Societies score				
Unruptured	11 (34)	3 (27)	2 (22)	0.921†
Good grade	13 (41)	4 (36)	4 (44)	
Poor grade	8 (25)	4 (36)	4 (33)	
Aneurysm size, mm, mean (range)	5.8 (2—17)	6.7 (2—21)	10.6 (5—20)	0.021*
Temporary occlusion, minutes, mean (range)	8.4 (0—64)	4.5 (0—11)	8.9 (0—46)	0.638*

Values are number (%) except where indicated otherwise.
*Analysis of variance.
†χ^2.

microsurgical clipping, 3 patients had complete occlusion and 1 patient had near-complete aneurysm occlusion. Clinical outcome was favorable in 3 patients and unfavorable in 1 patient. No clipped patients were referred to the endovascular service for further treatment.

Hospital Length of Stay

The mean length of stay (LOS) in unruptured, good-grade, and poor-grade cases was 12 days (range, 4—62 days), 17 days (range, 5—46 days), and 21 days (range, 2—59 days), respectively ($P = 0.141$). Two factors related to prolonged hospitalization were preoperative IVH and postoperative pneumonia. Patients with and without preoperative IVH had a mean LOS of 19 and 12 days, respectively ($P = 0.046$). The LOS in patients with and without postoperative pneumonia were 24 and 11 days, respectively ($P < 0.001$).

Aneurysm Radiographic Outcome

In 44 cases with postoperative imaging, a complete occlusion and near-complete/small neck remnant was achieved in 40 aneurysms (91%) and 3 aneurysms (7%), respectively. In the final angiography follow-up, all but 1 patient had a stable occlusion grade. Regarding aneurysm size, the very small, small, and medium-sized aneurysms had complete occlusion or a near-complete/small neck remnant rate of 100%, 96%, and 100%, respectively. In large aneurysms, the complete occlusion or near-complete/small neck remnant occlusion rate was 80%. Only 1 patient in our series had an incomplete occlusion (<80%) after microsurgical clipping.

DISCUSSION

Microsurgical clipping for VA and PICA aneurysms has technical challenges because of their deep location and their proximity to vital neurovascular structures. The far-lateral approach and its modifications provide wider working spaces and are most commonly used. However, the potential for morbidity related to the progressive drilling of the bony structures, such as occipitocervical instability, CSF leak, and VA injury, is higher with these approaches, which negatively influences the postoperative outcome.[21,31-36]

Several series of microsurgical treatment for VA and PICA aneurysms have been reported. Favorable outcomes in these series range between 65% and 91%.[18,37-42] A recent institutional experience reported the use of a similar simplified lateral suboccipital approach to VA and PICA aneurysms in 26 patients with good outcome (mRS score 0—3) in 22 patients (85%).[18] Another recent report of a modified far-lateral approach without condyle resection in 56 patients with VA and PICA aneurysms reported that this less-invasive approach also offers excellent surgical exposure, with complete occlusion rate achieved in all patients and good clinical outcome (Glasgow Outcome Scale score 4—5) achieved in 52 patients (93%).[43] Our series comprises 52 consecutive cases with a comparable favorable outcome of 100% in unruptured and 71% in good-grade patients.

Lateral Enough Is Enough

In the present series, we showed the classic lateral suboccipital approach with or without foramen magnum bone drilling. Lehto[44] reported that a simple lateral suboccipital or tic craniotomy can be used if the location of the aneurysm is at least 10 mm above the foramen magnum. However, for low-lying aneurysms (<10 mm above the foramen magnum), a more inferolateral approach is considered. We extend our craniotomy inferiorly to open the foramen magnum lip and term this a lateral-enough approach. Drilling some part of the upper rim of C1 or part of the occipital condyle is possibly needed if the aneurysm location is more toward the midline, but this is rare. We coagulate the venous plexus, but we never mobilize the VA, because it is not necessary.

The main obstacle in microsurgery of VA or proximal PICA aneurysms is not the bony structures of the skull base but the neurovascular structures that obscure the aneurysm neck. Therefore, careful study of three-dimensional preoperative imaging is important and the keys to increase the surgical exposure should be directed toward neuroanesthesiology techniques to maintain a slack brain and using high microscopic magnification during surgery.[45] In our experience, the bony structure that commonly obstructed the surgical visualization is the jugular tubercle. The trick used by our senior author (J.H.) to overcome this situation and minimize the risk of neurovascular injury is to drill partially the jugular tubercle and to raise the table high so that the surgeon visualizes the surgical field under the bony roof.

IAR, Temporary Clipping Strategy, and Brain Infarction

Generally, IAR has been shown to increase the risk of unfavorable outcome in well-powered microsurgical series.[46-50] Our series found that cases of IAR had a statistically insignificant increased likelihood of unfavorable outcome. It is possible that our series was underpowered to show worse outcomes in IAR cases.

Temporary clip placement in aneurysm surgery is a fundamental strategy to reduce or even prevent the risk of devastating IAR and facilitates clip placement. The maximum time limit for placing the temporary clip is still controversial, but several studies reported that occlusion times of 14—20 minutes are safe.[51-54] Schick et al. found that a mean temporary occlusion time of more than 8 minutes increased the risk of neurologic deficit to 80.9%, whereas occlusion time below 8 minutes led to neurologic deficits in only 30.7% of cases.[55] For posterior circulation aneurysms, occlusion times of 14—15 minutes are considered a safe cutoff point.[54,56] If the occlusion time is suspected to be more than 15 minutes, Eftekhar and Morgan[56] suggest using thiopentone to create temporary burst suppression before temporary clip application.

From our series, we suggest a cutoff point to safely occlude the parent artery of 6 minutes. We compared cases with temporary occlusion time of 6 minutes or less and those with more than 6 minutes and found a significant difference in the incidence of brain infarction ($P = 0.003$) and in final clinical outcome ($P = 0.043$). Our findings also suggest that in patients with WFNS grade 4—5, temporary occlusion of the parent artery should be performed even more cautiously. Applying a distal temporary clip may be difficult because it is often obstructed by the aneurysm. In the case of no access to distal temporary clipping, we usually used combined proximal temporary clipping and adenosine injection during aneurysm dissection and/or aneurysm clipping.

LCNP. LCNP has long been known as a frequent complication of microsurgical treatment for VA and PICA aneurysms. The incidence of LCNP ranges from 20% to 60%. Al-khayat et al.[57] reported that temporary parent artery occlusion was the most significant cause of postoperative LCNP. In the present series, we did not find a strong relationship of LCNP with the duration parent artery occlusion. We only found a correlation of aneurysm size to the incidence of LCNP. This finding offers evidence that manipulation of cranial nerves during surgery is the main factor contributing to postoperative LCNP.

Endovascular and Microsurgery Perspective

Endovascular therapy is also used to treat VA and PICA aneurysms, with varying results. The favorable clinical outcome of some larger series of endovascular procedures treating VA and PICA aneurysms was reported between 49% and 83%.[58-65] The complete aneurysm occlusion in endovascular treatment was reported between 65% and 83%.[60,63,65-67] The endovascular retreatment rate for VA and PICA aneurysms was reported around 20%—30%.[58,68] A recent comparative study between clipping and coiling in 102 patients with VA and PICA aneurysm[69] did not show any significant difference in the patients' clinical outcomes. Our results compare favorably with these endovascular results. The role of microneurosurgery in VA and proximal PICA aneurysm cases is still essential because many patients worldwide do not have access to endovascular treatment.

Limitations

The aim of our study was to describe our experience in using a simple lateral suboccipital approach to treat VA and proximal PICA aneurysm. Given that VA and proximal PICA aneurysms occur uncommonly, even at high-volume centers, we included cases of both ruptured and unruptured aneurysms to power the statistical analysis. Because of the many pathologic mechanisms of subarachnoid hemorrhage, there are worse outcomes in ruptured versus unruptured cases unrelated to the surgical approach. The limitations of a retrospective design are also present in this series.

CONCLUSIONS

We have described a 10-year experience using a simple lateral suboccipital approach by the senior author (J.H.) to treat VA and proximal PICA aneurysms. Aneurysms located 10 mm above the foramen magnum can be safely reached with a simple lateral suboccipital approach, whereas aneurysms located below this point can be accessed with a lateral suboccipital approach and opening of the foramen magnum (lateral-enough approach). The overall clinical and radiologic results in our series are comparable to other surgical and endovascular series. In the present series, unfavorable outcome was related to poor preoperative WFNS grade, preoperative IVH, and postoperative pneumonia.

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Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 12 July 2017; accepted 2 September 2017

Citation: World Neurosurg. (2017) 108:336-346.
https://doi.org/10.1016/j.wneu.2017.09.014

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