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Microsurgical Clipping of Ruptured Posterior Fossa Aneurysms in the Semi-Sitting Position

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■ OBJECTIVE: **Posterior fossa aneurysms, especially ruptured ones, are challenging to treat due to their deep location, complex anatomy, and proximity to the brainstem, and lower cranial nerves. The semi-sitting position, though historically controversial due to concerns over venous air embolism, may offer distinct advantages. The aim of this study was to evaluate the safety and efficacy of the semi-sitting position for the clipping of ruptured posterior fossa aneurysms.**

■ METHODS: **We retrospectively reviewed 39 consecutive patients with ruptured posterior circulation aneurysms treated with microsurgical clipping in the semi-sitting position between 1990 and 2023. Data included clinical presentation, surgical technique, intraoperative and postoperative complications, and functional outcomes measured by the Glasgow Outcome Scale at discharge and at 6 months.**

■ RESULTS: **Complete aneurysm occlusion was achieved in 92% (36/39). The most common aneurysm location was the posterior inferior cerebellar artery (79%). Intraoperative rupture occurred in 8% (3/39), and new neurological deficits attributable to surgery were seen in 13% (5/39). Venous air embolism was detected in 20% (3/15) of patients monitored with transesophageal echocardiography, though no cases required abortion of the procedure or resulted in serious complications. Surgical mortality was 0%, and 84% (21/25) of surviving patients achieved a Glasgow Outcome Scale >3 at 6 months.**

■ CONCLUSION: **Microsurgical clipping of ruptured posterior fossa aneurysms in the semi-sitting position is safe and effective when performed with appropriate monitoring. Close collaboration with the anesthesiology team is essential to ensure patient safety. Our findings reinforce the continued relevance of the semi-sitting position in posterior fossa aneurysm surgery.**

INTRODUCTION

Despite accounting for at most 15% of all intracranial aneurysms,[1] posterior circulation aneurysms have a higher risk of rupture and are associated with a worse clinical prognosis compared to their anterior counterparts.[2,3] Posterior circulation aneurysms present a unique therapeutic challenge for both endovascular treatment (EVT) and microsurgery, which is also evident in treatment outcomes.[2]

Patient positioning plays a crucial role in aneurysm surgery. While anterior circulation aneurysms are generally treated with the patient in the supine position, multiple positioning strategies have been described for the microsurgical clipping of posterior-circulation aneurysms, including the supine, park-bench, prone, and semi-sitting position.[4-9] For the semi-sitting position, the

Key words
- Aneurysm
- Microsurgical clip ping
- Posterior circulation aneurysm
- Semi-sitting position
- Subarachnoid hemorrhage

Abbreviations
AICA: Anterior inferior cerebellar artery
CVC: Central venous catheter
CSF: Cerebrospinal fluid
CT: Computed tomography
CTA: Computed tomography angiography
EVT: Endovascular treatment
GOS: Glasgow Outcome Scale
PICA: Posterior inferior cerebellar artery
TEE: Transesophageal echocardiography
VAE: Venous air embolism

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patient's upper body and lower extremities are gradually elevated, with the legs positioned above the level of the heart.[10] The degree of back-section elevation and head positioning is determined by the specific surgical approach.[11]

While some authors reported the use of the semi-sitting position for selected posterior inferior cerebellar artery (PICA) aneurysms or for obese patients with a short and thick neck, robust data from larger cohorts of ruptured infratentorial aneurysms remain notably absent.[6] However, to our understanding, the semi-sitting position offers several significant advantages. The position enhances venous outflow and improves patient ventilation, both contributing to brain relaxation and thus expansion of the operative corridor. Moreover, increased venous outflow reduces intraoperative venous bleeding, while the gravitational effect of the posture facilitates the drainage of cerebrospinal fluid (CSF) and blood away from the operative site. Together, these factors lead to a clearer surgical field, which improves visualization, reduces the need for retractor traction and constant suction, and enables a more controlled, two-handed microsurgical dissection.[12]

Although the semi-sitting position offers several advantages, it has remained a subject of considerable debate within the neurosurgical community. Frequently cited concerns include the necessity of a preoperative transesophageal echocardiogram (TEE), as well as the increased risk of venous air embolism (VAE).[12,13] Other potential complications include intraoperative hypotension, cardiac arrhythmias, and a higher incidence of postoperative pneumocephalus.[14]

Given our belief that the semi-sitting position offers distinct advantages in treating ruptured posterior fossa aneurysms, we present a surgical series reflecting 3 decades of experience with this technique.

PATIENTS AND METHODS

We present a consecutive series of patients diagnosed with a ruptured aneurysm of the posterior cerebral circulation, more precisely PICA, anterior inferior cerebellar artery (AICA), and intradural vertebral artery aneurysms. Aneurysms of the basilar tip and superior cerebellar artery, along with cases potentially requiring a bypass procedure, were excluded. All aneurysms were treated with microsurgical clipping in the semi-sitting position by the senior author between 1990 and 2023 (University Hospital Aachen from 1990 to 2004, and University Hospital Göttingen from 2005 onward). Clinical data were extracted from medical records, surgical reports, and imaging studies. Informed consent was obtained from all eligible patients or their legal representatives if the patient was unable to provide consent. The study complied with the Declaration of Helsinki and was reviewed by our institutional ethics committee (study ID: 2/7/25).

Diagnosis and Perioperative Management

Ruptured intracranial aneurysms were detected using computed tomography (CT)/CT-angiography (CTA) and/or digital subtraction angiography. Aneurysm clipping was conducted within 48 hours after ictus after interdisciplinary consensus. Whenever possible, stent-assisted coiling, stenting, or flow diversion was avoided in ruptured aneurysms due to the requirement for postprocedural antiplatelet therapy. Clipping was usually favored for broad-necked aneurysms and those located at the distal PICA or AICA, where EVT would have been limited to parent artery occlusion and as a salvage therapy if coiling was unsuccessful.

Prior to 2010, precordial Doppler echocardiography was routinely employed for the detection of VAE during the surgery. However, given the superior sensitivity of TEE in identifying VAE our protocol has evolved over time and TEE has been integrated as a standard monitoring tool.[15] Once the patient is sedated and intubated, the TEE probe is inserted and a Valsalva maneuver and bubble study are performed to exclude the presence of a right-to-left cardiac shunt. Beyond its sensitivity for air embolism detection, TEE facilitates precise placement of the tip of the central venous catheter, provides real-time evaluation of volume status, and enables early recognition and assessment of therapeutic interventions in the event of hemodynamically significant VAE.[16] Besides the TEE, all other standard intraoperative monitoring, including end-tidal carbon dioxide, is employed at this point.

If preoperative TEE showed a persistent foramen ovale with a spontaneous right-to-left shunt or a ventricular septal defect patients were not positioned semi-sitting. Other contraindications were severely impaired cardiac function defined as an ejection fraction below 20% and any condition that precluded safe transesophageal access, including recent surgical procedures or anatomical obstruction.

Patient Positioning and Surgical Strategy

To achieve the semi-sitting position, the patient's upper body and lower extremities are progressively elevated until the legs are situated above heart level. The hips are flexed to a maximum of 90 °, and the back section of the operating table is elevated 45 ° (**Figure 1**). It is crucial to preserve enough space approximately a two-finger distance between the chin and the sternal notch. This maneuver minimizes the risk of venous outflow obstruction and allows for effective jugular vein compression, thereby supporting the surgeon in identifying the point of air entry. However, this has been described in greater detail elsewhere.[12,17,18]

For PICA/vertebral artery aneurysms we use a tailored far lateral transcondylar approach. The head is fixed in a Mayfield Clamp, anteflexed, and kept in a neutral position to maintain the normal anatomical course of the vertebral artery. The approach begins with a linear skin incision approximately 2 fingerbreadths posterior to the mastoid process, extending from the superior nuchal line down to the level of C2. The muscles are detached from their occipital insertions and the lateral occipital condyle, the lateral arch of C1, and the extradural vertebral artery are exposed. A portion of the dorsal superior third of the condyle is drilled away, followed by a suboccipital, osteoclastic craniotomy, with removal of the lateral rim of the foramen magnum. C1 laminectomy or hemilaminectomy is routinely not performed. For laterally located PICA aneurysms, the jugular tubercle is kept intact; for ventrally located aneurysms, partial resection is required (**Figure 2**). Distal PICA aneurysms are approached via a midline suboccipital craniotomy (**Figure 3**). For AICA aneurysms, a standard retrosigmoid approach is utilized. The head is fixed in anteposition, 30–40 ° rotated to the ipsilateral side of the lesion and inclined with slight tilt towards the sternum. A

Figure 1. The semi-sitting position. The legs are elevated above the level of the heart and the back section of the operating table inclined 45° to bring the patient into a semi-sitting position.

C-shaped retro-mastoid skin incision is performed, followed by a standard right retrosigmoid osteoclastic craniectomy, exposing the transverse and sigmoid sinus.

Postoperative Management and Outcome

Due to aneurysm rupture, all patients were admitted to the intensive care unit for at least 14 days. Patients with consecutive hydrocephalus underwent CSF diversion with an external ventricular drain or lumbar drain. Nimodipine was administered continuously intravenously for cerebral vasospasm prophylaxis, and the blood flow velocity of the middle cerebral artery was measured daily using transcranial Doppler sonography. From 2012 onward, sedated patients diagnosed with transcranial Doppler sonography-vasospasm underwent additional CTA and CT-perfusion imaging to rule out large-vessel vasospasm and associated perfusion deficits. New cerebral infarctions identified on CT more than 24 hours after treatment were defined as delayed cerebral infarctions.

Primary outcome was defined as complete aneurysm occlusion, evaluated by CTA 4 h after the surgery. However, additional postoperative digital subtraction angiography was performed in some patients when an aneurysm remnant was suspected intraoperatively or when large-vessel vasospasm with associated perfusion deficits occurred. In addition, we assessed intraoperative complications, including air embolism requiring abortion of the surgery and intraoperative aneurysm rupture. Postoperative complications such as rebleeding, pneumocephalus, and others were also documented. Functional outcomes were evaluated with the Glasgow Outcome Scale (GOS) at the time of discharge and 6-months after surgery.

Statistics

Statistical analyses were performed using IBM SPSS Statistics (version 29.0; IBM Corp., Armonk, NY, USA). Categorical variables were presented as frequencies and percentages, and continuous variables as mean ± standard deviation. Comparisons between groups were performed using the chi-square or the Mann–Whitney U test, as appropriate. Within-group comparisons were conducted using the Wilcoxon signed-rank test. A P value < 0.05 was considered statistically significant.

RESULTS

A total of 39 patients who underwent microsurgical clipping of ruptured posterior fossa aneurysms in the semi-sitting position were included. Patient demographics and clinical characteristics are detailed in **Table 1**. Mean patient age was 51 (14) years, with a marked female predominance (77%). The average Glasgow Coma Scale score at presentation was 10 (5) points, and in 41% (16/39) of the cohort, the Hunt&Hess grade exceeded 3. Intraventricular hemorrhage "i.e. Fisher grade 4" was observed in three-quarters (29/39) of cases. Anisocoria was documented in one patient at the time of diagnosis. CSF diversion via external ventricular drain or lumbar drain placement was required in 67% (26/39) and 21% (8/39) of patients, respectively. The most frequent aneurysm location was the PICA, representing 79% (31/39) of cases, followed by the AICA at 13% (5/39), and the vertebral artery at 8% (3/39).

Aneurysm clipping was feasible in all cases. Temporary clipping was required in 7 patients (18%) during the procedure. Intraoperative rupture occurred in 3 cases, all of them were PICA aneurysms, but was managed effectively with proximal clipping of the vertebral artery. For patients treated prior to 2010, precordial Doppler echocardiography was used, and unfortunately this data were not available for analysis. However, no hemodynamically significant VAEs requiring termination of the procedure were observed until 2010. After the implementation of the revised protocol including the routine use of TEE, applied in 38% of cases (15/39), VAE was detected intraoperatively in 20% (3/15) of patients. All cases exhibited a transient drop in end-tidal carbon dioxide but without clinical consequences that would necessitate the abortion of the surgery.

Postoperative imaging confirmed complete aneurysm occlusion in 92% (36/39) of patients. Incomplete occlusion was observed in 3 cases, all of them were PICA aneurysms. Two of these aneurysms showed only a small residual neck, while one patient demonstrated complete refilling of the aneurysm on postoperative angiography, necessitating reoperation. Following surgical treatment, all patients were transferred to the intensive care unit for postoperative management. New neurological deficits attributable to surgery occurred in 5 patients, resulting in a procedure-related morbidity rate of 13% (5/39). No cases required intervention for postoperative pneumocephalus. Cerebral infarction attributable to surgery was observed in 3 patients, and 4 additional patients experienced delayed cerebral infarction. Permanent CSF diversion via ventriculoperitoneal shunt placement was required in 18% (7/39) patients.

Four patients died as consequence of the bleeding, though none of the deaths were attributable to the surgical procedure, leading to a surgical mortality rate of 0%. At the time of discharge, 51% (20/39) of patients achieved a GOS score greater than 3. Neurological function improved significantly over time. Excluding the patients who died, 84% (21/25) achieved a GOS score greater than 3 at the 6-month follow-up ($P = 0.005$).

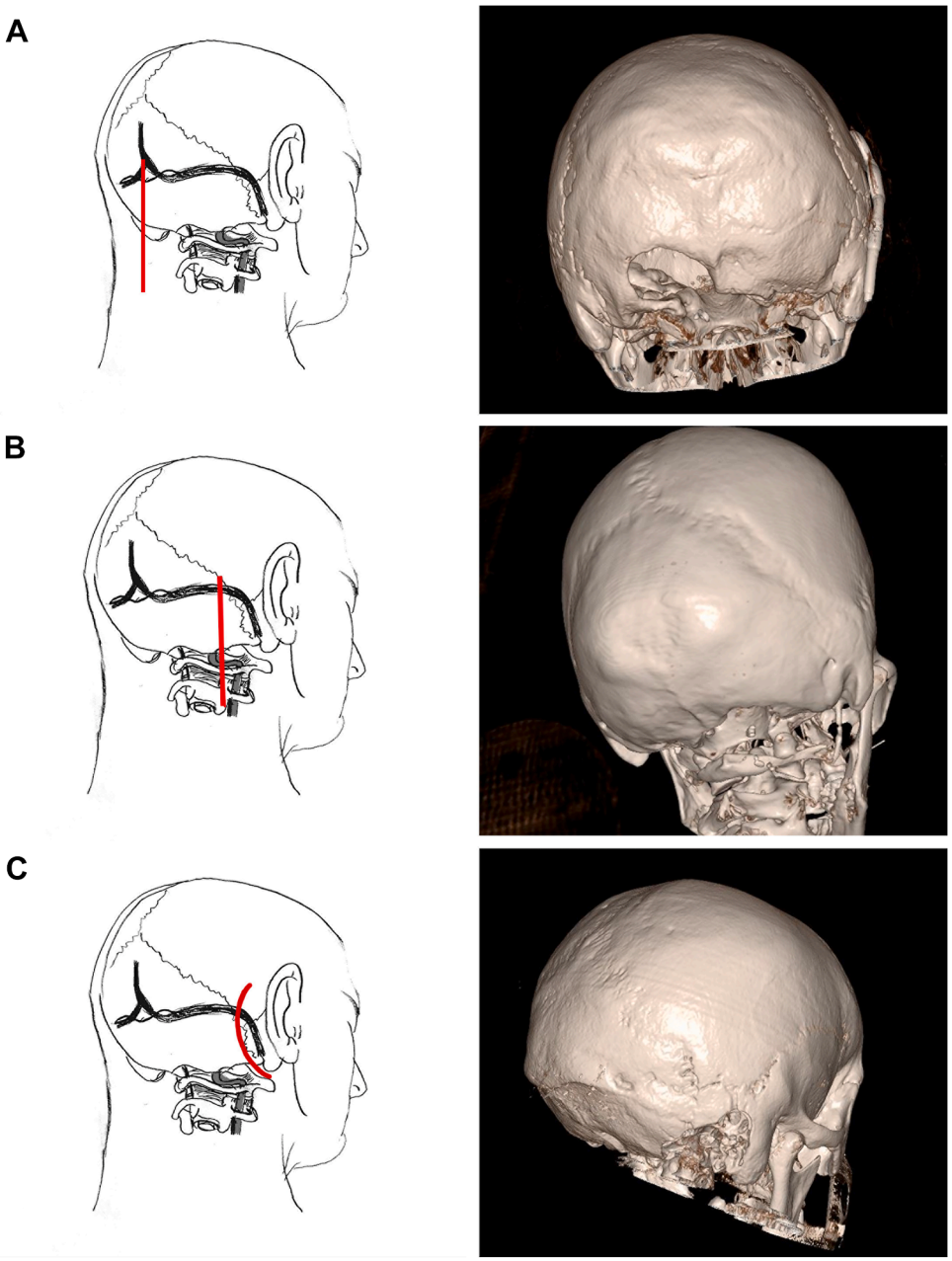

Figure 2. Surgical approaches based on aneurysm location. (**A**) Midline approach for distal PICA aneurysms. (**B**) Tailored far-lateral approach for posterior inferior cerebellar artery (PICA) and vertebral artery aneurysms. (**C**) Retrosigmoid approach for anterior inferior cerebellar artery (AICA) aneurysms. The head is maintained in a neutral position, except for the retrosigmoid approach.

DISCUSSION

This study presents three-decades of experience with the microsurgical clipping of ruptured posterior fossa aneurysms performed in the semi-sitting position. Our findings demonstrate that, when applied in selected patients and with adherence to perioperative protocols, the semi-sitting position proves to be a safe and an effective approach for managing these technically demanding aneurysms.

Posterior fossa aneurysms pose a distinct challenge for both endovascular and microsurgical treatment. Microsurgical management is particularly difficult due to the close proximity of these aneurysms to the brainstem and lower cranial nerves, the

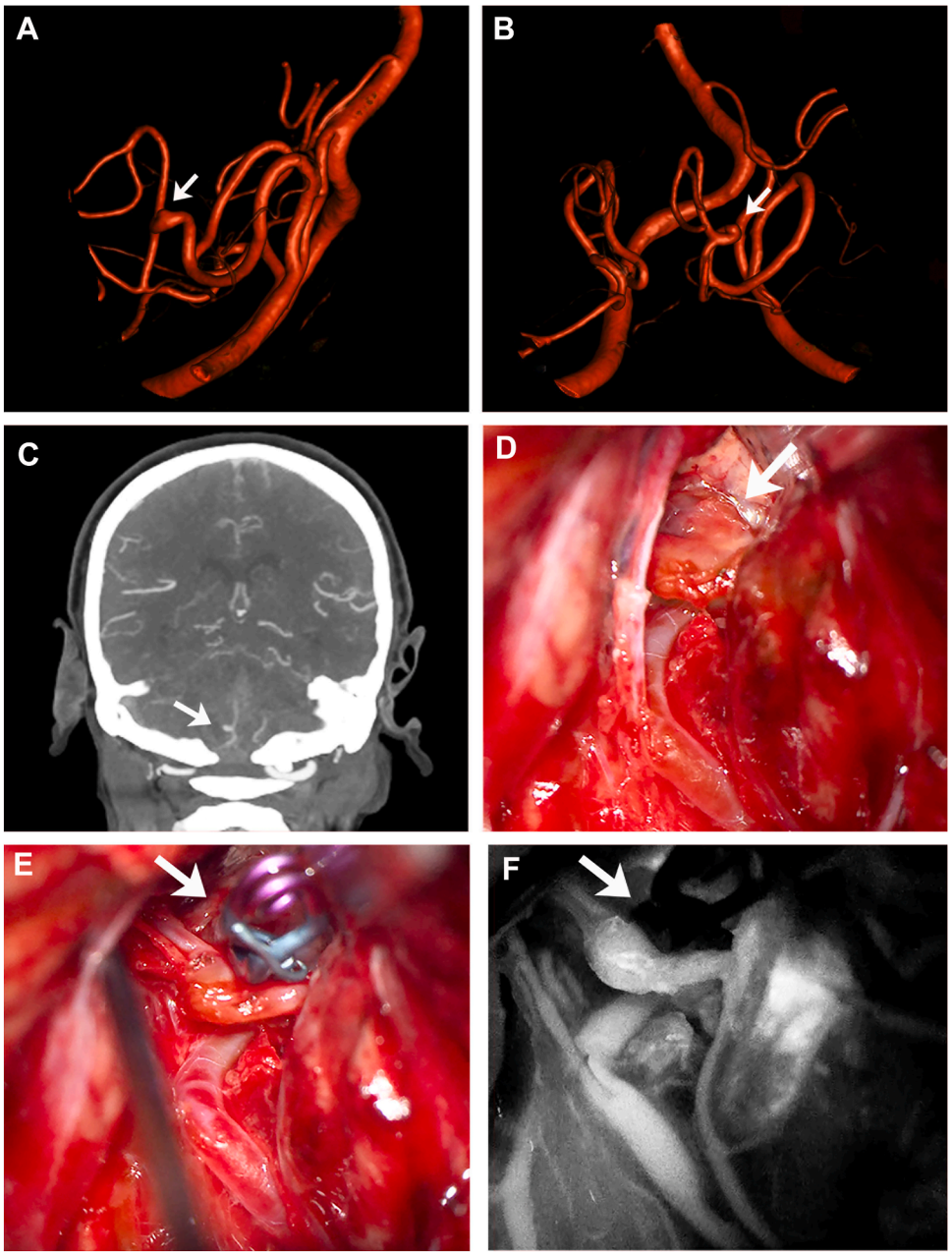

Figure 3. Illustrative case of a ruptured distal posterior inferior cerebellar artery (PICA) aneurysm. White arrows indicate the aneurysm (**A**–**D**) and the applied clip (**E**–**F**). (**A**) and (**B**) 3D angiography demonstrating a small, broad-necked aneurysm arising from the P4 segment of the PICA just before the bifurcation into the cortical branches. (**C**) Preoperative CTA showing the right-sided PICA aneurysm. (**D**) Intraoperative view after retraction of the right cerebellar tonsil, exposing the P4 segment and the aneurysm. (**E**) Intraoperative view after microsurgical clip application. (**F**) Indocyanine green video angiography confirming complete aneurysm occlusion with preserved patency of the parent artery and branches. CTA, computed tomography angiography.

restricted surgical corridor, and the anatomical variability of the vertebral artery, PICA, and AICA.[6,19] Furthermore, the small caliber of the PICA and the commonly broad neck of these aneurysms pose considerable difficulties in preserving parent artery patency with either technique.[20] With the outcome of the international subarachnoid aneurysm trial and technical

Table 1. Overview of Patient Demographics and Clinical Presentation at Admission. Values are Means ± SD Unless Otherwise Indicated

Age (years)	51 (14)
Sex	
Male	9 (23%)
Female	30 (77%)
Hunt&Hess	
I	3 (8%)
II	7 (18%)
III	15 (38%)
IV	5 (13%)
V	9 (23%)
GCS	10 (5)
Anisocoria	
Yes	1 (3%)
No	38 (97%)
Hemiparesis	
Yes	3 (8%)
No	36 (92%)
Seizures	
Yes	5 (13%)
No	34 (87%)
Fisher	
0	-
1	1 (3%)
2	3 (8%)
3	6 (15%)
4	29 (74%)
EVD	
Yes	26 (67%)
No	13 (33%)
LD	
Yes	8 (21%)
No	31 (79%)
Aneurysm location	
PICA	31 (79%)
Proximal	23 (74%)
Distal	8 (26%)
AICA	5 (13%)
Proximal	4 (80%)
Distal	1 (20%)
VA	3 (8%)
V4	3 (100%)
GOS at discharge	
1	4 (10%)
2	3 (8%)
3	12 (31%)
4	7 (18%)
5	13 (33%)

AICA, anterior inferior cerebellar artery; EVD, external ventricular drain; GCS, Glasgow Coma Scale; GOS, Glasgow Outcome Scale; LD, lumbar drain; PICA, posterior inferior cerebellar artery; VA, vertebral artery.

advancements, EVT has become increasingly popular for the treatment of ruptured aneurysms over the last decades.[21,22] Although broad-necked and fusiform aneurysms have historically posed challenges for EVT, ongoing advancements may help overcome these limitations. Recent endovascular series using newer devices such as WEB and flow diverters have reported complete occlusion rates of 80% and 81%, respectively.[23,24] As a result, EVT is now the preferred approach for ruptured posterior fossa aneurysms in most neurovascular centers, while microsurgery is typically reserved for anatomically complex or EVT-resistant cases.[20,24] Thus, microsurgical series on posterior fossa aneurysms have become rare, often limited in size, and typically reflect outcomes from highly experienced vascular neurosurgeons, limiting generalizability. In contrast, EVT requires less technical expertise, is faster, and more widely accessible, factors that likely contribute to its broader use.

Although recent advances in EVT[20,24] have expanded reconstructive options and improved occlusion rates, its superiority over microsurgical clipping remains a subject of ongoing debate. A meta-analysis comparing microsurgical clipping and coiling for PICA aneurysms showed higher occlusion rates with clipping (95% vs. 69%), while both approaches achieved similar rates of good neurological outcome (78%).[25] Another meta-analysis separately analyzing ruptured posterior fossa aneurysms found that surgery resulted in higher complete occlusion (97% vs. 84%) and lower recurrence (1% vs. 7%). Neurological morbidity was comparable (14% vs. 15%), but surgical treatment was associated with a lower mortality (10% vs. 17%).[26] In our series, the modified far lateral approach offered consistent access to PICA and vertebral artery aneurysms, while the retrosigmoid route was effective for AICA lesions, resulting in a 92% complete occlusion rate, comparable to the 96–100% reported in other microsurgical series.[9,27-29] Consistent with prior reports, we found that condyle resection is rarely necessary,[4,30] as adequate exposure of proximal PICA and vertebral artery aneurysms can typically be achieved with partial removal of the jugular tubercle.[31,32] In contrast to other series,[6] we did not perform C1 arch resection in any case, which may be partially attributed to a better working corridor due to the semi-sitting position.

The semi-sitting position gained widespread popularity in the 1960s and 1970s for procedures involving the cervicodorsal spine and the posterior and lateral cranial fossae.[12] Its use is currently experiencing a revival in vestibular schwannoma surgery. Supported by a recent meta-analysis reporting low complication rates together with superior facial nerve preservation.[13] Other investigations have emphasized that patient selection and positioning technique can significantly influence VAE risk. In a prospective study including 100 infratentorial procedures, Türe et al.[11] found that decreasing head elevation from 45 ° to 30 ° markedly decreased both VAE incidence (62.5% vs. 22.0%) and clinically relevant air emboli (50.0% vs. 8.0%). Khalaveh et al.[33] identified patient height and American Society of Anesthesiologists class as independent predictors of VAE. These findings indicate that with adherence to a standardized technique and careful patient selection, the semi-sitting position remains a safe and valuable approach.

Despite these findings, the use of the semi-sitting position for posterior fossa aneurysm treatment has largely diminished. Contemporary practice now favors the modified park-bench or three-quarter prone position.[4,6] Historically, Yasargil[34] and Koos et al.[35] described the use of the semi-sitting position for select posterior fossa aneurysms. Krayenbühl et al.[6] reported a preference for the sitting position in obese patients with short, thick necks. In Kleinpeter's series of 14 PICA aneurysms, the semi-sitting position was used in 10 cases.[19] One of the largest series published on the use of the semi-sitting position for posterior fossa aneurysms is the one by Pilipenko et al.[9] In their series, 52 of 80 patients were treated in the sitting position, with VAE reported in 3.8% of cases, though monitoring methods were not specified.[9] To our knowledge, the largest TEE-monitored series reported a VAE rate of 23.5% (4/17), comparable to our detection rate of 20%.[8] Notably, Al-Afif et al[8] also observed no serious complications, and all procedures were completed successfully.

While no major complications were associated with the semi-sitting position in our cohort, its anatomical and physiological advantages may have contributed to the low intraoperative rupture rate (8%) and surgical morbidity (13%), despite all cases involving ruptured aneurysms. Although 4 patients died due to the initial hemorrhage, none of the deaths were related to the surgical procedure itself. Our results are consistent with morbidity and mortality rates reported in a recent meta-analysis on ruptured PICA aneurysms treated with microsurgery, which were 11% and 2%, respectively.[26] Our results align with the morbidity and mortality rate reported by a recent meta-analysis on ruptured PICA aneurysms treated with microsurgery (11% and 2%, respecti. Functional outcomes were favorable, with 84% of patients achieving a GOS >3 at 6 months a promising result given the complexity of these cases, which is in alignment with the reports of others.[8]

Limitations

Our study has several important limitations. First and foremost, the small sample size significantly limits the strength of the study. The retrospective design further constrains the interpretation of the findings. The long time span introduces variability in perioperative care and neurocritical management. In addition, endovascular treatment options have evolved substantially over the past decades, and some aneurysms treated earlier in this series might be managed differently today. This temporal evolution in treatment paradigms should be taken into account when interpreting the results. Moreover, all procedures were performed by an experienced vascular neurosurgeon, which may limit the applicability of the results to other centers. Furthermore, the semi-sitting position is routinely used at our institution for posterior fossa lesions and cervicodorsal spine surgery, resulting in extensive experience within the entire surgical and anesthesiology team. This familiarity may contribute to the low complication rates observed and may not be reproducible in centers with limited experience.

CONCLUSIONS

Although the semi-sitting position has become less common in contemporary aneurysm surgery, particularly in the endovascular era, our data suggest that it remains a safe and effective option in selected patients. Over more than 3 decades, high rates of complete aneurysm occlusion were achieved with acceptable procedure-related morbidity and no surgery-related mortality. VEA was consistently detected and managed without clinical sequelae. These results support the continued use of the semi-sitting position for posterior fossa aneurysms in centers with established experience and close interdisciplinary collaboration.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Beate Kranawetter: Writing — original draft, Visualization, Formal analysis, Data curation, Conceptualization. **Tammam Abboud:** Writing — review & editing, Conceptualization. **Yury Popov:** Data curation. **Carl Philipp Schoppmeier:** Project administration, Data curation. **Dorothee Mielke:** Data curation. **Veit Rohde:** Writing — original draft, Supervision, Resources, Project administration, Data curation, Conceptualization.

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