



# Microneurosurgical Management of Posterior Inferior Cerebellar Artery Aneurysms: Results of a Consecutive Series

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## Introduction

PICA aneurysms are rare. Their incidence accounts for 0.49–3% of all intracranial aneurysms [1–3]. However, they are most common within the posterior circulation ones after those of the basilar tip. Most are left-sided due to the prevalence of the vertebral artery. The saccular geometry is usually the most frequent, but dissecting or fusiform aneurysms are also relatively more common than in other cerebral arteries [2, 3]. PICA has a complex and variable course among all of the intracranial arteries, it has a small diameter, projecting along the brainstem and cerebellum. According to Lister et al., five segments are classically described [4]. Because of the proximity to the lower cranial nerves and frequent involvement of perforating arteries from the proximal segments, both microsurgical and endovascular treatment of PICA aneurysms are challenging.

In 1953, Rizzoli and Hayes first reported successful surgical treatment of a PICA aneurysm operated in 1947 [5, 6]. Since then, several reports on the surgical management of PICA aneurysms were published, but only a few of them were based on a large patient's cohort. The aim of this retro-

spective study is to analyze the results of 25 PICA aneurysms surgically treated, mainly focusing on the choice of the approach and technical nuances.

## Materials and Methods

Between 2008 and 2018, 25 patients harboring 25 PICA aneurysms were surgically treated by the senior author (R.G.) at two institutions: San Salvatore City Hospital, L'Aquila, Italy, and Fondazione IRCCS Policlinico San Matteo, Pavia, Italy. Only patients harboring saccular aneurysms were selected and retrospectively reviewed. Aneurysms were classified according to the five PICA segments reported by Lister et al. [4]. Proximal aneurysms were defined as those arising from the vertebral artery-PICA junction to the tonsillo-medullary segment, the remnants being considered as distal. Factors affecting the choice of the approach were also analyzed. Overall neurological outcome was reported as good, moderate, severe, and death, on the basis of an mRS score of 0–2, 3–4, 5, and 6, respectively. The outcome evaluation was also reported according to the clinical onset and the involved PICA segment. The angiographic outcome was evaluated on the basis of the complete exclusion of the aneurysm at the sixth-month follow-up.

## Results

Nineteen patients were females and the average age was 43 years (range 18–69). Nine patients suffered from hypertension, two from diabetes, three from hypercholesterolemia, and one from obesity. Nineteen patients were smokers. In one patient, familiar history of aneurysms was found. Admission computed tomography (CT) angiography and digital subtraction angiography (DSA) were performed by default in all patients. A contrast-enhanced MRI was performed in all large

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**Table 1** Demographic and clinical presentation

Patients			
	No. of Patients [no. 25]	Ruptured aneurysms [no. 15]	Unruptured aneurysms [no. 10]
Gender			
Females	19 (76%)	11	8
Males	6 (24%)	4	2
Age: mean 43 years old (18–69)			
Comorbidities			
Hypertension	9	7	2
Diabetes	2	2	1
Hypercholesterolemia	3	2	–
Obesity	1	1	–
Smokers (76%)	19	16	3
Clinical presentation			
Ruptured Aneurysms	15		
SAH			
Hunt Hess scale I–III	11		
Hunt Hess scale IV	3		
Hunt Hess scale V	1		
Cerebellar life threatening hematoma	4		
Unruptured Aneurysms	10		
Vertigo and gait instability	3		
Asymptomatic	7		

and giant aneurysms to reveal intraluminal thromboses. In 15 aneurysms (72%) subarachnoid hemorrhage (SAH) was the onset, four of which being associated with a life-threatening cerebellar hematoma. Three giant aneurysms presented with vertigo and gait instability and seven further aneurysms were incidental. Table 1 summarizes demographics and clinical presentation data of the present series (Tab. 1) Nine aneurysms were small (<7 mm), 11 medium (7–14 mm), two large (15–24 mm) and three giant (>25 mm). Nineteen aneurysms were proximal and, among these, ten involved the VA-PICA junction. Six involved the anterior-medullary segment and three the lateral-medullary segment. Of the remaining distal aneurysms, two were located on the tonsillo-medullary segment, one on the telovelotonsillary segment, and one on the cortical segment. Peculiar patient characteristics involving PICA segment and bony anatomy were the main factors influencing the choice of approach. Far-lateral approach was the approach of choice for all proximal aneurysms, while median or paramedian suboccipital approaches were used for distal ones. An early surgery (within 24 h) was performed in all ruptured aneurysms. Since 2012, in all elective cases, intraoperative neurophysiological monitoring involving somatosensory, motor, and brainstem auditory-evoked potentials was implemented, adopting a defined protocol that is also used in all intracranial aneurysms and

brain arteriovenous malformations [7–15]. But we strongly believe that neurovascular training is the most important tool by far to improve the technique and avoid complications [16] Exclusion of the aneurysm was achieved in 23 cases treated by clipping. Two complex aneurysms underwent to an in situ PICA-PICA bypass before the trapping. Table 2 reports the overall data about the surgical management of the present series (Tab. 2). Neuronavigation and endoscope-assisted techniques were commonly employed, the latter being useful for both the aneurysms having a huge blind spot and those very close to perforating arteries. Micro-Doppler (20 MHz System, Mizuho Medical Co., Ltd., Tokyo, Japan) ultrasound-based evaluation of the flow was implemented. Indocyanine green video angiography (Flow 800 Infrared Module, OPMI Pentero 800, Zeiss, Oberkochen, Germany) and fluorescein angiography (Yellow 560 Fluorescence Module, Kinevo 900, Zeiss, Oberkochen, Germany) were also introduced since 2009 and 2018, respectively. Sixth-month postoperative DSA was available in all but one patient. Total exclusion of the aneurysm was achieved by means of a single procedure in 22 cases. In three cases, a remnant was revealed imposing a redo surgery. No recurrences occurred during the follow-up.

A good overall outcome was achieved in all but one unruptured aneurysm and in 60% of those ruptured. A moderate outcome was observed in 16% of patients, whereas a severe outcome occurred in one patient who suffered by a permanent deficit of the lower cranial nerves. One patient, having a giant ruptured proximal PICA aneurysm, died. Table 3 reports the overall outcome of the present series (Tab. 3).

## Illustrative Cases

**Case 1** The case of a medium VA-PICA aneurysm is reported (Fig. 1). A 35-year-old patient had an incidental finding of a left VA-PICA unruptured aneurysm after a mild traumatic brain injury (Fig. 1a). CT angiography and DSA demonstrated the involvement of PICA (Fig. 1b, c). A left far-lateral transcondylar approach was performed and the aneurysm was clipped (Fig. 1e, f). Postoperative CT angiography documented the complete exclusion of the aneurysm with a preserved flow into the left PICA (Fig. 1g). Patient had a good recovery (mRS 1).

**Case 2** The case of a giant distal PICA aneurysm is reported (Fig. 2). A 64 years-old patient suffering from a severe headache and dizziness underwent to an MRI showing a giant thrombosed aneurysm causing a right cerebellar compression (Fig. 2a). CT angiography and DSA demonstrated the involvement of the distal PICA (Fig. 2b, c). A median suboc-

**Table 2** Overall data of the surgical management

Aneurysms			
	Aneurysms no.	Approach	Treatment
<b>Size</b>			
Small (<7 mm)	9		9 Clipping
Medium (7–14)	11		11 Clipping
Large (15–24)	2		1 Clipping 1 Trapping + PICA-PICA by-pass
Giant (>25 mm)	3		2 Clipping 1 Trapping + PICA-PICA by-pass
<b>Anatomical distribution</b>			
VA-PICA	10	Far lateral	
Anterior medullary	6	Far lateral	
Lateral medullary	3	Paramedian suboccipital	
Tonsillomedullary	2	Paramedian suboccipital	
Telovelotonsillary	1	Median suboccipital	
Cortical	1	Median suboccipital	

**Table 3** Overall patient outcomes

mRS	Ruptured aeurysms		Unruptured aneurysms	
	Proximal	Distal	Proximal	Distal
0	–	1	3	1
1	2	3	4	–
2	4	1	–	–
3	3	–	1	–
4	1	–	–	–
5	1	–	–	–
6	1	–	–	–

cipital approach was performed and the aneurysm was clipped after thrombectomy, the indocyanine green video angiography confirmed the patency of the PICA (Fig. 2d–g). Postoperative CT and CT angiography documented the complete exclusion of the aneurysm (Fig. 2h, i). Patient had a good recovery (mRS 0).

## Discussion

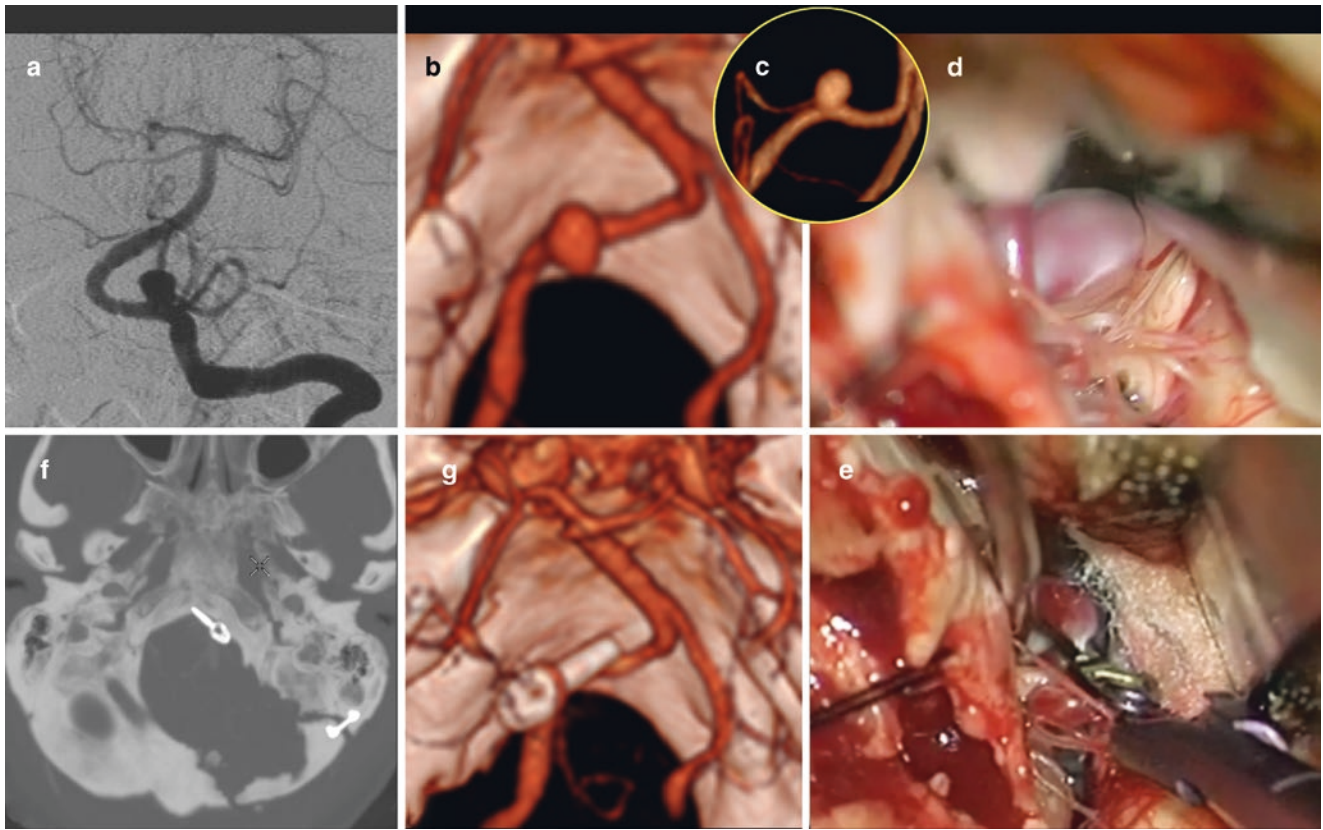
Historically speaking, posterior circulation aneurysms were always considered a tough dare for surgeons. In 1829, Cruvelhier reported the first description of a spherical aneurysm arising from the PICA-vertebral junction [17]. Afterward, in 1854, Fernet reported the first case of a distal PICA aneurysms [1]. The rarity of PICA aneurysms justifies the few large series reported [18–21]. Still today, with 146 cases, that of Peerless and Drake remains the largest ever reported series about PICA aneurysms. In these aneurysms, the need for treatment is dictated by their high risk of rupture, high mortality, and the usual younger age of the affected patients [19]. The mean reported age range is from 44.6–51 years [22, 23]. The average age was slightly lower in the present series, with a prevalence of female sex.

Interestingly, all but one of the distal aneurysms were ruptured, three of which of small size. Indeed, as already reported

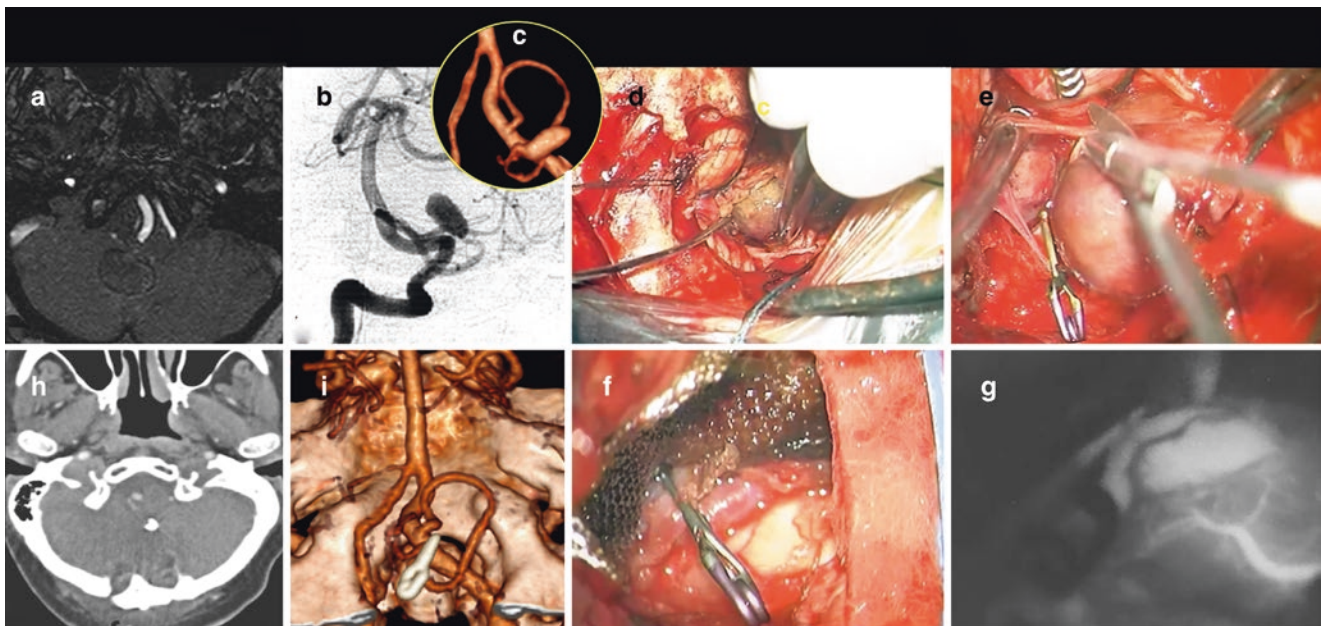
about distal aneurysms at all, this aspect has to be probably related to the thinner walls of the distal ones [24–26]. The well-known risk of rebleeding of ruptured PICA aneurysms, up to 78%, imposes an early treatment. In this series, all hemorrhagic patients underwent surgery within 24 hours and, for patients with an impending-life hematoma, the indication for surgery was mainly based upon an evidence-based management algorithm about intracerebral hemorrhages reported by our group [27]. Regardless of the clinical onset, all the patients underwent CTA and DSA. A 4- or 6-vessel DSA is recommended for all PICA aneurysms, depending by the need for flow replacement, is recommended for all PICA aneurysms, also because of the well-known risk to miss very distal ones [28]. Indeed, one of the authors reported a very rare case of an extra-cranial small aneurysm of the PICA which was initially missed by CT angiography. The labyrinth of neurovascular bundles present in the posterior fossa makes the surgical exposure of PICA aneurysms really challenging. A careful preoperative evaluation of the patient’s vascular and bony anatomy is needed to tailor any approach, especially to assess the relationships between VA-PICA complex, the jugular tubercle, and the occipital condyle. The choice of the correct surgical approach has to be considered the crossroads in the microsurgical treatment of these aneurysms. In this series, 19 proximal aneurysms were exposed through a far-lateral approach without drilling of the condyle in most cases. Conversely, Bertalanffy et al. used the transcondylar approach as a rule [29]. Ambrosio et al. suggest the routine use of the extreme-lateral approach to reach the proximal PICA from a corridor remaining below the lower cranial nerves [30].

In the elective treatment of proximal PICA aneurysms, the use of the endoscope as an adjuvant tool has to be considered. Our group have already stressed the importance of endoscope-assisted techniques in the treatment of several neurosurgical pathologies [31, 32], but particularly in aneurysm surgery where, often, the endoscope view allows sparing perforating branches within blind spots.





**Fig. 1** CT angiography and DSA revealing a VA-PICA unruptured regular aneurysm (a–c). Left far-lateral transcondylar approach and clipping of the aneurysm (d, e). Postoperative CT and CT angiography documenting the complete exclusion of the aneurysm with a preserved flow into the left PICA (f, g)



**Fig. 2** MRI angiography showing a giant thrombosed aneurysm causing a right cerebellar compression (a). CT angiography and DSA demonstrating the involvement of the distal PICA (b, c). Median suboccipital approach, exposure of the thrombosed aneurysm, dissection, clipping and virtual videoangiography with indocyanine green (d–g). Postoperative CT and CT angiography documenting the complete exclusion of the aneurysm (h, i)

The six aneurysms arising from the distal PICA were approached by a median or paramedian suboccipital craniotomy according to the length and the tortuosity of PICA.

The results of the present series, although made up of 25 cases, endorse the prominent role of microneurosurgery for PICA aneurysms, both proximal and distal, especially in young patients. In experienced hands, direct clipping allows for a definitive and durable exclusion of the aneurysm. Outcomes are strictly related to the preoperative neurological status.

The charm of PICA aneurysms is strictly related to the high anatomical variability of this artery and to their rarity. Surgeons who want to deal with them must have a deep knowledge of skull base approaches, vascular anatomy, and a profound familiarity with all the microsurgical techniques of vessel reconstruction.

**Ethical Approval** This study was approved by the Internal Advisory Board.

**Conflict of Interest Statement** The authors declare that they have no conflict of interest.

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