Posterior Circulation Aneurysms: A Critical Appraisal of a Surgical Series in Endovascular Era

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Introduction

Posterior circulation aneurysms have a worse natural history than anterior aneurysms, mainly because of their higher risk of rupture and poor outcome [1]. This aspect imposes the need for treatment in most cases, especially in younger patients. The advent of the endovascular era and its constant refinement through the continuous improvement of the devices has dramatically changed the treatment standard for many but not all of the posterior circle aneurysms. Exceptions are aneurysms involving the distal segments of the cerebellar arteries, most basilar tip aneurysms, and the giant ones for which microneurosurgery remains a rational option. The aim of this study is a critical appraisal of the overall results of a retrospective surgical series aimed to identify those posterior circulation aneurysms for which microneurosurgery still today maintains a key role.

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Materials and Methods

Collected data concerned demographics, clinical onset, the prevalence of site and size, approaches, and outcome of 149 patients surgically treated because they harbored one or more posterior circulation aneurysms have been retrospectively reviewed. All the patients were operated on by the senior author (RG) in three different hospitals over a period of 28 years between January 1990 and December 2018. Aneurysms were classified as proximal and distal. The proximal ones involved vertebral artery (VA), basilar artery (BA), and the proximal segments of the posterior cerebral artery (PCA) and cerebellar arteries. The remaining sites were considered as distal. For outcome evaluation, the patients were divided in to two groups: <65 and ≥65 years old. The Angiographic outcome was evaluated based on the complete exclusion of the aneurysm at a six-month follow-up. The Neurological overall outcome was reported according to patients' age, clinical onset, and site, and size of the aneurysms. Glasgow Outcome Score (GOS) 1 and 2 were considered as "good recovery," whereas GOS 3, 4, and 5 were considered as "moderate disability," "severe disability," and "death-vegetative state," respectively.

Results

Patients Demographics and Clinical Data

Average patient age was 56.7 ± 14.2 years. Admission contrast-enhanced computed tomography (CT) angiography was the rule for all patients. Preoperative digital subtraction angiography (DSA) was performed in all unruptured or complex aneurysms. In elective cases, the need for a balloon test occlusion (BTO) was assessed on a case-by-case basis. A contrast-enhanced MRI was performed in all very large and giant aneurysms to reveal

Table 1 Site and Size Prevalence of Posterior Circulation Aneurysms

Site		N (%)	Size			
			Small (7 mm) N (%)	Regular (7–12 mm) N (%)	Large (13–24 mm) N (%)	Giant (25 mm) N (%)
Proximal	Basilar tip + PCA (P1) + SCA	91 (58%)	17 (18.7%)	57 (62.6%)	7 (7.7%)	10 (11%)
	Midbasilar trunk + proximal AICA	9 (5.7%)	2 (22.2%)	4 (44.4%)	2 (22.2%)	1 (11.1%)
	VB Junction	10 (6.4%)	2 (20%)	5 (50%)	2 (20%)	1 (10%)
	VA (V4) + proximal PICA (anterior + lateral medullary segment)	27 (17.2%)	5 (18.5%)	16 (59.3%)	3 (11.1%)	3 (11.1%)
Distal	PCA (P2-P3)	7 (4.5%)	1 (14.3%)	2 (28.6%)	1 (14.3%)	3 (42.9%)
	Distal SCA	3 (1.9%)	–	1 (33.3%)	1 (33.3%)	1 (33.3%)
	Distal AICA	4 (2.5%)	2 (50%)	1 (25%)	–	1 (25%)
	Distal PICA (tonsillo-medullary + telovelotonsillar + cortical segment)	6 (3.8%)	–	2 (33.3%)	2 (33.3%)	2 (33.3%)
Tot.		157	29 (18.5%)	88 (56.1%)	18 (11.5%)	22 (14%)

PCA (P1) proximal segment of the posterior cerebral artery, SCA superior cerebellar artery, AICA anterior inferior cerebellar artery, VB junction, vertebro-basilar junction, VA (V4) intradural segment of the vertebral artery, PICA posterior inferior cerebellar artery, PCA (P2-P3) distal segments of the posterior cerebral artery

eventual intraluminal thromboses. In 98 patients, a hemorrhagic onset occurred. The Average admission Hunt-Hess score was 2.17 ± 0.8 and the mean Fisher grade was 1.9 ± 0.8 . One hundred thirty-seven aneurysms were classified as proximal and 20 as distal. Table 1 reports the prevalence of proximal and distal posterior circulation aneurysms according to site and size (Table 1). About ruptured aneurysms—apart from rare cases of young patients having an impending life hematoma, for whom the indication for surgery was based mainly upon an evidence-based management algorithm about intracerebral hemorrhages reported by our group [2]—mainly patients with an admission Hunt-Hess score of 1–3 underwent surgery. In 92% of cases, an early surgery (within 24 h) was performed. One hundred fifty-seven aneurysms were consecutively operated on; six patients had two aneurysms and one patient harbored three different aneurysms. In three cases, two different procedures were performed on the same patient. A total of 152 procedures were performed.

Surgery

Approach Selection

Approaches were selected according to site and angioarchitecture. Pterional and cranio-orbital approaches were utilized to basilar tip, proximal (P1) PCA, and superior cerebellar artery (SCA). For these aneurysms, pterional approach was usually “extended” to comprehend wide drilling of the lesser sphenoid wing, a large opening of the sylvian fissure, an extradural or intradural anterior clinoidectomy, and an intradural posterior clinoidectomy. Cranio-orbital corridors were preferentially employed in large

and giant aneurysms. Al-Mefty’s combined petrosal approach [3] was employed for the midbasilar trunk and proximal anterior inferior cerebella artery (AICA). The Far-lateral retrocondylar approach was the corridor of choice for aneurysms involving VB junction, VA, and the proximal PICA, although the transcondylar variant was rarely necessary. Regarding the distal localizations, a subtemporal trans-tentorial approach was commonly used to treat P2-P3 PCA aneurysms. Conversely, aneurysms involving the distal segments of AICA, SCA, and PICA were elegantly treated by a retrosigmoid route.

Direct vs. Indirect Treatment

In all but three aneurysms a direct treatment was possible. A total of 128 aneurysms were successfully clipped. Trapping was the solution to aneurysms that were not amenable for clipping, under two conditions: if the patient tolerated the BTO, and the aneurysms were far distal having no need for revascularization. In one elective case of complex giant posterior projecting basilar tip aneurysm, an extracranial to intracranial (EC-IC) occipital artery (OA)—right P3 PCA bypass, with a radial artery graft, was performed. In two other elective patients, an intracranial to intracranial (IC-IC) PICA-PICA in situ bypass was carried out preceding, in both cases, the trapping of a complex VB junction aneurysm. Table 2 reports the types of treatment and the surgical techniques comprehensively employed in the current series (Table 2).

Temporary Clipping and Neurophysiological Monitoring

In the present series, the anesthesia protocol used by our group was specifically designed to allow the intraoperative neurophysiological monitoring during neurovascular surgery

Table 2 Type and Prevalence of the Employed Surgical Techniques

Type of treatment	Technique	N (%)
Direct	Clipping	128 (81.5%)
	Trapping	19 (12.1%)
	Wrapping	7 (4.5%)
Indirect	OA-P3 PCA bypass	1 (0.6%)
	PICA-PICA bypass	2 (1.3%)
Tot.		157

OA occipital artery, P3 PCA P3 segment of the posterior cerebral artery, PICA-PICA posterior-inferior cerebellar artery to posterior-inferior cerebellar artery side to side in situ by pass

and was the same as employed for brain arteriovenous malformations and giant aneurysms in general [4–13]. A combined somatosensory-motor-brainstem auditory evoked potentials and EEG-based intraoperative neurophysiological monitoring were implemented in 2012. Neurophysiological Monitoring was performed in all proximal or complex aneurysms electively treated.

Technological Adjuncts and Flow Assessment Techniques

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. Since 2007, a 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 introduced in 2009 and 2018, respectively.

Neurological Outcome

The best outcome was achieved in patients <65 years old harboring an unruptured aneurysm. Table 3 reports the overall outcome according to the clinical onset and patient age (Table 3). The best results were also observed in small-to-regular aneurysms involving basilar tip, distal branches of the cerebellar arteries, VA, and the proximal PICA. Figures 1 and 2 report the overall patient outcomes in proximal and distal aneurysms, respectively, according to their site and size (Figs. 1 and 2).

Angiographic Outcome

Six-month postoperative angiography was available in all but 17 patients. If no remnants were revealed at the first postoperative angiography, patients underwent a CT angiography for further annual follow-ups.

In 88.5% of patients, total exclusion of the aneurysms was achieved using a single procedure. In three cases, a remnant was revealed, causing a redo surgery. Along with an average follow-up of 67.1 ± 61 months, no recurrences occurred.

Illustrative Case

The case of a left giant VA-PICA aneurysm is reported (Fig. 3). A 42-year-old patient suffering from long-lasting dizziness underwent a contrast-enhanced MRI that showed a left giant VA causing a brainstem compression (Fig. 3a). CT angiography and DSA demonstrated the involvement of PICA (Fig. 3b, c). No crossflow was revealed by BTO (Fig. 3d). A left far-lateral retrocondylar approach was performed and the aneurysm was clipped using stacking-seating technique (Fig. 3e, f). Postoperative DSA documented the complete exclusion of the aneurysm with a preserved flow into the left PICA (Fig. 3g). The patient had a good recovery (GOS 5).

Table 3 Patients' overall outcome according to the clinical onset and the patients' age

Outcome	Clinical onset		Patients' age	
	Hemorrhagic	Non-hemorrhagic	<65 years-old	≥65 years-old
Good Recovery [No. of patients (%)]	80 (81.6%)	45 (88.2%)	66 (83.5%)	33 (47.1%)
Moderate disability [No. of patients (%)]	4 (4.1%)	2 (3.9%)	8 (10.1%)	14 (20%)
Severe disability [No. of patients (%)]	3 (3.1%)	1 (2%)	1 (1.3%)	9 (12.9%)
Death-vegetative state [No. of patients (%)]	11 (11.2%)	3 (5.9%)	4 (5.1%)	14 (20%)

Fig. 1 Bar graph showing the overall patient outcome in proximal aneurysms according to their site and size

Discussion

Although not free from possible complications, neuroendovascular techniques have reached a level of effectiveness that certainly makes them suitable for a large part of posterior circulation aneurysms. Conversely, microneurosurgery still has a very important role in the treatment of aneurysms involving distal segments of the cerebellar arteries, giant aneurysms, a large number of aneurysms affecting basilar tip and proximal SCA, an equally large part of VA-PICA aneurysms and, more generally, complex aneurysms not amenable to endovascular treatment [6, 14–22]. Particularly, the well-established role that microneurosurgery plays in the treatment of distal infratentorial aneurysms is the same, in terms of durability, as its role in treating distal supratentorial ones [23].

The present retrospective series also confirms these data, suggesting that microneurosurgery should be considered as the treatment of choice especially for elective patients younger than 65 years old. Some technical aspects as follow ought to be considered to achieve the best results: First, a detailed static and dynamic preoperative evaluation of the aneurysm's angioarchitecture and the flow-related aspects are both imperative to plan the treatment strategy. A 4- or 6-vessel DSA, depending on the need for flow replacement, is recommended for all the posterior circulation aneurysms, and also addresses the well-known risk of missing very distal PICA ones [24]. Indeed, one of the authors reported a very rare case of an extracranial small aneurysm of the PICA which was initially missed by CT angiography. Second, a careful preoperative evaluation of the patient's vascular and bony anat-

Fig. 2 Bar graph showing the overall patient outcome in distal aneurysms according their site and size

omy allows practical tailoring of any approach. The third remark regards the technological adjuvants, which are part of the surgeon's armamentarium. For instance, our group has already stressed the importance of endoscope-assisted techniques in the treatment of several neurosurgical pathologies, but particularly aneurysm surgery where, often, the endoscope view prevents perforating branches within blind spots [25, 26]. Noteworthy, apart from the aforementioned aspects, a constant microneurosurgical training remains essential for aneurysms surgery, as already reported by our group [27].

The results of the present series confirm that microneurosurgery continues to have a paramount role in the treatment of many posterior circulation aneurysms, especially in

young patients. In experienced hands, direct clipping allows for a definitive and durable exclusion of the aneurysm. Microneurosurgery also leads to a flow replacement before trapping for those aneurysms not amenable to coiling, stenting, or clipping.

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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.

Fig. 3 Contrast-enhanced MRI showing a left giant VA causing a brainstem compression (a). CT angiography and DSA demonstrating the involvement of PICA (b, c). BTO revealing no crossflow (d). Left

far-lateral retrocondylar approach and clipping of the aneurysm (e, f). Postoperative DSA documenting the complete exclusion of the aneurysm with a preserved flow into the left PICA (g)

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