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Microsurgical clipping of paraclinoid aneurysms. A single centre experience

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ABSTRACT

Background. Paraclinoid aneurysm is a nonspecific term that includes ophthalmic segment aneurysms and distal cavernous internal carotid artery (ICA) aneurysms. The literature mostly described the frequency to be in the range of 1.3-5%. and a high incidence of being multiple or having a large size.

Methods. A retrospective review of 18 consecutive patients surgically treated for paraclinoid aneurysm was performed. The data of all our consecutive patients were searched to obtain patient and aneurysm characteristics, treatment details, complications and follow up. Clinical outcome was graded according to the modified Rankin scale. The follow-up period varied widely from 3 to 62 months (mean 26 months).

Results. Surgical clipping was performed for 15 ruptured paraclinoid aneurysms; only in 3 cases the aneurysm was unruptured. Post-operative control angiography was performed in 10 patients (55.56%), from which we reported a full occlusion of the aneurysm in 9 patients (90%). Best results were obtained in patients who preoperatively were included in 1st and 2nd grade of Hunt & Hess scale. Two months postoperative follow-up was complete for all but one patient who died 12 days after surgery, from cerebral ischemia resulting from severe cerebral vasospasm. There were excellent and good results (mRS 0–2) in 88% of the cases (15 out of 17 patients) at two months follow-up, and 94% (16 out of 17 patients) at six months follow-up. Three patients with slight disabilities, ranked mRS 1-2 at two months follow-up, improved to mRS 0, with no symptoms at all, at 6 months postoperative control. All 3 patients with a surgically treated non-ruptured paraclinoid aneurysm had an excellent outcome (mRS 0).

Conclusions. Most appropriate treatment is to occlude aneurysms without compromising patency of the parent artery. Anterior clinoidectomy and microsurgical clipping can still be a standard treatment despite of recent development of endovascular coiling procedures.

Keywords
paraclinoid aneurysm, surgical clipping, endovascular treatment, postoperative results

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INTRODUCTION

Paraclinoid aneurysms is a nonspecific term that includes ophthalmic segment aneurysms and distal cavernous internal carotid artery (ICA) aneurysms. These aneurysms arise near the anterior clinoid process and represent a considerable surgical challenge owing to their anatomic features, their proximity to the optic nerves and chiasm, and their relationship to complicate dural structures.

Paraclinoid aneurysms are classified according to the ICA segments from which they arise. There are clinoidal segment aneurysms and ophthalmic segment aneurysms. Each variant can be differentiated according to the site of origin, the direction of projection, and relationship with arterial branches, cranial nerves and adjacent dural and osseous structures within the segment (4).

Clinoidal segment aneurysms have two variants: (a) anterolateral variant and (b) medial variant. Ophthalmic segment aneurysms are intradural and include: (a) ophthalmic artery aneurysms, (b) superior hypophyseal artery aneurysms and (c) rare variants of dorsal ICA aneurysms (21).

This article summarizes the results of microsurgical treatment of 18 paraclinoid aneurysms operated in our department, by two senior neurosurgeons, and discusses treatment strategy and potential complication, comparing them with the results reported in the neurosurgical literature.

Methods

This article presents the results of a retrospective study of paraclinoid aneurysms, surgically treated in the Department of Neurosurgery of Institute of Neurology and Neurovascular Diseases, Bucharest. In the period from January 2014 until June 2019, 18 consecutive patients with paraclinoid aneurysms, from a total of 296 patients with carotid system aneurysms, were operated on by two senior neurosurgeons. Admission data, operative reports and imaging studies were reviewed to obtain information on patient's age, gender, aneurysm size and orientation, treatment details, complication and follow-up. From this series of 18 patients, two harboured another middle cerebral aneurysm, both on ipsilateral side.

Most of the patients (15 patients - 83.34%) presented with acute subarachnoid haemorrhage and only 3 presented an unruptured paraclinoid aneurysm. However, in a patient with multiple aneurysms, the source of the haemorrhage was clearly defined to be a middle cerebral artery aneurysm. Digital subtraction angiography with 3D reconstruction or computerized tomography (CT) angiography were used to image the intracranial circulation and to achieve proper orientation and visualization of the paraclinoid aneurysm. At admission, the clinical condition of all patients was classified according to the Hunt and Hess scale. Clinical outcome was assessed according the modified Rankin scale.

An ipsilateral pterional approach was used in all patients and medial sphenoid wing was resected extradurally to the level of the lateral clinoid process. Proximal control was achieved by neck dissection and temporary clipping of either internal carotid artery (ICA) or common carotid artery (CCA). After a standard dural opening, the anterior limb of the Sylvian fissure is split to gain access to the ICA, anterior clinoid process, and optic nerve. The arachnoid layers were cut form distal to proximal, identifying the distal ICA and posterior communicating artery. We continued the microdissection proximally until the neck of the aneurysm on the ICA was identified. The optic nerve partially blocked the origin of most ophthalmic artery aneurysms, and it was untethered and gently mobilized by sectioning the falciform ligament. Visualization of the entire aneurysm neck during clip application was often impossible, so clip deployment proceeded with visualization of one blade and inspection of the other only after the clip was applied.

Distribution of carotid system aneurysms	
Aneurysm location	**Number of patients**
Anterior communicating artery aneurysm	126 (42.5%)
Posterior communicating artery aneurysm	55 (18.5%)
Medial cerebral artery aneurysms	86 (29,33%)
Anterior cerebral artery aneurysm	2 (0.67%)
Anterior choroidal artery aneurysm	3 (1%)
Pericallosal artery aneurysm	6 (2%)
Paraclinoid aneurysms	18 (6%)
Total	**296 (100%)**

Table 1. Distribution of carotid system aneurysms in a series of 296 patients.

Characteristic	No of patients (%)
Female	12 (66.67%)
Male	6 (33.33%)
Hunt &Hess scale	
Grade 0	3 (16.67%)
Grade 1 and 2	10 (55.55%)
Grade 3	4 (22.33%)
Grade 4	1 (5.45%)
Grade 5	0
Modified Fischer Grading Scale	
No SAH present	3 (16.67%)
Focal or diffuse thin SAH	12 (66.67%)
Focal or diffuse thick SAH	2 (11.21%)
Intraventricular haemorrhage	1 (5.45%)

Table 2. Characteristics of patient with paraclinoid aneurysms in our series.

Charactersitic	No of patients (%)
Left paraclinoid aneurysms	10 (55.55%)
Right paraclinoid aneurysms	8 (44.45%)
Location	
Ophthalmic artery aneurysms	16 (94%)
Superior hypophyseal artery aneurysms	1 (4.3%)
Clinoidal segment aneurysms (medial variant)	1 (1.7%)
Size	
≤ 5 mm	3 (16.67%)
5-10 mm	10 (55.55%)
≥ 10 mm	5 (27.78%)

Table 3. Aneurysm characteristics.

Results

Eighteen patients with paraclinoid aneurysms were operated on in our department between January 2014 and June 2019. Of these, two were asymptomatic, two presented with visual symptoms of decreased visual acuity of the relevant eye, and there were 14 ruptured aneurysms without eye involvement. The patient characteristics at admission are presented in Table 2.

Most of the patients were women (66.67%). At the time of surgery, 13 patients were with no subarachnoid haemorrhage or in grade 1 or 2 on Hunt&Hess scale. The aneurysms characteristics are summarized in Table 3. Paraclinoid aneurysms had usually larger diameter than aneurysms in other location. In our series, there were 5 (27.78%) aneurysms with a maximum size more than 10 mm. The patients with ruptured aneurysms, except one, who was in poor neurological status, were operated on in the first 5 days following the symptoms onset.

In only one case we delayed the surgical treatment of the aneurysm, due to severe vasospasm, and important secondary neurological deterioration of the patient. Two patients harboured a coincidental non-ruptured middle cerebral artery aneurysm, which was clipped in the same surgical procedure. Post-operative control angiography was performed in 10 patients (55.56%), from which we reported a full occlusion of the aneurysm in 9 patients (90%).

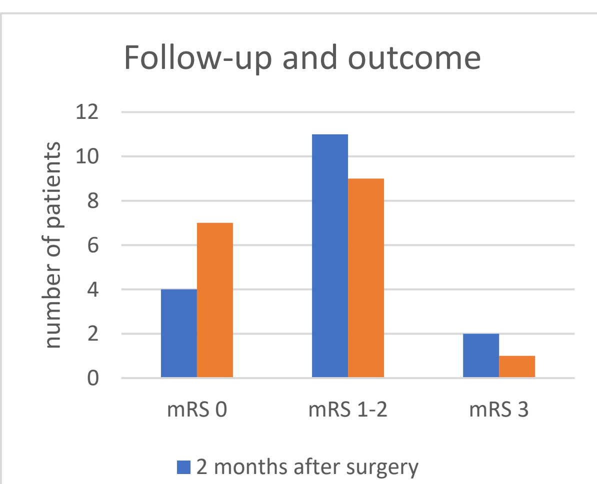
Preoperative vasospasm was demonstrated on cerebral angiography in 3 patients (16.67%) and clinically was manifested in 1 patient (5.56%). On control angiography, cerebral vasospasm was detected on near half of the patients (40%), but, as postoperative event, 2 patients, including the one with preoperative neurological signs, presented clinical symptoms of vasospasm, with decreased level of consciousness, affected speech and motor deficits.

The follow-up period varied widely from 3 to 62 months (mean 26 months). Best results were obtained in patients who preoperatively were included in 1st and 2nd grade of Hunt & Hess scale. Two months postoperative follow-up was complete for all but one patient who died 12 days after surgery, from cerebral ischemia resulting from severe cerebral vasospasm. The mean follow-up was 26 months, obtained in 89% of the patients. The outcome was evaluated using modified Rankin Scale. Overall outcome was assessed at first (two months after surgery) and respectively, second (six months after surgery) postoperative controls. There were excellent and good results (mRS 0–2) in 88% of the cases (15 out of 17 patients) at two months follow-up, and 94% (16 out of 17 patients) at six months follow-up. The most important improvement was recorded for patients graded mRS 1-2 at the first postoperative follow-up. Three patients with slight disabilities, ranked mRS 1-2 at two months follow-up, improved to mRS 0, with no symptoms at all, at 6 months postoperative control. All 3 patients with a surgically treated non-ruptured paraclinoid aneurysm had an excellent outcome (mRS 0).

Complications	No of cases
Intraoperative rupture	2 (11.12%)
Re-ruptured before surgery (waiting)	0

Post-operative rupture		0
Pre-operative vasospasm	angiography	3 (16.67%)
	clinic	1 (5.56%)
Post-operative vasospasm	angiography	**4/10 (40%)**
	clinic	2 (11.12%)
Post-operative subdural hematoma		0
Meningitis		0
Hydrocephalus		1 (5.56%)
VP shunt (within 30 days from surgery)		1 (5,56%)
Complications		**No of cases**
Intraoperative rupture		2 (11.12%)
Re-ruptured before surgery (waiting)		0
Post-operative rupture		0
Pre-operative vasospasm	angiography	3 (16.67%)
	clinic	1 (5.56%)
Post-operative vasospasm	angiography	**4/10 (40%)**
	clinic	2 (11.12%)
Post-operative subdural hematoma		0
Meningitis		0
Hydrocephalus		1 (5.56%)
VP shunt (within 30 days from surgery)		1 (5,56%)

Table 4. Procedural and perioperative complications.



Outcome of the surgically treated paraclinoid aneurysms after 2, and respectively, 6 months follow-up (17 patients; one died at 12 days after surgery). Excellent= mRankin 0, good=mRankin 1–2, fair= mRankin 3.

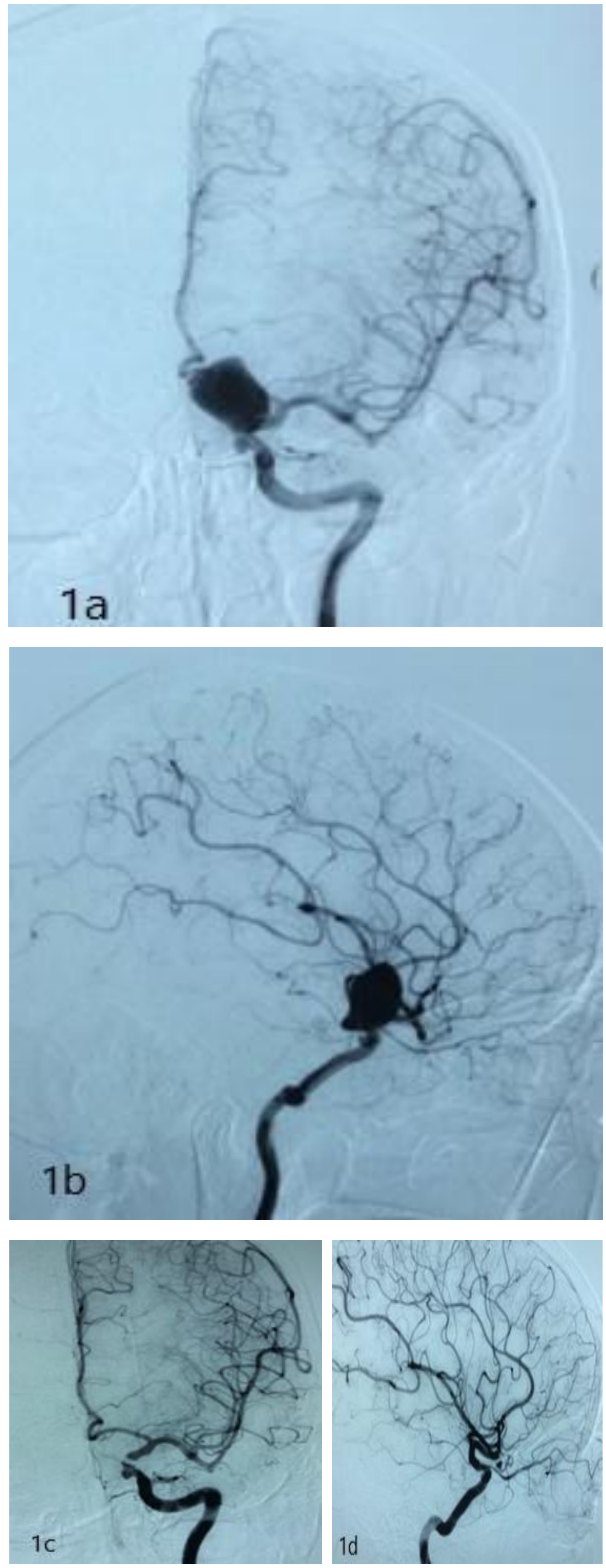
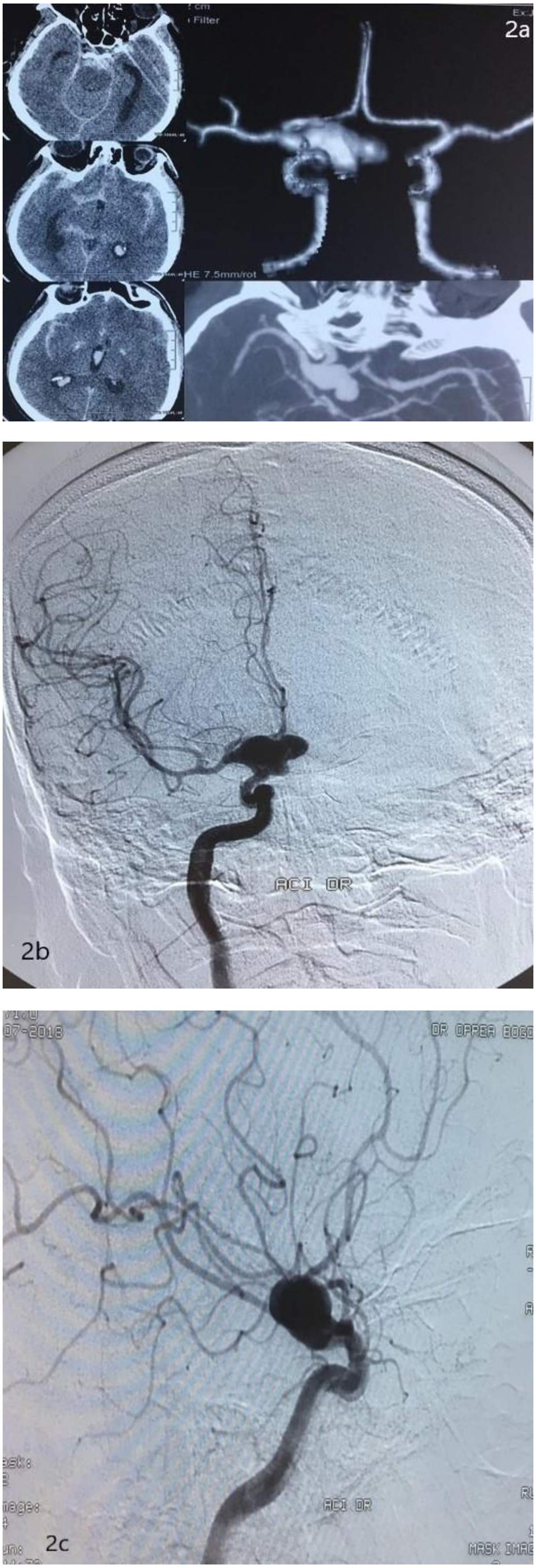


Figure 1: (1a,1b) Preoperative four vessels cerebral angiography showed a large, 14 mm length, ruptured, left ophthalmic artery aneurysm; (1c,1d) Postoperative control cerebral angiography showed the correct clipping of the aneurysm.



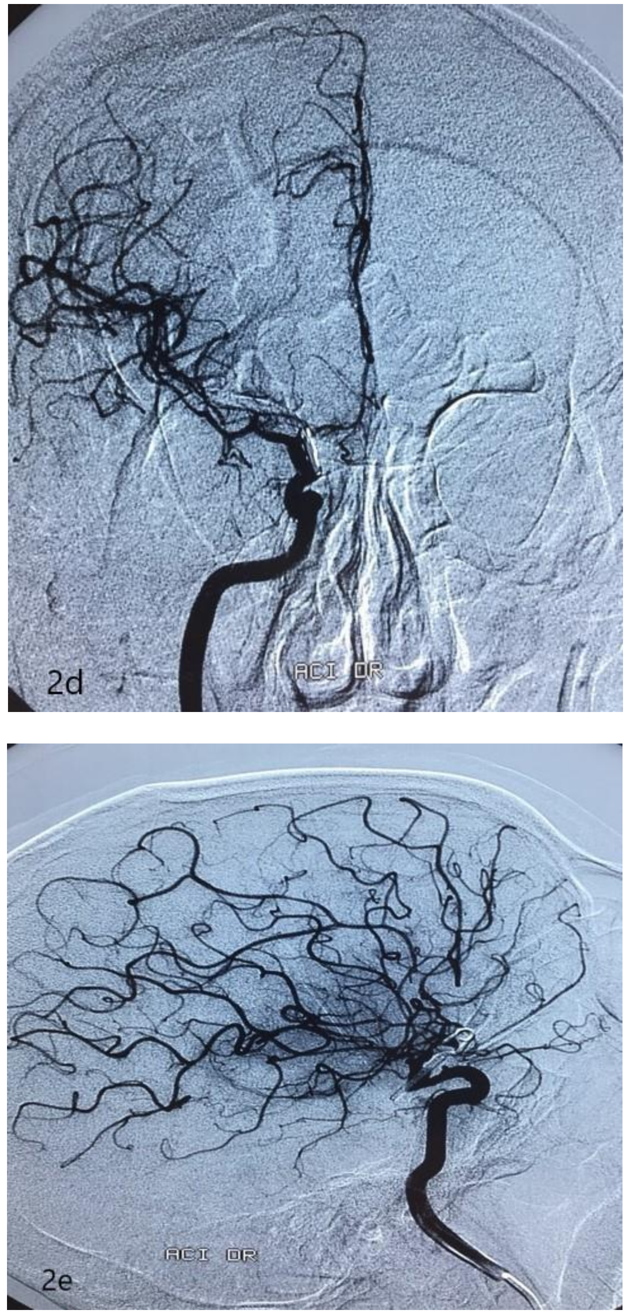


Figure 2: (2a) Preoperative cerebral computed tomography (CT) showed subarachnoid haemorrhage; computed tomography angiography (CTA) demonstrated a large right-sided paraclinoid aneurysm and the relation with the anterior clinoid process; (2b,2c) Preoperative four vessels cerebral angiography showed a 16 mm length right superior hypophyseal artery aneurysm; (2d,2e) Postoperative control cerebral angiography showed the correct obliteration of the aneurysm with a straight 11 Yasargil clip.

Discussion

Paraclinoid aneurysms are classified in clinoidal segment (C5) aneurysms and ophthalmic segment

(C6) aneurysms. This classification system offers prognostic information about lesion's propensity for subarachnoid haemorrhage (SAH) or cranial nerve deficits as well as the anatomic knowledge required for successful low-risk operative management of these lesions (28).

Paraclinoid aneurysms have a female preponderance (female:male ratio 9:1) and a high incidence of being multiple (4,12). Small (<5 mm) asymptomatic clinoidal segment aneurysms carry a very low risk of SAH, and isolated lesions should generally be treated with a conservative management plan including periodic follow-up imaging. Small symptomatic lesions (visual deficits or focal, unrelenting headache) and a lesion, whose protective anterior clinoidal process roof has been removed for treatment of another pathology in the same region, should be treated.

The most frequent paraclinoid aneurysms are ophthalmic aneurysms. The literature mostly described the frequency to be in the range of 1.3-5% (8,30). Although ruptured ophthalmic aneurysms require treatment, unruptured small asymptomatic aneurysms can undergo observation with serial imaging. Up to half of patients with ophthalmic segment aneurysms have additional intracranial aneurysms elsewhere (6,22). Most small aneurysms in the ophthalmic segment have a lower rupture risk than those at other intracranial locations. In this situation and for middle age or older adults, observation is a very reasonable option.

In the past, unless symptomatic, these aneurysms were usually not treated due to higher mortality and morbidity rates compared with other intracranial aneurysms (3). With the development of microsurgical technique, most of these aneurysms became operable, with lower mortality and morbidity (12). Potential management options for paraclinoid aneurysms include observation, endovascular treatment, microsurgical clip ligation, and carotid occlusion with or without bypass. Treatment is indicated for virtually all symptomatic aneurysms and for those larger than 1 cm. The patient presenting with visual loss should be treated urgently, ideally with surgery if the patient's risk factors and the experience of the operating team are reasonable. Endovascular technique is a viable option for the treatment of many aneurysms. The development of endoluminal flow-diverting devices applied to large or giant lesions has become a very good alternative to surgery for very complex paraclinoid lesions.

We considered that with all paraclinoid aneurysms, the patient's neck should be sterilely prepared and marked for dissection if proximal control becomes necessary. Some authors consider proximal control (4,6,27) is often unnecessary for small unruptured aneurysms, but often prudent for aneurysms that are ruptured or large. Proximal control can be achieved by temporary clipping of either the internal carotid artery (ICA) or common carotid artery (CCA). Clamping the CCA avoids potential injury to the ICA. Despite proximal ICA occlusion in the neck, back bleeding from the posterior communicating and ophthalmic arteries can be brisk if intraoperative rupture occurs.

The classic pterional craniotomy is used for adequate exposure of almost all ophthalmic artery aneurysms. An orbital osteotomy can be performed to provide additional exposure for larger aneurysms. The lesser wing is removed extradurally down to the base of the anterior clinoid process. The supraorbital craniotomy through the eyebrow incision is reasonable route for uncomplicated aneurysms.

The patient's head position during surgery for these medially situated aneurysms demands less neck rotation (15-20 degrees) to allow the surgeon to look under the optic nerve after the clinoidectomy. Slightly less head extension lessens the steep viewing trajectory under the anterior clinoid process.

Anterior clinoidectomy has great value in surgical exposure and treatment for most paraclinoid aneurysms. It can be completed both extradurally (Dolenc approach) or intradurally (8). In our opinion, intradural removal is preferred because it allows simultaneous visualization of the optic nerve and aneurysm during the entire dissection and enables immediate bleeding control if the aneurysm ruptures prematurely.

Extradural removal of the anterior clinoidal process is performed by extension of the medial dissection of lesser sphenoid wing (8). It uses of a high-speed diamond drill to hollow out the process until it is disconnected at its points of bony fixation. It is then extracted from its dural attachments, and cavernous sinus bleeding can be controlled with packing. This procedure should be avoided if a clinoidal segment aneurysm is suspected, because such aneurysm can erode into and through the anterior clinoidal process (4,21).

With **intradural** anterior clinoid process removal, the dura is opened in a curvilinear fashion based on the sphenoid ridge, and the sylvian fissure is widely split, allowing the aneurysm, ICA, and visual system to be partially visualized (9). Two incision are made: first, a 3- to 4-cm longitudinal incision along the lesser sphenoid wing, starting from the tip of the anterior clinoid process and a second dural incision made perpendicular to the first, extending to and including sectioning of the falciform ligament (20). The dura is stripped free from the underlying bone and clinoid process is removed as in extradural way but with better visualization of the optic apparatus and the aneurysm. After anterior clinoidectomy is complete, the optic canal is unroofed, and the optic strut is drilled down to the base of the sphenoid bone. The optic nerve sheath is then sectioned laterally to allow further access to the medial portion of the ICA and mobilization of the optic nerve.

Aneurysm dissection and clip application

Small ophthalmic artery aneurysms are technically easy to clip. After extradural or intradural removal of the anterior clinoid process, opening of the falciform ligament and mobilization of the ICA, the origin of the ophthalmic artery and the neck of the small aneurysm should be readily visible. At the moment of clip application, it is advisable to gently retract the ICA laterally rather the optic nerve medially (2). We consider that temporary clipping of the cervical ICA greatly aids in the dissection maneuver by softening the aneurysmal sac.

Ophthalmic artery aneurysms can be ligated with a strait, curved or side-angled clip, depending on their size, complexity and surgeon preference. Cohen-Gadol considered that side-angled clips orient the blades parallel to the long axis of the parent ICA and allow efficient neck closure without causing accordion-like shortening of the carotid trunk. Especially in broad neck aneurysms he underlined that a perpendicular clipping technique across the ICA leads to partial neck closure, hemodynamic turbulence within the sac, and potentially intraoperative rupture (4).

There is a distinct difference in the technical complexity of ligation for superiorly projecting and anteromedially projecting ophthalmic aneurysms. Although the former is relatively straightforward, the latter are hidden under the optic nerve and often require a tandem clipping technique: a fenestrated clip around the ICA can often be used to close a remnant (18).

Whereas ophthalmic artery aneurysms are often well visualized, superior hypophyseal aneurysms project medially away from the surgeon, with the ICA blocking any substantial view of the neck (14,16). These aneurysms usually require an angled fenestrated clip with the ICA within the fenestration and the clip blades pointing toward the distal dural ring. Because the superior hypophyseal arteries are often very proximal, the tips of the clip blades must extend up to or past the distal dural ring to completely close the neck. If the ring is not circumferentially dissected, the clip blades will remain partially splayed open and the aneurysm sac will continue to fill (14,27).

In paraclinoid aneurysms, usually in large ones, visualization of the entire aneurysm neck during clip application is often impossible, and clip deployment proceeds with visualization of one blade and often inspection of the other, only after the clip is applied. Inspection should reveal no perforator injury. Depending on the anatomy, one or several angled or right angled fenestrated clips may be necessary (14).

Large and giant aneurysms present technical challenges, especially if their neck is extending into the carotid cave (4,14). They require the use of complete flow arrest (aneurysm trapping) or suction-decompression technique for their decompression, manipulation and clip placement. The purpose is not only to prevent intraoperative rupture, but also to obtain adequate neck visualization and reliable neck closure. With large to giant aneurysms, aneurysmal decompression using the retrograde suction-decompression technique can be lifesaving. With this technique, endovascular inflation of a balloon in the cervical ICA is followed by temporary clip occlusion of the distal ICA within the operative field. Retrograde suction of the blood using a balloon catheter in the neck provides dramatic deflation and clip reconstruction of the patent ICA (4).

In our cohort, surgical clipping of 18 paraclinoid aneurysms was performed. Overall, one patient got worse and died after surgery (5.5%; cerebral ischemia resulting from severe cerebral vasospasm), one patient (5.5%) did not improve and the remainder (88.8%) improved in terms of mRS, at six months follow-up. No new visual field deficits or eye movement defects were recorded postoperatively.

Comparing the results in the literature, Kothandaram et al (19) in 1971, reported two deaths (20%) and two hemiplegic patients (20%) out of ten operated on with ophthalmic aneurysms. Fox (11), reported in 1988, that two of eight patients (25%) with paraclinoid ophthalmic aneurysms showed a transient reduction in visual acuity or ipsilateral blindness. Kobayashi et al (17), in 1989, operated on seven patients with the carotid cave subtype of ophthalmic aneurysms, two (29%) of which presented with visual disturbance postoperatively. In 1990, on a series of 54 patients operated for paraclinoid aneurysms, Day et al (6) reported a morbidity rate of 7% and a mortality rate of 6%. In a very large study by Hoh et al (13), presented in 2000, on 238 patients with carotid-ophthalmic aneurysms from which 180 where clipped, he reported a 6% morbidity rate and only a 0.4% mortality. On a series of 81 patients operated for paraclinoid aneurysms, published in 2005, Yonekawa et al (15), reported a surgery-related permanent morbidity in 6 patients (13%), and a surgery-related mortality rate of 0%. The more recent publication of Sames et al. (2014), on a series of 37 carotid-ophthalmic clipped aneurysms, reported two patients got worse after surgery (5.4%, one unruptured), three patients (8.1%) did not improve and the remainder (86.5%) improved in the terms of GOS (25).

Microsurgery with clip ligation, including skull base approaches, is a proven effective and durable means to permanently securing paraclinoid aneurysms with good outcomes (1,6,26). Complications generally revolve around the anatomic structures encountered within the region—the ICA, arterial perforators, and neighboring cranial nerves. Even though intraoperative angiography may demonstrate initial ICA patency, delayed stenosis or thrombosis can still occur. Any evidence of focal neurological deficits after surgery should be immediately addressed with CT and angiography, and the patient returned to the operating room for emergency re-exploration and clip adjustment if obstruction is identified.

Postoperative visual deterioration, a potential complication in all paraclinoid aneurysm operations, is usually attributable to excessive optic nerve manipulation or perforator compromise during the exposure or clip placement. The clip should not compress or rotate the optic nerve that is especially intolerant of torsion. Delayed visual worsening indicates a need for re-exploration to assure the clip is not displaced, causing compression (4). The first series to define the microsurgical anatomy of the ophthalmic segment and meticulously analyze operative results reported excellent outcomes, defined as no postoperative neurological deficit, in 87% of the patients (6). Ischemic injury and/or increased visual deficits occurred in 11% of patients, almost all of whom had had very large or giant aneurysms of the superior hypophyseal artery (6).

In a later study, Nanda and Javalkar (23) observed an 8.7% rate of visual deterioration after surgery. No statistically significant difference in outcome was noted between giant and non-giant aneurysms (23). De Oliveira and colleagues (24) reported that most patients had improved visual function after surgery. Dehdashti and colleagues (7) found an overall surgery-related visual complication rate of 14%.

A far as the recovery of visual dysfunction is concerned, the results reported in the literature suggest first few months (10,29) or three months (5) for an operation to be done from the onset of symptoms. Furthermore, results in the literature suggest that symptomatic unruptured C6 aneurysms should preferably be treated surgically as the actual cause of the symptoms is eliminated in that way. Coiling or flow diverter implantation can exclude the aneurysm from the circulation by inducing thrombosis in the sac, but will not eliminate its expansive behaviour.

Postoperative oculomotor, trochlear, and abducens palsies, as well as ptosis and miosis secondary to sympathetic fiber disruption, are generally the result of surgical trauma during ACP removal, clip blade advancement, excessive cranial nerve manipulation, or cavernous sinus packing. These deficits are usually partial and transient in nature and are best avoided through careful dissection of the cranial nerves and their blood supply.

Conclusion

Paraclinoid aneurysms are known to demand special therapeutic considerations due to their special location of close vicinity to bony structures and important neural and vascular structures. Size and location of the aneurysm, and the fact that it is ruptured or not, are main determinants in the decision to perform surgery. Large and giant aneurysms are daunting the handle without generating new visual deficits. Even it is a small series, the mortality and morbidity of paraclinoid aneurysm surgically treated in our department, both ruptured and unruptured, are relatively low and comparable with the results presented in the literature. For an experienced neurovascular team, microsurgical aneurysm clipping can currently be a good therapeutic option for paraclinoid aneurysms.

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