

Case report of 2 Carotid cave aneurysms: Microsurgical anatomy and technical pitfalls

Abstract

Background: The carotid cave is a virtual space located in the clinoid region. It can be found in up to 77% of patients and be a site of aneurysm formation. The surgery of the paraclinoid aneurysms presents special difficulties due to complicated osseous, dural and neurovascular structures (optic nerve, cavernous sinus, sella turcica) relationships. The authors report two cases of microsurgical clipping of carotid cave aneurysms through Dolenc's approach associated to the pitfalls of the carotid cave microanatomy focusing on its relationship with Internal Carotid Artery (ICA).

Methods: Two cadaveric formalin fixed head was used to show the relevant surgical anatomy of the surrounding area of the clinoid segment of the ICA. The microsurgical anatomy of the region and the surgical technique for approaching carotid cave aneurysm were reviewed. Two illustrative cases are presented to reinforce the surgical technique described.

Results: Based in the anatomical study, the authors performed the extradural clinoidectomy in all cases, aiming to discuss the choice between the extradural and intradural technique. Extradural drilling diminishes surgical time and avoids contamination of the subarachnoid space with bone dust. The anatomical study of extradural approach demonstrates better orientation and extensive unroofing of the optic canal and, consequently, absence of visual impairment.

Conclusion: The ICA has a complex anatomy, especially when all the relationships with the nearby structures are considered. It is relevant to note that proximal control and anterior clinoidectomy are important strategies for managing the carotid cave aneurysms.

Keywords: aneurysms, intracranial aneurysm, internal carotid artery, carotid cave aneurysms

Volume 8 Issue 2 - 2018

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Received: September 09, 2017 | **Published:** March 29, 2018

Abbreviations: ACP, anterior clinoid process; CN II, optic nerve; CN III, oculomotor nerve; CN IV, trochlear nerve; CSF, cerebrospinal fluid; CT, computed tomography; ICA, internal carotid artery; IDR, inferior dural ring; PcomA, posterior communicating artery; SDR, superior dural ring; SHA, superior hypophyseal artery; EVT, endovascular therapy

Introduction

The anatomy of the paraclinoid region is complex and neurosurgeons need precise microsurgical knowledge and ability to treat the aneurysms of this region. The detailed study of the clinoid region aiming to understand the anatomical landmarks and relationships between neurovascular structures (optic nerve, cavernous sinus, sella turcica) and Internal Carotid Artery (ICA) shows a crucial methodology for a safe surgical treatment of the paraclinoid aneurysms.¹ This study presents a review carotid cave anatomy and aneurysms, the surgical technique to reach this area and the report of two cases.

Materials and methods

Two cadaveric formalin fixed head was used to show the relevant surgical anatomy of the surrounding area of the clinoid segment of the ICA. The microsurgical anatomy of the region and the surgical technique for approaching carotid cave aneurysm were reviewed.

Two illustrative cases are presented to reinforce the surgical technique described.

Case report

Two cases are presented in this study. In both situations, the clinoidectomy was performed via Dolenc's extradural approach.

Case 1: A 27-year old woman presented in the office referring chronic headache. The initial screening with magnetic resonance imaging showed a carotid cave aneurysm. Further investigation with angiography (Figure 1) confirmed the diagnosis and the treatment options were proposed to the patient. Surgical treatment was chosen and a microsurgical clipping was performed (Figure 1) using a Dolenc's approach to the clinoidal segment of the ICA. The patient was discharged on the fifth postoperative day without neurological deficits.

Case 2: A 47-year old woman was admitted to the emergency department complaining of strong headache. No neurological deficits were noticed and no meningeal signs were present. The patient had high blood pressure and smoking history. A computed tomography (CT) scan with angio-CT was performed and an incidental aneurysm was noticed. No signs of subarachnoid hemorrhage were noticed on imaging, but it was confirmed by lumbar cerebrospinal fluid analysis. She was discharged and during the follow up an elective surgery was programmed. The patient was submitted to a microsurgical clipping

of the aneurism through a Dolenc's approach (Figure 2) and was discharged on the fifth postoperative day without complications.

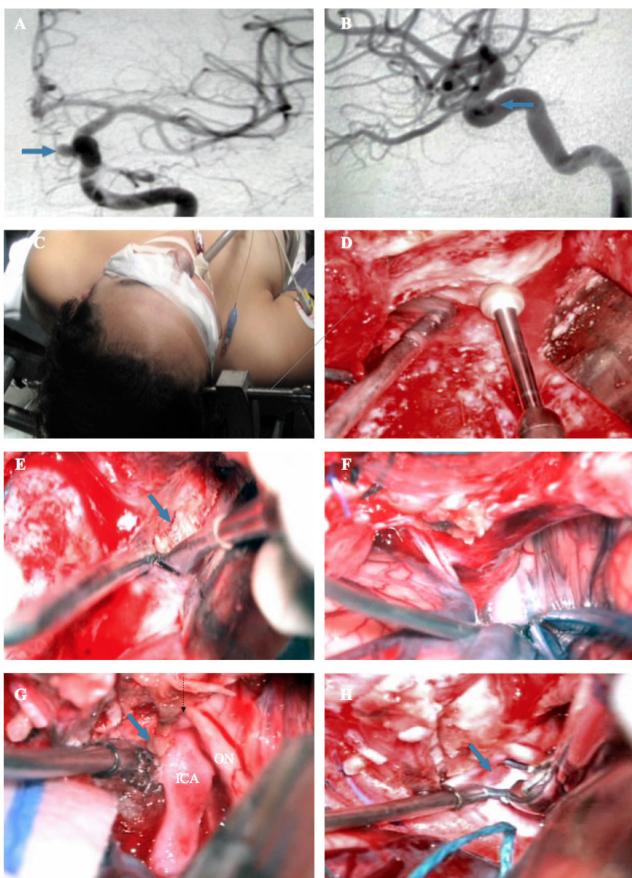


Figure 1 Illustrative Case 1 A and B-Angiography showing a left side aneurism (arrows) of the clinoid segment of ICA with the domus facing medially. C - Patient positioning. D- Sphenoid wing and orbital roof drilling. E- Extradural anterior clinoidectomy. F- Subfrontal approach for CSF drainage. G- Distal dural ring opened (blue arrow) and clinoid segment of the ICA exposed along with the aneurism neck under the ON. H- Aneurism clipping.

CSF, cerebrospinal fluid; ICA, internal carotid artery; ON, optic nerve

Anatomical study and discussion

The Clinoid Segment of the Internal Carotid Artery and its nearby structures

The clinoid is the fifth portion of the Carotid Artery according to the division proposed by Bouthillier et al.¹ in 1996,^{1,2} who segmented the artery in seven portions: C1, cervical; C2, petrous; C3, lacerum; C4, cavernous; C5, clinoid; C6, ophthalmic; and C7, communicating. This classification is practical and accounts for anatomic information and clinical interests.³ Based on anatomical study, the clinoid segment of the Internal Carotid Artery (ICA) is in the transition area from the cavernous sinus to the subarachnoid space, between the proximal (or inferior) dural ring and the distal (or superior) dural ring. Although this location is controversial because not all authors agree it is extracavernous and extradural,³ our results confirmed this description.

The segment has an important relationship with the anterior clinoid process (ACP), which is closely juxtaposed to the lateral wall

of the artery⁴ and must be removed to a better exposure of the medial aspect of the clinoid segment.⁵ The anatomical dissection showed that this carotid portion is tightly surrounded on its lateral, medial and anterior sides by osseous structures, presenting just a narrow space between the bone and artery.⁶ The ACP is projected posteromedially from the optic strut to the minor sphenoid wing.³ The optic strut is a small bridge that extends medially from the inferomedial aspect of the base of the anterior clinoid process to the body of the sphenoid bone in front of the carotid groove (or sulcus). The anterior bend (or genu) of the clinoid segment of the ICA is accommodated on the posterior surface of the optic strut as it ascends on the medial side of the ACP,⁶ which is generally solid, but can be pneumatized and may connect the optic strut with the sphenoid sinus during surgical act. Therefore, this aspect must be considered during the preparation of the surgery to avoid the development of cerebrospinal fluid (CSF) leakage.^{1,7} A recent study suggests examining the ACP with a CT scan before surgery.⁷

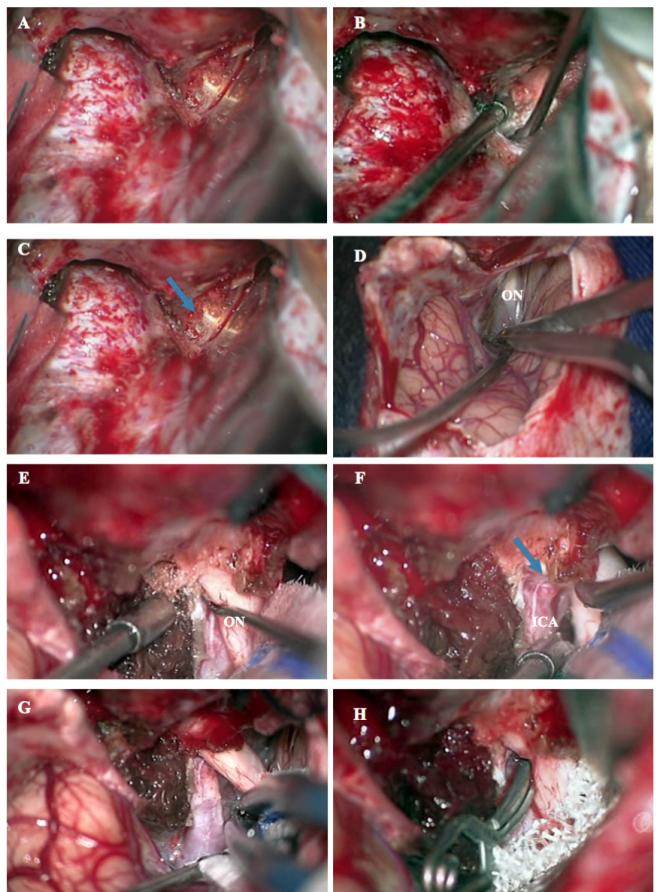


Figure 2 Illustrative Case 2 A, B and C- Extradural anterior clinoidectomy - Dolenc's approach. D - Subfrontal approach for CSF drainage. E- Opening of the distal dural ring. F- Identification of the distal neck of the aneurism (blue arrow). G- ICA rotation to dissect the aneurism proximal neck. H- Aneurism clipping.

CSF, cerebrospinal fluid; ICA, internal carotid artery; ON, optic nerve

The anatomical dissection showed that as the ICA emerges from the cavernous sinus, it closely faces the inferomedial surface of the ACP. At the anterior bend, the ICA curves from anterior to posterior

and from lateral to medial. Distal to the anterior genu, it curves from medial to lateral.³ The posterior aspect of the clinoid segment is in contact with the cavernous sinus if no rigid bony structures are present. The carotid sulcus is excavated in the medial aspect of the wall of the artery. In this area, the dural anchoring of the artery is not tight to the nearby structures as it is in its lateral and anterior aspects. The dural attachments are from the medial surface of the ACP to the lateral wall and from the posterior aspect of the optic strut to the anterior wall.⁶ The anatomical considerations are schematized in Figure 3.

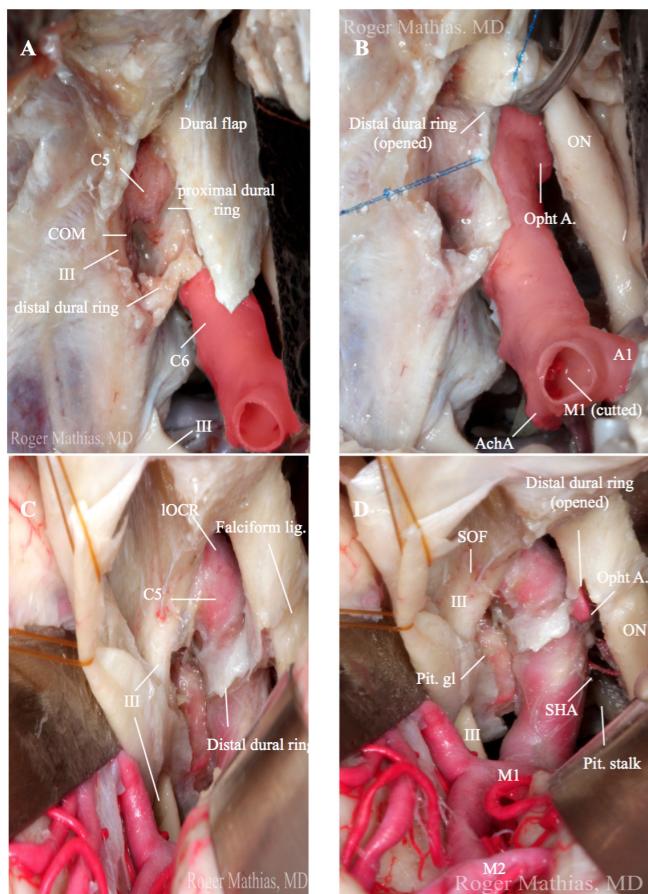


Figure 3 Clinoid segment of the ICA and its surrounding structures. **A** - after intradural anterior clinoidectomy, the clinoid segment of the ICA is exposed. It extends from the proximal to the distal dural ring. The proximal dural ring is contiguous with the COM which is the roof of the cavernous sinus. Below, the final portion of the cavernous carotid lies. **B** - In order to expose the ophthalmic artery the distal dural ring must be resected following the inferior border of the ON. The artery runs from medial to lateral in the majority of the cases. **C & D** - the III cranial nerve entering the SOF after extradural anterior clinoidectomy and further opening of the cavernous sinus roof (COM). In the superomedial aspect of the clinoid segment of the ICA is the IOCR where the optic strut of the anterior clinoid was. At the inferomedial aspect of the clinoid segment of the ICA the pituitary gland can be founded. The pituitary stalk and the SHA are located in the depth of the optic-carotid triangle. And by opening the distal dural ring following the inferior border of the ON, the ophthalmic artery is founded. AchA, anterior choroidal artery; COM, carotidoculomotor membrane; C5, cloned segment of the internal carotid artery; III, oculomotor nerve; ICA, internal carotid artery; IOCR, lateral optic-carotid recess; ON, optic nerve; SHA, superior hypophyseal artery; SOF, superior orbital fissure

The dural rings of the Internal Carotid Artery

The two dural rings of the region are the boundary of the clinoid segment.⁵ The inferior dural ring (IDR) is just above the cavernous sinus, forming its roof. It is continuous with the dura covering the inferolateral aspect of the ACP⁴ and extends to the medial aspect of the oculomotor nerve (CN III).¹ The dura extends anteriorly from the skull base to the ACP and involves the ICA when it enters the subarachnoid space; in this way the superior dural ring (SDR) is determined.¹ In its medial aspect, the SDR continues with the falciform ligament, overlying the optic nerve (CN II) and connecting itself to the superomedial aspect of the ACP.^{4,8} This upper ring is anatomical related to bone structures: ACP in its posterior, superior and medial aspects. Although the SDR is firmly tight to the adventitia of the lateral wall of the ICA, it can form a virtual space in the medial aspect of the artery: the carotid cave.³ Because the posteromedial wall of the ICA is not strictly in contact with bone structures, this is the site in which carotid cave aneurysms could emerge.^{1,9} The SDR is fused with the IDR posteriorly, but they are separated anteriorly.⁴

Arterial and neural structures

Surgically, the two arteries that arise from the ICA close to the carotid cave region are the ophthalmic and the superior hypophyseal artery (SHA) and the latter may arise in the carotid cave. The ophthalmic artery is distant 3mm to the SDR, ranging from 2 to 4mm. It is uncommon, but the artery can arise from the clinoid segment below the distal ring. Also rarely, it can arise from the middle meningeal or from the basilar artery.¹⁰ The usual origin of the ophthalmic artery is in the anteromedial wall of the ICA. The SHA usually originate from the ventromedial wall.³

The dissection showed that the CN III is separated from the lower margin of the ACP by the dural ring. The trochlear nerve (CN IV) is also part of the anatomy of the region, as it enters the roof of the cavernous sinus just posterolateral to the entry point of the CN III.¹⁰

The Carotid Cave

The Carotid Cave was named by Kobayashi et al.¹¹ in 1989 to describe the virtual small pouch limited superiorly by the medial surface of the SDR, laterally by the medial wall of the ICA and medially by the carotid groove.^{3,10} This virtual space is found in approximately 68% to 77% of the specimens, according to some studies¹² and can be a site of aneurysm formation. The cave may extend downward near the lower ring¹⁰ and its apex is formed by connective tissue communicating with the clinoidal venous plexus. This fact may explain why enormous aneurysms could origin in this area, as showed in the cases, and why they could expand into the extradural and intradural spaces.³ It is also important to consider during the surgical act that Kobayashi et al.¹¹ reserve the term of “clinoid space” to the lateral aspect of the ICA, usually considered an extracavernous and extradural region. On the other hand, the carotid cave can contain the subarachnoid space.⁴ Some studies identified three patterns of the cave: slit (34% of the cases), pocket (24%) and mesh (10%).^{1,9}

Paraclinoid aneurysms

Nutik was the first one to use the term “paraclinoid aneurysm”. It is used to describe the aneurysms arising from the portion of the ICA between the roof of the cavernous sinus and the origin of the

posterior communicating artery (PcomA), in a region opposed to the ophthalmic artery.^{3,13}

The paraclinoid aneurysms rupture rate is lower than the supraclinoidal aneurysms. The growth of the latter is limited by the sphenoid bone medially and the ICA laterally. The absence of bone contact in the posteromedial portion of the SDR facilitates the formation of aneurysms in this region.^{1,3} Various classification systems have been proposed for the paraclinoid aneurysms, based on intraoperative or angiographic findings.^{1,10,13} In 2003, Barami¹⁰ proposed a new classification system based on angiographic findings and many other authors have used his classification.^{1,3,13} The paraclinoid aneurysms are divided in six classes:^{10,13}

- i. Type Ia: arising from the superior ophthalmic segment of the ICA and related to the ophthalmic artery.
- ii. Type Ib: arising from the superior ophthalmic segment but without relationship with ICA branches.
- iii. Type II: arising from the ventral ophthalmic segment of the ICA without ICA branches relations.
- iv. Type IIIa: arising from the medial ophthalmic segment of the ICA and related to the SHA.
- v. Type IIIb: arising from the medial clinoid segment of the ICA below the dural reflection.
- vi. Type IV: involving the ventral clinoid and the ophthalmic segment of the ICA

The original study found that type Ia was the most common, corresponding to the 43% of the cases.¹⁰ A recent study¹³ suggested a modification of Barami's classification merging types Ia and Ib into a single group: the "carotid ophthalmic aneurysm". Type II was named "ventral paraclinoid aneurysm" and type IIIa was classified "superior hypophyseal aneurysm". The authors suggested that this system is more straightforward for surgical decision-making.

Angiography and diagnosis

Based in the literature and present cases, the diagnosis is confirmed by angiography and/or other image complementary exams and the carotid cave aneurysm can be differentiated from other paraclinoid aneurysms by some angiographical findings. The carotid cave aneurysms are projected medially in semicircular berry shape in anteroposterior view. In the lateral view, these aneurysms don't have the axillary space that, according to Zang,¹⁴ is the site between the axilla (area inside the genu of the ICA) and the anterior wall of the aneurysm, which is usually present in other paraclinoid aneurysms.¹⁴ As reported in both cases, the angiography usually doesn't precise the localization of the paraclinoid aneurysms in relation to the SDR, which may be better visualized by magnetic resonance as demonstrated by Lee.⁸

Treatment options

Due to complicated osseous, dural and neurovascular structures (optic nerve, cavernous sinus, sella turcica) showed during dissection and cases, the surgery of the paraclinoid aneurysms presents special difficulties.³ The ACP usually is an obstacle in clipping these aneurysms. Some measures of the ACP show the average length from the level of cranial edge of the optic canal roof to the tip of the process

of 7.7mm and 4mm of width. The visualization of the proximal ICA is increased without entering the cavernous sinus when the ACP is removed, exposing the distal C4, C5 and the proximal C6 segments of the ICA. The clinoid space is also better analyzed after the removal of the ACP.^{5,13}

We performed the extradural clinoidectomy in all cases reported, as originally proposed by Dolenc,¹⁵ but there is no consensus between extradural and intradural technique. Extradural drilling is claimed to be quicker and diminishes contamination of the subarachnoid space with bone dust. It also may facilitate anatomical orientation and unroofing of the optic canal. In a different point of view, some authors assume that the dura is not a safe barrier with current high-speed drills.¹³

There isn't also a consensus about the craniotomy side. Between 1980 and 1998, Sheikh et al postulated the ipsilateral approach for exposure and securing of carotid cave aneurysms. However, in 4 patients, the authors had the opportunity to use a contralateral approach to carotid cave aneurysms, with easier dissection and application of a simple aneurysm clip, demonstrating that the visual acuity did not deteriorate from the preoperative level,¹⁶ which is feared, common and important complication,^{17,18} as discussed later in this study.

Moreover, some authors perform a carotid occlusion test before surgery in patients with complex ICA aneurysms to evaluate the safety of ICA temporary occlusion,¹⁷ but the argument is still controversial.³ Some authors believe the endovascular therapy (EVT) is the primary treatment option for clinoid segment aneurysms.¹³ For this topic, a recent study¹⁹ compared the endovascular and the microsurgical treatments. The EVT was considered the first option for medial and ventral paraclinoid aneurysms and the microsurgery was indicated for large or giant aneurysms, wide neck or irregular shape. The surgery was also indicated for the dorsally located paraclinoid aneurysm if an easily surgical access and a non-extensive resection of the ACP was predicted based on the pre-operative studies and exams. This study found 65.6% of complete occlusion for initial results of EVT (based on Raymond grading system) and 100% for microsurgery. The follow-up results reported 94.2% stable status for embolization of EVT and 96.8% for microsurgery.

Another recent study²⁰ compared the visual outcomes of EVT to microsurgery treatment for large or giant paraclinoid aneurysms. It reported that visual field deficits had different patterns depending on the different strategies used: worsening of the upper visual field in patients treated with EVT and ipsilateral nasal inferior quadrantanopia after microsurgical clipping. As expected in the study, the severity of the optic nerve compression was related to the outcome and prior visual deficit was predictor of a poor visual outcome.^{17,20} Some techniques may help prevent the occurrence of visual complications, such as unroofing of the optic canal, gentle and brief retraction of the CN II, and continuous irrigation during drilling.¹⁸

Conclusion

The ICA has a complex anatomy, especially when all the relationships with the nearby structures are considered. A precise understanding of the paraclinoid anatomy is necessary for a safe approach of aneurysms arising in that region. It is also relevant to note that proximal control and anterior clinoidectomy are important strategies for managing the carotid cave aneurysms.¹⁸

Acknowledgments

None.

Conflicts of interest

The authors declare no conflict of interest.

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