Review Article

DOI: https://doi.org/10.55684/2024.82.e00005

The role of clinocarotid foramen in ophatalmic artery aneurysms surgery

O papel do forame clinocarotídeo na cirurgia de aneurismas da artéria oftálmica

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ABSTRACT

Introduction: The anterior clinoid process may present anatomical variations between individuals, even with changes in the same individual (between sides), mainly related to the formation of a bone bridge between it and the middle clinoid process and the clinoid process later. Recognition of the clinocarotid foramen is important in the treatment of aneurysms of the ophthalmic segment of the internal carotid artery, since the need to perform anterior clinoidectomy may result in inadvertent injury to the vascular structures.

Objective: To review the incidence of clinocarotid foramen and interclinoid bone bridge in current literature.

Methods: Integrative review collecting existing information on virtual platforms using the descriptors "brain aneurysm, skull base, internal carotid artery, sphenoid bone" with AND or OR search.

Result: Twenty-five articles were found who met the objective, being read and summarized for this review.

Conclusion: The presence of aneurysms in the paraclinoid region/ophthalmic segment of the internal carotid artery has a higher incidence in both the clinocarotid foramen and the interclinoid bone bridge.

KEYWORDS: Brain aneurysm. Skull base. Internal carotid artery. Sphenoid bone.

RESUMO

Introdução: O processo clinoide anterior pode apresentar variações anatômicas entre os indivíduos, até mesmo com alterações no mesmo indivíduo (entre os lados), principalmente relacionado à formação de ponte óssea entre ele e o processo clinoide médio e o processo clinoide posterior. O reconhecimento do forame o clinocarotídeo é importante no tratamento de aneurismas do segmento oftálmico da artéria carótida interna, uma vez que a necessidade de realizar a clinoidectomia anterior pode proceder-se com lesão inadvertida das estruturas vasculares.

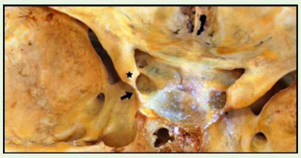
Objetivo: Revisar a incidência do forame clinocarotídeo e ponte óssea interclinoide na literatura atual.

Métodos: Revisão integrativa colhendo informações existentes em plataformas virtuais através dos descritores "aneurisma cerebral, base do crânio, artéria carótida interna, osso esfenoide" e "brain aneurysm, skull base, internal carotid artery, sphenoid bone" com busca AND ou OR.

Resultado: Incluiu-se o total de 25 artigos que foram lidos e resumidos para esta revisão.

Conclusão: A presença de aneurismas na região paraclinoide/segmento oftálmico da artéria carótida interna tem maior incidência tanto do forame clinocarotídeo quanto da ponte óssea interclinoide.

PALAVRAS-CHAVE: Aneurisma cerebral. Base do crânio. Artéria carótida interna. Osso esfenoide.



Presence of the clinocarotid foramen by ossification (black arrow) between the anterior and middle clinoid processes

Central message

The recognition of the clinocarotid foramen is important in the treatment of aneurysms of the ophthalmic segment of the internal carotid artery, since the need to perform anterior clinoidectomy may result in inadvertent injury to the vascular structures. Thus, this article aims to review the incidence of clinocarotid foramen and interclinoid bone bridge described in the current literature.

Perspective

The presumably initial factor for the formation of cerebral aneurysms is the injury to the vascular endothelium, in direct relation to changes in the shear stress of the wall. This theme is the object of study of new imaging methods. It is believed that with further studies, mainly related to the analysis of intra-arterial flow and wall shear stress, it would be possible to evaluate the relationship with the formation of cerebral aneurysms.

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Conflict of interest: None | Funding: None | Received: 2023-08-27 | Accepted: 2023-12-03 | Correspondence: gisolan@yahoo.com.br | Editor Associado: Thelma Larocca Skare

How to cite:
Cândido DNC, Monteiro JM, Barbosa B, Brito JNPO, de Araújo RL, Almeida TAL. O papel do fora-me clinocarotídeo na cirurgia de aneurismas da artéria oftálmica. BioSCIENCE. 2024;82(1):e005

INTRODUCTION

Cerebral aneurysms correspond to severe cerebrovascular disease and require surgical expertise for their treatment. They can be found in various topographies of the intracranial arteries; however, when they are located in the ophthalmic/paraclinoid segment of the internal carotid artery (ICA), they correspond to only 3-5% of these intracranial lesions.[1,2] When dealing with its treatment in the paraclinoid region, the neurosurgeon needs extensive anatomical knowledge, especially of the relationship between the anterior clinoid process and the ophthalmic segment of the ICA, since in the vast majority of cases it is necessary to surgically remove this process in order to achieve the ideal treatment.[1-3] However, there are some anatomical variations, such as ossification between the anterior clinoid process (APP) and the middle clinoid process, forming the clinocarotid foramen, ossification between the APP and the posterior clinoid process, forming the interclinoid bony bridge. These occurrences make the surgical approach difficult and may increase the risk of inadvertent injuries to the ICA during its exposure.[4,5]

Although some studies have shown the incidence of the clinocarotid foramen in different populations, few have mentioned its finding through the use of new techniques in imaging studies. There are also no studies in the literature that correlate this anatomical variation with specific aneurysms of the ophthalmic/paraclinoid segment of ICA. It is hypothesized that the occurrence of this foramen makes the ICA more fixed and immobile, responsible for changes in intra-arterial flow with greater turbulence and consequent increase in the incidence of these aneurysms. Thus, it is expected to find a higher incidence of clinocarotid foramen and interclinoid bone bridge in patients with aneurysms of this arterial segment, when compared to the findings in the general population.

The aim of this study was to review the presence of interclinoid bone bridge in patients with aneurysms of the ophthalmic/paraclinoid segment of the ICA.

METHOD

Integrative review made by collecting published and existing information on virtual platforms (SciELO – Scientific and Electronic Library Online, Pubmed, Scopus and Google Scholar). We began by searching for descriptors using MESH, defining the terms "cerebral aneurysm, skull base, internal carotid artery, sphenoid bone" and "brain aneurysm, skull base, internal carotid artery, sphenoid bone" with AND or OR search. A total of 25 articles were read and summarized for this review.

RESULT

The parasellar region is a surgical corridor for accesses to the skull base. The anatomical complexity of this region and surrounding structures confer a great challenge for the treatment of its diseases, even for more experienced neurosurgeons.[6,7] APP is a key structure due to its close relationship with ICA, cavernous sinus, optic nerve and optic canal, superior orbital fissure and its contents (oculomotor nerve, trochlear nerve, ophthalmic division of the trigeminal nerve and vascular structures).

The removal of APP through the procedure of extradural anterior clinoidectomy for the treatment of paraclinoid/carotid-ophthalmic aneurysms was first described by Dolenc (1985). This procedure redefined the neurosurgeon's armament not only for the treatment of vascular diseases, but also improved the possibility of complete removal of tumor lesions with extension to the optic canal and cavernous sinus.

APP is a bony prominence that originates from the medial and posterior extension of the lesser wing of the sphenoid bone, attaching to it through 3 points, namely, anterolateral that continues in the minor wing of the sphenoid, anteromedial in extension to the planum sphenoidale and corresponding to the roof of the optic canal, and posterior fixation - also called optic abutment - that composes the inferolateral wall of the optic canal and separates it from the superior orbital fissure.[8] This structure may present some anatomical variations, such as the pneumatization of the anterior clinoid process, and other less frequent ones, such as the clinocarotid foramen (in relation to the middle clinoid process) and the interclinoid bony bridge (in relation to the posterior clinoid process).[5,6,8,9-18]

The clinocarotid foramen consists of the ossification of the carotidoclinoid ligament that extends from the medial side and tip of the anterior clinoid process and attaches to the tip of the middle clinoid process, creating a bony canal around the ICA at the point where it exits the cavernous sinus at the level of the distal dural ring of the ICA (Figure 1).[5-8,13]

This situation makes it very difficult and risky to remove this anterior clinoid process with the possibility of vascular injury in the ICA. The interclinoid bony bridge is related to the ossification of the interclinoid ligament between the anterior clinoid process and the posterior clinoid, as a component of the oculomotor trigone at the posterior part of the roof of the cavernous sinus.[5,7,8,13]

To remove the anterior clinoid, a procedure described as anterior clinoidectomy, frontotemporal craniotomy (pterional) must initially be performed.[9] The duramater is then separated from the roof of the orbit medially and the superior orbital fissure laterally. Through careful drilage, part of the roof of the orbit and crest of the sphenoid is removed retrogradely to the anterior clinoid and entrance to the optic foramen; In this way, the anterolateral fixation of the anterior clinoid is removed. With high-rotation drilling, the anteromedial fixation of the clinoid to the optic canal roof is removed under continuous irrigation to prevent injury to the optic nerve. Then it is followed by the drilage of the most central part towards the optic pillar, which corresponds to its most posterior fixation and which separates the optic canal from the superior orbital fissure, a place of intimate contact with the ICA when emerging from the cavernous sinus.[3,8]

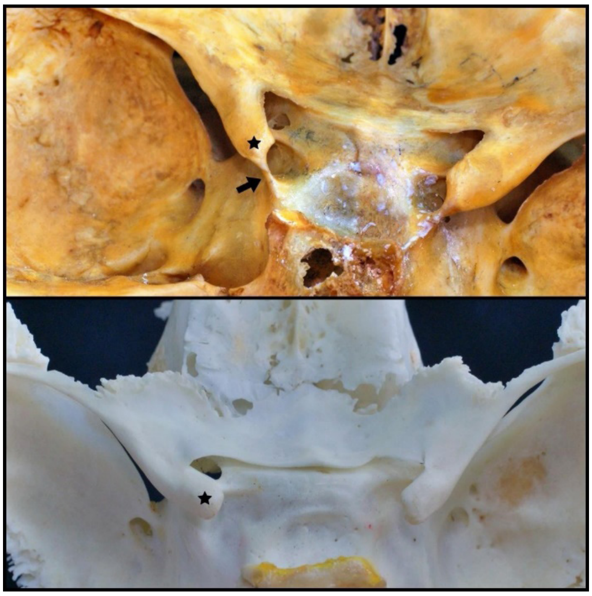
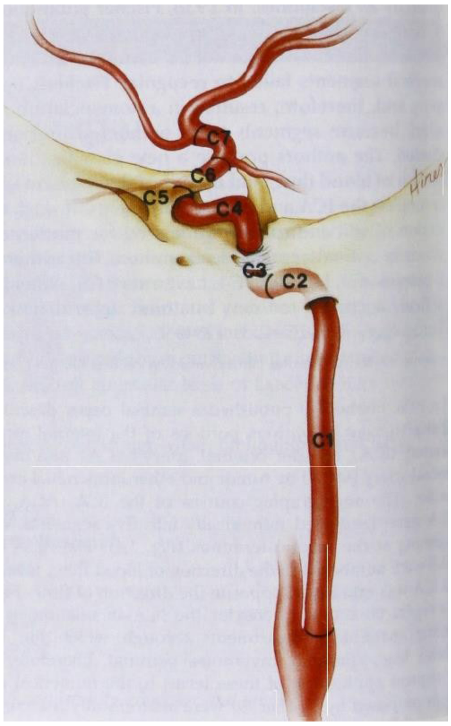


FIGURE 1 — Top photo: anatomical specimen demonstrating the presence of the clinocarotid foramen due to ossification (black arrow) between the anterior clinoid and middle clinoid processes. Bottom photo: anatomical specimen without the clinocarotid foramen variant

Several classifications have been proposed for the segments of the ACI.[2,8] Bouthillier, Van Loveren & Keller et al.[19,] classified it on a numerical scale, dividing it into 5 segments and starting at the intracranial carotid termination (where it divides into the anterior cerebral artery and the middle cerebral artery). Although the middle cerebral artery and the anterior cerebral artery were numbered according to the direction of flow, the ICA was in the opposite direction (anti-flow). To avoid confusion, it is preferable to use the modified Fischer classification, proposed by Bouthillier, Van Loveren & Keller et al.[19,] as it has a more precise clinical-anatomical purpose.

In this classification, the ICA is divided into the following 7 segments: 1) cervical (C1), from the bifurcation of the artery to its entrance into the carotid canal of the petrous bone, just in front of the jugular foramen; 2) petrous (C2), from the entrance into the carotid canal to the posterior border of the foramen lacerum, divided into vertical, posterior curve (posterior loop of the ICA) and horizontal portions; 3) lacerum (C3), from the end of the carotid canal, terminating at the superior margin of the petrolingual ligament, lacerum, containing the lateral curve of the ICA as it ascends towards the cavernous sinus; 4) cavernous (C4), from the petrolingual ligament (superior margin) to the proximal dural ring below the anterior clinoid process with vertical, posterior curve (medial curve of ICA), horizontal and anterior curve (anterior curve of ICA); 5) clinoid (C5), from the proximal dural ring to the distal dural ring, forming part of the anterior curve of the ICA; 6) ophthalmic (C6), starting at the intradural ICA, starting at the distal dural ring and ending proximal to the posterior communicating artery (AComP), this segment being related to the superior pituitary artery (originating from the medial aspect of the ICA) and ophthalmic (originating predominantly on the anterosuperior aspect of the ICA; 7) communicating (C7), starting at the origin of the posterior communicating artery and ending at the bifurcation of the ICA, into the middle cerebral artery and the anterior cerebral artery, which includes the AComP and the anterior choroidal artery (AChA).



Source: Bouthillier, Van Loveren & Keller (1996)19

FIGURE 2 — Segments of the internal carotid artery as described by Bouthillier et al.19

The incidence of clinocarotid foramen has been defined by some authors in different populations and with variations within them. It is reported in about 16.[6%] of the Japanese population,7 35.[67%] in the Turkish,13 27% in the Brazilian4 and 34.[8%] in the Caucasian American.[5]

In 1935, Keyes[5] classified this anatomical variation into 3 types: 1) complete, when 1 bone bridge (or foramen) is present; 2) contact, when the foramen is apparently formed, but on careful inspection there is a line of separation or suture; 3) incomplete, even with a prominent bone spicule and space in the posterior part of the foramen between both clinoids.

In surgical approaches, special attention should be paid to the first 2 types, since they are directly related to high risks due to the anterior clinoid process with the fixed tip, involving the entire ICA and limiting mobilization during anterior clinoidectomy.

In vascular neurosurgery procedures, APP has a great impact on surgery when it is mainly related to the specific location in paraclinoid aneurysms (also classified as the ophthalmic segment of the internal carotid artery), since they are in direct contact with this process.[3,16,20]

Using the classification of Bouthillier, Van Loveren & Keller (1996)19 to better understand paraclinoid aneurysms (ophthalmic segment of the ICA), they are related to the C4 (clinoid) and C5 (ophthalmic) segments.[21.22]

From a surgical perspective, they can be divided into 6 groups, according to the anatomical characteristics of the aneurysms into: clinoid, carotid cavum, superior pituitary artery, ophthalmic, ventral and dorsal.[2,21,23]

Clinoid aneurysms

It is located in the C5 segment, between the proximal and distal dural rings, just below the anterior clinoid process and projecting superolaterally from the ICA, proximally to the ophthalmic artery.

Carotid cavum aneurysms

They are located in the transition from segment C5 to C6, projecting medially from the ICA, in the region of the carotid cavum, but more proximal than the aneurysm of the superior pituitary artery.

Superior pituitary artery aneurysms

They project inferomedially from the ICA in close relation to the sella turcica.

Ophthalmic artery aneurysms

They arise in close relation with the ophthalmic artery, projecting superiorly/superomedially from the ICA in contact with the optic nerve.

Ventral aneurysms

They emerge from the ICA inferiorly, but proximal to the AcomP.

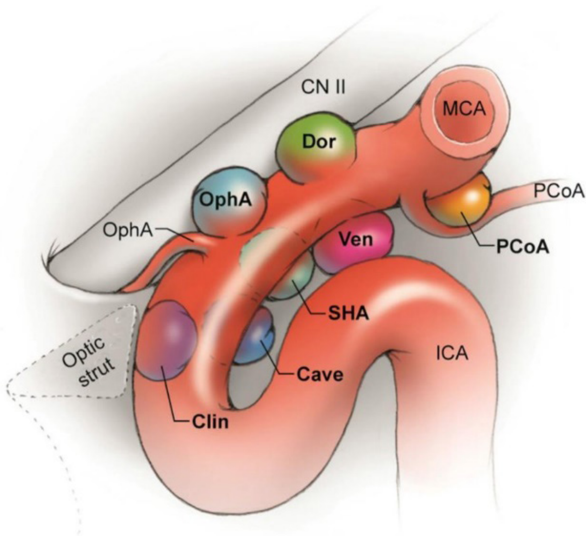
Dorsal aneurysms

They arise in the dorsal wall of the ICA, in the C6 segment, a few millimeters away from the origin of the ophthalmic artery (unrelated to it).

While these last 3 can be seen intradural, cavum and clinoid aneurysms, because they extend from the extradural space to the subarachnoid space, can only be visualized after complete removal of the APP.[2,3,23,24]

When the anterior clinoid process is removed, triangular space is found between the 2 dural rings (proximal and distal) that surround the ICA, called the clinoid trine, where the so-called "carotid cavum" is also identified, in the medial and anterior part of the genu of the ICA, between it and the carotid groove (in the lateral wall of the body of the sphenoid bone). where the distal dural ring is looser or incompletely fixed, as described by Kobayashi et al.[24.]

If it is possible to define the exact point where the lesion has intradural extension, it is possible to predict whether the patient will be at risk of subarachnoid hemorrhage and, thus, a surgical option is offered as a treatment.[21,24] These aneurysms, related to the ophthalmic/paraclinoid segment, will only be accessible to surgical treatment if anterior clinoidectomy is performed safely, which is why each case must be meticulously evaluated with preoperative images so that there is no risk of inadvertent injury when manipulating the clinocarotid foramen.



Source: Lawton (2010)2

FIGURE 3 — Image showing the subtypes of paraclinoid aneurysms: ICA = ACI; MCA = middle cerebral artery; CN II = second cranial nerve; Clin = subtype of clinoid aneurysms; Cave = carotid cavum aneurysm subtype; SHA = subtype of superior pituitary artery aneurysms; OphA = subtype of ophthalmic artery aneurysms; Vent = subtype of ventral aneurysms; Pain = subtype of dorsal aneurysms.

Cerebral aneurysms of the ophthalmic segment of the ICA are uncommon lesions, with an incidence of about 3-5% among all cerebral aneurysms.[1,2] that the incidence of clinocarotid foramen ranges from 6.27% to 34.8% in the general population.[4,7,13,23]

Most studies related to this anatomical variation have not yet been able to define whether it is a congenital or acquired alteration, or whether it may have some relationship with an increased incidence of vascular lesions, such as cerebral aneurysms in this region, since such studies were carried out on specimens of dry skulls or through findings in imaging exams. 4,7,13,23

In the Turkish population, Erturk, Kayalioglu, Govsa 13, reported a high incidence of clinocarotid foramen (35.67%) in a sample of 171 skulls (dry and cadaver), corresponding to 342 sides. However, the complete and contact subtypes were 4.09% and 4.68% of their series. The interclinoid bone bridge was found in about 8.4% of the specimens.

In 1989, Azeredo, Liberti & Watanabe4 studied 270 skulls of adults of both sexes and identified the presence of the clinocarotid foramen in about 6.27% and the interclinoid bone bridge in 2.22% of the specimens; however, they did not differentiate between the 3 subtypes, as described by Keyes (1935).

The results of Ota et al. (2015)7, showed a higher prevalence of bone beams of the skull base surrounding the ICA, with about 16.6% (12/72) cases of clinocarotid foramen and 2.8% (2/72) cases of interclinoid bone bridge. These authors found these findings in the investigation of patients with paraclinoid aneurysms, but they did not subclassify or determine exactly which subtypes of aneurysms they were. This can lead to selection bias, since it ends up encompassing aneurysms in the intracavernosal portion (C4) of the ICA, since these lesions are totally extradural. The classification of "paraclinoid" aneurysms is somewhat confusing in the literature and comprises a very broad group of lesions. Thus, the authors of this review adopt a more anatomical classification that is directly related to the anterior clinoid process, using the C5 (clinoid) and C6 (ophthalmic) segments to define this paraclinoid segment well

Several studies have been emerging with a focus on identifying factors related to the genesis, expansion and risk of rupture of cerebral aneurysms. Notably, there has been great evolution with advances in imaging with 3D fluid flow models, known as "computational fluid dynamics". The various parameters that have been studied evaluate the relationship between hemodynamic stressors and the pathogenesis of cerebral aneurysms, such as Wall Shear Stress (WSS).[25]

The presumably initial factor for the formation of cerebral aneurysm is the vascular endothelial lesion, which has already demonstrated a direct relationship with changes in this wall shear stress (WSS), which is the object of study of new imaging methods. It is believed that further studies, mainly related to the analysis of intra-arterial flow and wall shear stress (WSS) in patients with these variations, would be necessary to evaluate the relationship with the formation of cerebral aneurysms in this region.

CONCLUSION

The presence of aneurysms in the paraclinoid region/ ophthalmic segment of the ICA has a higher incidence of both the clinocarotid foramen and the interclinoid bone bridge.

Authors' contributions

Conceptualization: Duarte Nuno Crispim Cândido
Methodology: Duarte Nuno Crispim Cândido
Writing (original draft): All authors
Writing (proofreading and editing): All authors

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