Acta Neurochirurgica (2019) 161:2583–2586
https://doi.org/10.1007/s00701-019-04066-1

HOW I DO IT - NEUROSURGICAL ANATOMY

How I do it: extradural clinoidectomy

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Received: 14 June 2019 / Accepted: 9 September 2019 / Published online: 15 October 2019

Abstract

Background Removal of the anterior clinoid process expands the anterolateral corridor. Performed extradurally, the dura provides intracranial contents some protection.

Methods The anatomy of the anterior clinoid process is described along with variants of the surrounding structures. In addition to an operative video, the anatomy and surgical technique is demonstrated in virtual reality space to enhance the didactic clarity.

Conclusion The anatomical nuances of the lesser sphenoid wing in general, and the anterior clinoid process in particular, are complex. A demonstration in virtual reality takes advantage of the technological flexibility of multi-angled perspectives and focuses on the relevant key structures.

Keywords Anterior clinoid process · Optic strut · Carotid artery · Optic nerve · Virtual reality

Abbreviations

ACP	Anterior clinoid process
MCP	Middle clinoid process
PCP	Posterior clinoid process
OC	Optic canal
OS	Optic strut
SOF	Superior orbital fissure
CSF	Cerebrospinal fluid
CT	Computer tomography

Relevant surgical anatomy

The anterior clinoid process is part of the lesser wing of the sphenoid bone, and a clinoidectomy can increase the exposure in the anterolateral corridor. Laterally, it hangs above the superior orbital fissure. Medially, it is attached to the body of the sphenoid bone via two roots: (1) the roof of the optic canal and (2) the optic strut (Fig. 1). A middle clinoid process is present 40% of the time [2], and in a quarter of those, an osseous bar extends all the way to the ACP forming a complete "carotidcoclinoid foramen" [2, 5, 6].

A clinoidectomy can be performed after the dura is opened (intradural), or before (extradural). Compared to the intradural

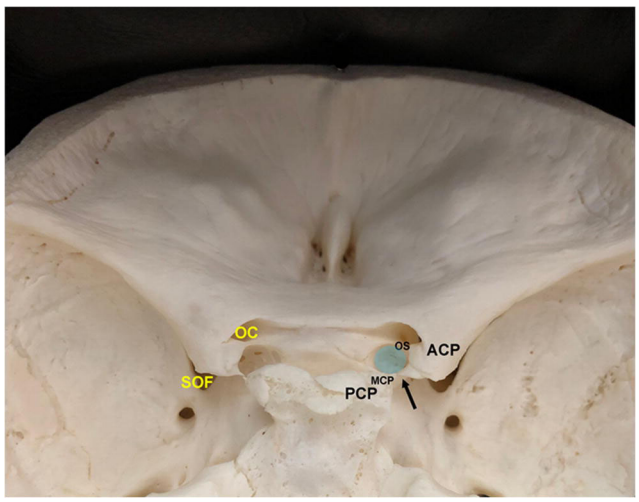

Fig. 1 Anatomy and variants of the anterior clinoid process. The anterior clinoid process hangs over the superior orbital fissure and attaches medially to the body of the sphenoid bone via the roof to the optic canal and the optic strut. A middle clinoid process is present 40% of the time, and in a quarter of those, an osseous bar extends all the way to the ACP (black arrow) forming a complete caroticoclinoid foramen (shaded in blue). OC, optic canal; OS, optic strut; ACP, anterior clinoid process; MCP, middle clinoid process; PCP, posterior clinoid process; SOF, superior orbital fissure

This article is part of the Topical Collection on *Neurosurgical Anatomy*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00701-019-04066-1) contains supplementary material, which is available to authorized users.

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variant, the extradural method prevents the "bone dust" from the drilling to permeate the cerebrospinal fluid and reduces the risk of postoperative headache [1, 7].

Description of the technique

The technique for extradural clinoidectomy is demonstrated in the accompanying video in virtual reality space, as well as in a patient with a medial sphenoid wing meningioma (Video 1, Fig. 2). The virtual reality "simulation" can serve as useful rehearsal prior to the actual operation.

In order to remove the ACP extradually, it must be detached from all its anchors to the lesser wing of the sphenoid bone. To access the lateral sphenoid wing, the cranial opening can be a pterional craniotomy or variations such as an orbitozygomatic craniotomy. The patient is positioned supine with the head turned to the contralateral side, and the temporalis muscle can be reflected inferolaterally with the skin flap. The lateral aspect of the lesser wing is removed in common fashion all the way up to the SOF. The meningo-orbital band can then be coagulated and cut to improve the exposure to the ACP attachments [3]. Next, the base of the ACP, directly above to the medial portion of the SOF, is drilled away.

The next crucial step is uncovering the optic nerve. The posterior roof of the orbit is carefully drilled away until the underlying periorbital is completely uncovered. Tracing this posteriorly, the optic nerve is unroofed, all the way back to the optic canal. At this point, one of the two medial anchors of the ACP has been detached. Back to drilling the ACP itself, the medial edge bordering the uncovered optic nerve is drilled away, proceeding deep into the operative field. By hugging first the lateral border of the optic nerve, and then inferolateral to it, the drilling progressively removes the optic strut.

When the drilling of the optic strut is nearing completion, one might notice that the ACP is loose. When this is readily apparent, a dissector is used circumferentially around the rest of the ACP to strip away its dural attachments. The ACP can then be fractured away from the rest of the OS and removed with graspers.

Indications

A clinoidectomy can be useful to increase exposure for vascular lesions, such as ophthalmic or internal carotid artery aneurysms, and tumors, such as medial sphenoid wing meningiomas.

Limitations

When the clinoid process is pneumatized (Fig. 3), a clinoidectomy would create a direct communication with the paranasal sinuses. An arduous dural closure and risk of cerebrospinal fluid leak may render the clinoidectomy ill-advised. A complete caroticoclinoid ring amounts to an additional medial attachment of the ACP to the sphenoid bone and makes the extradural clinoidectomy more difficult and risky. Rarely, a paraclinoid aneurysm can erode the ACP, making extradural clinoidectomy exquisitely dangerous [4]. In this unusual situation, if the clinoidectomy is unavoidable, it should be done intradurally and with the cervical carotid artery exposed for control.

How to avoid complications

During the drilling of the roof of the optic canal and the optic strut, the optic nerve and carotid artery are vulnerable to injury. A "feathered" touch with the diamond drill bit is critical to prevent mechanical damage to these structures. Careful preoperative assessment of thin-cut CT scan is important for detection of anatomic variants, such as pneumatization or

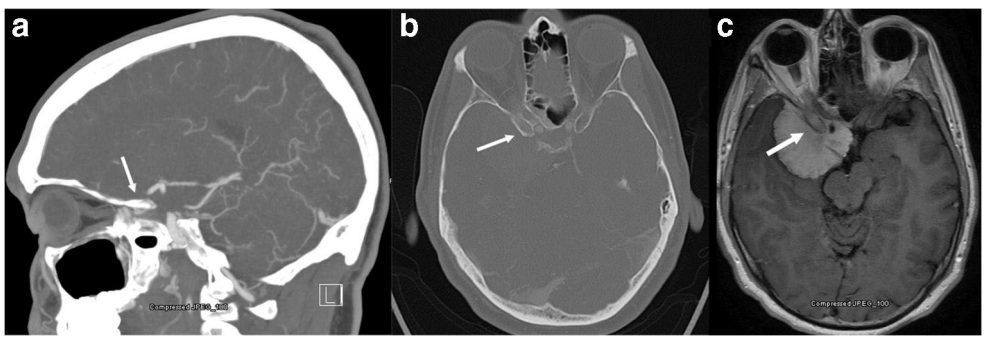

Fig. 2 Extradural clinoidectomy in a patient with a meningioma. **a** Sagittal CT, **b** axial CT, and **c** axial MRI with gadolinium of the patient in the video demonstration. The patient had a large medial sphenoid wing meningioma. Since the ACP (white arrow) was infiltrated with tumor, the clinoidectomy was done not only to expand the surgical exposure but also to increase the extent of tumor resection

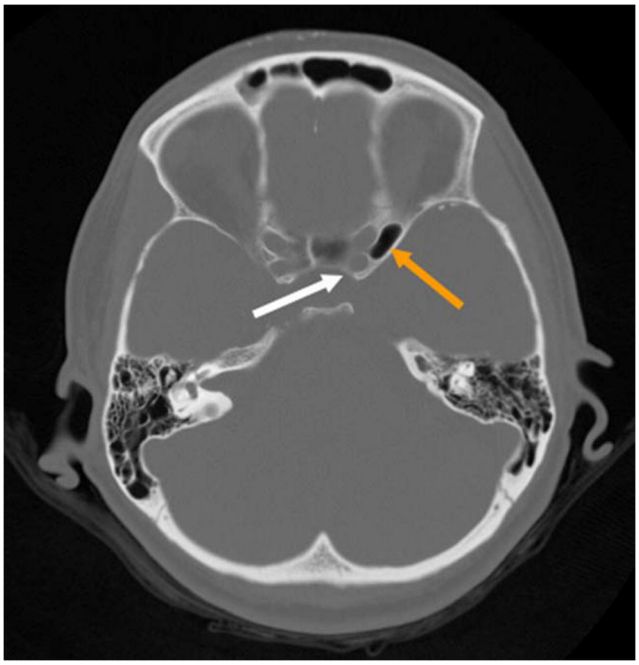

Fig. 3 Pneumatized clinoid. A CT scan shows a subject with a pneumatized left anterior clinoid process (orange arrow). Note also that a complete caroticoclinoid foramen is also present (white arrow)

aneurysmal erosion, which can make extradural clinoidectomy dangerous or impossible.

Specific perioperative considerations

A thin-cut CT angiogram is important to evaluate the surrounding vascular and osseous anatomy prior to an extradural clinoidectomy. Particular attention must be paid to the existence of clinoid pneumatization and the presence of a middle clinoid process (Fig. 3). A complete caroticoclinoid ring may be difficult to see on two-dimensional images, and if its presence is suspected, thee-dimensional renderings should be considered for preoperative anatomic assessment. If the clinoidectomy is done for aneurysm surgery, the position and projection of the aneurysm must be inspected in detail (Fig. 4).

Specific information to give to the patient about surgery and potential risks

The balance between the potential risks of injury to the carotid artery and optic nerve and the benefits of expanding the surgical corridor must be explained to the patient. Unless the anatomy is prohibitive, the latter makes surgery safer, and experience and skill of the surgeon can mitigate the likelihood of the former in the majority of cases.

Summary of key points

1. The anterior clinoid process is a part of the lesser wing of the sphenoid bone overhanging the superior orbital fissure. On its medial side, it attaches to the sphenoid body via the roof of the optic foramen and optic strut.
2. Clinoidectomy can dramatically improve the exposure of the anterolateral corridor for vascular and oncological lesions of the paraclinoid region.
3. During an extradural clinoidectomy, the dura provides some protection to intradural contents from injury, and osseous debris is less likely to permeate the subarachnoid space.
4. Unroofing the optic canal and drilling the optic strut are essential steps to an extradural clinoidectomy.
5. Drilling the optic strut must be done with extreme care, as the exposed optic nerve is medial and the internal carotid artery is directly inferior to the operative area.

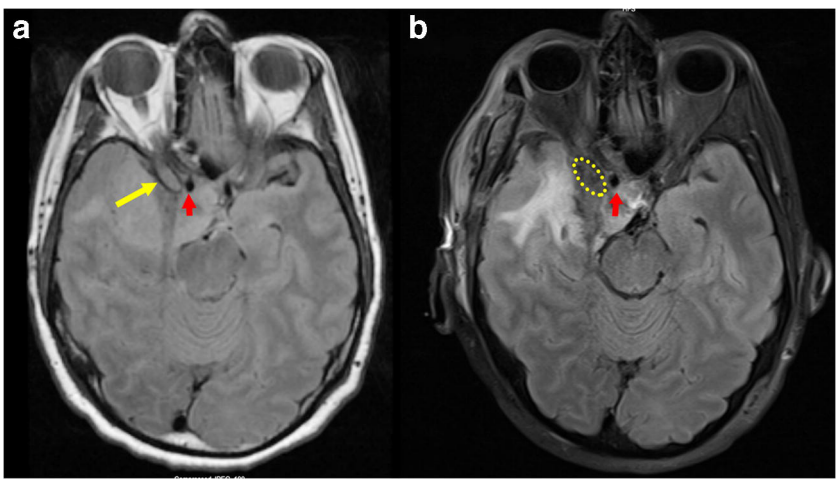

Fig. 4 Before and after clinoidectomy. **a** Preoperative flair MRI with yellow arrow showing the ACP and red arrow showing the internal carotid artery. **b** Postoperative flair MRI with yellow oval showing the absence of the ACP and red arrow showing the same ICA position as the preoperative image. ACP, anterior clinoid process; ICA, internal carotid artery

6. After disconnection from all its anchors to the rest of the lesser sphenoid wing, the dural attachments to the ACP is stripped and then the ACP can be removed with grasper.
7. Careful preoperative anatomic assessment requires detailed inspection of thin-cut CT angiogram studies, and 3D renderings may yield critical information about anatomic variants.
8. For aneurysm surgery, the position and projection of the paraclinoid aneurysm must be inspected carefully as the aneurysm can erode the ACP, making the drilling hazardous.
9. A complete caroticoclinoid ring is a bony anatomic variant extending laterally from a middle clinoid process, and if it exists, an extradural clinoidectomy may not be feasible. Drilling into a pneumatized clinoid can significantly increase the risk of CSF leak, and this must be considered during preoperative assessment
10. A rehearsal in virtual reality may prove useful for teaching and training for a complex procedure such as extradural anterior clinoidectomy.

Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

Consent statement The patient has consented to submission of this How I Do It to the Acta Neurochirurgica.

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