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HOW I DO IT - VASCULAR NEUROSURGERY - ANEURYSM

Surgical clipping of a non-ruptured ophthalmic aneurysm through an extradural micropterional keyhole approach

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Abstract

Background Clipping continues to be one of the treatment strategies for ophthalmic artery aneurysms not amenable for stenting or coiling, or when long-term treatment durability is a concern. However, crescent development of endovascular techniques demands minimal invasiveness in the transcranial approaches while ensuring satisfactory results.

Methods We describe an extradural micropterional keyhole approach (eMKA) to the paraclinoid region and highlight the key anatomical elements of this surgical approach.

Conclusion The eMKA is a minimally invasive approach that provides access to the paraclinoid region using an extradural corridor. Therefore, it is suitable for clipping of ophthalmic artery aneurysms and other paraclinoid aneurysms.

Keywords Minimally invasive · Complications · Morbidity · Paraclinoid · Results

Abbreviations

ACP	anterior clinoid process
eMKA	extradural micropterional keyhole approach
MOB	meningo-orbital band

Relevant surgical anatomy

Authors consider relevant highlighting two important aspects (Fig. 1). The lateral limit of the superior orbital fissure is marked by a fold formed by the periosteal dura covering the frontal and temporal lobes, called the meningo-orbital band (MOB). The MOB sticks the temporal lobe to the wall of the cavernous sinus and the anterior clinoid process (ACP). The ACP is a triangular-shaped structure that obscures the visualization of the paraclinoid region [5]. Anatomically, the ACP is attached to the sphenoid wing by 3 osseous pillars: (1) the lateral pillar, which is constituted by the sphenoid ridge and inferiorly limited by the superior orbital fissure; (2) the medial pillar, which forms the roof of the optic canal; and (3) the inferomedial pillar or optic strut, that separates the supraclinoid internal carotid artery (ICA), inferolaterally, from the optic nerve, superomedially [8].

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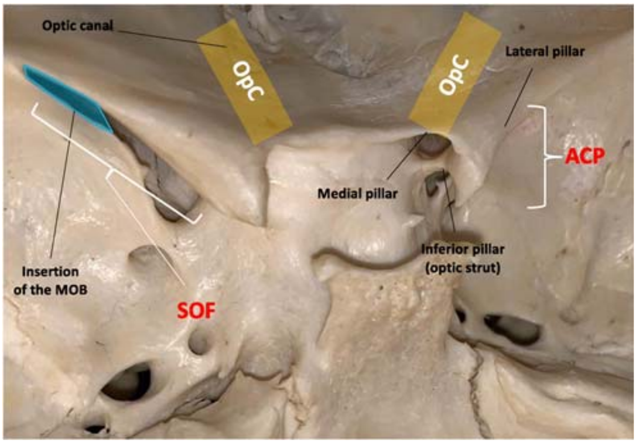

Fig. 1 Dry skull showing the anatomic configuration of the anterior clinoid process (ACP) and its relationship with the optic canal (OC, yellow shadow), the superior orbital fissure (SOF), and the meningo-orbital band (MOB) and the relationships between the meningo-orbital band, the anterior clinoid process, and the optic nerve. The ACP is attached to the lesser sphenoid wing by three pillars: medial, which constitutes the roof of the OC; lateral, and inferior or optic strut. The meningo-orbital band is an important landmark for the interdural dissection (aka minipeeling of the middle fossa) and for exposing the tip of the anterior clinoid process

Description of the technique, extradural micropterional keyhole approach (eMKA) (video)

Positioning and skin incision

Patient's head is positioned using a Mayfield clamp in a similar manner to that described for the pterional approach [10] (Fig. 2). Authors regularly expose the cervical carotid artery for proximal control. A 5 cm curvilinear skin incision behind the hairline extending from a point 1 cm above the zygoma to the mid-pupillary line is usually enough to expose the pterion (Fig. 2). Temporalis muscle is dissected using the interfascial technique and retracted inferiorly until the orbital rim and the pterion are exposed.

Craniectomy

A keyhole 2.5-cm craniectomy centered over the pterion and beneath the superior temporal line (aka micropterional) is carried out (Fig. 3). The dura covering the temporal and frontal lobe is exposed (Fig. 4a). Then, the sphenoid ridge is drilled out until the MOB is exposed (Fig. 4b). At this point, a partial orbitotomy on the lateral and superior wall of the orbit is performed. This step is a key to allow the visualization of the optic canal from the orbit through such a narrow corridor.

Extradural work

The MOB is coagulated and sectioned. Thereafter, the periosteal layer of the dura is incised over the lateral wall of the cavernous sinus in order to allow lateral mobilization of the temporal lobe and expose the tip of the anterior clinoid process (Fig. 4c).

Extradural anterior clinoidectomy

This step is carried out using non-drilling techniques as described by Iwasaki and colleagues [2]. At this point, just the medial and inferomedial pillar or optic strut are still holding the ACP in place since after the sphenoid ridge drilling the lateral pillar is gone. So then, we proceed with the decompression of the optic canal and removal of the optic strut using rotating Kerrison and 1-mm rongeurs (Sontec instruments, Centennial, CO, USA) (Fig. 4c). Once liberated from its bony attachments, the ACP is released from the petroclinoidal and interclinoidal ligaments using a no.5 Rhoton dissector (Symmetry surgical, Antioch, TN, USA). Finally, the ACP is removed and the clinoidal segment is exposed. Venous bleeding at this point can be controlled using fibrin glue (Beriplast) and gentle irrigation.

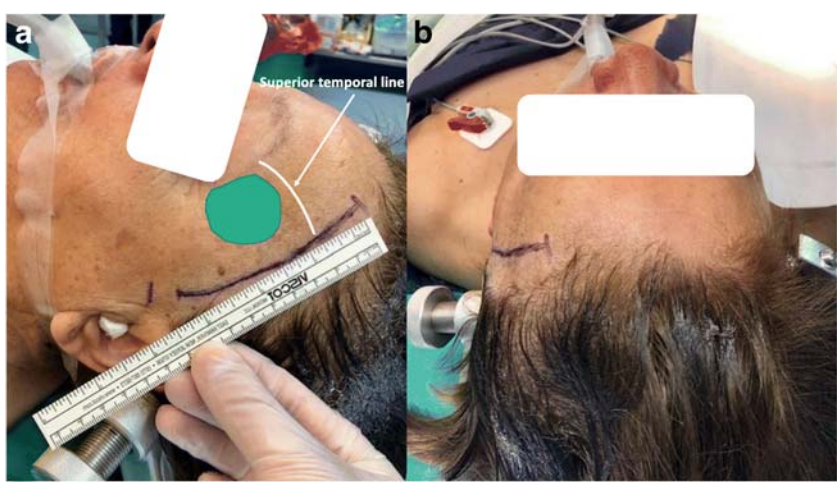

Fig. 2 Patient positioning and skin incision marking. Patient is positioned supine, with the head slightly posteriorly tilted. Axial rotation of the head can be modified from its original position during some parts of the procedure, by changing the orientation of the rotating bet if needed. An arcuate skin incision is placed right behind the hairline, 1 cm above the zygoma and directed toward the midpupillary line, lateral to the supraorbital notch at the level of the upper third of the eyebrow

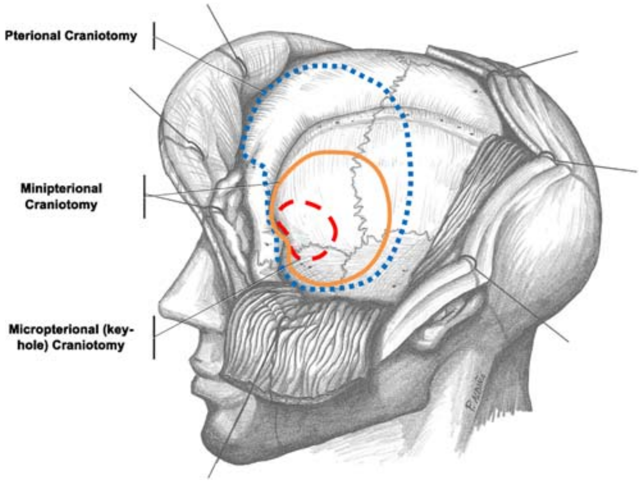

Fig. 3 Schematic representation comparing the different pterion-centered craniotomies. Pterional craniotomy (blue line) includes variable extension of the frontal, parietal, temporal, and sphenoid bone, and its superior limit extends abode the superior temporal line. The minipterional craniotomy (orange line) is a 3 to 4-cm craniotomy, and its superior limits are constituted by the superior temporal line. The micropterional or keyhole pterional craniotomy is a 2 to 3-cm craniotomy centered over the pterion

Dural incision

The dura and optic sheath are incised linearly following the axis of the Sylvian fissure in the direction of the optic nerve (Fig. 4) [3]. The distal dural ring is sectioned to allow supraclinoid ICA mobilization and aneurysm exposure (Fig. 4D).

Intradural work and clipping

The extradural work provides a straightforward corridor to the paraclinoid region. Hence, none or minimal Sylvian dissection is required. In non-ruptured aneurysms, opening of the opticocarotid cistern and cerebrospinal fluid drainage induce enough brain relaxation to manipulate small and medium size aneurysms [4].

Once the aneurysm neck is adequately identified and dissected, we proceed with the aneurysm clipping. Once both blades are located in each side of the neck, it is a key to ensure that any perforator would be trapped by the clip. For carotid-ophthalmic superomedially-pointing aneurysms, we advise using a laterally curved low profile clip, as the clip itself allows visualization of both clip blades during clipping, following a curvilinear trajectory from lateral-to-medial and anterior-to-posterior.

Closure

The dura is closed in a watertight fashion at its distal part and approximated at its proximal side using 3–0 silk. Small tiny holes are plugged using temporalis fascia and fibrin glue.

Indications

– Broad-based carotid-ophthalmic aneurysm not suitable for endovascular treatment [4, 6, 7] (Fig. 5)

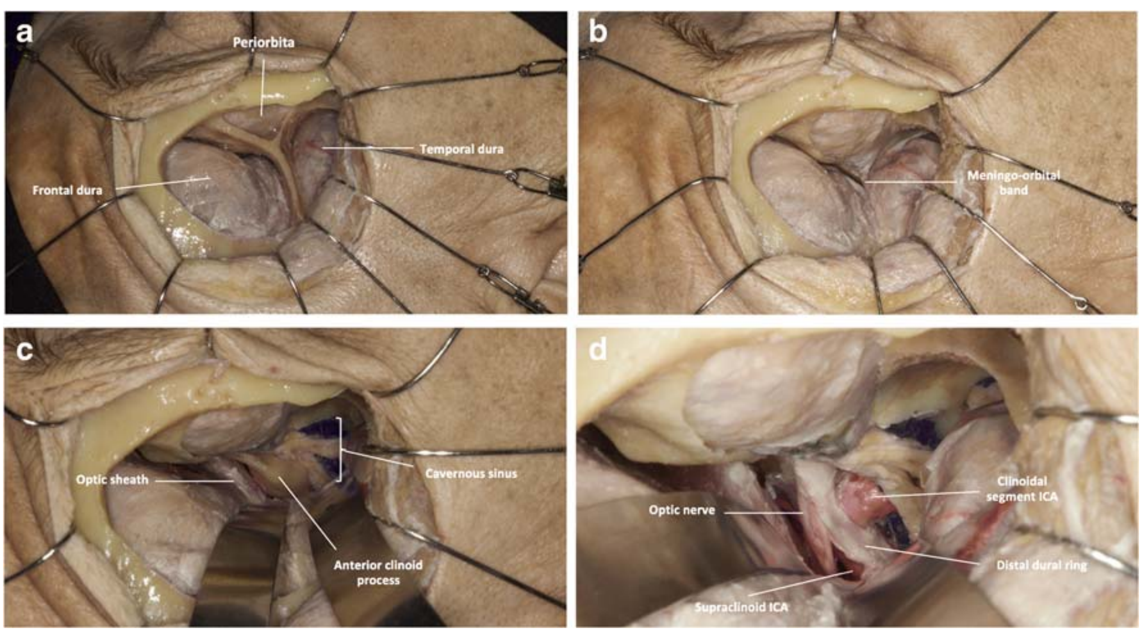

Fig. 4 Stepwise dissection in a cadaveric specimen. **a** Micropterional craniectomy. Dura of the frontal and temporal lobe is exposed, and a partial orbitotomy of the lateral wall of the orbit is performed. **b** Extradural phase. Sphenoid ridge is drilled out until the meningo-orbital band is exposed. **c** Anterior clinoidectomy. Section of the meningo-orbital band and the minipeeling of the temporal fossa are key to expose the lateral wall of the cavernous sinus and the tip of the anterior clinoid process. The optic nerve is decompressed using no-drilling techniques. **d** Intradural view. Once the anterior clinoid process is removed, dural opening provides a direct and straightforward access to the paraclinoid region following a lateral-to-medial trajectory. *(ICA = internal carotid artery)*

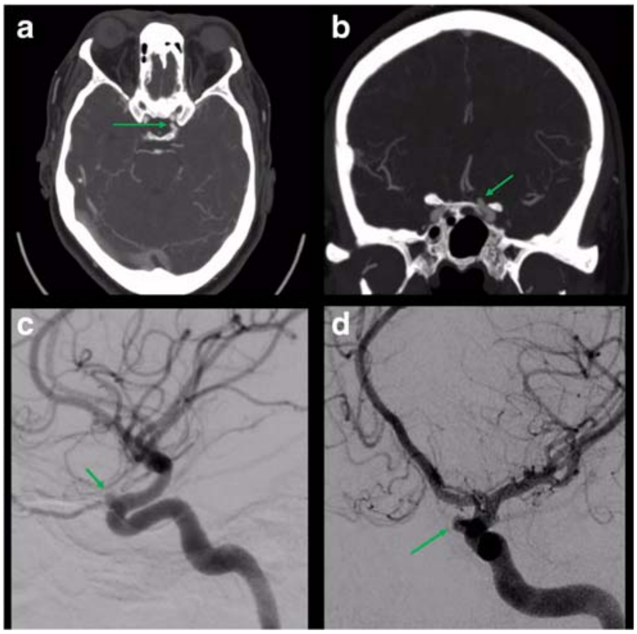

Fig. 5 Preoperative imaging. Preoperative angio-CT (axial -**a**- and coronal -**b**- views) demonstrate a superiorly pointing aneurysm (green arrow) partially obscured by the anterior clinoid process. **c** and **d** Preoperative digital subtraction angiography (lateral -**c**- and oblique -**d**- views) shows the presence of a broad based aneurysm (green arrow) arising at the origin of the ophthalmic aneurysm

- Paraclinoid aneurysms other than carotid-ophthalmic type (cavum, lateral wall, superior-hypophyseal) [4]
- Some large and posteriorly pointing posterior communicating aneurysms [5]
- Optic canal decompression [8]

Limitations

As a main limitation, this narrow extradural corridor could be insufficient in the context of a subarachnoid hemorrhage, or when requiring broader maneuvers because of large size aneurysms. The surgical maneuverability and exposure are not enough to use temporary clips. Thus, the eMKA is contraindicated in the treatment of ruptured aneurysms or in cases of complex vascular reconstructions.

In addition, operating through such constricted spaces precludes the simultaneous work of two surgeons, requires of an appropriate surgical training and expertise, and requires adequate surgical instruments. For instance, bayonet tools and special rotating-shaft clip appliers are imperative to avoid any viewing obstruction through the miscroscopic view. Similarly, a suction-irrigation aspirator is helpful to keep the surgical field clean in the absence of assistance.

How to avoid complications

1) Clips should be selected preoperatively. In the case of a carotid-ophthalmic aneurysm, the anatomic conformation of a low profile laterally curved 747 clip avoids any contact with the optic nerve, which reduces the risk of optic nerve injury (Fig. 6).
2) Indocyanine green angiography is helpful to confirm aneurysm occlusion and patency of distal branches intraoperatively.
3) It is advised to avoid using any oxidative cellulose products for cavernous sinus hemostasis, as they bloat in

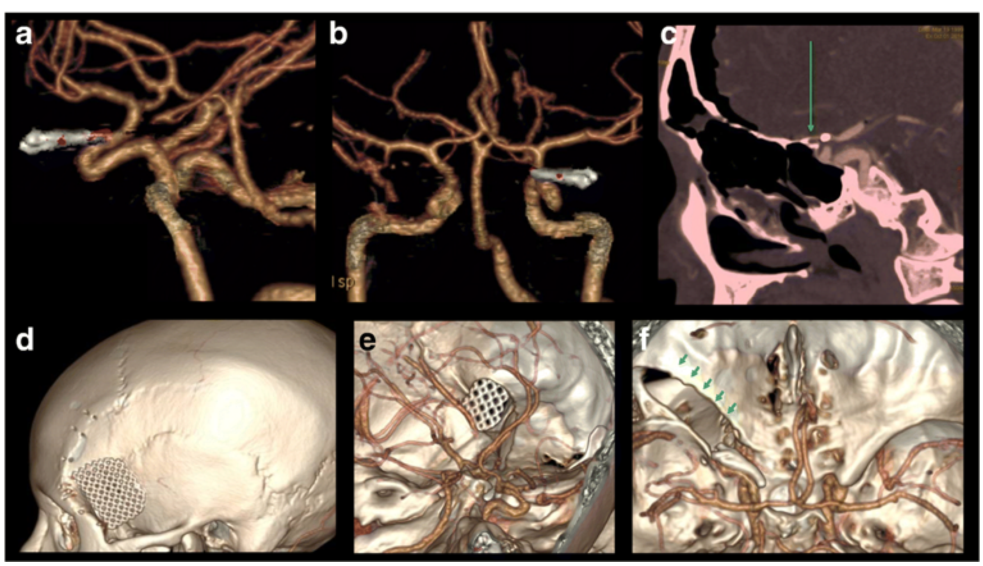

Fig. 6 Postoperative angio-CT. **a** and **b** The 3D view demonstrates the complete occlusion of the aneurysm and the correct position of the clip away from the optic nerve. **c** The sagittal reconstruction allows to identify and corroborate the patency of the ophthalmic artery (green arrow) after clipping. **d**, **e** and **f** Bone reconstruction provides a view of the narrow 20 mm craniectomy (**d** and **e**) beneath the superior temporal line, as such as the small lateral orbitotomy (**f**, arrow heads) required to perform the extradural anterior clinoidectomy

contact with blood, which can injure cranial nerves encased in the cavernous sinus [3].

4) Preoperative imaging assessment of the ACP anatomic configuration using high-resolution CT scan is recommended. Existence of a middle clinoid process connected to the ACP hinders the ACP removal. Non-delicate movements in this situation may cause an ICA disruption.

Specific perioperative considerations

Along with the preoperative angiogram study, it is recommended to perform a multi-slice CT scan of the skull in order to assess the anatomic osseous configuration of the ACP and anticipate risks of CSF leakage in cases of prominent pneumatization (Fig. 5).

Specific information to give to the patient and potential risks

The patient must know there is a small risk which is less than 15% of developing transient diplopia due to oculomotor nerve manipulation during the clinoidectomy [4]. Intraoperative rupture might exceptionally occur in non-ruptured anterior circulation aneurysms, so then proximal control at the cervical carotid is required [4, 6]. Risk of visual deterioration is less than 6% in large paraclinoid aneurysms [1], and mortality is less than 1% for non-ruptured cerebral aneurysms [8].

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (name of institute/committee) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

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Key points

- As a minimally invasive approach, the eMKA reduces operative times and risk of infection, while offers excellent cosmetic results [9].
- Section of the MOB and the middle fossa minipeeling are key for enabling the extradural corridor and perform an extradural clinoidectomy.
- Use of the extradural corridor exponentially increases the surgical maneuverability around the paraclinoid region in an eMKA, while reduces brain retraction and potential venous injury, since minimal Sylvian dissection is required.
- Removal of the ACP using no-drilling techniques is safe and reduces the risk of optic nerve heat injury.
- Opening the distal ring is essential in carotid-ophthalmic aneurysms, as it facilitates supraclinoid ICA mobilization and provides intracranial proximal control (Fig. 6).
- For superiorly pointing aneurysms, laterally curved low profile clips are preferred for avoiding any contact between the clip and the optic nerve.