Extradural anterior clinoidectomy

Technical note

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Anterior clinoidectomy is a technique of paramount importance in the management of aneurysms involving the paraclinoid region and upper basilar artery. In addition, removal of the ACP has facilitated the removal of certain tumors in this vicinity to provide better access to the anterior portion of the cavernous sinus or the posterior portion of the orbit, 2,5,7,23 The benefits of an anterior clinoidectomy include the following: 1) enhanced visualization of the ophthalmic artery and the proximal neck of its aneurysm; 2) early decompression and mobilization of the optic nerve; and 3) improved surgical exposure as evidenced by Evans and colleagues 7 in a cadaveric study whose results revealed a twofold increase in the exposed length of the optic nerve and the opticocarotid triangle as well as a three- to fourfold increase in the maximum width of the opticocarotid triangle. The extradural anterior clinoidectomy procedure coupled with the opening of the optic sheath was introduced into the neurosurgical armamentarium in 1985 by Dolenc. 3 The procedure allows for the complete removal of the ACP with minimal brain retraction, while the dura mater acts as a natural barrier to protect neurovascular structures and does not expose the subarachnoid space to bone debris. We report on a technically simpler means of performing an extradural anterior clinoidectomy after reviewing the anatomy of the ACP and its anatomical variations. The key element in the procedure involves cutting the MOB and its named vessels once the SOF is unroofed, which facilitates dural elevation as well as exposure of the ACP and the intracranial aperture of the optic canal. The ACP is centrally hollowed prior to its extirpation to avoid damage to the oculomotor nerve, which is very close to the lateral underside of the ACP. In this report, the original Dolenc procedure and its subsequent derivatives are compared and contrasted to our simpler and less laborious technique. We report on different clinical situations from our experience in 60 cases (40 aneurysm cases and 20 tumor cases) during a 4-year period.

KEY WORDS • anterior clinoid process • anterior clinoidectomy • extradural • paraclinoid aneurysm • surgical anatomy • skull base surgery

Abbreviations used in this paper: ACP = anterior clinoid process; CSF = cerebrospinal fluid; CT = computerized tomography; ICA = internal carotid artery; MOB = meningoorbital band; SOF = superior orbital fissure.
Fig. 1. Photographs representing the left ACP.  

A: The ACP forms a triangular spine of bone. It is a posteromedial bone continuation of the lesser wing of the sphenoid bone, and its base merges with the roof of the optic canal. Hatched areas represent the base of the ACP, which is removed using a diamond drill in the direction indicated by the arrow, which in turn facilitates detaching of the ACP from two of its three supporting structures, and the body of the ACP, which is centrally hollowed prior to its extirpation.  

B: The ACP is located between the optic canal medially and the SOF laterally. It is also connected to the sphenoid bone by its posterior root, the optic strut, which forms the lateral and ventral walls of the optic canal. Hatched area represents the portion of the optic strut that is drilled off as needed after drilling of the base of the ACP, as indicated in panel A.  

C: Dural elevation is performed and directed medially toward the orbital roof overlying the optic canal. Asterisk represents the dural fold entering the apex of the SOF. FL = frontal lobe dura; LWS = lesser wing of the sphenoid bone; TL = temporal lobe dura.  

D: The SOF is unroofed, which involves complete removal of the lesser wing of the sphenoid (LWS) overlying the superolateral margin of the SOF and the partial removal of the greater wing of the sphenoid (GWS) forming the inferolateral wall of the SOF. The apex of the SOF is exposed to reveal the MOB.  

E: The MOB has been coagulated and cut to leave a stump. The dura propria of the tempo-
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artery. Anteriorly, the base of the ACP has one lateral and two medial components: 1) laterally, it is the continuation of the lesser wing of the sphenoid bone overlying the SOF (Fig. 1B); and 2) medially, the base connects to the sphenoid bone via the anterior and posterior roots. The anterior root, located superiorly, is the continuation of the flat roof of the optic canal. The posterior root, located inferomedially, is the optic strut and connects the ACP to the basisphenoid bone. Parkinson describes the optic strut as a small pillar of bone with a rounded anterior aspect and a posterior sharp edge corresponding respectively to the leading and trailing edge of an aerofoil. The optic strut forms the lateral and ventral walls of the optic canal. It is also completely surrounded by dura mater from the middle and anterior fossae. The ACP is generally composed circumferentially of dense cortical bone with an interior of cancellous bone that may contain small venous channels, which in turn communicate with the cavernous sinus, and the diploic veins of the orbital roof. On occasion, the ACP is pneumatized and contains air cells that communicate with the sphenoid sinus via the optic strut, which resembles a bone conduit. Although pneumatization is rare, its potential existence should be verified preoperatively on CT scans to take steps to avoid CSF leaks. The ACP is attached to a number of dural folds: 1) the falciiform ligament extends from the planum sphenoidale over the roof of the optic canal and attaches to the base of the ACP; 2) the anteromedial aspect of the tentorium; 3) anterior and posterior petroclinoid ligament; and 4) interclinoid dural folds.

The course of the clinoideal segment of the ICA is intimately related to the inferior aspect of the ACP. The junction of the optic strut and the inferomedial aspect of the ACP are grooved by the clinoideal segment of the ICA. The posterior medial projection of the ACP, located posterior and superior to the optic strut, frequently contains a rounded impression, which accommodates the lateral surface of the clinoideal segment of the ICA. The oculomotor, trochlear, and ophthalmic divisions of the trigeminal and abducens nerves run together in a dural fold from the lateral wall of the cavernous sinus located just below the lateral side of the ACP to the medial wall of the SOF. Of these nerves, the oculomotor one is the closest to the body and base of the ACP. Nutik reports that the oculomotor nerve often grooves the inferolateral surface of the ACP. Note that the dural layer inferior to the ACP, which adjoins the lower dural ring of the clinoideal segment of the ICA to the dural covering of the oculomotor nerve, is referred to as the “carotico-oculomotor membrane.” This dural membrane can be thin and friable, although data from two different cadaveric studies indicate that the membrane is incomplete 16% of the time.

The posterior tip of the ACP often projects medially behind the lateral portion of the clinoideal segment of the ICA and may be involved in an osseous bridge forming a bone foramen for the ICA. In a study involving a total of 70 ACPS, Kim and colleagues reported the occasional presence of an interosseous bridge from the ACP to either the middle (13%) or the posterior clinoid process (6%). The presence of an interosseous bridge from the ACP would prevent an extradural resection and necessitate a combined intra- and extradural procedure.

The optic canal is located at the orbital apex. It is bounded by the body of the sphenoid bone medially, the lesser wing of the sphenoid bone superiorly, and the optic strut laterally and inferiorly (Fig. 1B). The optic canal assumes a vertically oval shape at its orbital end, where it measures approximately 5 to 6 mm in diameter. In its central portion it is round in cross-section, and on the cranial end it is oval in the horizontal plane. The canal attains its adult size by the age of 3 years. In approximately 4% of normal individuals the ophthalmic artery will notch the canal floor, forming a keyhole deformity. The optic canal is 8 to 12 mm in length. The ACP has a mean length of 7.7 mm (range 3–8 mm) from the roof of the optic canal to its tip (Fig. 1A). Its mean width is 5.6 mm (range 4–7.8 mm) and mean height is 5.3 mm (range 4–6.8 mm) at the widest portion. In summary, the ACP has three supporting structures: 1) the lesser wing of the sphenoid bone; 2) the roof of the optic canal; and 3) the optic strut. Extradural removal of the ACP involves disengaging the ACP from these three structures.

Extradural Removal of the ACP

The extradural removal of the ACP is performed using microscopic magnification and illumination after the sphenoid ridge is flattened following a modified orbitozygomatic craniotomy. First, the dura is elevated and directed medially toward the orbital roof overlying the optic canal to delineate the intracranial roof of the optic canal (Fig. 1A and C). The SOF is then identified and unroofed (Fig. 1B and D), which involves removing two bone structures with either rongeurs or a diamond burr: 1) complete removal of the lesser wing of the sphenoid bone overlying the superolateral margin of the SOF—the first of three supporting structures for the ACP; and 2) partial removal of the greater wing of the sphenoid bone, which forms the inferolateral wall of the SOF. This step provides mobility for the contents of the SOF and exposes the dural fold at the apex of the SOF (Fig. 1D) where the MOB is located with its named artery and vein. There is no need to unroof the foramen rotundum unless required by the pathology at hand. The MOB together with its vessels can be coagulated and divided with impunity (Fig. 1E) for a distance of 3 to 5 mm, and a cleavage plane by sharp dissection is established between the...
dura propria of the temporal tip and the inner cavernous membrane. The temporal tip dura is then peeled away from the anterior aspect of the cavernous sinus and the orbital apex. This maneuver is key because it facilitates further dural elevation in a posteromedial direction along the lateral aspect of the ACP. It also facilitates dural elevation medially to identify the intracranial aperture of the optic canal. This cleavage plane can also be extended, if required, along the second and third divisions of the trigeminal nerve on the middle fossa floor and medially to the tentorial edge.

The optic canal—the second of three supporting structures for the ACP—is unroofed from a lateral to medial direction (Fig. 1A, *hatched area with embedded arrow*) by using a 2-mm diamond burr (Fig. 1F) and constant-cooling irrigation to prevent thermal damage of surrounding neural structures from the elevation in bone temperature. Care is taken not to open either the ethmoid or sphenoid sinus at the medial edge of the optic canal. If the sinuses are entered, we do not violate the mucous membrane and close the bone opening with wax. The ACP is now connected only at the floor of the optic canal by the optic strut (Fig. 1B)—the third of three supporting structures for the ACP—which is drilled off as needed. A final step involves centrally hollowing out the dense cortical bone in the center of the ACP with the aid of a diamond burr and constant-cooling irrigation. During this procedure, the surgeon must be ever cognizant about the relative positions of the optic nerve, the carotid artery, and the oculomotor nerve with reference to the ACP. A circumferential dissection plane between the surrounding dural folds and the centrally shelled ACP is established (Fig. 1G). Caution is exercised at the site of the carotico-oculomotor membrane, which is friable and occasionally incomplete,22,23 prior to extirpating the ACP by using fine rongeurs. As a direct extension of this procedure, the optic sheath and the distal dural ring are excised following dural opening, which allows early decompression and mobilization of the optic nerve with minimal brain retraction. This technique was successfully used during a 4-year period for the removal of the ACP in aneurysm pathology (40 cases) and selective tumors lesions (20 cases).

**Discussion**

In this paper we compare and contrast the original Dolenc procedure and its derivatives16-20 with a simpler and less laborious technique that can be easily implemented (Table 1). First, the required dural elevation commences from the SOF following the flattening of the sphenoid ridge and is directed medially toward the optic canal (Fig. 1C). This step is less cumbersome compared with performing dural separation from the orbital roof to the SOF.3 The key maneuver in this extradural technique is the excision of the MOB after unroofing the SOF (Fig. 1D), which can be performed without risk to the third or fourth cranial nerve. This procedure provides for an easier lateral extradural exposure of the ACP when the dura propia is peeled off the inner cavernous membrane through sharp dissection (Fig. 1E). If bleeding occurs from the inner membrane of the cavernous sinus, it is easily halted with oxycellulose and gentle compression. Subsequent to exposure of the ACP, the dura overlying the posterior orbital roof can be easily elevated in a medial direction to identify the intracranial aperture of the optic canal without ambiguity. These advantages are not easily available in the other extradural procedures in the literature,2,3,23 because the dura remains tethered by the MOB and the dura propia of the temporal tip.

Second, the ACP can be disengaged from its base by drilling from a lateral to medial direction toward the midpoint of the intracranial opening of the optic canal under direct vision (Fig. 1A, *hatched area with embedded arrow*) to expose the optic nerve in the optic canal. The trough created is progressively deepened and the optic strut is drilled off as required (Fig. 1B, *hatched area*). Only for large and difficult paraclinoid aneurysms should the optic canal be completely opened to facilitate subsequent untethering of the optic nerve intradurally with less than gentle manipulation to avoid visual deficits. In addition, one should avoid violating either the ethmoid or sphenoid sinuses to avert CSF rhinorrhea when completely opening the optic canal. Our technique is simpler compared with others in the literature, which are lengthy because of an inability to judge the location of the intracranial aperture of the optic canal. This characteristic is demonstrated in the reports of Yonekawa, et al.,23 who proposed that drilling of the ACP should commence at the sphenoid bone overlying the lateral margin of the dural insertion into the SOF and continue medially in a perpendicular direction to the optic nerve at a point 1 cm anterior to the falciform ligament, and Dolenc,4 who, in a recent report on carotid artery–ophthalmic artery aneurysms, advocated drilling of the ACP starting on its inferolateral side and proceeding in a posteromedial direction toward the intracranial aperture of the optic canal.

Last, the ACP should be centrally shelled or hollowed out using a diamond drill to the point that the walls can be easily fractured and circumferentially dissected free of the surrounding dural folds (Fig. 1G). In this respect, the extradural approach facilitates removal of the ACP, because of the dural protection provided to the neurovascular elements in the vicinity, and provides a tidier option, because it does not expose the subarachnoid space to bone debris—advantages unavailable in the extradural debulking procedure. En bloc removal of the ACP is not recommended,23 given that it would likely require additional extradural manipulation. The risk imposed by this action involves damage to the oculomotor nerve, which runs close to the lateral undersurface of the ACP.12,19 These patients can exhibit temporary postoperative dysfunction of the oculomotor nerve, which can range from a palsy in which the superior division of the oculomotor nerve is involved to complete ptosis. Functional recovery of the damaged nerve usually returns in 3 months. When there is concern for intradural pathology or anomaly, the extradural anterior clinoidectomy can always be performed with the aid of intradural surveillance or a combined intradural procedure. In the event of dorsally pointing paraclinoid aneurysms, the ACP can be removed extradurally through intradural surveillance. When surgery is performed following subarachnoid hemorrhage of an aneurysm in close anatomical association with the ACP, however, removal of the extradurally hollowed ACP should be performed intradurally to avoid inadvertent rupture from extradural manipulation. Furthermore, particularly with paraclinoid aneurysms, it is important to establish preoperatively through CT studies whether the ACP is eroded, which could result in fatal intraoperative rupture during drilling of the ACP by using either an extradural23 or an intradural16 technique. In the event of an eroded ACP, Korosue and Heros48 have sug-
**TABLE I**  
*Extradural removal of the ACP*

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<tr>
<td>procedural step 1</td>
<td>flattening of sphenoid ridge</td>
<td>sphenoid ridge shaved flat along w/ regularities of orbital roof &amp; ant middle fossa</td>
<td>flattening of sphenoid ridge</td>
<td>flattening of sphenoid ridge</td>
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<tr>
<td>procedural step 2</td>
<td>dura separated medially from orbital roof to SOF laterally</td>
<td>dura elevated from a lat to medial direction from FR to anterosuperior ethmoidal artery</td>
<td>dura separated medially from ACP up to orbital roof overlying optic sheath</td>
<td>dural elevation medially from the SOF to orbital root overlying OC</td>
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<tr>
<td>procedural step 3</td>
<td>roof of orbit removed from orbital edge along w/ sphenoid wing backward to ACP &amp; to entrance of OC</td>
<td>skeletonize lat dural wall of the SOF &amp; unroof FR</td>
<td>sphenoid bone overlying lat margin of dural insertion into SOF is drilled medially in a perpendicular direction to the ON &amp; ~1 cm ant to the falciform ligament</td>
<td>SOF is opened; removal of lesser wing overlying the superior lat margin of SOF &amp; partial removal of greater wing to expose inferior lat margin of SOF</td>
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<tr>
<td>procedural step 4</td>
<td>partial removal of lat orbital wall b/w SOF &amp; FR</td>
<td>unroof OC</td>
<td>OC is unroofed from its medial margin laterally to include lat border of OC &amp; optic strut</td>
<td>MOB (w/ named vessels) is divided at apex of SOF</td>
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<tr>
<td>procedural step 5</td>
<td>ACP drilled off medially &amp; separated from lat wall of OC</td>
<td>central portion of ACP drilled, leaving thin shell of bone</td>
<td>dissection plane created b/w dura &amp; ACP</td>
<td>dura propria of temporal tip elevated from inner cavernous membrane from SOF to FR or FO if required</td>
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<td>procedural step 6</td>
<td>OC unroofed from lat to medial direction w/ opening the ethmoid sinus</td>
<td>ACP dissected from medial wall of SOF &amp; thin shell of bone removed</td>
<td>ACP is removed en bloc; if en bloc removal impossible, remnants are removed in piecemeal fashion or drilled. Small piece of optic strut usually remains laterocaudally to ON &amp; can be drilled if required</td>
<td>dura elevated from inner cavernous membrane in a pst &amp; medial direction to expose ACP &amp; intracranial aperture of OC</td>
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<tr>
<td>procedural step 7</td>
<td>central portion of ACP drilled, leaving thin shell of bone</td>
<td>ACP tip extirpated</td>
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<td>procedural step 8</td>
<td>blunt dissection of shelled ACP from dura</td>
<td>dura propria of temporal tip elevated from inner cavernous membrane</td>
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<tr>
<td>procedural step 9</td>
<td>ACP extirpated</td>
<td>MOB w/ vessels are divided at apex of SOF</td>
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<td>procedural step 10</td>
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<td>Differences</td>
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* Ant = anterior; FO = foramen ovale; FR = foramen rotundum; OC = optic canal; ON = optic nerve; pst = posterior.*
gested drilling the base of the ACP while leaving a thin col-
lar of bone around the aneurysm dome. On occasion, the
ACP forms an interosseous bridge with either the middle or
posterior clinoid process to form the caroticoclinoid fora-
men, a feature that can be identified on preoperative imag-
ing. In such cases, the ACP should be disengaged from its
three supporting structures and hollowed extradurally, al-
though its tip should be removed intradurally.

A pneumatized ACP is usually connected to the
sphenoid sinus by the bone conduit of an optic strut. Al-
though an extradural procedure reduces the risk of a CSF
leak after the removal of a pneumatized ACP, we recom-
mand that the optic strut be plugged tightly with muscle or
wax and sealed with fibrin glue and a fascial graft. This cau-
tionary step is performed to prevent tension pneumo-
cephalus as well as CSF rhinorrhea. On the other hand, a
pneumatized ACP does not usually require central hollowing
because the walls can be easily fractured. Nevertheless, a pneu-
matized ACP should be clearly distinguished from an
eroded one, which is identified by a round “punched out”
defect on CT scans.

Conclusions

This modified extradural anterior clinoidectomy offers
the following advantages: 1) technical simplicity; 2) de-
creased incidence of neurovascular damage; 3) obviates
postoperative CSF leaks and tension pneumocephalus; and
4) the option of either intradural surveillance or a combined
intradural procedure when required. It is key initially to un-
roof the SOF and excise the MOB—steps that facilitate
dural elevation and exposure of the ACP and the intracra-
nial aperture of the optic canal without ambiguity. One can
safely disengage the ACP from its three supporting struc-
tures: 1) the lesser wing of the sphenoid bone; 2) the roof of
the optic canal; and 3) the optic strut. Finally, the ACP is
centrally hollowed prior to its extirpation to avoid damage
to the oculomotor nerve, which is very close to the lateral
underside of the ACP. The technique presented here repre-
sents further refinements to the original Dolenc procedure
and its derivatives.

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