Lateral orbital wall approach to the cavernous sinus

Laboratory investigation

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Lesions in the cavernous sinus were long considered inoperable because of the danger of bleeding from the venous plexus or the injury to important neurovascular structures, such as the ICA, the abducent nerve, and the sympathetic nerves. During the past 2 decades, however, meticulous microsurgical studies have described numerous approaches with acceptable morbidity and mortality.1,2,7–9,11,13–15,19,21,23,24 Nevertheless, controversy related to the optimal approach for different kinds of lesions continues, and the cavernous sinus is still a challenging and unfamiliar place for many neurosurgeons.

In the present study, we describe a novel surgical approach to access the cavernous sinus that involves the removal of the lateral orbital wall.

Methods

Materials

We performed 12 procedures using standard microsurgical equipment and instruments in 5 fresh uninject ed and 1 latex-injected and formalin-fixed adult cadaver heads. The specimens were maintained in surgical position using a table-mounted Mayfield head clamp. An operating microscope and an electric drill with cutting and diamond burs were used in all dissections. Morphometric distances between the key anatomical landmarks were measured.

Key Words • cavernous sinus • orbital wall • surgical approach • craniotomy • diagnostic and operative techniques

Abbreviations used in this paper: GSPN = greater superficial petrosal nerve; ICA = internal carotid artery.
Surgical Procedure

The head is positioned as in a pterional approach, rotated 30° to the contralateral side (Fig. 1). A transverse lateral canthotomy incision is made, extending from the lateral epicanthus 2 cm laterally as far down as the lateral orbital ridge (Fig. 2A). Next, the periorbitalis is dissected off of the lateral orbital rim until the orbitozygomatic and frontoorbital junctions are exposed. Then, the temporalis muscle and the periorbita on both sides of the lateral orbital wall are dissected (Fig. 2B). The dissection on these planes is continued introrbitally to the lateral projection of the superior orbital fissure, and, extraorbitally, a 2-cm segment of temporal bone along with the orbitotemporal junction is cleared off the temporalis muscle. Attention is paid so as not to tear the periorbita during the dissection. Once the intended exposure is achieved, the globe and temporalis muscle are gently retracted medially and laterally, respectively. A 2-cm segment of lateral orbital rim, along with the anterior lateral orbital wall, is cut using a rotating drill or oscillating saw (Fig. 2C). The cut line is extended to the inferior orbital fissure inferiorly, the orbitotemporal junction posteriorly, and up to the lower margin of the sphenoid ridge superiorly. Then, a high-speed drill is used to drill the lateral orbital wall and release the lateral orbital bone and rim.

Once the superior orbital fissure is reached, it is opened wide and its inferior edge, which constitutes part of the lateral orbital wall, is removed. The initial craniocaudal borders are the base of the middle fossa inferiorly and the lesser sphenoid wing and the anterior clinoid process superiorly. A dissection plane is created between the dura of the temporal lobe and the lateral wall of the cavernous sinus, cutting the dural fold that enters the superior orbital fissure and contains the meningoorbital artery at its lateral end. This plane is followed sharply posteriorly, inferiorly, and laterally, until the entire lateral wall of the cavernous sinus is exposed. The extradural removal of the anterior clinoid process is accomplished easily, following the lateral orbital wall with drilling down to the optic strut and thinning the lateral wall of the optic canal. After the anterior clinoid process is detached from the superomedial part of the optic canal and the optic strut and removed, the clinoid segment of the ICA, the proximal and dural rings, and the superior wall of the cavernous sinus are exposed (Figs. 3 and 4).

The initial approach with removal of the lateral orbital wall alone is limited by the temporal bone laterally, which prevents complete access to the V3 segment of the trigeminal nerve, the foramen ovale, and the petrous carotid artery and lateral temporal fossa (Fig. 5). To access these surgical territories by a more extended version of the approach, an additional 0.5-cm-wide segment of the anterior middle fossa (greater wing of the sphenoid) is removed laterally. This further facilitates posterolateral dissection and expands the limits of this approach to the foramina ovale and spinosum, the GSPN, and the petrous carotid artery (Figs. 6 and 7). At this stage, to assess the intradural access through this approach, we opened the dura and excised the distal dural ring. This provided us complete visualization of the clinoid and supraclinoid segments of the ICA as well as the direct takeoff of the posterior communicating artery (Figs. 8 and 9).

The retractions used throughout the procedure are limited to modest globe retraction medially and to the temporalis muscle laterally. Suction assistance is the only

![Fig. 1. Left: Illustration showing the lateral orbital rim and wall to be removed for the translateral orbital approach to the cavernous sinus. Right: Illustration showing the parasellar area and middle fossa structures after removal of the lateral orbital rim and wall in the translateral orbital approach. Printed with permission from KTB Studios, LLC.](image-url)
retraction needed for the intracranial phase of the procedure.

Closure is simple. The lateral orbital rim is replaced using cranial repair mesh or Medpor (Stryker Corp.) placed between the globe and the temporalis muscle. This is optional if the periorbita is left intact. The frontoorbital and orbitozygomatic junctions are bridged by the removed piece of the lateral orbital rim attached by titanium miniplates. Finally, the layers of the transverse skin incision are sutured in a subcuticular fashion for optimal cosmetic results.

Results

Morphometric Analysis

The distances between the anatomical landmarks are shown in Table 1. The average distances from the frontozygomatic suture to the superior edge of the zygomatic arch, and from the mid-lateral orbital wall to the edge of the greater sphenoid wing, which are the vertical and horizontal extensions of the bone opening, were 20.8 ± 0.73 mm.

Fig. 3. Cadaver dissection after lateral orbital removal, demonstrating initial exposure of the anterior cavernous sinus and anterior clinoid process (ACP). III = oculomotor nerve; IV = trochlear nerve.

Fig. 2. Cadaver dissection demonstrating the surgical incision (A), exposure of the lateral orbital rim (B), and removal of the lateral orbital rim and anterior lateral orbital wall (C). Note the gentle retraction of the temporalis muscle and the orbital structures.

Fig. 4. After removal of the anterior clinoid process, the intradural carotid artery is exposed after opening the distal dural ring (DDR). The temporal dura mater is dissected off the lateral wall of the cavernous sinus. Then, the dura is opened and the distal dural ring is excised.
and 12.0 ± 1.08 mm, respectively. The distance from the periorbita to the greater sphenoid wing level to the edge of the greater sphenoid wing was 15.4 ± 1.37 mm. We calculated the average working area to be approximately 3.6 cm², based on a rectangular shape. The average retraction of the globe was 9.25 ± 2.17 mm at the level of the lateral orbital rim. The distance from the base of the greater sphenoid wing to the lateral end of the superior orbital fissure was 13.0 ± 0.90 mm. The working depth to the anterior cavernous sinus was calculated as the sum of the distances from the mid-lateral orbital rim to the base of the greater sphenoid wing and the base of the greater sphenoid wing to the posterior edge of the foramen rotundum, which averaged 50.4 ± 1.69 mm. The deepest point reached was at the petrous edge at the trigeminal impression. This averaged 67.6 ± 1.62 mm.

In the extended version of the approach, only the horizontal extension of the bone opening differed from the initial exposure, averaging 19.16 ± 2.12 mm. The average difference was 7.08 ± 2.53 mm. The distance from the periorbita to the edge of greater sphenoid wing was 22.4 ± 2.02 mm. We calculated the average working area to be 46.5 cm² based on a rectangular shape.

Anatomical Observations

The superior orbital fissure was consistently and easily found when either of the following 2 anatomical markers was noted: a perpendicular line to the midpoint of the segment of the removed piece of the lateral orbital rim, or the trajectory immediately below and parallel to the sphenoid ridge.

Retraction of the orbital contents was not required more than 1 cm, and this permitted immediate establishment of the plane between the temporal dura and the periorbita following the cut of the dural fold in the superior orbital fissure and fast access to the anterior cavernous sinus. This also allowed us to use a more lateral angle, avoiding a significant temporal craniectomy.
Removing the anterior clinoid process facilitated the excision of the distal dural ring and opening the dura in the parasellar area. Once the dura was opened, the optic nerve, the clinoid and supraclinoid segments of the ICA, and the posterior communicating artery takeoff were visualized. The takeoff of the ophthalmic artery was hidden behind the ICA and could not be visualized in any of our cadaver dissections in earlier steps of the procedure. It could only be seen when the clinoid segment of the ICA was mobilized after the excision of the distal dural ring.

Our approach was satisfactory to reach the entire cavernous sinus from the superior orbital fissure anteriorly to the Meckel cave posteriorly, but it had limitations in exposing the middle fossa structures, including the foramina ovale and spinosum, the GSPN, and the petrous carotid artery. Expansion of the approach into the so-called “extended version” by removing an additional part of the anterior greater sphenoid wing laterally enough to expose these structures achieved the expected goal.

Lateral canthotomy followed by reconstruction of the lateral orbital wall and replacement of the orbital rim provided good cosmesis.

**Fig. 7.** A more inferior trajectory demonstrates the lateral aspects of all 3 branches of the trigeminal nerve and gasserian ganglion. Illustration used with permission from KTB Studios, LLC.

**Fig. 8.** Cadaver dissection (left) and illustration (right) depicting the entrance to the cavernous sinus through its lateral wall between V1 and V2. The V1 segment is retracted to expose the proximal part of the cavernous carotid artery and the abducent nerve coursing lateral to it. Illustration used with permission from KTB Studios, LLC.
This 70-year-old man presented with a 5-year history of progressive visual loss in his right eye. Ophthalmological evaluation demonstrated some decline in his visual acuity and a small superior right temporal and nasal visual field defect. Magnetic resonance imaging showed an enhancing lesion of the right cavernous sinus with optic canal involvement (Fig. 10). A lateral orbitotomy approach was used to decompress the optic nerve, remove the anterior clinoid process and the lateral wall of the cavernous sinus, and obtain a biopsy specimen of the lesion (Video 1).

Postoperative CT scans demonstrated the extent of bone removal (Fig. 11). Postoperatively, the patient had an uneventful recovery day with stable vision. Pathological analysis identified the tumor as a WHO Grade I meningioma. The patient will be monitored with serial observations, including MR imaging studies and ophthalmological evaluations every 6 months.

**Discussion**

Beginning with the first direct surgical approaches reported by Browder and later by Parkinson and Ramsay, the belief that the cavernous sinus was inoperable has been abandoned, and courageous attempts have been made to surgically treat lesions located in this area. Numerous approaches have been developed that are based on the philosophy of more extensive bone removal with the aim of minimizing cerebral retraction. Yaşargil and colleagues popularized the transsylvian approach to lesions in the sellar and parasellar regions. They used the frontotemporal craniotomy with frontoorbital and sphenoidal osteotomy, the so-called “pterional” craniotomy, to take advantage of the cisternal route. This

<table>
<thead>
<tr>
<th>Key Anatomical Structures</th>
<th>Mean Length (mm)†</th>
<th>Range (mm)</th>
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<tr>
<td>FZS to superior edge of ZA (vertical extension)</td>
<td>20.8 ± 0.73</td>
<td>20–22</td>
</tr>
<tr>
<td>mid-LOR to base of GSW</td>
<td>22.5 ± 0.79</td>
<td>21–24</td>
</tr>
<tr>
<td>mid-LOW to edge of GSW (transverse extension)</td>
<td>12.0 ± 1.08</td>
<td>10–14</td>
</tr>
<tr>
<td>mid-LOW to edge of GSW (transverse extension)‡</td>
<td>19.25 ± 2.05</td>
<td>17–23</td>
</tr>
<tr>
<td>base of GSW to lat end of SOF</td>
<td>13.0 ± 0.90</td>
<td>12–15</td>
</tr>
<tr>
<td>junction of LOR/superior edge of ZA to lat end of IOF</td>
<td>17.6 ± 1.55</td>
<td>15–19</td>
</tr>
<tr>
<td>base of GSW to posterior edge of FR</td>
<td>27.9 ± 0.90</td>
<td>27–29</td>
</tr>
<tr>
<td>base of GSW to tip of ACP</td>
<td>34.9 ± 0.79</td>
<td>34–36</td>
</tr>
<tr>
<td>base of GSW to tip of PCP</td>
<td>40.5 ± 1.08</td>
<td>38–42</td>
</tr>
<tr>
<td>base of GSW to posterior edge of FO</td>
<td>37.1 ± 1.11</td>
<td>36–39</td>
</tr>
<tr>
<td>base of GSW to Meckel cave</td>
<td>41.9 ± 1.16</td>
<td>40–43</td>
</tr>
<tr>
<td>base of GSW to petrosal edge at trigeminal impression</td>
<td>45.1 ± 0.83</td>
<td>44–46</td>
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* ACP = anterior clinoid process; FO = foramen ovale; FR = foramen rotundum; FZS = frontozygomatic suture; GSW = greater sphenoid wing; IOF = inferior orbital fissure; LOR = lateral orbital rim; LOW = lateral orbital wall; PCP = posterior clinoid process; SOF = superior orbital fissure; ZA = zygomatic arch.
† Presented as ± SD.
‡ Extended version.
approach has led to the development and modification of most anterior and anterolateral approaches for various pathological conditions. Hakuba et al.\textsuperscript{13} reported 19 cases in which they used 4 mainly intradural approaches for the treatment of tumors and vascular lesions in this region under normothermic conditions. In their series, entry to the cavernous sinus was achieved through the lateral wall at the Parkinson triangle via the frontotemporal or subfrontopterional approach. They also described the first combined transpetrosal-subtemporal approach to tumors in the posterior cavernous sinus extending to the petroclival area. Shortly after that successful outcome, Dolenc\textsuperscript{7–9} pioneered the intra- and extradural approach to the cavernous sinus, which combined a pterional approach with a subtemporal approach and exposure of the intrapetrous part of the ICA when necessary. After removal of the anterior clinoid process, the cavernous sinus is entered through its lateral wall at anteromedial, paramedial, and Parkinson triangles. In the early 1980s after the combined orbitomalar osteotomy with a frontal cranial flap was introduced by Pellerin et al., Hakuba et al.\textsuperscript{14} described the combined orbitozygomatic infratemporal epidural and subdural approach for lesions in the cavernous sinus, which were accessed through the lateral and superior wall, respectively. An anterior transpetrosal osteotomy could also be done through this approach to obtain access to the posterior fossa. The approach provided the shortest possible distance and maximum inferior-to-superior angle with minimal brain retraction. Pieper and Al-Mefty\textsuperscript{22} further modified the approach and described the technique used today, while others have reported additional modifications in the technique.\textsuperscript{6,12}

Fujitsu and Kuwabara\textsuperscript{11} and Al-Mefty and Anand\textsuperscript{2} proposed zygomatic approaches that incorporated some other differences. These approaches were intended to be the

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**Fig. 10.** Axial (left) and coronal (right) MR images demonstrating an enhancing lesion of the right cavernous sinus with optic canal involvement.

**Fig. 11.** Postoperative axial (left) and coronal (right) CT scans showing the extent of bone removal.
lowest possible supratentorial route to the cavernous sinus and the interpeduncular cistern. The approach described by Fujitsu and Kuwabara11 required detachment of the entire lateral orbital rim and the zygomatic arch, and entry to the cavernous sinus was achieved through the Parkinson triangle. The zygomatic approach that Al-Mefty and Anand2 described differed in that, after detachment of the zygomatic arch, the coronoid process of the mandible was sectioned and the temporalis muscle was elevated to expose the lower anterior temporal bone to gain access to the cavernous sinus and infratemporal fossa. Ponczekzy et al.21 and Knosp et al.15 favored a small preauricular subtemporal approach to reach the cavernous sinus from various angles through the Parkinson triangle at its lateral wall. They tailored the subtemporal approach depending on the localization of the lesion using either an anterior subtemporal craniotomy with orbitopterional extension or a mid- to posterior subtemporal craniotomy. They obtained similar outcomes by using their approach, as did the authors of studies describing large-scale approaches but with less morbidity. Sekhar et al.23 used a subtemporal–preauricular infratemporal fossa approach for large lateral and posterior cranial base tumors invading multiple middle and posterior fossa as well as infratemporal compartments. In 1997, Couldwell et al.4 described the use of a transmaxillary route to the cavernous sinus, traversing the pterygopalatine fossa and exposing the cavernous sinus by enlarging the foramen rotundum.

Each of the aforementioned approaches has had a significant role in the improvement of surgical treatment of cavernous sinus lesions. Most of them are based on a large cranial bone flap, however, and thus require extensive bone drilling, wide intra- and/or extradural exposure, manipulation of critical neurovascular structures, and detachment of temporal muscle to varying degrees. Some of these are also technically demanding procedures and have significantly longer operation times. Considering all these factors, we considered a less invasive approach for lesions primarily or secondarily involving the cavernous sinus. The aim was to take advantage of the easy and quick accessibility to the cavernous sinus through the removal of the lateral orbital rim and wall as far back as the neural elements in the superior orbital fissure.

The lateral orbitotomy by removing the lateral orbital wall was first used in 1889 by Krönlein to remove an intraorbital tumor. Later, Dollinger used this approach for the treatment of exophthalmos. Andaluz et al.3 described removal of the superolateral wall of the orbit to access the anterior cranial fossa with inclusion of a mini-supraorbital craniotomy. Recently, Marienello et al.17 reported a series of 18 patients harboring lateral sphenoid wing meningiomas in whom the authors removed the lateral orbital wall including the lateral orbital rim and temporal portion of the sphenoid wing. The common features of the tumors in their series were variable involvement of the sphenoid wing, temporal fossa, and superolateral orbital cavity without extension to the anterior clinoind process and superior orbital fissure. Our review of the literature did not reveal any study reporting access to the cavernous sinus through the removal of the lateral orbital wall without a formal craniotomy.

The initial exposure obtained by the translateral orbital wall approach we describe was the anteromedial face of the temporal pole. This precluded the necessity of brain retraction. The superior orbital fissure was centered in the angle of the approach, which enabled easy detachment of the temporal dura from the lateral wall of the cavernous sinus once we reached the dural fold entering the fissure. The neural elements in the superior orbital fissure and V2 in the anterior two-thirds of the lateral cavernous sinus as well as part of V3 were readily accessible. Extradural removal of the anterior clinoind process by drilling enhanced access to the cavernous sinus through the entire course of its superior wall. This also facilitated more posterior exposure as far back as the gasserian ganglion at a wider craniocaudal angle and provided an immediate proximal control of the ICA at its clindoid segment. By further drilling superiorly in the lower aspect of the sphenoid ridge and inferiorly in the remaining lateral orbital wall toward the inferior orbital fissure, the Meckel cave and the foramen rotundum, respectively, were within reach.

Our initial approach with removal of only the lateral orbital wall was limited by the edge of the sphenoid wing laterally; this prevented us from entirely accessing V3, the foramina ovale and spinosum, the GSPN, the petrous carotid artery, and the middle and lateral temporal fossae. The extended version of our approach expanded the surgical borders to include these structures. We were also able to reach the posterior fossa after dissecting the middle fossa dura from the petrous ridge.

Several techniques have been described to achieve optimal cosmesis after transorbital approaches. Stallard reported a modification in the operation described by Krönlein, making the skin incision in the eyebrow line. Pelton and Patel described the superomedial lid crease approach to the medial intracranial space, and Andaluz et al.3 and Marienello et al.17 used a similar technique with successful outcomes. In our study, we decided to use a lateral canthotomy, another cosmetically appealing technique that involves collaboration with the ocular plastic surgery department. This technique was simply based on the utilization of a natural skin crease in the lateral canthus at a length of 2 cm, followed by a subcuticular skin closure, which provided optimal cosmesis.

There are several advantages of the approach described here over the previously described approaches. Principally, there is no requirement for any kind of brain retraction during the procedure. Another advantage is that it is performed through a small skin incision without any of the formal conventional craniotomies, thus avoiding wide exposure of the cerebrum and the associated complications of that surgical technique. The temporalis muscle insertion is left intact, and thus the risk of atrophy is eliminated. The frontalis branch of the facial nerve as well is left intact without retraction, as may occur in a standard frontotemporal approach. The translateral orbital wall approach uses a quick and safe drilling of the lateral orbital wall with an immediate exposure at the anterior cavernous sinus, which provides a shorter operative time.

The disadvantages of this approach include the unfamiliar anatomy of the sphenocavernous region from below at a translateral orbital angle of view. Practice in the ca-
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daver laboratory is mandatory to develop familiarity with
the approach. In addition, excessive globe retraction or the
use of improper equipment for retraction could cause po-
tential injury to the periorbita or globe. Furthermore, al-
though this step appeared to be easy, removal of the ante-
rior clinoid process requires utmost care, as it does in other
conventional approaches, because of its proximity to vital
neural and vascular structures.

Conclusions
In this study, we have described a novel approach to
the cavernous sinus. Based on this initial cadaveric study,
it appears that this approach may be applicable to a variety
of lesions, especially tumors, in or around the cavernous si-
inus. Lesions mostly confined to the cavernous sinus can
be resected by this technique in its simple form, whereas the
extended version is suitable for lesions that extend laterally
or posterolaterally in the middle fossa.

Disclosure
The authors report no conflict of interest concerning the ma-
terials or methods used in this study or the findings specified in this
paper.

Author contributions to the study and manuscript preparation
include the following. Conception and design: Couldwell, Altay.
Acquisition of data: Altay. Analysis and interpretation of data:
Altay. Drafting the article: Altay. Critically revising the article: all
authors. Reviewed submitted version of manuscript: all authors.
Approved the final version of the manuscript on behalf of all authors:
Couldwell. Administrative/technical/material support: Couldwell.

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