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Lateral orbital wall approach to the cavernous sinus

Laboratory investigation

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Object. Lesions of the cavernous sinus remain a technical challenge. The most common surgical approaches involve some variation of the standard frontotemporal craniotomy. Here, the authors describe a surgical approach to access the cavernous sinus that involves the removal of the lateral orbital wall.

Methods. To achieve exposure of the cavernous sinus, a lateral canthal incision is performed, and the lateral orbital rim and anterior lateral wall are removed, for later replacement at closure. The posterior lateral orbital wall is removed to the region of the superior and inferior orbital fissures. With reflection of the dural covering of the lateral cavernous sinus and removal of the anterior clinoid process, the cavernous sinus is exposed.

Results. Exposure and details of the procedure were derived from anatomical study in cadavers. After the approach, with removal of the anterior clinoid process, the entire cavernous sinus from the superior orbital fissure anteriorly to the Meckel cave posteriorly is exposed. More exposure to the lateral middle fossa, foramen spinosum, and petrous carotid artery is obtained by further removal of the lateral sphenoid wing. An illustrative case example for approaching a cavernous sinus meningioma is presented.

Conclusions. The translateral orbital wall approach provides a simple, rapid approach for lesions with primary or secondary involvement of the cavernous sinus. Advantages of this simple, extradural approach include the lack of brain retraction and no interruption of the temporalis muscle. *(DOI: 10.3171/2011.12.JNS111251)*

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

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. This translateral orbital wall approach offers a quick, relatively easy, and less invasive access to the cavernous sinus with adequate exposure, obviating a formal craniotomy that is needed in previously described approaches. The approach also provides excellent cosmesis with a lateral orbital canthotomy skin incision.

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

Methods

Materials

We performed 12 procedures using standard microsurgical equipment and instruments in 5 fresh uninjected 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.

This article contains some figures that are displayed in color online but in black and white in the print edition.

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 periosteum 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 intraorbitally 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

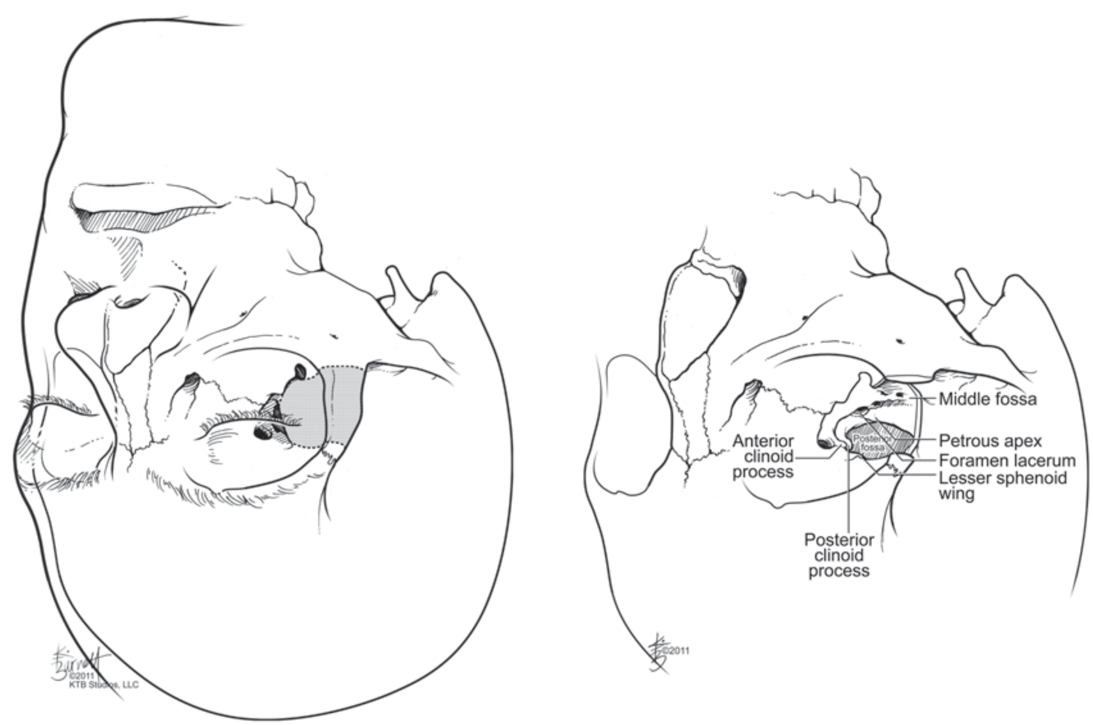

Fig. 1. Left: Illustration showing the lateral orbital rim and wall to be removed for the translateral orbital approach to the cavernous sinus. **Right:** Illustration showing the parasellar area and middle fossa structures after removal of the lateral orbital rim and wall in the translateral orbital approach. Printed with permission from KTB Studios, LLC.

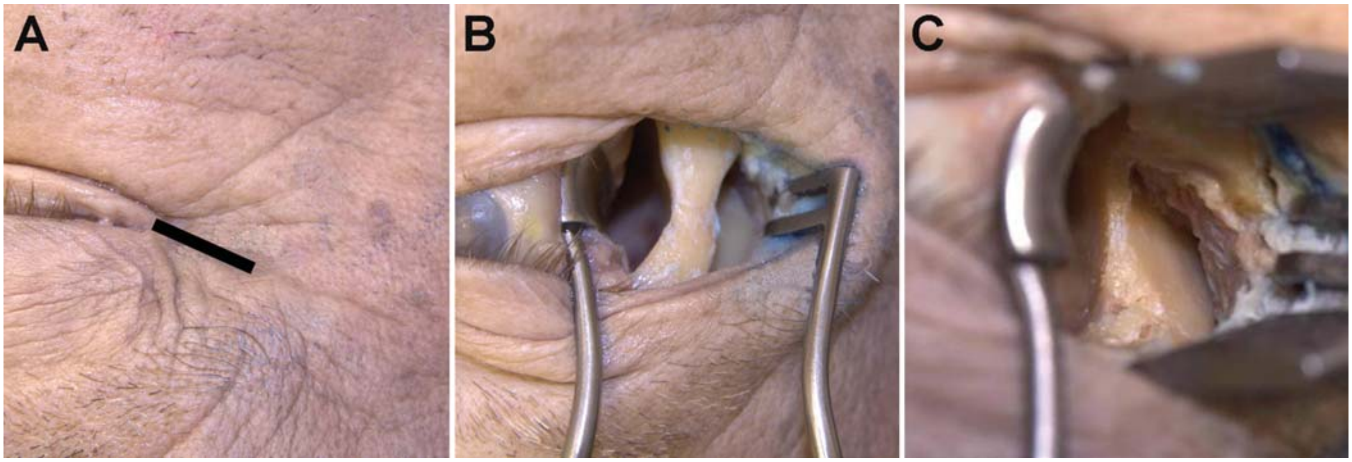

Fig. 2. Cadaver dissection demonstrating the surgical incision **(A)**, exposure of the lateral orbital rim **(B)**, and removal of the lateral orbital rim and anterior lateral orbital wall **(C)**. Note the gentle retraction of the temporalis muscle and the orbital structures.

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

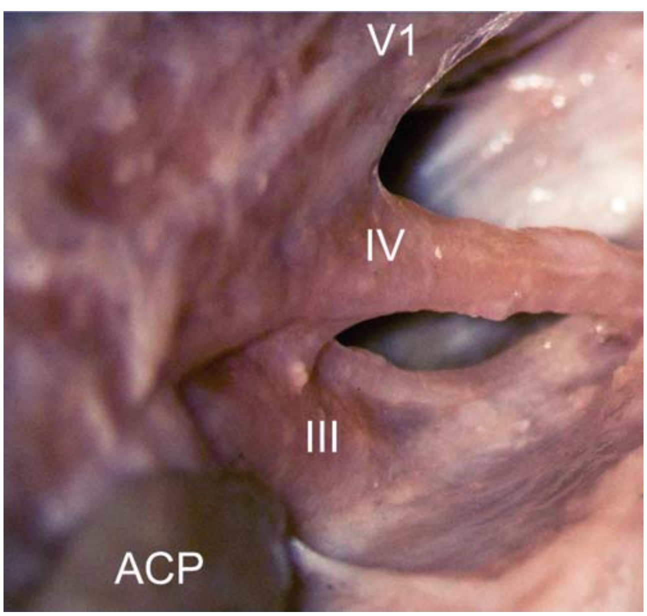

Fig. 3. Cadaver dissection after lateral orbital removal, demonstrating initial exposure of the anterior cavernous sinus and anterior clinoid process (ACP). III = oculomotor nerve; IV = trochlear nerve.

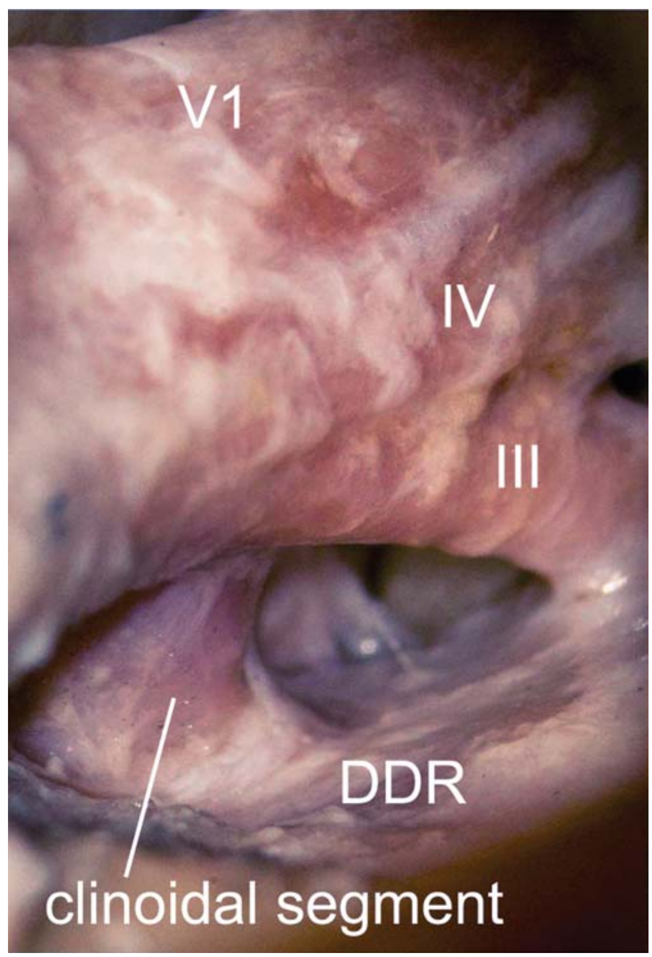

Fig. 4. After removal of the anterior clinoid process, the intradural carotid artery is exposed after opening the distal dural ring (DDR). The temporal dura mater is dissected off the lateral wall of the cavernous sinus. Then, the dura is opened and the distal dural ring is excised.

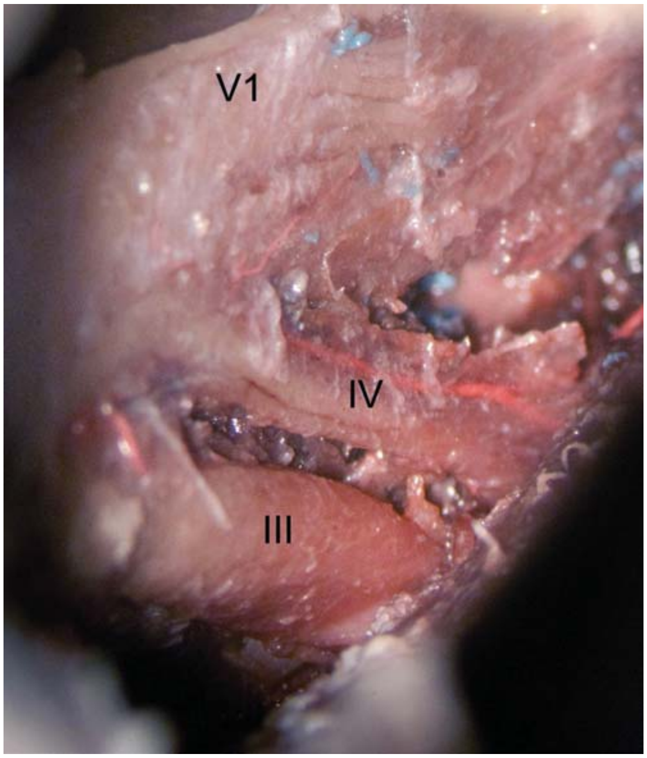

Fig. 5. A more inferior exposure enables clear visualization of the trigeminal nerve.

and 12.0 ± 1.08 mm, respectively. The distance from the periorbita at 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 cm^2, 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 cm^2 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.

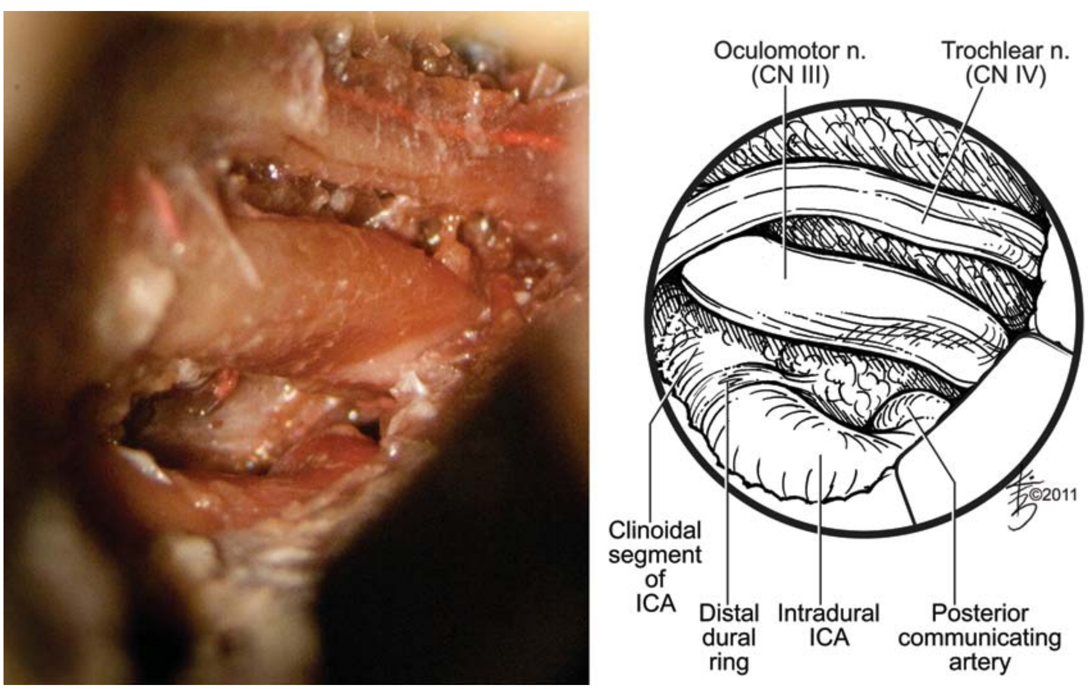

Fig. 6. Cadaver dissection **(left)** and illustration **(right)** showing exposure of the intradural carotid artery with the posterior communicating artery takeoff after exposure of the cavernous sinus. The oculomotor and trochlear nerves are exposed. Both clinoid and intradural segments of the ICA are also seen. CN = cranial nerve. Illustration used with permission from KTB Studios, LLC.

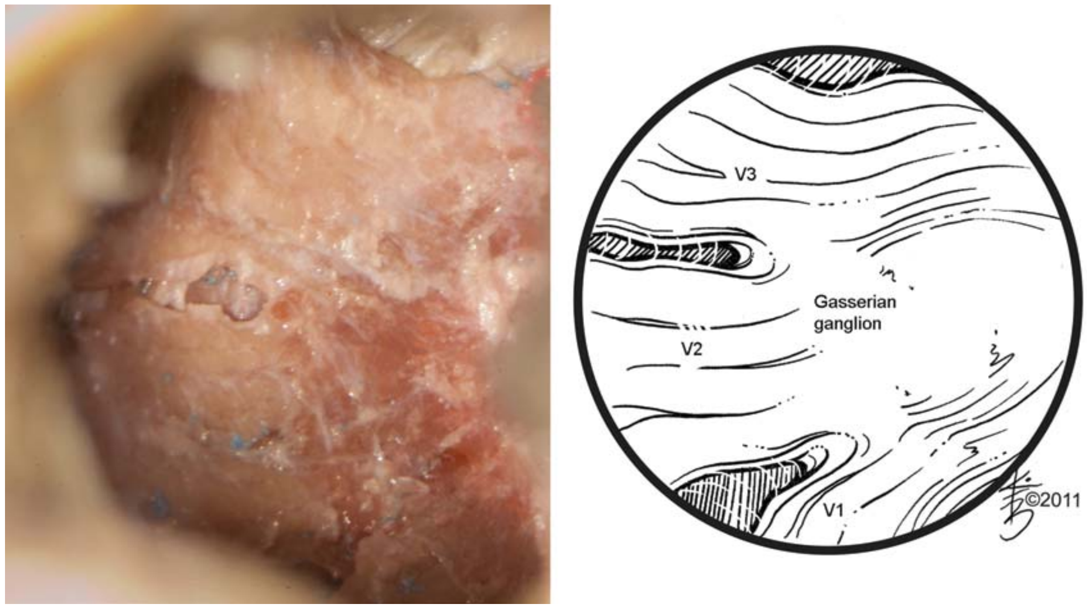

Fig. 7. A more inferior trajectory demonstrates the lateral aspects of all 3 branches of the trigeminal nerve and gasserian ganglion. Illustration used with permission from KTB Studios, LLC.

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.

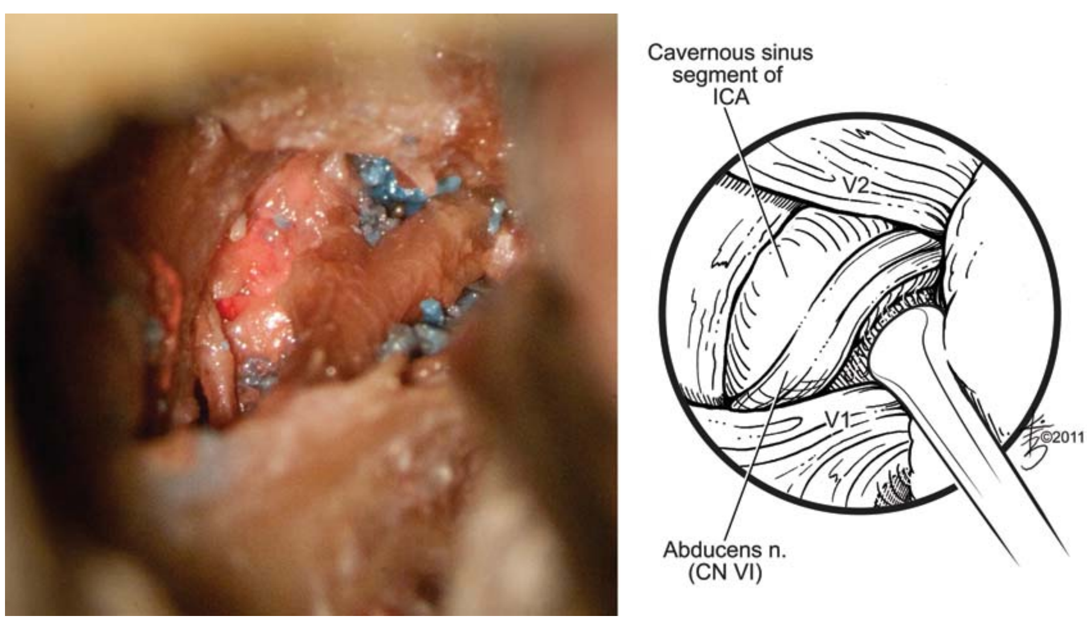

Fig. 8. Cadaver dissection **(left)** and illustration **(right)** depicting the entrance to the cavernous sinus through its lateral wall between V1 and V2. The V1 segment is retracted to expose the proximal part of the cavernous carotid artery and the abducent nerve coursing lateral to it. Illustration used with permission from KTB Studios, LLC.

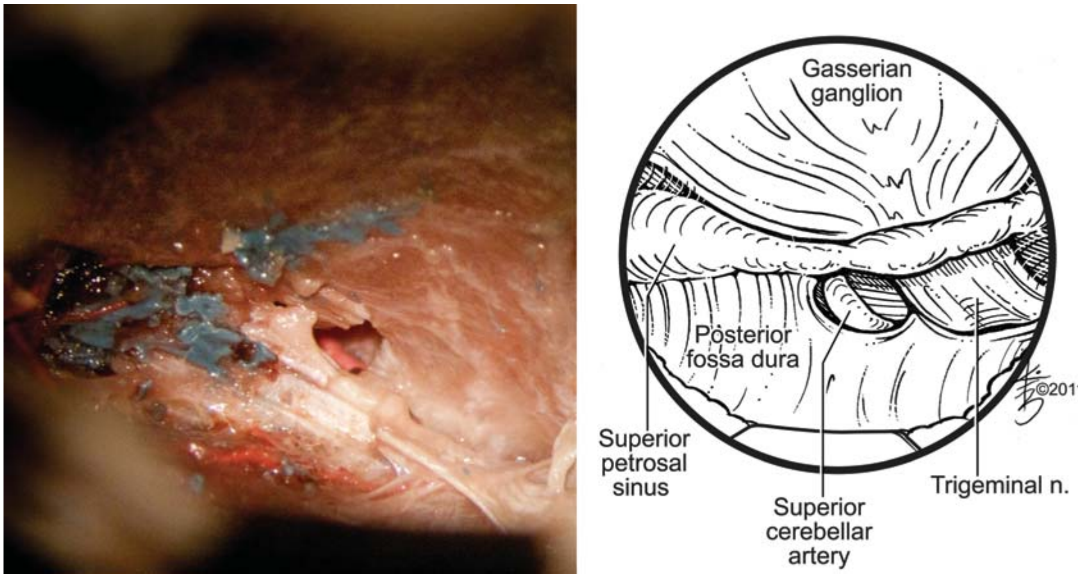

Fig. 9. Cadaver dissection **(left)** and illustration **(right)** of the "extended version" of the translateral orbital approach. The medial temporal fossa is followed as far back as the Meckel cave and the petrous ridge. The posterior fossa dura is opened above the superior petrosal sinus, revealing the superior cerebellar artery in the posterior fossa. Illustration used with permission from KTB Studios, LLC.

Illustrative Case

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).

TABLE 1: Morphometric analysis of the surgical exposure*

Key Anatomical Structures	Mean Length (mm)†	Range (mm)
FZS to superior edge of ZA (vertical extension)	20.8 ± 0.73	20–22
mid-LOR to base of GSW	22.5 ± 0.79	21–24
mid-LOW to edge of GSW (transverse extension)	12.0 ± 1.08	10–14
mid-LOW to edge of GSW (transverse extension)‡	19.25 ± 2.05	17–23
base of GSW to lat end of SOF	13.0 ± 0.90	12–15
junction of LOR/superior edge of ZA to lat end of IOF	17.6 ± 1.55	15–19
base of GSW to posterior edge of FR	27.9 ± 0.90	27–29
base of GSW to tip of ACP	34.9 ± 0.79	34–36
base of GSW to tip of PCP	40.5 ± 1.08	38–42
base of GSW to posterior edge of FO	37.1 ± 1.11	36–39
base of GSW to Meckel cave	41.9 ± 1.16	40–43
base of GSW to petrous edge at trigeminal impression	45.1 ± 0.83	44–46

* 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.

Video 1. Intraoperative video demonstrating the use of the translateral orbital approach in a 70-year-old man who had an enhancing lesion of the right cavernous sinus with optic canal involvement. Illustrations are used with permission from KTB Studios, LLC. Click here to view with Windows Media Player. Click here to view with Quicktime.

Postoperative CT scans demonstrated the extent of bone removal (Fig. 11). Postoperatively, the patient had an uncomplicated course and was sent home on the first postoperative 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[4] and later by Parkinson and Ramsay,[18] 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[26–28] 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

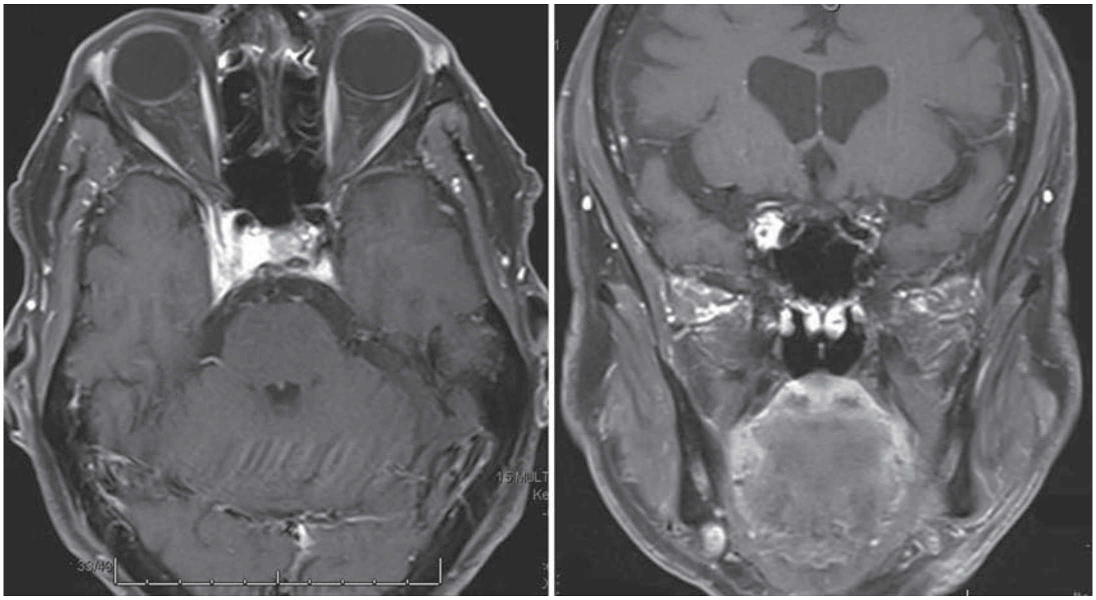

Fig. 10. Axial **(left)** and coronal **(right)** MR images demonstrating an enhancing lesion of the right cavernous sinus with optic canal involvement.

approach has led to the development and modification of most anterior and anterolateral approaches for various pathological conditions. Hakuba et al.[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[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.,[19] Hakuba et al.[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[22] further modified the approach and described the technique used today, while others have reported additional modifications in the technique.[6,12]

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

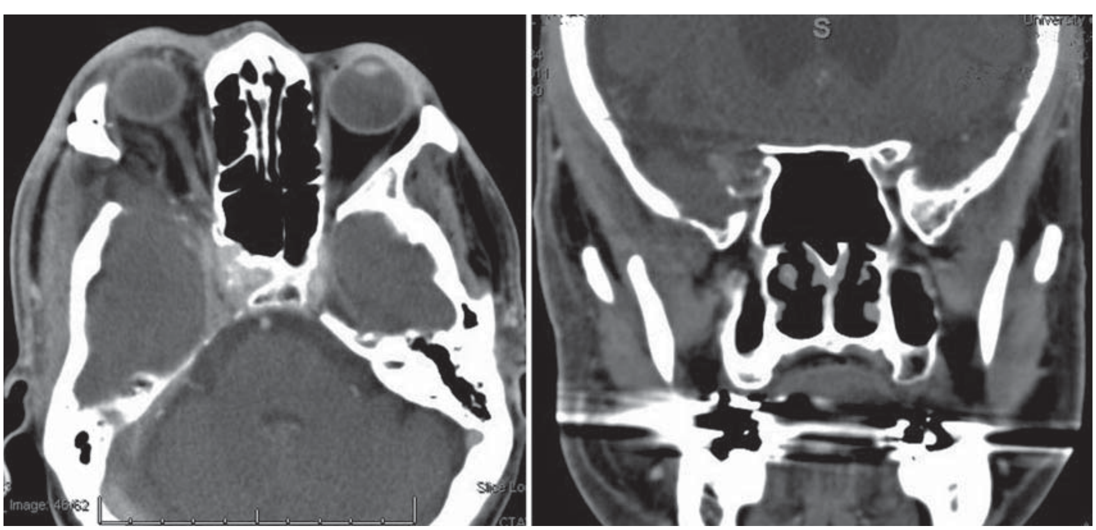

Fig. 11. Postoperative axial **(left)** and coronal **(right)** CT scans showing the extent of bone removal.

lowest possible supratentorial route to the cavernous sinus and the interpeduncular cistern. The approach described by Fujitsu and Kuwabara[11] 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 Anand[2] 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. Perneczky 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.[5] 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[16] to remove an intraorbital tumor. Later, Dollinger[10] 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, Mariniello 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 clinoid 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 clinoid 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 clinoid 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[25] reported a modification in the operation described by Krönlein,[16] making the skin incision in the eyebrow line. Pelton and Patel[20] described the superomedial lid crease approach to the medial intraconal space, and Andaluz et al.[3] and Mariniello 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 cadaver laboratory is mandatory to develop familiarity with the approach. In addition, excessive globe retraction or the use of improper equipment for retraction could cause potential injury to the periorbita or globe. Furthermore, although this step appeared to be easy, removal of the anterior 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 sinus. 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 materials 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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References

1. Al-Mefty O: Supraorbital-pterional approach to skull base lesions. **Neurosurgery 21:**474–477, 1987
2. Al-Mefty O, Anand VK: Zygomatic approach to skull-base lesions. **J Neurosurg 73:**668–673, 1990
3. Andaluz N, Romano A, Reddy LV, Zuccarello M: Eyelid approach to the anterior cranial base. Technical note. **J Neurosurg 109:**341–346, 2008
4. Browder J: Treatment of carotid artery-cavernous sinus fistula. Report of a case. **Arch Ophthalmol 18:**95–102, 1937
5. Couldwell WT, Sabit I, Weiss MH, Giannotta SL, Rice D: Transmaxillary approach to the anterior cavernous sinus: a microanatomic study. **Neurosurgery 40:**1307–1311, 1997
6. Delashaw JB Jr, Tedeschi H, Rhoton AL: Modified supraorbital craniotomy: technical note. **Neurosurgery 30:**954–956, 1992
7. Dolenc V: Direct microsurgical repair of intracavernous vascular lesions. **J Neurosurg 58:**824–831, 1983
8. Dolenc VV: A combined epi- and subdural direct approach to carotid-ophthalmic artery aneurysms. **J Neurosurg 62:**667–672, 1985
9. Dolenc VV: Transcranial epidural approach to pituitary tumors extending beyond the sella. **Neurosurgery 41:**542–552, 1997
10. Dollinger J: Die Druckentlastung der Augenhöhle durch Entfernung der äusseren Orbitalwand bei hochgradigem Exophthalmus (Morbus Basedowii) und konsekutiver Hornhauterkrankung. **Dtsch Med Wochenschr 37:**1888–1890, 1911
11. Fujitsu K, Kuwabara T: Zygomatic approach for lesions in the interpeduncular cistern. **J Neurosurg 62:**340–343, 1985
12. Golshani KJ, Lalwani K, Delashaw JB Jr, Selden NR: Modified orbitozygomatic craniotomy for craniopharyngioma resection in children. Clinical article. **J Neurosurg Pediatr 4:**345–352, 2009
13. Hakuba A, Nishimura S, Shirakata S, Tsukamoto M: [Surgical approaches to the cavernous sinus. Report of 19 cases.] **Neurol Med Chir (Tokyo) 22:**295–308, 1982 (Jpn)
14. Hakuba A, Tanaka K, Suzuki T, Nishimura S: A combined orbitozygomatic infratemporal epidural and subdural approach for lesions involving the entire cavernous sinus. **J Neurosurg 71:** 699–704, 1989
15. Knosp E, Perneczky A, Koos WT, Fries G, Matula C: Meningiomas of the space of the cavernous sinus. **Neurosurgery 38:** 434–444, 1996
16. Krönlein R: Zur Pathologie und operativen Behandlung der Dermoidzysten der Orbita. **Beitr Klin Chir 4:**149–163, 1889
17. Mariniello G, Maiuri F, de Divitiis E, Bonavolontà G, Tranfa F, Iuliano A, et al: Lateral orbitotomy for removal of sphenoid wing meningiomas invading the orbit. **Neurosurgery 66 (6 Suppl Operative):**287–292, 2010
18. Parkinson D, Ramsay RM: Carotid cavernous fistula with pulsating exophthalmus: a fortuitous cure. **Can J Surg 6:**191–195, 1963
19. Pellerin P, Lesoin F, Dhellemmes P, Donazzan M, Jomin M: Usefulness of the orbitofrontomalar approach associated with bone reconstruction for frontotemporosphenoid meningiomas. **Neurosurgery 15:**715–718, 1984
20. Pelton RW, Patel BC: Superomedial lid crease approach to the medial intraconal space: a new technique for access to the optic nerve and central space. **Ophthal Plast Reconstr Surg 17:** 241–253, 2001
21. Perneczky A, Knosp E, Matula C: Cavernous sinus surgery. Approach through the lateral wall. **Acta Neurochir (Wien) 92:** 76–82, 1988
22. Pieper DR, Al-Mefty O: Cranio-orbito-zygomatic approach. **Oper Tech Neurosurg 2:**2–9, 1999
23. Sekhar LN, Schramm VL Jr, Jones NF: Subtemporal-preauricular infratemporal fossa approach to large lateral and posterior cranial base neoplasms. **J Neurosurg 67:**488–499, 1987
24. Sekhar LN, Sen CN, Jho HD, Janecka IP: Surgical treatment of intracavernous neoplasms: a four-year experience. **Neurosurgery 24:**18–30, 1989
25. Stallard HB: A plea for lateral orbitotomy: with certain modifications. **Br J Ophthalmol 44:**718–723, 1960
26. Yaşargil MG: **Microneurosurgery, Vol IVB: Microneurosurgery of CNS Tumors.** New York: Thieme, 1996
27. Yaşargil MG, Antic J, Laciga R, Jain KK, Hodosh RM, Smith RD: Microsurgical pterional approach to aneurysms of the basilar bifurcation. **Surg Neurol 6:**83–91, 1976
28. Yaşargil MG, Fox JL: The microsurgical approach to intracranial aneurysms. **Surg Neurol 3:**7–14, 1975

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http://mfile.akamai.com/21488/mov/digitalwbc.download.akamai.com/21492/qt.digitalsource-global/JNS11-1251_video_NEW.mov (Quicktime).

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