Tumors of the lateral wall of the cavernous sinus

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The lateral dural wall of the cavernous sinus is composed of two layers, the outer dural layer (dura propria) and the inner membranous layer. Tumors arising from the contents of the lateral dural wall are located between these two layers and are classified as interdural. They are in essence extradural/extracavernous. The inner membranous layer separates these tumors from the venous channels of the cavernous sinus.

Preoperative recognition of tumors in this location is critical for selecting an appropriate microsurgical approach. Characteristics displayed by magnetic resonance imaging show an oval-shaped, smooth-bordered mass with medial displacement but not encasement of the cavernous internal carotid artery. Tumors in this location can be resected safely without entering the cavernous sinus proper by using techniques that permit reflection of the dura propria of the lateral wall (methods of Hakuba or Dolenc).

During the last 5 years, the authors have identified and treated five patients with interdural cavernous sinus tumors, which included two trigeminal neurinomas arising from the first division of the fifth cranial nerve, two epidermoid tumors, and one malignant melanoma presumed to be primary. The pathoanatomical features that make this group of tumors unique are discussed, as well as the clinical and radiological findings, and selection of the microsurgical approach. A more favorable prognosis for tumor resection and cranial nerve preservation is predicted for interdural tumors when compared with other cavernous sinus tumors.

Key Words: cavernous sinus • dural wall • interdural tumor • dura propria • operative technique

A thorough understanding of the anatomy of the lateral wall has been critical to the evolution of cavernous sinus surgery. The lateral wall is composed of two layers, the outer dural layer (dura propria) and the inner membranous layer. These two layers are loosely attached and easily separable. The outer layer is thicker and more complete than the inner layer. The inner membranous layer is formed by the sheaths of the third and fourth cranial nerves, of the ophthalmic and occasionally the maxillary division of the fifth cranial nerve, and a reticular membrane extending between these nerve sheaths. The inner layer separates the lateral wall and its contents from the venous channels of the cavernous sinus.6, 24, 25 Based on our experience with cavernous sinus tumors and on a review of the literature, we believe it is important to differentiate between tumors confined to the lateral wall and those in or invading the cavernous sinus proper. Tumors of the lateral wall include trigeminal neurinoma of the ophthalmic nerve and oculomotor and trochlear neurinomas.2, 9, 10, 13, 16, 17, 20, 22, 23 Other tumors that may be confined to the lateral wall are epidermoid cysts, melanomas, and cavernous angio-

mas.1, 3, 12, 14, 18, 19 These tumors tend to have a greater chance of radical resection and a more favorable prognosis than other types of cavernous sinus tumors.13, 15, 22

We report five cases of tumors of the lateral wall of the cavernous sinus and discuss their pathoanatomical features, clinical and radiological findings, and selection of the microsurgical approach.

Clinical Material and Methods

Patient Presentation

During the 5 years from 1987 to 1991, we identified and treated five patients with interdural cavernous tumors including two trigeminal neurinomas arising from the first division of the fifth cranial nerve, two epidermoid tumors, and one primary malignant melanoma. Patient data are summarized in Table 1 for the two women and three men, who ranged in age from 24 to 63 years (mean 50.8 years). All patients presented with cavernous sinus syndrome in the form of third, fourth, fifth (first and occasionally second division), and sixth nerve palsy. The two patients with trigeminal neurinomas presented with progressive facial numbness (Case
Tumors of the cavernous sinus

1) and facial pain (Case 2) associated with partial third and sixth cranial nerve palsies, respectively. Another patient (Case 4) also presented with decreased visual acuity in the right eye to 20/200.

Imaging Studies

In four cases, computerized tomography was performed to reveal an oval-shaped, smooth-contoured mass in the cavernous sinus. The mass was isodense with homogeneous enhancement in Case 1 (Fig. 1 left), hypodense with only enhancement of the lateral wall in Case 2, hypodense without contrast enhancement in Case 3, and hyperdense without obvious enhancement in Case 5.

In all cases, magnetic resonance (MR) imaging revealed an oval-shaped, smooth-contoured mass in the cavernous sinus with medial displacement of the intracavernous portion of the internal carotid artery (ICA) without narrowing or encasement. Signal characteristics on MR imaging helped to predict the histological diagnosis. In Cases 1 and 2 (trigeminal neurinoma), the mass was isointense on T1-weighted MR images and hyperintense on T2-weighted images with homogeneous enhancement following gadolinium infusion (Fig. 1 center and right). In Case 3 (epidermoid tumor), the mass was hypointense on T1-weighted images (Fig. 2 right) and hyperintense on T2-weighted images (Fig. 2 left) without enhancement after gadolinium infusion. In Case 4 (epidermoid tumor), the mass was hyperintense on T1-weighted images (Fig. 3 left) and hyperin-
tense with multifocal areas of low-signal intensity on T2-weighted images. The histological diagnosis of a white epidermoid tumor was made. In Case 5 (melanoma), the mass was hyperintense on T1-weighted images (Fig. 3 right), hyperintense with multifocal areas of low-signal intensity on T1-weighted images, and without obvious enhancement after gadolinium infusion. These MR signal characteristics were interpreted as consistent with either subacute hemorrhage into a tumor or a melanotic tumor.4 The possibility of white epidermoid tumor was excluded on the basis of heterogeneity of signal intensity when compared with the homogeneous signal in Case 4.

Operative Technique

The surgical approach is detailed in Table 1. The lateral wall of the cavernous sinus was exposed via frontotemporal craniotomy. Bulging of the lateral wall was noted in all five cases. The dura propria was incised in Parkinson's triangle,4,25 and was extended forward along the first division of the fifth nerve. In the trigeminal neurinomas, a grayish-white, soft, mildly vascular, well-circumscribed tumor was identified arising from the first division, displacing the second division inferolaterally. The tumor's origin from the trigeminal fibers was resected along the tumor. The tumor was easily dissected from the oculomotor and trochlear nerves as well as from the intact inner membranous layer. Brisk venous hemorrhage was noted only when dissection penetrated the membranous layer, but was controlled easily with Surgicel packing.

In Case 4, a soft waxy epidermoid material was removed by curettage. The inner membranous layer of the lateral wall was intact and venous bleeding was not encountered. In Case 5, a brownish discoloration of the bulging lateral wall was noted. An incision in the lateral wall revealed a vascular spongy mass surrounded by hemorrhage. The tumor was literally shelled out of its cavity without entering the cavernous sinus proper. Use of the whole Dolenc technique4,5,25 enabled us to expose fully the extent of the bulging lateral wall and to achieve a more radical resection in Cases 2 and 3.

Illustrative Case

Case 3

This 24-year-old woman with mild right ptosis and mydriasis since childhood presented with diplopia due to oculomotor nerve palsy. Computerized tomography

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**TABLE 1**

Case summary of five patients with tumors of the lateral wall of the cavernous sinus

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Symptoms</th>
<th>Signs</th>
<th>CT Findings</th>
<th>MR Findings</th>
<th>Surgical Approach</th>
<th>Histopathology</th>
<th>Follow-Up MR Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53, M</td>
<td>diplopia (5 mos), progressive facial numbness (14 mos)</td>
<td>mild rt ptosis, hypalgesia in V1 &amp; V2; diminished corneal reflex</td>
<td>isodense mass in right CS, homogeneous enhancement</td>
<td>T1; iso T2; hyperintense</td>
<td>rt frontotemporal craniotomy, zygomatic osteotomy</td>
<td>trigeminal neurinoma</td>
<td>no residual tumor</td>
</tr>
<tr>
<td>2</td>
<td>63, M</td>
<td>previous resection of V neurinoma in 1975, progressive facial pain, horizontal diplopia (3 yrs)</td>
<td>progressive VI nerve palsy</td>
<td>hypodense oval-shaped mass, enhancement of lateral wall</td>
<td>T1; iso T2; hyperintense</td>
<td>lt frontotemporal craniotomy, Dolenc technique</td>
<td>trigeminal neurinoma</td>
<td>no residual tumor</td>
</tr>
<tr>
<td>3</td>
<td>24, F</td>
<td>diplopia (6 mos)</td>
<td>IV nerve palsy; rt ptosis, mydriasis</td>
<td>hypodense, no enhancement</td>
<td>T1; hyperintense T2; hyperintense (no enhancement)</td>
<td>1st op: rt frontotemporal craniotomy; 2nd op: rt frontotemporal craniotomy, Dolenc technique</td>
<td>epidermoid tumor</td>
<td>no residual tumor after 2nd op</td>
</tr>
<tr>
<td>4</td>
<td>53, M</td>
<td>headaches, V1, V2, V3; diplopia (3 mos)</td>
<td>decreased rt visual acuity to 20/200; IV nerve palsy; partial III nerve palsy</td>
<td>not done</td>
<td>T1; hyperintense T2; multifocal areas of low signal</td>
<td>rt frontotemporal craniotomy</td>
<td>epidermoid tumor</td>
<td>recurrence</td>
</tr>
<tr>
<td>5</td>
<td>61, F</td>
<td>left facial pain, diplopia</td>
<td>dense hypalgesia in V1 &amp; V2, mild in lt VI nerve palsy</td>
<td>hyperdense without obvious enhancement</td>
<td>T1; hyperintense</td>
<td>1st op: rt frontotemporal craniotomy; 2nd op: rt frontotemporal craniotomy</td>
<td>melanoma</td>
<td>tumor recurrence after 1st op (radiation therapy after 2nd op)</td>
</tr>
</tbody>
</table>

*Abbreviations: V1, V2, V3 = first, second, and third divisions of the fifth cranial nerve; CS = cavernous sinus; CT = computerized tomography; MR = magnetic resonance.*
Tumors of the cavernous sinus

Fig. 4. Case 3. Intraoperative photographs and interpretive drawings. A and B: The bulging lateral wall (LW) of the cavernous sinus is seen. Typical epidermoid material (arrow) extrudes through the oculomotor foramen and splays the oculomotor nerve (III). Artist’s depiction shows the optic nerve (II) and the internal carotid artery (ICA). C and D: Incision of the lateral wall in the area of Parkinson’s triangle reveals “pearly” epidermoid material. E and F: The epidermoid contents have been evacuated. The cavernous sinus contents are protected by a thin tumor capsule (TC) and inner membranous layer (arrows).

and MR imaging documented the presence of a tumor of the lateral wall of the right cavernous sinus (Fig. 2), which was identified as black epidermoid tumor by MR imaging.

First Operation. The lateral wall of the cavernous sinus was exposed via frontotemporal craniotomy. A severely bulging lateral wall was noted with typical pearly epidermoid material exuding through the oculomotor foramen and splaying the nerve. Epidermoid material was curetted from the interdural space, but no attempt was made to remove the tumor wall beyond the opening in the dura propria (Fig. 4). Postoperatively, diplopia resolved in the primary gaze but persisted in the upward gaze. Progressive oculomotor palsy returned 2 years after surgery; MR imaging showed that the tumor had recurved and was slightly larger than at original presentation (Fig. 2 right).

Second Operation. The patient underwent a second operation using a standard Dolenc technique as described elsewhere.5,6,25 The epidermoid contents were removed and a near-total resection of the tumor capsule was achieved (with minimal venous bleeding) including dissection of that portion attached to the inner membranous layer. A small portion of the capsule was left adherent to a segment of thinned oculomotor nerve.

Postoperative Course. Following surgery, diplopia in primary gaze again resolved while diplopia in upward gaze remained unchanged. Follow-up MR imaging revealed no evidence of residual tumor or capsule.

Results

Immediately after surgery, three patients (Cases 1, 2, and 3) showed significant improvement of their diplopia and objective improvement of their cranial nerve palsy. The relatively long-standing abducens nerve palsy in Case 2 resolved completely within 24 hours of surgery, which implied that nerve dysfunction had been due to a chronic sustained neuropraxia. In Case 4, there was no change in the partial oculomotor palsy, and trochlear paralysis persisted. In Case 5, postoperative oculomotor palsy developed but resolved completely over 5 months. In Case 1, ophthalmic division sensory loss changed to denervation dysesthesia, which responded to amitriptyline. Immediately after surgery in Cases 4 and 5, facial pain and numbness improved significantly. In Case 4, visual acuity was restored to 20/25.

After follow-up periods of 6 months to 5 years (mean 1.3 years) in this series, no residual tumor occurred in either case of trigeminal neurectomy; however, epidermoid tumors recurred in Cases 3 and 4. The recurrence
in Case 4, discovered 3 years later on follow-up MR imaging, will likely increase in size and eventually require reoperation. In Case 5 (melanoma), a routine 6-month MR image revealed recurrence of tumor even though the patient remained asymptomatic. At re-exploration, multiple metastatic nodules of melanoma were found throughout the dura of the lateral wall and middle cranial fossa. Following surgery the patient underwent radiation therapy.

Discussion

Surgical resection (partial or total) of cavernous sinus tumors can be achieved with acceptable morbidity if the anatomy of the cavernous sinus is understood, the pathoanatomy of the tumor is carefully considered, and the case is properly selected. A small subset of cavernous sinus tumors, which we classify as interdural tumors of the lateral wall of the cavernous sinus, highlights these principles.

Anatomy of the Lateral Wall of the Cavernous Sinus

The cavernous sinus is a kind of pentahedron with five walls: lateral, medial, posterior, superior, and inferior. The lateral wall is composed of two layers, the outer dural layer (dura propria) and the inner membranous layer. The oculomotor nerve, trochlear and ophthalmic nerves, and occasionally the maxillary division of the trigeminal nerve course between the two layers of the lateral wall of the cavernous sinus. The inner membranous layer separates the lateral wall and its contents from the venous channels of the cavernous sinus.

The anterior petroclinoid fold forms the superior border of the lateral wall. The petroclinoid fold extends from the anterior clinoid process to the petrous apex where it blends with the tentorial edge. Additionally, it separates the lateral wall from the superior wall (roof) of the cavernous sinus. The inferior border of the lateral wall follows the line of the ophthalmic division from Meckel's cave to the superior orbital fissure. The dura propria continues across this border to become the lateral wall of Meckel's cave. The inner membranous layer continues as a single layer covering the contents of the superior orbital fissure into the periorbita. The outer dura propria does not follow the superior orbital fissure but rather is reflected to form the dura of the temporal fossa.

Pathoanatomy of Interdural Tumors

We designated tumors of the lateral wall of the cavernous sinus as interdural because of their location within the potential space between the outer dura propria and the inner membranous layer. Based on a thorough understanding of the microsurgical anatomy of the cavernous sinus and experience with tumors of the cavernous sinus region, we classify cavernous sinus tumors as one of three types: intracavernous, interdural, or invasive (Table 2). Intracavernous tumors, arising within the cavernous sinus, are rare (Fig. 5); they include meningioma and hemangiopericytoma. In theory, meningiomas may arise from residual arachnoidal epithelium or pacchionian granulations around the ICA. Invasive tumors involving the cavernous sinus arise from structures outside the cavernous sinus and invade through its walls or along neurovascular structures to traverse the cavernous sinus. Sphenoid wing and petroclival meningiomas are the most common invasive tumors of the cavernous sinus (Table 2). Interdural tumors arise infrequently and remain between the two layers of the lateral wall of the cavernous sinus (Fig. 1). These tumors include trigeminal neurinomas of the first division of the trigeminal nerve and, less frequently, oculomotor and trochlear neurinomas. Other tumors that may be confined to the lateral wall are epidermoid, melanoma, and cavernous angioma. Although relatively rare, interdural tumors are classified separately because preoperative recognition and appropriate surgical planning will enhance the prognosis for resection and cranial nerve preservation.

Magnetic resonance imaging has facilitated the recognition of interdural cavernous sinus tumors by their typical smooth contours, oval shape, and medial displacement of the intracavernous portion of the ICA without encasement or narrowing. In contrast, intracavernous and invasive tumors tend to encase and narrow the ICA. Once an interdural location is suspected, MR imaging signal characteristics will generally define the histology. Trigeminal neurinomas are isointense on T1-weighted images and hyperintense on T2-weighted images, and show homogeneous contrast enhancement. Cavernous angioma of the lateral wall (not encountered in this series) is similar to neurinoma but showed more intense contrast enhancement without an associated mass in Meckel's cave. Black epidermoid tumor is hypointense on T1-weighted images and hyperintense on T2-weighted images, and shows no contrast enhancement. White epidermoid tumor, as in Case 4, is homogeneously hyperintense on T1-weighted images. Other specific MR imaging signal characteristics will help predict additional rare tumors of the lateral wall such as melanoma in Case 5.

<table>
<thead>
<tr>
<th>Type</th>
<th>Location</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>intracavernous</td>
<td>meningiomas, hemangiopericytomas, ganglioneuroblastomas</td>
</tr>
<tr>
<td>II</td>
<td>interdural</td>
<td>tumors of the lateral wall of the cavernous sinus</td>
</tr>
<tr>
<td>III</td>
<td>invasive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>medial</td>
<td>invasive pituitary adenomas</td>
</tr>
<tr>
<td></td>
<td>lateral</td>
<td>sphenoid wing meningiomas</td>
</tr>
<tr>
<td></td>
<td>superior</td>
<td>clino&amp; medial sphenoidal meningiomas</td>
</tr>
<tr>
<td></td>
<td>inferior</td>
<td>carcinomas, chordomas, chondrosarcomas</td>
</tr>
<tr>
<td></td>
<td>posterior</td>
<td>petroclival meningiomas</td>
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TABLE 2
Classification of cavernous sinus tumors

M. El-Kalliny, et al.

J. Neurosurg. / Volume 77 / October, 1992

512
Tumors of the cavernous sinus

Neurinomas are the most common benign tumor of the lateral wall. 9,10,12,14,17,20,22 Because neurinomas of motor nerves are rare, most will arise from the ophthalmic division of the trigeminal nerve. The inner membranous layer restricts tumors arising in or entering the interdural space from invading the cavernous sinus proper. This restriction may be short-lived and confined to early tumor growth; a few tumors grow relatively large without violating the layer. Therefore, it is not clear if the ability of the inner membranous layer to contain tumor growth in some cases relates to variability in strength, integrity, and completeness, or the biological characteristics of the tumor. We recently encountered a case of trigeminal neurinoma with malignant features that clearly invaded the inner membranous layer.

Our observations are not unique. Inoue, et al. 10 reported that two trigeminal neurinomas arising from the ophthalmic division were located in the lateral space of the cavernous sinus. In surgical resection of both neurinomas, the intracavernous portion of the ICA was not exposed; these tumors were probably interdural. Because the inner membranous layer separates these tumors from the cavernous ICA, test occlusion of the ICA is usually not required preoperatively. Cranial nerve morbidity is less with resection of interdural tumors versus intracavernous or invasive tumors because the need to skeletonize the cranial nerves in the lateral wall from their vascular supply is decreased or eliminated.

Our decisions not to remove the capsule at first operation in Cases 3 and 4 were based on the assumption that symptomatic recurrence would be extremely slow. Growth of ectodermally derived tumors is described as linear rather than exponential. After aggressive removal of the epidermoid material, the time to symptomatic recurrence has been described as the patient’s age at the time of presentation plus 9 months. 13 Although one might speculate that epidermoid tumors in this location may grow more rapidly, the actual growth rate may have been underestimated due to the increasing tumor bulk compressed within a closed cavity of the lateral wall.

In this small series, there is ample evidence that too limited an exposure and failure to fully understand the anatomy of the lateral wall can result in incomplete resection. 7,15,21 We recommend a frontotemporal cranietomy with orbitozygomatic osteotomy to approach directly the cavernous sinus lateral wall. A Dolenc or Hakuba technique is necessary to explore the full extent of the lateral wall, but this is not required in every case. The morbidity associated with these approaches is outweighed by the disadvantages of limited exposure and incomplete resection with other approaches.

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References


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