Management of bone-invasive, hyperostotic sphenoid wing meningiomas

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Object. The hyperostosis frequently associated with sphenoid wing meningiomas is actual invasion of bone by the tumor. The intracranial portion of the tumor is usually thin with en plaque spread, and the tumor tends to invade the orbit through the superior orbital fissure.

Methods. The authors reviewed the records of 67 patients with sphenoid wing meningiomas who underwent surgery at the University of Arkansas for Medical Sciences between 1994 and 2004. In all 67 cases, the surgery was performed by the senior author. Seventeen of the patients had the distinguishing characteristics of hyperostotic sphenoid wing meningiomas—extensive bone invasion, en plaque dural involvement, and a minimal intracranial mass with minimal orbital involvement. In all patients, hyperostosis was determined on the basis of preoperative neuroimaging. Histopathological evaluation of bone specimens was performed in 14 cases. Estrogen and progesterone receptor expression and Ki 67 labeling were evaluated in all specimens. Chromosome analysis was performed in all tumors resected since 2001 (seven cases). Particular attention was paid to removing all involved bone and dura mater.

Results. Total removal was achieved in 14 cases (82.3%), with only one recurrence (7.1%) over a mean follow-up period of 36 months (range 5–72 months). Radical resection was followed by cranioorbital reconstruction to prevent enophthalmos and to obtain good cosmetic results. No deaths or serious complications occurred in association with surgery. Proptosis was corrected in all cases and visual acuity improved in seven (70%) of 10 cases. Revision of the orbital reconstruction was required because of postoperative enophthalmos (two cases) or restricted postoperative ocular movement (one case).

Conclusions. Sphenoid wing meningiomas frequently invade bone, although such invasion does not represent malignancy. These lesions are generally histologically benign. Total removal with a prospect for cure and visual preservation should be the goal of treatment. This requires extensive drilling of the invaded bone and extensive excision of the involved dura. When the optic canal is involved, it should be decompressed. Extensive bone resection should be followed by cranioorbital reconstruction for good cosmesis and to prevent enophthalmos. (DOI: 10.3171/JNS-07/11/0905)

Key Words • bone invasion • hyperostosis • meningioma • sphenoid wing

HYPEROSTOSIS is a well-known phenomenon associated with meningiomas. It was first described by Brissaud and Lereboullet in 1903. Hyperostosis is seen in 25 to 49% of meningiomas10,11,16,39 with the convexity and sphenoid wing most frequently affected.11,13 In 1952, Castellano and colleagues8 reported high surgical mortality for patients with meningioma en plaque and concluded that these tumors should be operated upon only as a last resort. Since that time, there has been significant progress in preoperative neuroimaging evaluations and in surgical techniques (including microsurgical techniques), but recurrence rates remain higher than those for other meningiomas because of the difficulty of achieving total removal.27,30

We report our experience with the radical removal of sphenoid wing meningiomas that invaded the bone in 17 patients. Our review confirms the results of previous reports,6,12,35 which show that hyperostosis associated with sphenoid wing meningiomas is caused by bone invasion. We also document the significance of total removal, including invaded bone and involved dura mater, to lower the recurrence rates. Lastly, we emphasize the importance of orbital reconstruction for good cosmesis and ocular motility.

Clinical Material and Methods

Between 1994 and 2004, 17 patients with hyperostotic sphenoid wing meningiomas underwent surgery at the University of Arkansas for Medical Sciences. In all cases the surgery was performed by the senior author (O.A.M.). Patients with extensive hyperostosis, en plaque dural invasion, and minimal intracranial tumor were included in the study. We did not include patients with nonhyperostotic sphenoid wing meningiomas, hyperostotic sphenoid wing meningiomas with a moderate or large intracranial tumor portion, or clinoid or primary optic nerve sheath meningiomas. All patients underwent detailed neurological
and ophthalmological examinations during the preoperative and postoperative periods. Preoperative neuroimaging evaluations included CT, MR imaging with and without gadolinium enhancement, especially postcontrast fat suppression T1-weighted images; MR angiography; and MR venography. Total resection was achieved as described under Surgical Technique.

Intraoperative monitoring included electromyographic recordings of ocular muscles, brainstem evoked potentials, and somatosensory evoked potentials. Intraoperative neuronavigation was used in all but one case. During surgery, portions of the hyperostotic bone and dural tail were removed and sent for histological analysis. The histopathological examination included routine examination of formalin-fixed specimens as well as evaluation of Ki 67 labeling and estrogen and progesterone receptor expression. All histopathological specimens were reviewed by one of the authors (R.M.). All patients were followed up with serial clinical and neuroimaging examinations (mean 36 months, range 5–72 months).

Surgical Technique

The skin incision is initiated 1 cm anterior to the tragus at the level of the zygomatic arch and extended behind the hairline toward the contralateral superior temporal line. This incision location allows the surgeon to preserve the superficial temporal artery that courses behind it and the branches of the facial nerve that pass anterior to it.2 The scalp flap is reflected anteriorly, leaving thick areolar tissue with the pericranial layer adhering to the calvaria. Both the superficial and the deep layers of the temporal fascia are incised 1 cm posterior and parallel to the course of the frontal branches of the facial nerve, along the zygomatic arch. The deep and superficial layers with their intervening fat pad, which contain the facial branches, are then reflected with the skin flap.

The B-1 attachment of the Midas Rex drill (Medtronic, Inc.) is used for the zygomatic osteotomy, but the zygoma is left attached to the masseter muscles. The temporal muscle is carefully dissected and reflected inferiorly with the zygoma. Great attention is paid during dissection of the temporal muscle to prevent damage to the blood supply and nerve innervation, with the goal of avoiding muscle atrophy.20 Any tumor involvement noticed during elevation of the temporal muscle is excised. At this point, titanium mesh is laid over the skull and contoured to preserve the patient’s appearance. The mesh is then removed to be prepared for precise reconstruction, to be performed after the resection is completed.

Numerous bur holes are made around the invaded (hyperostotic) bone to prevent excessive bleeding. The drill is then used to connect the bur holes and remove the invaded bone. This process continues until all hyperostotic tissue is removed from the sphenoid wing, the middle fossa, and the pterygoid plate. Hyperostotic tissue is subsequently removed in a similar manner from the lateral and superior rims and walls of the orbit if they have been infiltrated by tumor. The superior orbital fissure is then identified and the bone is completely removed from this area. The anterior clinoid process is removed after the optic canal is unroofed and the inferior optic strut is removed. If necessary, the optic foramen is decompressed to allow the patient better vision or at least to prevent worsening. This is one of the most important steps that directly influences clinical outcome.

Further attention is focused on resecting the dura and the intradural portion of the tumor. The intraoperative navigational system helps confirm the resection of all invaded bone and identify all infiltrated dura mater. The dura is resected beyond the enhanced dural tail along with any intracranial portion of the tumor. Any intraorbital extension with involvement of the periorbita and extraocular muscles should also be removed. Abdominal fat is harvested from the left lower quadrant of the patient’s abdomen and placed into the frontal, maxillary, and ethmoid sinuses if they have been opened. To prevent postoperative development of a cerebrospinal fluid fistula and rhinorrhea, a duraplasty is performed using fascia lata or cadaveric dura mater.

The extent of orbital reconstruction depends on the size of the defect. If the superior and lateral orbital rims have been removed then the Porex (Porex Surgical) orbital prosthesis is used. If only the superior and lateral walls of the orbit have been removed, the area can be reconstructed using one of several different methods, including the use of a prosthesis, mesh, or split bone. The titanium mesh prepared earlier is used to repair the rest of the bone defect. Fixation is performed with a plate and screws, and the pericranial flap is brought over the orbit and frontal sinus. The temporal muscle is then reattached and the skin is closed in two layers.

Illustrative Case

This 48-year-old woman (Case 16) presented with proptosis of her left eye and headache. Neurological and ophthalmological examinations were normal other than the proptosis of the left orbit. Neuroimaging evaluation with CT, including bone window images, and MR imaging revealed abundant hyperostosis of the sphenoid wing and anterior clinoid with involvement of the optic canal (Fig. 1A), the middle fossa (Fig. 1B), and the lateral wall of the sphenoid sinus and the pterygoid plate (Fig. 1C). Fat-suppression and contrast-enhanced MR imaging sequences demonstrated the dural tail sign and intraorbital involvement (Fig. 2).

Surgery was performed with the aid of a drill, and tumor was totally removed from all involved bones and the dura mater. Cranioorbital reconstruction was performed during the same operation as described under Surgical Technique (Fig. 3).

The results of histological evaluation, including examination of the invaded bone and the dura mater, showed the lesion to be a meningioma (Figs. 4 and 5). The Ki 67 labeling index was between 2 and 3%; the results of hormone receptor testing were negative for estrogen and positive for progesterone. Postoperative course was uneventful and the patient was discharged on postoperative Day 6. She had experienced no recurrence as of the 3-year follow-up evaluation.

Results

Our series included 15 women and two men, ranging in age between 36 and 70 years (mean 51.7 years). Two patients had undergone surgery (subtotal resection) previously at other hospitals. One patient had undergone a biopsy 3 months before the radical surgery. The clinical manifesta-
tions present at the onset of disease in these cases are summarized in Table 1. The most common presenting symptom was proptosis, which was observed in 12 patients (71%), followed by progressive visual loss in 10 patients (59%), and headache in seven patients (41%).

Preoperative neuroradiological evaluations demonstrated hyperostosis in all 17 patients. The sphenoid ridge was a constant location for hyperostosis (observed in all cases), followed by the lateral and superior walls of the orbit, in 71 and 41% of patients, respectively (Table 2).

The tumor was resected and the orbit reconstructed during one operation in all patients. Two patients who had preoperative enophthalmos underwent later revitalization of their orbital reconstruction, which resolved the enophthalmos.

Surgical Results

There were no deaths related to the surgical procedures in this series of cases. In the early postoperative period, one patient with cavernous sinus invasion had transient sixth and third nerve palsies. The tumor was resected and the orbit reconstructed during one operation in all patients. Two patients who had postoperative enophthalmos underwent subsequent revitalization of their orbital reconstructions, which resulted in resolution of the enophthalmos (Fig. 6). One patient had restricted motor function in the extraocular muscles after reconstruction, but this problem was corrected with an additional surgical procedure. Cerebrospinal fluid rhinorrhea in one patient was successfully treated by placement of a lumbar drain. Preoperative proptosis was corrected in all patients, and 70% of patients had improved vision after surgery. There was no worsening of vision in any patient.

Total tumor removal was achieved in 14 patients (82.3%). Three patients had small residual tumor foci located around the cavernous carotid artery and along the orbital apex. One patient had a recurrence 6 years after surgery, which was treated with surgery and radiosurgery.

Histological Results

The results of histopathological evaluation are summarized in Table 3. Bone invasion was confirmed histologically, but most of the hyperostotic bone was removed by drilling. In 15 of the 17 cases, the tumors were histologically benign (WHO Grade I); the other two tumors showed some chordoid features and were thus classified as WHO Grade II. Meningotheliomatous growth patterns predominated in most of the tumors (11 of 16), with transitional growth patterns often present as a minor component. Three tumors showed some atypical features, but did not meet the criteria for “atypical meningioma.” Bone invasion by the tumor was confirmed histologically in 12 of 13 patients (Fig. 5). Histological examination did not show tumor invasion into the bone in one case, but this finding can be attributed to a loss of involved bone through aggressive drilling and the consequent evaluation of an inappropriate specimen because of the drilling. None of the tumors expressed estrogen receptors, and all but three expressed progesterone receptors. In most of the tumors, the Ki 67 labeling index was less than 1%. Chromosome analysis was performed in the seven most recent cases; in two of those seven, analysis demonstrated abnormal karyotypes.
Discussion

Cause of Hyperostosis

The association of hyperostosis with meningiomas was first described by Brissaud and Lereboullet in 1903. Theories of the cause have included vascular disturbances of bone caused by the tumor, irritation of the bone without actual invasion, previous trauma, the production of bone by the tumor itself, and the stimulation of osteoblasts in normal bone by factors secreted by tumor cells. The most widely accepted theory, however, is that of tumor invasion of the bone. Bonnal and colleagues linked hyperostosis of the sphenoid wing and anterior clinoid process with tumor invasion. In a previous report, we confirmed bone invasion by the tumor histologically in 35 of 51 resected specimens from meningioma patients. Our review of the present series again confirms this association.

Symptoms and Their Correction

The symptoms arising from bone-invasive sphenoid wing meningiomas are due to hyperostosis. The most common presenting symptom is proptosis, which is unilateral, nonpulsating, irreducible, and slowly evolving. Hyperostosis of the orbital walls, periorbital tumor invasion, intraorbital tumor, and venous stasis from compression of the ophthalmic vein could all cause proptosis. Other symptoms include headache, visual loss, ptosis, diplopia, and seizures. Unilateral visual loss is generally due to narrowing of the optic foramen. The findings in our series reflect those of the literature: proptosis was the most common presenting symptom, followed by visual loss, and headache, with rates of 71, 59, and 42%, respectively. Decompressing the optic canal and superior orbital fissure is important for correcting the symptoms of visual loss and diplopia. We strongly recommend decompressing the optic canal in all involved cases to at least prevent greater loss of vision. Correcting proptosis also requires extensive excision of the invaded bone, which should be done in all cases in addition to adequate reconstruction of the orbit.

Imaging Evaluation

A comprehensive neuroimaging evaluation should include an MR imaging study with gadolinium enhancement and fat suppression as well as a special oblique cut along the optic nerve. These images should be complemented with high-resolution CT scans to accurately delineate bone involvement. Kim and associates showed the cardinal CT features of en plaque meningiomas well. They subclassified hyperostotic patterns into the following four types: homogeneous, periosteal, three layer, and diploic. They found that inward bulging of the inner aspect of the hyperostotic bone and surface irregularity of the hyperostotic bone are important features, especially in the differential diagnosis of other hyperostotic conditions, such as osteoma and fibrous dysplasia. Additional useful features include intracranial changes such as mass effect on the brain, cerebral edema, an intracranial enhancing mass, and subdural ossification. These are also important differentiating features for preoperative imaging evaluation.

Common locations for bone thickening are the greater and lesser sphenoid wings, the clinoid process, and the roof.
There is no relation, however, between the size of the tumor and the degree of hyperostosis. Hyperostosis is mostly seen from outside to inside, from the greater sphenoid wing to the lesser sphenoid wing, and from the lesser wing to the sphenoid corpus. Widening of the vascular grooves, superior orbital fissure, and sphenoparietal sinus, and narrowing of the optic canal are other features of these tumors.

With the modern improvements in imaging technology (thin-cut coronal bone CT scans, 3D reconstructed bone CT scans), even a small amount of hyperostosis can be easily defined. Although hyperostosis is best visualized on CT scans, the tumor and invaded dura are best seen on contrast-enhanced MR images. Postcontrast, fat suppression, T1-weighted MR images are also useful for evaluating meningeal enhancement, especially in tumors that extend into the orbit. Carotid angiography is not essential, and MR angiography or CT angiography provide adequate information about the arterial anatomy. We agree with Maroon and colleagues that postcontrast, fat suppression, T1-weighted MR images are necessary to define the limits of the dural

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Areas of Hyperostosis on Neuroimages</th>
<th>Histological Confirmation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50, F</td>
<td>sphenoid ridge, lat &amp; sup walls of orbit, sphenoid sinus, pterygoid process</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>52, F</td>
<td>sphenoid ridge, lat &amp; sup walls of orbit, sphenoid sinus, pterygoid process</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>45, M</td>
<td>sphenoid wing, lat wall of orbit</td>
<td>NA</td>
</tr>
<tr>
<td>4</td>
<td>51, F</td>
<td>sphenoid wing</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>63, F</td>
<td>sphenoid wing, lat &amp; sup walls of orbit</td>
<td>yes</td>
</tr>
<tr>
<td>6</td>
<td>55, F</td>
<td>sphenoid ridge, lat wall of orbit</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>36, F</td>
<td>sphenoid wing, lat wall of orbit, zygoma</td>
<td>yes</td>
</tr>
<tr>
<td>8</td>
<td>37, F</td>
<td>sphenoid wing, lat wall of orbit</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>53, F</td>
<td>sphenoid ridge, optic canal</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>61, F</td>
<td>sphenoid ridge</td>
<td>no</td>
</tr>
<tr>
<td>11</td>
<td>39, F</td>
<td>sphenoid wing, lat &amp; sup walls of orbit, ant wall of middle fossa</td>
<td>yes</td>
</tr>
<tr>
<td>12</td>
<td>60, F</td>
<td>sphenoid wing, sphenoid bone, sup &amp; lat walls of orbit, ACP</td>
<td>yes</td>
</tr>
<tr>
<td>13</td>
<td>47, F</td>
<td>sphenoid wing, sup wall of orbit</td>
<td>yes</td>
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<tr>
<td>14</td>
<td>70, M</td>
<td>sphenoid wing, lat wall of orbit</td>
<td>yes</td>
</tr>
<tr>
<td>15</td>
<td>58, F</td>
<td>sphenoid wing</td>
<td>yes</td>
</tr>
<tr>
<td>16</td>
<td>48, F</td>
<td>sphenoid wing, lat wall of orbit</td>
<td>yes</td>
</tr>
<tr>
<td>17</td>
<td>54, F</td>
<td>sphenoid wing, lat &amp; sup walls of orbit</td>
<td>yes</td>
</tr>
</tbody>
</table>

*ACP = anterior clinoid process; ant = anterior; NA = not applicable (analysis not performed); sup = superior.
tail and show any intraorbital extension, as the periorbita contains a lot of fat. We also recommend using intraoperative navigation for precise resection of the area of the dura mater in which the dural tail sign was identified.

Differential Diagnosis

Fibrous dysplasia and osteoma are the most common misdiagnoses arrived at on the basis of preoperative neuroradiograms. Two of the patients in the series of cases presented here were referred to us for treatment of fibrous dysplasia. Nonetheless, metastases from prostate and breast malignancies should be kept in mind in the differential diagnosis.

TABLE 3

Histological tumor growth patterns and pathological features of bone-invasive sphenoid wing meningiomas*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Predominant Minor</th>
<th>Atypical Features</th>
<th>WHO Grade†</th>
<th>Ki 67 Index (%)</th>
<th>Estrogen</th>
<th>Progesterone</th>
<th>Cyogenetic Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mixoid secretary</td>
<td>—</td>
<td>I</td>
<td>2</td>
<td>—</td>
<td>+</td>
<td>abnormal</td>
</tr>
<tr>
<td>2</td>
<td>meningotheliomatous</td>
<td>—</td>
<td>I</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>meningotheliomatous transitional/secretory</td>
<td>patternless growth (focal)</td>
<td>I</td>
<td>2</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>4</td>
<td>meningotheliomatous angiomatous</td>
<td>—</td>
<td>I</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>transitional</td>
<td>—</td>
<td>I</td>
<td>&lt;5</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>6</td>
<td>meningotheliomatous</td>
<td>—</td>
<td>I</td>
<td>1</td>
<td>—</td>
<td>+</td>
<td>normal</td>
</tr>
<tr>
<td>7</td>
<td>meningotheliomatous transitional</td>
<td>—</td>
<td>I</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>8</td>
<td>meningotheliomatous</td>
<td>—</td>
<td>I</td>
<td>1</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>9</td>
<td>meningotheliomatous</td>
<td>—</td>
<td>I</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>10</td>
<td>meningotheliomatous transitional/psammomatous</td>
<td>—</td>
<td>I</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>normal</td>
</tr>
<tr>
<td>11</td>
<td>meningotheliomatous chordoid</td>
<td>—</td>
<td>II</td>
<td>1–2</td>
<td>—</td>
<td>+</td>
<td>normal</td>
</tr>
<tr>
<td>12</td>
<td>meningotheliomatous transitional</td>
<td>—</td>
<td>I</td>
<td>3–4</td>
<td>—</td>
<td></td>
<td>abnormal</td>
</tr>
<tr>
<td>13</td>
<td>meningotheliomatous transitional</td>
<td>patternless growth, increased cellularity (both foci)</td>
<td>I</td>
<td>1–2</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>14</td>
<td>transitional</td>
<td>—</td>
<td>I</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>normal</td>
</tr>
<tr>
<td>15</td>
<td>chordoid</td>
<td>—</td>
<td>II</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>normal</td>
</tr>
<tr>
<td>16</td>
<td>transitional</td>
<td>—</td>
<td>I</td>
<td>2–3</td>
<td>—</td>
<td>+</td>
<td>NA</td>
</tr>
<tr>
<td>17</td>
<td>transitional</td>
<td>—</td>
<td>I</td>
<td>&lt;1</td>
<td>—</td>
<td>+</td>
<td>normal</td>
</tr>
</tbody>
</table>

* — = not present.
† Tumors with chordoid growth patterns are graded as WHO Grade II.

Tumor Recurrence

The literature abounds with proof that the recurrence rates in cases of benign meningioma inversely and markedly relate to the extent of surgical removal of the lesion. Clinical entities such as fibrous dysplasia and Grave disease, 2) inadequate resection due to the involvement of important neurovascular structures, and 3) the surgeons’ fear of iatrogenic death and serious complications in radical resections.

Thus, literature reports and our own experience suggest that factors that increase recurrence rates in patients with meningioma include bone invasion, incomplete resection of the involved dura mater, and the grade of resection. Furthermore, biologically aggressive meningiomas (WHO Grade II–III, a high proliferative index, and a complex karyotype) are associated with high recurrence rates despite radical resection.

To lower the chance of recurrence of a meningioma, extensive resection of the invaded bone and dura mater is essential. This should be the goal in all cases regardless of the extent of tumor invasion. Extensive resection of the hyperostotic bone in this area is technically challenging and requires experience and patience. This invasion is not limited to the sphenoid wing and may extend from the optic canal and superior orbital fissure to the periorbita, the middle fossa, the anterior clinoid process, and the cavernous sinus. It may also involve important neurovascular structures. A thorough knowledge of the anatomy of the region, coupled with good microsurgical skills and precise drilling techniques, enables the surgeon to resect these lesions.

The literature contains only a few reports of bone-invasive sphenoid wing meningiomas. Pompili et al. reviewed the cases of 49 patients who underwent surgery over a 20-year period. This group constituted 9% of all meningioma cases treated during this period. They divided the patients into two groups: those with primary osseous involvement (42 patients), and those with osseous involvement at the time of recurrence (seven patients). Both groups had a
markedly high proportion of women. The pteron was the most common location and exophthalmos was the most common symptom. In evaluating the neuroimages, the authors observed hyperostosis primarily of the sphenoid wing. The mortality rate was 4%.

De Jésus and Toledo\textsuperscript{13} reviewed six cases of hyperostotic sphenoid wing meningiomas among 150 patients who were treated surgically over a 7-year period. They concluded that patients younger than 70 years who did not have any other medical complications should undergo surgery immediately to avoid progressive deformities and incomplete resection that could lead to early recurrence.

Bonnal and associates\textsuperscript{8} reviewed 21 cases of bone-invasive meningioma of the sphenoid wing. They divided the cases into three groups as follows: clinoidal or sphenocavernous tumors (seven cases), en plaque invading meningiomas (seven cases—true hyperostotic group), and en masse invading meningiomas (seven cases—combination of the first two groups). As documented on postoperative imaging, only three tumors were totally removed. Two patients in the first group had recurrences in the first 2 years after surgery. There was one recurrence in the second group and five in the third group. The authors found that tumors of the cavernous sinus, sella turcica, or sphenoid body, invasion of the pterygomaxillary fossa, and lack of total removal were the most likely causes of early recurrence.

None of these studies examined the potential relationship between histological features of the tumor and hyperostosis. Among our 12 patients in whom the invasion of bone was histologically confirmed, all but two of the tumors were histologically benign meningiomas with Ki 67 labeling rates of less than 4%. The results of testing for progesterone receptor expression were positive in most of the cases, which is also a sign of good prognosis. In two tumors (both in female patients) the results of chromosome analysis were abnormal. Among the WHO Grade I tumors, a meningotheliomatous pattern of growth predominated. Two meningiomas showed chordoid features and were designated WHO Grade II. Thus, we found no relationship between bone invasion and a higher pathological grade of the meningioma.

Reconstruction Technique

Because the treatment of these meningiomas is radical removal of the involved bone and dura mater, resection may cause enophthalmos postoperatively. Furthermore, as the superior orbital rim and the lateral wall of the orbit are removed in most cases, there may be severe cosmetic defects postoperatively. To prevent these complications, cranioorbital reconstruction should be done after tumor removal. For precise reconstruction, we recommend placing titanium mesh over the bone before the tumor is removed and mounding the mesh into the original configuration of the patient’s skull for later reconstruction of the orbit. Precise reconstruction is critical to prevent restriction of the extraocular muscles postoperatively. If ocular movement is inadequate, the reconstruction should be corrected.

Unfortunately, the appearance of hydroxyapatite mimics that of meningioma on neuroimages. This phenomenon holds true for most materials that might be used for reconstruction, a fact that the surgeon should keep in mind in evaluating follow-up imaging studies and one that the patient should be informed about as well.

Conclusions

Hyperostosis related to a meningioma is due to bone invasion by the tumor, and a perfectly benign meningioma (according to pathological and biological parameters) may invade bone. Therefore, invaded bone should be aggressively removed through drilling. Any dura mater that appears enhanced on T1-weighted sequences obtained after administration of a contrast agent should also be removed. Intraoperative neuronavigation helps determine the borders of involved bone and dura mater. The goal of aggressive resection is to reduce the risk of recurrence. Aggressive resection can be accomplished with low mortality and morbidity rates. Cranioorbital reconstruction is necessary for good postoperative cosmesis and to prevent enophthalmos, but the reconstruction material may mimic the meningioma itself on postoperative images. Decompressing the optic canal and superior orbital fissure is important for alleviating visual loss and diplopia.

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