Parasellar Meningiomas: Incidence of Involvement of Extracavernous Structures as Determined by Magnetic Resonance and Computed Tomography

Abstract—Parasellar meningiomas frequently extend beyond the cavernous sinus into adjacent structures. In order to determine the incidence of involvement of adjacent sites, we retrospectively evaluated the computed tomography and nuclear magnetic resonance scans of 65 consecutive patients with meningiomas invading the cavernous sinus. Thirteen nearby anatomic sites were analyzed for tumor involvement. The sites most frequently involved were the lateral sphenoid sinus wall (93%), the ipsilateral petrous apex (70%), the ipsilateral posterior petrous bone surface (59%), the sella (59%), the intracranial clival surface (44%), and the suprasellar cistern (41%). The sella, clival bone marrow, orbital apex, pterygopalatine fossa, and prestyloid parapharyngeal space were more commonly involved in recurrent tumors. Lesions were also subdivided into five groups according to whether or not they involved only one part of the cavernous sinus (grade 1), two parts of the cavernous sinus (grade 2), surrounded the cavernous carotid artery (grade 3), surrounded and narrowed the cavernous carotid artery (grade 4), or involved both sides of the cavernous sinus (grade 5). Among the 63 cases that could be assigned to a category, seven were grade 1 lesions, 13 were grade 2, 13 were grade 3, 16 were grade 4, and 14 were grade 5. Tumor grade is helpful in predicting the difficulty of resection of the cavernous component of the tumor. The incidence of involvement of adjacent sites is also helpful in assessment of imaging studies and in planning the most appropriate surgical approach. (*Skull Base Surgery*, 3(3):152–158, 1993)

Skull base meningiomas are challenging. Their particular location and relationships with the adjacent important structures make their surgical removal very difficult. Those involving the cavernous sinus are even more problematic due to the involvement of the neurovascular structures present in this restricted space. In the last decade new, often very aggressive, surgical approaches have been

advocated.^{1–11} Precise assessment of the extension and of the relationships of the tumor with surrounding structures^{12–14} allows the surgeon to plan the most appropriate operative strategy.

In the present study we report the neuroradiologic findings in a series of 65 meningiomas involving the cavernous sinus operated on during a 6-year period.

MATERIAL AND METHODS

We retrospectively evaluated the computed tomography (CT) and nuclear magnetic resonance (NMR) scans of 65 consecutive patients with meningiomas that involved the cavernous sinus who were operated on at our institution between 1985 and 1990.

Initially, 29 anatomic sites were analyzed for tumor. However, determination of involvement of specific regions was ambiguous in some cases, so we limited our analysis to 13 sites in which the presence or absence of tumor was easy to establish. These included the pterygopalatine fossa, prestyloid parapharyngeal space, orbital apex, sella turcica, suprasellar cistern, lateral wall of the sphenoid sinus, petrous apex, posterior surface of the petrous bone, endocranial surface of the clivus, contralateral petrous apex, contralateral posterior surface of the petrous bone, and the foramen magnum. Both the CT and MR scans were used together in this analysis. One patient was excluded because a poor quality CT scan was available and the involvement of particular areas could not be adequately assessed. Most of the CT scans were performed on a 9800 CT scanner (General Electric, Milwaukee, WI) using 3 mm contiguous sections through the skull base in axial and coronal planes with a 16 to 18 cm field of view (FOV). Contrast was administered in all patients without a significant history of contrast reaction. Bone algorithms were available in 29 patients. The involvement of the lateral wall of the sphenoid sinus was only evaluated in this subgroup because subtle hyperostosis could be overlooked by MR or standard algorithm CT. Most of the MR scans were performed on a 1.5 T Signa system (General Electric). Axial and coronal spin echo (500–700/20–25/2–4) TR/TE excitations, 3 to 5 mm thick, 1 mm apart, sections were obtained in the axial and coronal planes using a 16 to 18 cm FOV. Since the introduction of gadolinium-DTPA in 1988, the same locations were scanned before and after intravenous gadolinium-DTPA. Sagittal (500–700/20/2) and axial (2000–3000/25–100/1–2) spin echo sequences were also performed.

Two groups of patients have been considered: those who had not received prior operations for their tumor and those with recurrent tumors who had already received previous surgery at other institutions.

The degree of involvement of the cavernous sinus was graded according to a classification system developed by one of our group (L.N.S.) (Table 1).¹⁴ The volume of the tumor was calculated from the anteroposterior, transverse, and longitudinal diameters.¹⁵

RESULTS

Most parasellar meningiomas are detected on imaging because they alter the contour of the cavernous sinus. On standard CT scans, this is often the only sign of small tumors because the enhancement of the neoplasm, cav-

Table 1. Classification System

Grade	Cavernous Sinus* Involvement	ICA	
		Encasement	Narrowing
1	One region	None	None
2	Two or more	Partial	None
3	All	Total	None
4	All	Total	Narrowed or occluded
5	Bilateral		

*The cavernous sinus was divided into four regions: anterior, posterior, medial, and lateral.

ernous sinus, and parasellar carotid artery is very similar. Hyperostosis or bone erosion can only be seen well on bone algorithms. Extension below the skull base is usually easily detected because the high-density enhancing tumor is contrasted with very low-density fat.

On noncontrast MR, meningiomas are similar in signal to brain parenchyma on most pulsing sequences. However, extension beneath the skull base or into the marrow of the skull base is easy to detect on unenhanced scans because the tumor is lower in signal and contrasts with normal fat. After contrast, the enhancing tumor is difficult to differentiate from adjacent fat. This problem can be overcome if more recently developed fat suppression sequences are used. Most of our cases were done without the benefit of fat suppression techniques.

Cavernous sinus meningiomas in patients who had not undergone previous surgery ranged in size from $10 \times 5 \times 10$ mm to $56 \times 40 \times 50$ mm, with mean values of $29.4 \times 24.3 \times 26.9$ mm (mean volume, 14,057 mm³). Recurrent or residual meningiomas involving the cavernous sinus ranged in size from $19 \times 15 \times 14$ mm to $60 \times 60 \times 48$ mm, with mean values of $32.8 \times 28.2 \times 26.9$ mm (mean volume, 18,722 mm³).

Extracavernous Involvement

In many cases the cavernous sinus involvement was only part of a tumor that involved the skull base extensively (Fig. 1). The incidence of extracavernous tumor detected by imaging is shown in Table 2 and illustrated in Figures 1–6. The four most common sites of extracavernous involvement considering all patients were the lateral wall of the sphenoid sinus (93%) (Figs. 2, 4), the ipsilateral petrous apex (70%), the posterior surface of the ipsilateral petrous bone (59%), and the sella (59%). Five sites were more commonly involved in the previously operated patients; the sella (Fig. 2), suprasellar cistern, clival bone marrow, pterygopalatine fossa (Fig. 4), and the prestyloid parapharyngeal space (Fig. 1). We found no statistically significant difference between the two groups in the eight other sites we evaluated.

Figure 1. Recurrent meningioma. Postcontrast coronal MR (SE,550/20) shows a very large meningioma in the left middle cranial fossa extending into the infratemporal fossa (arrows). The tumor involves the prestyloid parapharyngeal space and the masticator space. The tumor abuts the left cavernous sinus (arrowheads), but it does not engulf the carotid.

Figure 2. Coronal MR (SE,800/20). This is previously operated right cavernous meningioma that completely engulfs and slightly narrows the right cavernous carotid (black arrow). Note the supraclinoid segment of the right carotid artery (outlined arrow) and the optic chiasm (wavy arrow). The carotid artery narrowing makes this a grade 4 lesion. The mass has extended into the sella displacing the pituitary gland to the left (open black arrow). The tumor is adjacent to the right lateral wall of the sphenoid sinus (white arrow), but it does not extend into the sinus.

Grading System

The grading system is based on two factors: the location of the tumor within the cavernous sinus and the tumor's relationship to the intracavernous carotid artery (ICA). The cavernous sinus is divided into four anatomic locations: anterior, posterior, middle, and lateral. Grade 1 lesions involve one anatomic site and do not surround the carotid artery; grade 2 lesions involve two or more anatomic sites and partially encase or abut on the carotid artery (Figs. 3B, 7); grade 3 lesions completely encase the carotid, and grade 4 lesions encase and narrow the arterial

lumen as visualized by MR (or angiography) (Fig. 2). Grade 5 lesions have bilateral cavernous sinus involvement. The distribution of meningiomas involving the cavernous sinus considered in the present study according to the grade is shown in Table 3.

Table 2. Incidence of Extracavernous Tumor

	<i>Total (%) (n = 64)</i>	<i>Previous Operation (n = 35)</i>	<i>No Previous Operation (n = 29)</i>
Lateral sphenoid sinus wall*	27 (93%)	15 (100%)	12 (86%)
Ipsilateral petrous apex	45 (70%)	22 (63%)	23 (70%)
Ipsilateral posterior petrous bone surface	38 (59%)	21 (60%)	17 (59%)
Sella	38 (59%)	26 (74%)	12 (41%)
Endocranial clival surface	28 (44%)	17 (49%)	11 (38%)
Suprasellar cistern	26 (41%)	15 (43%)	11 (38%)
Orbital apex	25 (39%)	18 (51%)	7 (24%)
Clival bone marrow	13 (20%)	11 (31%)	2 (7%)
Pterygopalatine fossa	12 (19%)	11 (31%)	1 (3%)
Prestyloid parapharyngeal space	10 (16%)	9 (26%)	1 (3%)
Contralateral petrous apex	7 (11%)	5 (14%)	2 (7%)
Contralateral posterior petrous bone surface	4 (6%)	1 (3%)	3 (10%)
Foramen magnum	1 (2%)	1 (3%)	

*We limited our analysis to those patients who had bone algorithms available (15 patients previous operation and 14 patients with no previous operation).

Figure 3. A 55-year-old woman was previously operated on for a right cavernous meningioma. A: Noncontrast axial MR (SE,600/20) shows a right cavernous meningioma extending through the anterior margin of the middle cranial fossa (large black arrows). The mass replaces the fat in the right orbital apex (arrowhead). Compare this with the normal fat in the left orbital apex (curved arrow). The mass has also extended into the right sphenoid air cells (white arrow). B: Postcontrast scan at the same level as A shows uniform enhancement of the tumor. C: Axial postcontrast CT, bone algorithm. There is erosion of the lateral wall of the right sphenoid air cell (wavy arrow) where the tumor protrudes into the right sphenoid sinus and enlargement of the superior orbital fissure (small black arrows).

DISCUSSION

The grading system we have developed has been of great help in planning the most appropriate surgical strategy. This classification system stresses the importance of ICA encasement, because tumor removal from the ICA presents one of the greatest technical problems during operation. Usually grades 1 and 2 tumors involve the dura of the lateral, superior, or posterior walls of the cavernous sinus. With grades 3 and 4 tumors, however, the dura of the medial wall of the cavernous sinus is involved, and invasion of the sella turcica, sphenoid bone, and sphenoid sinus is frequently present (Fig. 2). The grade of tumor has shown a good correlation with the ease of surgical removal

of the tumor from the ICA.¹⁵ Cavernous sinus extension of the tumor could be dissected free from the intracavernous internal carotid artery in 91% of patients with grade 1 or 2 tumors without injury, sacrifice, or grafting of the carotid artery (Figs. 1, 3, 4). This could be done in only 46% of grade 3 or 4 lesions.¹⁵ In addition, this grading system has been shown to be a good predictor of the occurrence of some of the complications of cavernous sinus surgery.¹⁶ For example, patients with grade 1 or 2 lesions have a better chance to recover their previous extraocular muscle function after surgery compared with patients with higher grade lesions.¹⁵

Recurrent tumors involving the cavernous sinus and other skull base sites are particularly challenging. Previous surgery makes the anatomic structures (such as cranial nerves) more difficult to recognize and the dissec-

Figure 4. Involvement of the pterygopalatine fossa. Axial postcontrast CT shows expansion of the left pterygopalatine fossa that is filled with enhancing tissue (large black arrow). Compare this with the normal fat-filled right pterygopalatine fossa (open arrow).

Figure 5. Axial postcontrast MR (SE,650/20) shows a large enhancing meningeoma involving the lateral wall of the orbit and the anterior wall of the middle cranial fossa. The mass extends into the temporal fossa (large black arrow) and into the orbit (arrowheads). The mass involves the anterior and the lateral aspect (smaller black arrow) of the right cavernous sinus but does not engulf or narrow the parasellar carotid artery. This is a grade 2 lesion.

A

B

Figure 6. A: Axial noncontrast MR (SE,480/25) shows tumor in the cavernous sinus medial to the right parasellar carotid (white arrow). B: Axial MR at the level of C1 vertebral body. In continuity, the tumor has extended inferiorly from the right cavernous sinus along the petrous segment of the carotid into the upper neck. The tumor (large white arrows) surrounds the cervical internal carotid (small white arrow) and is in the poststyloid parapharyngeal space as well as the prevertebral space. (Figure continued on next page)

tion plane at the margin of the tumor more difficult to follow. In this setting complications are more likely to occur compared with patients with no previous surgery.¹⁷ Extracranial sites such as the pterygopalatine fossa (Fig. 4), the prestyloid parapharyngeal space (Fig. 1), and the clival bone marrow were much more frequently involved in cases of recurrent tumors than in patients without

Figure 6, cont. C: Axial postcontrast CT at approximately the same level as B. The mass (large black arrows) displaces the cervical internal carotid (small black arrow) anteriorly. This lesion is very unusual in that it enhances less than surrounding muscle. Most meningiomas enhance more than this tumor. Involvement of the post-styloid parapharyngeal space ("carotid space") was seen only in previously operated tumors.

Figure 7. Postcontrast coronal MR (SE, 600/20) shows a meningioma (arrow) involving the superior and lateral aspects of the left cavernous sinus. It does not engulf or narrow the parasellar carotid artery. This is a grade 2 lesion.

prior surgery. Although these differences were statistically significant, they reflect a selection bias, since many patients with extensive tumors and failed previous surgery are referred to our institution. Once a tumor has already invaded extracranial sites (such as the pterygopalatine fossa, or prestyloid parapharyngeal space) (Figs. 1, 3–6), it is much more difficult to achieve gross total removal, although recent advances in surgical approaches and techniques allow gross total removal in most cases.

Bilateral involvement of the cavernous sinus was also more frequent in cases of recurrent tumors (10 of 35 patients who had recurrent tumors compared with 4 of 29 patients who had not undergone previous surgery). Bilateral cavernous sinus invasion jeopardizes both internal carotid arteries and makes gross total removal very diffi-

cult to achieve. In many of these cases surgery can achieve removal of tumor from one side of the cavernous sinus and other strategies must be used to manage the contralateral involvement (such as observation and radiosurgery).

Meningiomas involving the cavernous sinus may start outside the cavernous sinus and invade it or these tumors may start within the cavernous sinus and spread beyond its confines. Preoperative imaging assessment of the location of these tumors is critical in order to choose the best approach. Involvement of the anterior cranial fossa and other middle fossa sites (other than the cavernous sinus) can be managed through an anterolateral approach (such as frontotemporal orbital-zygomatic).^{1–3,6–9} When extensive involvement of the petroclival region is present, more sophisticated approaches may be required.^{16,18}

Table 3. Distribution of Meningiomas According to the Cavernous Sinus Grade*

Grade 1	7
Grade 2	13 (17) [†]
Grade 3	13 (19) [†]
Grade 4	16 (20) [‡]
Grade 5	14
Total	63

*In two cases the tumor could not be graded accurately because the cavernous sinus-ICA had been ligated from previous surgery.

[†]In parenthesis, the distribution of cases when grade V tumors are considered according to the side of greatest involvement.

[‡]In one patient the intracavernous carotid artery was occluded by the tumor and this patient was considered to have a grade IV tumor.

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