Management of Vascular Invasion During Radical Resection of Medial Sphenoid Wing Meningiomas

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ABSTRACT

Invasive meningiomas involving the medial sphenoid wing are difficult tumors to resect completely. They often have invaded the surrounding arteries at the time of diagnosis making total resection challenging. Attempts at removing these tumors from adherent carotid or middle cerebral arteries have resulted in high complication rates. Nine cases of medial sphenoid wing meningiomas with arterial invasion were operated between March 1994 and August 1998. Total resection was possible in only four cases. Two arterial-related complications occurred during resection with one resulting in permanent hemiplegia.

KEYWORDS: Meningioma, vascular, invasion

Invasive meningiomas of the medial sphenoid wing represent a formidable challenge to even the most experienced neurosurgeons. They frequently invade the carotid and middle cerebral arteries adding substantial surgical risk.^{1,2} Currently, there is no accurate preoperative test that can predict arterial invasion. This retrospective study evaluates and reviews the vascular risks associated with attempted radical resection of these tumors.

MATERIALS AND METHODS

Nine cases of medial sphenoid wing meningiomas with arterial invasion presented between March 1994 and August 1998. Patients ranged in age from 41 to 66 years (mean of 55.6 years). There were 8 women and 1 man. Two cases were anterior clinoid meningiomas. Seven cases exhibited extension into the cavernous sinus and four of these

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cases also had posterior orbit and/or optic canal invasion. Angiography or MRA was performed on all cases. Tumors suggestive of arterial invasion underwent balloon test occlusion with a 30-min clinical examination. Embolization was done with polyvinyl acetate (PVA) if middle meningeal feeders were identified.

In most cases, a standard pterional craniotomy was performed. All cases had somatosensory evoked potentials monitored during resection. Extensive removal of the sphenoid wing was done extradurally to remove hyperostotic and invaded bone. This also allowed devascularization of the tumor from transosseous feeding arteries. The anterior clinoid was also removed extradurally; to facilitate visualization of the anterior clinoid base, a 5-mm incision of the orbitomeningeal reflection was made.

Once the required amount of bone was removed, the dura was opened in typical Sylvian fashion. The Sylvian fissure was widely dissected to expose the middle cerebral artery (MCA) and the artery was followed to the MCA-tumor interface.

At this point, debulking of the tumor was performed. The capsule was then retracted away from the MCA and internal carotid artery (ICA) and dissection of the interface between tumor and artery was executed from a distal to proximal fashion. Once the intradural tumor was removed, the cavernous sinus, orbital, and invaded dura components were attacked. Closure was done with a combination of fascia and fat grafting.

RESULTS

Carotid invasion was identified at surgery in nine patients (Table 1). Two cases were anterior clinoid meningiomas, and the other seven cases involved extensive cavernous and/or orbital invasion. Total resection of tumors with carotid artery invasion was possible in only four patients. One carotid artery was injured during dissection of an adherent tumor from the tumor-artery interface. This artery was repaired intraoperatively with no resulting

Table 1 Patients with Medial Sphenoid Wing Meningiomas and Vascular Invasion

Patient No.	Age (yr)/ Gender	Tumor Invasion	Resection	Clinical Outcome
1	47/Male	Right cavernous sinus, SOF, posterior orbit, ICA	Partial	Transient 3rd nerve palsy (superior division)
2	63/Female	(Recurrent) Left clinoid, cavernous sinus, ICA, suprasellar	Partial	Excellent
3	50/Female	Right cavernous sinus, optic canal, ICA	Total	Transient 3rd nerve palsy
4	41/Female	Optic canal, right ICA, right cavernous sinus	Total	3rd nerve palsy
5	56/Female	Suprasellar, right ICA	Partial	Transient 3rd nerve palsy
6	64/Female	(Recurrent) ICA, right cavernous sinus, orbit, SOF	Partial	Carotid rupture; 3rd nerve palsy
7	54/Female	Right cavernous sinus, posterior orbit, ICA	Partial	Excellent
8	59/Female	Left cavernous sinus, posterior orbit, ICA	Total	Excellent
9	66/Female	Right anterior clinoid, ICA/MCA	Total	Left hemiplegia

SOF, supraorbital fissure; ICA, internal carotid artery; MCA, middle cerebral artery.

morbidity. No postoperative carotid rupture occurred in any of the cases. One case of hemiplegia occurred as a result of damaging a lenticulostriate artery while dissecting the tumor from MCA.

CASE STUDY

A white male, age 47, presented with decreasing visual acuity in the right eye (patient 1). Imaging studies revealed a right orbital apex mass invading the superior orbital fissure and cavernous sinus (Fig. 1A,B).

The patient underwent a right frontotemporal craniotomy with visual-evoked monitoring and somatosensory evoked potentials. The tumor was exposed via a modified Dolenc's procedure. Intra-orbital exploration was performed between the lateral and superior rectus muscles. The tumor had extended through the superior orbital fissure and was adherent to the extraocular muscles and both branches of the CNIII and CNVI. Tumor was found to be adherent to the lateral aspect of the an-

terior loop of the C₃-C₄ portion of the carotid artery. Only partial resection was possible.

Histopathology was compatible with an atypical meningioma. The patient's vision improved after the procedure; however, a transient CNIII palsy resulted from the superior division. Due to the close proximity of the optic nerve, radiosurgery was not performed, and the patient will be monitored closely. A 2-year follow-up magnetic resonance image (MRI) showed the tumor to be stable (Fig. 2).

DISCUSSION

Meningiomas involving the "inner clinoidal third," sphenocavernous region, sphenoorbital region, cranio-orbital junction, and the anterior clinoid can all involve the carotid artery. Historically, meningiomas in this region have been defined based on anatomic location and/or clinical presentation.¹⁻⁶ However, these classifications do not assist the surgeon in determining preoperative risk.

Figure 1 (A) Axial T₂-weighted MR with fat suppression reveals a right sphenoorbital mass. The lesion involves the orbital apex through the superior orbital fissure into the cavernous sinus. (B) Coronal enhanced MR of the cavernous sinus exhibited tumor along the lateral aspect of the C₄ carotid artery. During resection, the tumor was adherent to the lateral aspect of the anterior loop and C₄ horizontal portion. Only partial resection was performed.

Figure 2 Axial enhanced MR at 2-year follow-up reveals residual tumor in the cavernous sinus along the C₄ carotid artery.

The inability to accurately identify arterial invasion on any preoperative imaging studies remains a significant problem in determining resectability, surgical morbidity, and classification of these tumors.

Invasive medial sphenoid wing meningiomas with carotid artery invasion are associated with a high complication rate. Al-Mefty¹ published three cases of anterior clinoid meningiomas with carotid invasion. One patient died of postoperative vasospasm, and another patient experienced hemiplegia. Bonnel et al.³ described five cases of medial sphenoid wing meningiomas with "difficult arterial dissection" from adherent tumor. Two of these patients experienced postoperative deaths. One patient had an intraoperative stroke with resulting aphasia. Our series had only one case of hemiplegia. However, complete resection was attempted in only four cases. The overall complication rate of the above three studies was 17.6% morbidity and 17.6% mortality.

Thorough knowledge of the surrounding major vessels in relationship to the tumor is mandatory before surgery to minimize the risks of

vascular injury during resection. Angiography and MRI will provide valuable information about the location of these vessels. It is important to note that identification of narrowing, effacement, or stretching does not necessarily mean invasion of the arterial wall. If tumor is identified around the C₃ or C₄ portion of the carotid, it is more likely to be adherent. Al-Mefty¹ hypothesized that this location allowed the tumor to extend under the interfacing arachnoid membrane of the carotid cistern.

Surgeons should also prepare for the possibility of arterial injury during aggressive removal of these tumors.^{1,2} Knowledge about the collateral reserve, obtained through a balloon test occlusion, can help in understanding whether the carotid artery can be sacrificed whether it is substantially injured. The patients in this study underwent a 30-min clinical examination, which is 93 to 97% accurate.^{9,10} Supplementation with cortical blood flow studies, EEG, somatosensory evoked potential, and hypotension has not statistically shown any benefit over the 30-min clinical examination.⁸

During the removal of these meningiomas, proximal control of the carotid artery should be established before dissecting any adherent tumor from the middle cerebral or carotid artery. We prefer to perform cervical dissection, but petrous carotid exposure is also an option. We do not recommend exposure of the clinoid segment of the carotid artery through Dolenc's triangle as a means of proximal control because carotid invasion is frequently found in this location.^{11,12}

A wide Sylvian fissure exposure for larger tumors is helpful. This allows better visualization of the middle cerebral artery (MCA) and carotid artery (CA) in relationship to the tumor. The dissection of the tumor from the MCA and CA should move in a distal to proximal direction. This requires careful attention to prevent damage to any of the MCA perforators. Pial feeders can be coagulated and cut simultaneously during this portion of the dissection away from the middle cerebral artery. If any significant adherent tumor arterial in-

terface exists, the risk of direct arterial damage may be substantial; therefore, a conservative approach may be preferred in these circumstances.

PARTIAL RESECTIONS

In cases of partial resection, there is enough evidence to support the use of postoperative radiation therapy. Meningioma recurrence after a partial resection may be as short as 3.9 years.¹³ In a retrospective study of 140 patients, Goldsmith et al.¹⁴ reported an 89% survival rate with a 5-year progression-free rate after radiation therapy. This rate compares with a 33 to 59% progression-free rate follow-up in 5 years with subtotal resections and observation only. Miralbell et al.¹⁵ showed that radiation therapy immediately after subtotal resection increased a failure-free survival rate of 8 years with 88%. Treatment given at the first recurrence resulted in a failure-free survival rate of 78%.

Stereotactic radiation shows great promise in treating residual meningiomas, which is especially true if the tumor volume is $<8 \text{ cm}^3$ (or if the main tumor diameter is less than three centimeters).¹⁶ A 2-year progression-free survival can be as high as 100% in such cases.¹⁷ When considering stereotactic radiation for these tumors, however, careful evaluation of the location of the optic nerve in relation with the residual tumor is required to avoid damage to vision.¹⁸

CONCLUSION

Invasive meningiomas of the medial sphenoid region are formidable lesions. Considerable morbidity and mortality are associated with arterial invasion of these tumors. Our recommendations in managing these lesions with regard to preventing vascular injury are as follows:

1. Preoperative planning for large invasive meningiomas should consist of MRI and angiography. This will not indicate if invasion has occurred, but will identify the location of major vessels in relationship to the tumor. Balloon test occlusion provides valuable information about the collateral reserve if severe arterial damage is encountered intraoperatively.
2. Proximal control should be established before removing any adherent tumor from major blood vessels.
3. Dissection should move in a distal to proximal direction along the middle cerebral and internal carotid artery. Special attention should be placed to preserving the lenticulostriate arteries as well as disrupting pial feeders before debulking of the tumor. This is especially important if a significant amount of the blood supply comes from the intracerebral circulation.
4. Significant tumor adherence to the middle cerebral or internal carotid artery should be considered for conservative management. Residual tumors could be observed, but radiation therapy in the form of conventional fields or stereotactic treatments seem to show better control rate of tumor growth, when applicable.

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