J Neurosurg 105:148–152, 2006

Decompression of cavernous sinus meningioma for preservation and improvement of cranial nerve function

Technical note

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Meningiomas are the most common tumors affecting the cavernous sinus (CS). Despite advances in microsurgery and radiosurgery, treatment of CS meningiomas remains difficult and controversial. As in cases of other meningiomas, the goal of treatment for CS meningioma is long-term growth control and preservation of neural function. Gross-total resection, the ideal treatment for meningioma, is not always possible to obtain in patients with CS meningiomas with an acceptable level of morbidity. Therefore, microsurgery and radiosurgery have recently been advocated as a combined therapy to achieve good control of tumor growth and favorable functional outcome. The authors describe a technique in which tumor volume can be reduced to a minimal residual amount, while preserving cranial nerve function. This enables the smallest field to be treated radiosurgically. The optic nerve is decompressed, and the tumor mass is reduced to provide at least a 5-mm interpositional distance between the optic nerve and the residual lesion. Direct decompression of the CS, with opening of the lateral and superior sinus walls, and piecemeal removal of the tumor in "safe" locations are performed to facilitate an improvement in cranial nerve function. The authors describe the use of this technique in a series of patients and demonstrate improvement of cranial nerve function in a subset of these patients.

KEY WORDS • **meningioma** • **skull base neoplasm** • **cavernous sinus** • **radiation therapy** • **radiosurgery** • **surgery**

THE incidence of transient and permanent cranial neuropathy after resection of CS meningiomas has led to the increasing use of radiosurgery in the management of these lesions. The control rate for radiosurgical treatment of a CS meningioma is very good, exceeding a 90% actuarial control rate over 5 years in many series.[7,9,12,14,15] This has made radiosurgery an attractive alternative for the management of meningiomas in this important location.

Given the overall excellent results with the adjuvant use of radiosurgery for the management of CS meningiomas, we have adopted a more conservative approach to the management of meningiomas in this location. In this paper we describe a technical approach used to treat primary CS lesions with the following goals: 1) reduction of tumor volume to the minimal residual amount, while preserving cranial nerve function, to enable the smallest field to be treated radiosurgically; 2) decompression of the optic nerve and reduction of tumor mass to provide a minimal 5-mm interpositional distance between the optic nerve and the residual lesion; and 3) direct decompression of the CS, with opening of the lateral and superior sinus walls, and piecemeal removal of the tumor in "safe" locations to facilitate improvement in cranial nerve function in the CS region.

Abbreviations used in this paper: CA = carotid artery; CS = cavernous sinus; IMRT = intensity-modulated radiation therapy; SOF = superior orbital fissure.

Surgical Technique

A standard frontotemporal (pterional) craniotomy is performed, and extradural dissection is undertaken using the Dolenc[5,6,20] method of posterior orbital decompression, anterior clinoid removal, optic canal opening and nerve decompression, and drilling of the SOF and the respective foramina (foramen rotundum and foramen ovale) of the other two divisions of the trigeminal nerve (Fig. 1). All portions of tumor in the anteromedial triangle of the CS are removed. The middle meningeal artery is cauterized and ligated above the foramen spinosum. As was well described by Dolenc,[6] this technique enables freedom of manipulation of the nerves at their respective foramina.

The second part of the procedure enables the piecemeal removal of the tumor from regions of the CS in which little risk of inducing cranial nerve deficit will be incurred. The outer dural layer of the lateral wall of the sinus is elevated in an extradural fashion (in the manner described by Hakuba and Kawase, as discussed by Abdel-Aziz, et al.[1]) to expose the trigeminal ganglion and the three branches of the nerve. Pieces of tumor are removed from the inferior aspect of the CS between the first and second divisions of the tri-

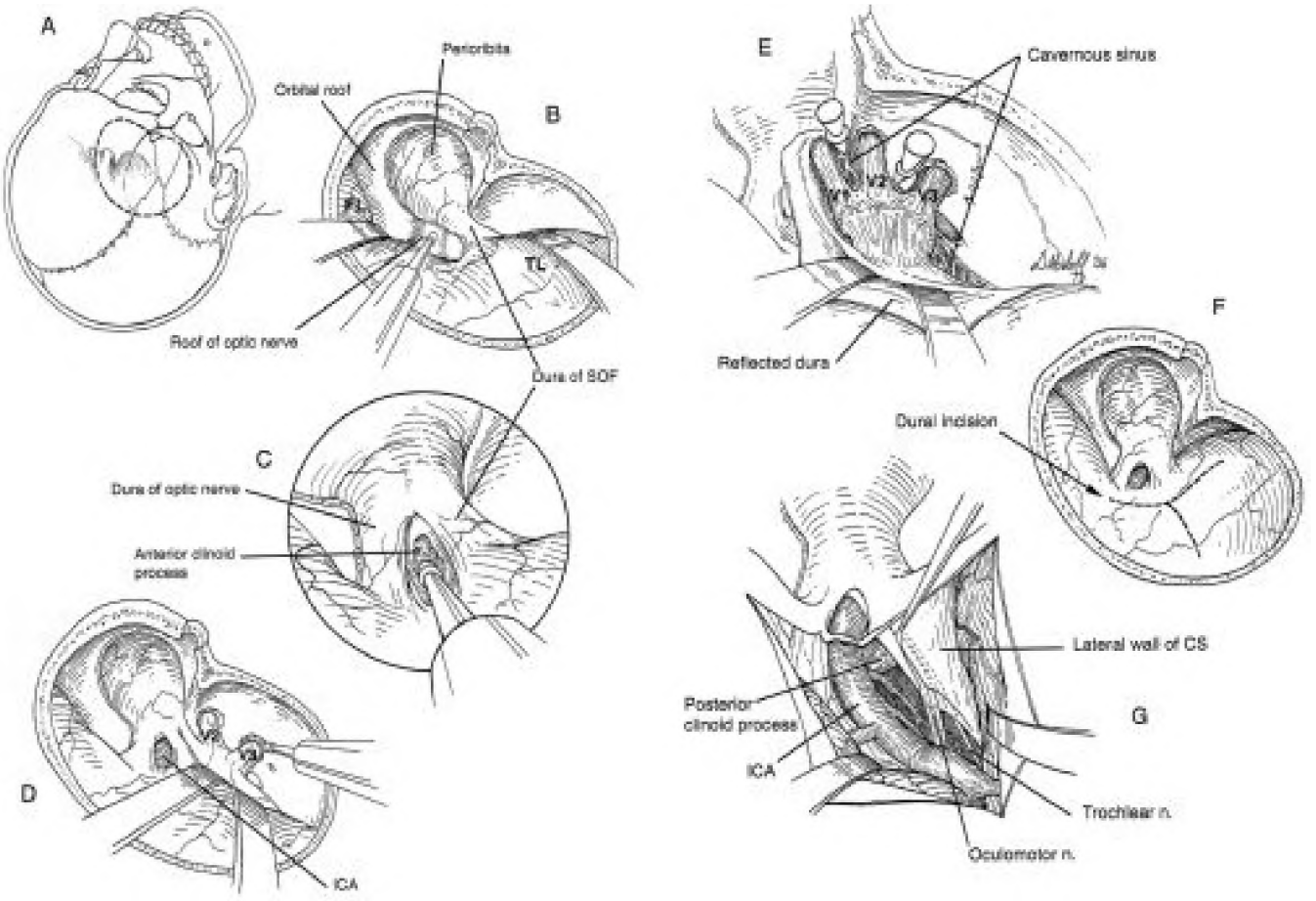

FIG. 1. Artist's drawings depicting the CS meningioma resection–decompression technique. A frontotemporal craniotomy is performed (A), with extradural dissection of the lateral and superior orbit. The bone of the posterior orbit is drilled, and the SOF is exposed (B). The anterior clinoid process is removed and the optic canal roof is drilled to decompress the optic nerve (C). Any tumor within the anteromedial triangle of the CS is removed. The foramina rotundum and ovale are enlarged to provide mobilization of the 2nd and 3rd divisions of the trigeminal nerve (D). The lateral dural wall of the CS is then dissected and elevated free from the trigeminal ganglion and its branches (E). This provides decompression of the lateral aspect of the CS. Portions of tumor in the inferior CS, located between the 1st and 2nd divisions (anterolateral triangle) and between the 2nd and 3rd divisions (lateral triangle), are removed to provide further decompression. More of the tumor is removed medial to the CA in the petrous bone (medial to the Glasscock triangle) and in the region of the Kawase triangle. Care must be taken to avoid injury to the petrous CA, located just posterior to the foramen ovale. Following the extradural procedure, the dura mater is opened in a T-shaped fashion, along the frontotemporal skull base with an arm opening to the CA at the base just lateral to the optic nerve (F). The final decompression is achieved by opening the oculomotor foramen anteriorly to the orbit along the course of the oculomotor nerve (G). Care is taken to avoid injury to the trochlear nerve as it crosses the oculomotor nerve at the SOF. At the completion of the dissection, the portion of the tumor between the oculomotor nerve and the optic nerve has been removed to reduce the volume of tumor adjacent to the optic nerve. The CS has been decompressed from the inferior, lateral, and superior directions. FL = frontal lobe; ICA = internal CA; n = nerve; TL = temporal lobe; V1, V2, V3 = divisions of the fifth cranial nerve.

geminal nerve (the anterolateral triangle) and between the second and third divisions (the lateral triangle). The portion of the tumor located medial to the CA in the posterolateral (Glasscock) triangle is removed beneath the posterior border of the trigeminal ganglion. Any part of the tumor that extends towards the petrous apex in the contiguous region of the posteromedial (Kawase) triangle is correspondingly removed. Exposure of the SOF and enlargement of the foramen rotundum and foramen ovale allows increased freedom of movement of the respective nerve branches to facilitate tumor removal from the inferior aspect of the sinus.

Subsequently, the dura mater is opened in a T-shaped fashion along the frontotemporal base, and an incision is made along the axis of the sylvian fissure to end between the optic nerve and the CA. Attention is then paid to the oculomotor foramen, the entry point of the oculomotor nerve into the CS proper. The dura is opened superiorly along the course of the oculomotor nerve to the region of the SOF. This achieves further decompression of the superior aspect of the CS. Any portion of tumor superior to the oculomotor nerve may be removed without risk of cranial nerve injury. Care must be taken at the region of the SOF, where the trochlear nerve crosses the oculomotor nerve, as injury to the nerve may occur at this juncture.

At the end of the procedure, the CS has been decompressed inferiorly between the branches of the trigeminal

TABLE 1
*Characteristics in 11 patients with CS meningiomas**

Case No.	Age (yrs) at Diagnosis	Prior Treatment	Presenting Symptoms	Follow Up (mos)	Subsequent Therapy
1	34	none	headaches	15	SRS
2†	58	Gamma Knife surgery, surgery	lt-sided facial pain, 4th and 6th nerve palsies	39	SRS
3	71	multiple surgeries, field radiation	lt-sided visual loss	24	SRS
4	55	none	generalized tonic–clonic seizures, lt-sided facial paresthesia, diplopia	25	IMRT
5	59	none	rt-sided proptosis & temporal mass	25	SRS
6	58	multiple surgeries, radiation	lt-sided visual loss, diplopia	22	SRS
7	58	none	headache, nausea/vomiting, lt-sided visual loss	22	SRS
8	44	surgery	lt-sided proptosis	27	SRS
9	69	none	lt-sided visual loss	9	SRS
10†	58	surgery, radiation	progressive 6th nerve palsy	12	IMRT
11†	53	none	progressive 6th nerve palsy	20	SRS

* SRS = stereotactic radiosurgery.
† Indicates patients with a preoperative cranial nerve deficit affecting oculomotor function in whom improvement was noted following surgery.

nerve. The lateral wall has been dissected free and all tumor lateral to the trigeminal nerve removed, and the superior aspect of the CS has been opened and any superficial parts of the tumor removed. The last step provides the opportunity to leave several millimeters of distance between any piece of tumor remaining within the CS and the optic apparatus in preparation for anticipated radiosurgery or stereotactic IMRT. Radiographic imaging is performed after radiosurgery or IMRT and repeated every 6 months thereafter.

Results

The senior authors (W.T.C. and R.I.A.) performed the decompression–reduction operation in 11 patients harboring CS meningiomas with evidence of true primary cavernous involvement (not merely lateral wall involvement or extension from clinoidal involvement) whose lesions were categorized as Hirsch[8] Grade 2 or 3 (tumor encasing the CA with or without arterial narrowing) (Table 1). In three patients, significant ophthalmoparesis existed before surgery. All patients underwent stereotactic radiosurgery or stereotactic IMRT 2 to 6 months after surgery.

Of the patients who presented with a lack of ocular motility due to a tumor-induced cranial nerve deficit, two achieved complete improvement in their abducent paresis before radiation treatment (Fig. 2). A third patient experienced partial improvement, which has continued to progress during and following stereotactic IMRT. No patient suffered additional cranial nerve deficits or visual loss following surgery. Of the four patients who presented with visual loss, visual function improved in two and stabilized in the other two. One patient experienced an unpleasant dysesthetic facial sensation 3 months after radiosurgery; that symptom resolved by 7 months posttreatment. Control of tumor growth has been achieved in all patients as of the most recent follow-up examination.

Discussion

Meningiomas are the most common tumors affecting the CS.[3] Despite modern advances in microsurgery and radiosurgery, treatment of cavernous sinus meningiomas remains difficult and controversial. Proposed treatments have ranged from radical resection[4,18] to stereotactic radiosurgery.[12] As with other meningiomas, the goal of treatment for patients with CS meningiomas is long-term growth control and preservation of neural function. Despite improved understanding of the microsurgical anatomy of the CS[6,17] and advances in microsurgical techniques, the risk of morbidity, especially cranial neuropathy, associated with aggressive resection of these lesions remains quite high. O'Sullivan and colleagues[16] reported that seven of 10 patients with normal preoperative oculomotor function experienced a significant new permanent ocular deficit postoperatively, and DeMonte and associates[4] reported the occurrence of new cranial neuropathies in 18% of patients postoperatively. Because gross-total resection, the ideal treatment for meningioma, cannot always be obtained with acceptable levels of morbidity for meningiomas in the CS, there has been a recent shift in the treatment paradigm from a single-treatment modality with radical surgery to a multimodal therapy with conservative resection followed by radiosurgery.[13,15] We have adopted a technique of conservative tumor debulking to reduce tumor volume and decompress the cavernous sinus before radiosurgery so that we can improve functional outcomes and reduce the volume of the treated field in patients with primary CS meningiomas. We are currently using the procedure in patients harboring symptomatic primary cavernous sinus meningiomas (a Hirsch[8] Grade 2 or 3 tumor encasing the CA with or without arterial narrowing) and in patients in whom the CS tumor is encroaching on or is encompassing the optic nerve (which would limit the radiosurgical dose used to treat a tumor in this location).

In support of this concept, recent reports substantiate improved functional outcomes with conservative surgical strategies. In the treatment of large sphenoid wing meningiomas involving the CS, Abdel-Aziz, et al.,[1] advocate the limited resection of only the lateral portion of the intracavernous tumor, leaving treatment of the residual lesion to radiosurgery. The percentage of patients with ocular nerve dysfunction during the late postoperative period decreased from 55 to 16%. Compared with radical resection, conservative CS decompression may be associated with a lower risk of cranial nerve morbidity and better functional out-

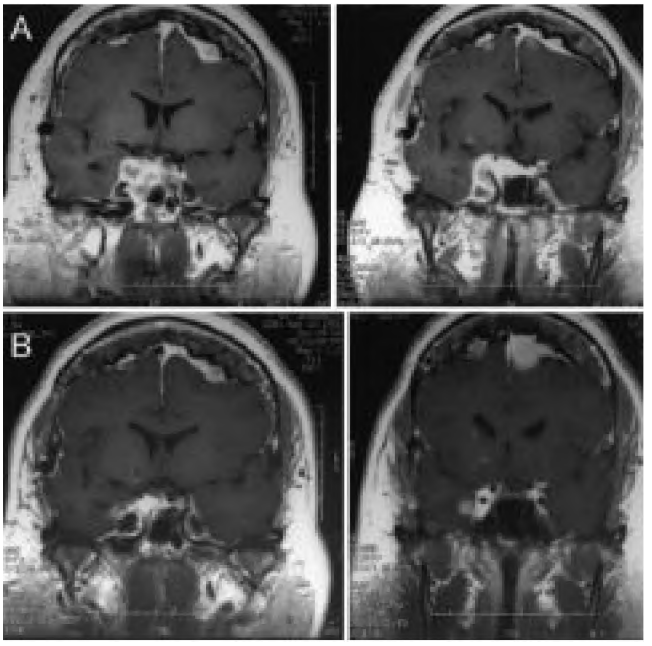

FIG. 2. Case 11. A: Preoperative, coronal contrast-enhanced magnetic resonance images obtained in a patient with meningiomatosis and a right CS meningioma encasing the CA. B: Magnetic resonance images obtained 12 months after surgery and postoperative radiosurgery showing nearly complete regression of the residual tumor in the CS. The patient's abducent paresis improved postoperatively, prior to stereotactic radiosurgery.

come for several reasons. Apart from direct injury to the nerve during aggressive resections, the fine blood supply to oculomotor nerves may be disrupted during extensive dissection of the dural sheaths covering the nerves, decreasing their chance of functional improvement. Furthermore, tumor encasement and infiltration of the cavernous CA often necessitate a bypass procedure in radical resections.[10] Apart from the additional risks of morbidity and mortality associated with bypass surgery, sacrifice of the cavernous CA and its branches may also devascularize the cavernous cranial nerves and diminish their chance of a good functional recovery.

In addition to reducing the risk of cranial nerve morbidity, limited surgery followed by radiosurgery or radiotherapy appears to provide an advantage in long-term tumor control. Maruyama and coworkers[15] reported a tumor control rate of 94.1% at 5 years after combined nonradical surgery and radiosurgery or radiosurgery alone. Lee, et al.,[12] noted a similar tumor control rate of 93% at 5 and 10 years following a similar treatment protocol. This is in contrast to the surgical series in which O'Sullivan and colleagues[16] reported a tumor recurrence or progression rate of 13% at 2 years, and DeMonte and associates[4] reported an 11% recurrence at a mean follow up of 45 months. The higher rate of recurrence in surgical series, even in those in which gross-total resection was obtained, may be related to microscopic tumor deposits remaining on the cranial nerves,[11,19] which supports the use of multimodal therapy with radiosurgery for residual disease in the treatment of patients with CS meningiomas. The tumor control rate in this small series of patients is 100%, but we acknowledge that the follow-up period is too short to estimate long-term tumor control. We anticipate that the combined treatment will produce control rates approaching those published for primary radiosurgical therapy for meningiomas in this location.

With multimodal therapy, the surgical strategy varies as to the aggressiveness of tumor resection before radiosurgery. After the removal of all extracavernous tumor to decompress critical structures such as the optic apparatus and brainstem, we perform a conservative approach of tumor debulking to decompress the CS inferiorly, laterally, and superiorly, leaving the residual tumor in the medial CS to treat with radiosurgery. As most CS meningiomas are compressive rather than invasive in nature,[4] the goal of our strategy is to decompress and release the CS while preserving the blood supply to all cranial nerves, allowing better functional recovery. This recovery was noted in several patients in this series following surgical decompression. The small series and relatively short follow-up review do not allow evaluation of long-term cranial nerve function or determination of whether cranial nerve outcome will be superior to that following radiosurgery alone. The close association of these tumors to the optic apparatus, however, places some constraints on effective radiosurgical treatment. The tumor can extend out of the CS into the subarachnoid space and abut against, compress, or encase the optic nerve, tract, or chiasm; or the sinus may be expanded by the tumor within it to the point at which it is in apposition to the optic nerve. This proximity can limit the tumor dose that can be safely applied and, conversely, result in a loss of optic nerve function secondary to radiation therapy. By removing the more easily accessible subarachnoid piece of tumor and also debulking the superior portion of the intracavernous tumor, a plane of separation can be created between the residual tumor that will be targeted radiosurgically and the optic apparatus. As in other locations,[2] a small fat graft may also be used to increase the interpositional distance. This allows for a more optimal radiation dosage to the residual tumor while reducing the risk of radiation damage to the optic system.

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Manuscript received April 6, 2005.
Accepted in final form January 6, 2006.
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