Operative management of tumors involving the cavernous sinus

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In the past, neurosurgeons have been reluctant to operate on tumors involving the cavernous sinus because of the possibility of bleeding from the venous plexus or injury to the internal carotid artery (ICA) or the third, fourth, or sixth cranial nerves. The authors describe techniques for a more aggressive surgical approach to neoplasms in this area that are either benign or locally confined malignant lesions.

During the last 2 years, seven tumors involving the cavernous sinus have been resected; six totally and one subtotally. The preoperative evaluation included axial and coronal computerized tomography, cerebral angiography, and a balloon-occlusion test of the ICA. Intraoperative monitoring of the third, fourth, sixth, and seventh cranial nerves was used to assist in locating the nerves and in avoiding injury to them. The first major step in the operative procedure was to obtain proximal control of the ICA at the petrous apex and distal control in the supraclinoid segment. The cavernous sinus was then opened by a lateral, superior, or inferior approach for tumor resection. Temporary clipping and suture of the ICA was necessary in one patient.

None of the patients died or suffered a stroke postoperatively. Permanent trigeminal nerve injury occurred in three patients; in two, this was the result of tumor invasion. One patient suffered temporary paralysis of the third, fourth, and sixth cranial nerves, and in another the sixth cranial nerve was temporarily paralyzed. Preoperative cranial nerve deficits were improved postoperatively in three patients. Radiation therapy was administered postoperatively to four patients. These seven patients have been followed for 6 to 18 months to date and none has shown evidence of recurrence of the intracavernous tumor.

KEY WORDS: intracavernous tumor, cavernous sinus, cranial nerve function, intraoperative monitoring, internal carotid artery, operative approach
TABLE 1
Clinical summary of patients with tumors of the cavernous sinus*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Clinical Presentation</th>
<th>Tumor Type</th>
<th>Extent of Tumor</th>
<th>Cavernous Sinus Operation</th>
<th>Postop Therapy</th>
<th>Follow-Up Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53, F</td>
<td>facial swelling, V2, V3 numbness, eustachian tube obstruction, previous op</td>
<td>recurrent meningioma</td>
<td>infratemporal &amp; middle fossae, clivus, cavernous sinus</td>
<td>1: infratemporal fossa, sphenoid sinus, petroclival area inferior cavernous sinus resection; 2: cavernous sinus (lateral &amp; superior approach), &amp; tentorial notch resection</td>
<td>extracranial irradiation</td>
<td>6 mos: transient III &amp; VI palsies; permanent V3 injury; no residual tumor; patent ICA</td>
</tr>
<tr>
<td>2</td>
<td>24, M</td>
<td>VI palsy, III paresis</td>
<td>chordoid chordoma</td>
<td>cavernous sinus, middle, posterior &amp; infratemporal fossae</td>
<td>lateral approach: subtotal resection</td>
<td>irradiation</td>
<td>1 yr: III &amp; VI palsies resolved; residual tumor in infratemporal fossa; patent ICA</td>
</tr>
<tr>
<td>3</td>
<td>76, F</td>
<td>facial pain, III, IV, &amp; VI palsy</td>
<td>invasive pituitary adenoma</td>
<td>sella, sphenoid, cavernous sinus</td>
<td>1: transsphenoidal op; 2: cavernous sinus op, lateral &amp; superior approach, total resection</td>
<td>irradiation</td>
<td>8 mos: ophthalmoplegia resolved; no residual tumor; patent ICA</td>
</tr>
<tr>
<td>4</td>
<td>23, M</td>
<td>VI palsy, previous partial resection</td>
<td>well differentiated chondrosarcoma</td>
<td>petrous apex, clivus, cavernous sinus</td>
<td>lateral approach, total resection</td>
<td>irradiation</td>
<td>2 yrs: VI palsy resolved; no tumor recurrence‡</td>
</tr>
<tr>
<td>5</td>
<td>40, M</td>
<td>VI palsy</td>
<td>well differentiated chondrosarcoma</td>
<td>petrous apex, clivus, cavernous sinus</td>
<td>lateral approach, subtotal resection</td>
<td>irradiation</td>
<td>2 yrs: VI palsy resolved; no tumor recurrence‡</td>
</tr>
<tr>
<td>6</td>
<td>42, F</td>
<td>dementia, hemiparesis, previous ops</td>
<td>trigeminal neurinoma</td>
<td>cavernous sinus, petroclival area</td>
<td>lateral approach, total resection</td>
<td>none</td>
<td>1 yr: temporary VI palsy; no residual tumor</td>
</tr>
<tr>
<td>7</td>
<td>39, M</td>
<td>transtentorial herniation due to massive temporal lobe edema</td>
<td>meningioma</td>
<td>middle fossa, cavernous sinus</td>
<td>lateral approach, total resection</td>
<td>none</td>
<td>2 mos: transient V1, V3, V3 numbness; no residual tumor‡</td>
</tr>
</tbody>
</table>

* Roman numerals denote cranial nerves; ICA = internal carotid artery.
† This patient died suddenly of an acute myocardial infarction after a good recovery. See text.
‡ No postoperative arteriography or digital subtraction angiography.

The cavernous sinus (Table 1). Indications for removal of these tumors from the cavernous sinus included recurrence of the tumor from a residue left in the region of the cavernous sinus during a previous operation, the appearance of cranial nerve symptoms (ophthalmoplegia or intractable pain), and the prospect of achieving a total cure of the lesion by excision.

Clinical Material and Methods

Preoperative Evaluation

Preoperative evaluation included neurological assessment, axial and coronal computerized tomography (CT) scans, cerebral angiography, and neurophysiological testing of the function of the second, fifth, seventh, and eighth cranial nerves. In more recent cases, a balloon-occlusion test of the ipsilateral ICA was performed, with repeat neurological examinations and measurement of cerebral blood flow and postocclusion arterial stump pressure. The balloon-occlusion test gives an indication of the collateral flow reserve and of the risk of stroke after permanent or temporary ICA occlusion.

Intraoperative Monitoring

Intraoperative monitoring of the third, fourth, and sixth cranial nerves was performed by electromyography (EMG) of the action potentials from the extracocular muscles (Fig. 1). The cranial nerves were stimulated with 150-μsec rectangular pulses at 5 or 10/sec using a
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Fig. 1. Drawing of the placement of intraoperative monitoring devices. A bicoronal incision (shown here) or a curvilinear incision extending in front of the hairline is utilized for these procedures. The locations of all monitoring devices except that of the light-emitting diode contact lens used for optic nerve monitoring are shown. BSER = brain-stem evoked responses.

hand-held monopolar stimulator electrode* and a No. 25 metal hypodermic needle placed in the wound as a reference electrode. To monitor the sixth cranial nerve, the lateral rectus muscle was reached by placing a needle electrode† through the skin at the lateral corner of the eye, aiming away from the globe to avoid injury to the conjunctiva. The medial rectus and the superior oblique muscles were reached in a similar way to monitor the third and fourth cranial nerves, respectively. Reference electrodes were placed on the opposite side of the forehead and ground electrodes were placed nearby. Responses from the facial muscles were recorded individually from two electrodes, one placed in the mentalis muscle and one in the orbicularis oculi muscle. The recorded potentials were amplified by four separate amplifiers‡ with a bandpass of 0.3 to 3 kHz and were displayed on oscilloscopes. The potentials could also be made audible through a loudspeaker, one channel at a time, and the stimulus artifacts were suppressed by a technique described earlier.21

In some patients, the optic nerve was also monitored by recording visual evoked potentials (VEP's) from electrodes placed on the scalp and directly on the optic nerve. The stimuli used were short light flashes generated by light-emitting diodes that were glued to plastic contact lenses. Scalp VEP's were recorded by placing needle electrodes in the occipital and parietal areas (O2 and C2), with a reference electrode placed on the opposite side of the head. Direct VEP's were recorded by placing a malleable Teflon-insulated silver wire with a cotton wick sutured to its uninsulated tip directly on the optic nerve (AR Möller, J Burgess, unpublished data, 1985). The reference electrode was a No. 25 all-metal hypodermic needle which was placed in the wound. These VEP's were also amplified with a bandpass of 0.3 to 300 Hz and were averaged using a minicomputer. The results were displayed on an oscilloscope and stored on computer disk.

Operative Technique

All patients are operated on under endotracheal inhalation anesthesia. Short-acting neuromuscular blocking agents are used during induction of anesthesia. After the conclusion of the major portion of the operation, the anesthesiologist is allowed to paralyze the patient so that the requirements for inhalational agents can be reduced. Furosemide, 40 mg, is administered intravenously at the time of skin incision and, if required, mannitol (50 gm) can also be given intravenously. Cerebrospinal fluid (CSF) drainage is accomplished only by the opening of cisterns at operation, and not by lumbar catheterization.

The patient's head is placed in a three-point fixation device in the usual fashion for a frontotemporal craniotomy. A "reverse question mark" incision is made starting in front of the tragus of the ear and extending in front of the hairline for not more than 2 cm. The temporalis muscle and fascia are incised in the line of the skin incision and reflected from the bone forward to the lateral orbital angle. The temporalis muscle is then dissected from its fascia and reflected downward. When necessary, the zygomatic arch is divided with a Stryker saw, which permits further mobilization of the temporalis muscle and a more basal approach to the floor of the middle fossa. Following the elevation of a free bone flap, the bone of the pterion is drilled away until the lateral aspect of the superior orbital fissure is reached. The dura is then opened and, with the aid of the operating microscope and self-retaining retractors, the optic nerve and the carotid cisterns are opened for initial inspection of the extent and location of the tumor. If the tumor has already elevated and thinned the temporal lobe considerably as a result of extensive middle fossa involvement, the sylvian fissure is split and gentle temporal lobe retraction is used to gain exposure. If, on the other hand, the tumor is mostly medially situated and localized to the region of the cavernous sinus, the anterior 4 cm of the temporal lobe is excised, starting in the middle temporal gyrus and sparing the medial temporal lobe structures, in order to prevent postoperative contusion and swelling of the temporal lobe.

For proximal control of the ICA, the dura of the middle fossa is elevated from the floor of the middle fossa (from posterior to anterior) to identify the greater superficial petrosal nerve, the middle meningeal artery, and the mandibular nerve, exiting through the foramen
ovale. The horizontal portion of the petrous ICA lies parallel and deep to the greater superficial petrosal nerve and posterior to the middle meningeal artery and the mandibular nerve. When the anatomy is altered by tumors, the most consistent landmark is the mandibular nerve. The greater superficial petrosal nerve and the middle meningeal artery are divided, and the ICA is unroofed for a length of about 2 cm with the aid of a diamond drill. The peristeme covering the ICA is then opened and an area is prepared for temporary clipping and grafting, should this become necessary. Great care must be taken during drilling so as not to damage the geniculate ganglion of the facial nerve, which lies posterior and lateral to this area. This ganglion can be found by following the greater superficial petrosal nerve posteriorly and by electrical stimulation.

The cavernous sinus is entered via one or more of three approaches: 1) a lateral approach through the triangle of Parkinson, or between the first and second divisions of the trigeminal nerve; 2) a superior approach through its superior surface; and 3) an inferior approach from the infratemporal fossa following the ICA (Fig. 2).

Lateral Approach. The lateral wall of the cavernous sinus is composed of two dural layers, the outer layer being thicker and more complete than the inner. A cruciate incision is made in the outer layer, which is peeled away from the ophthalmic division of the trigeminal nerve, the oculomotor nerve, and the trochlear nerve with the aid of a Rosen microdissector. The location of the third and fourth cranial nerves is relatively constant in the anterosuperior lateral wall of the cavernous sinus, and they may also be identified as they enter the lateral wall of the cavernous sinus. However, the first and second divisions of the fifth and sixth cranial nerves are often displaced by tumors of the cavernous sinus. Electrical stimulation and observation of the induced EMG responses are performed to identify the location of the cranial nerves. The cavernous sinus is then entered between the fourth and the first division of the fifth cranial nerves, or sometimes between the first and second divisions of the fifth cranial nerve. The tumor is removed with sharp and blunt microinstruments and the bipolar coagulator; the use of the laser is discouraged.

Superior Approach. The superior surface of the cavernous sinus becomes more accessible after mobilization of the optic nerve and removal of the anterior clinoid process. The superior wall of the cavernous sinus is devoid of any cranial nerves; however, the ICA emerges through the superior wall and is firmly attached to the dura at its point of emergence. After removal of the anterior clinoid process, the dura underlying it is very thin. An incision is started here and extended toward the posterior clinoid process. The edge of the tentorium, which forms the boundary between the superior and lateral surfaces, can be retracted laterally with sutures to improve the exposure. The ICA is then followed into the cavernous sinus, removing all tumor surrounding it. The anterior and medial aspects of the cavernous sinus and the ICA are better visualized with this approach than with the lateral technique.

Inferior Approach. The inferior approach to the cavernous sinus is possible only when the mandibular branch of the trigeminal nerve is divided because of invasion by tumor, or during operations on tumors that extend into the infratemporal fossa. The ICA can be followed from the petrous apex into the basal cavernous sinus and tumor can be removed from here. The abducens nerve crossing the ICA can be dissected free of tumor; however, it is not possible to remove all the tumor from the cavernous sinus by this route.

Management of the Cavernous ICA. Usually a plane between the ICA and the tumor can be found and followed with the aid of a Rosen microdissector and bipolar forceps. The surgeon should be prepared to temporarily clip the artery and to place 8-0 nylon microsutures if the artery is torn during dissection. If the tumor is found to be inseparable from the ICA, one can either leave residual tumor attached to the artery or excise the invaded section of artery. If the latter
course is chosen, the artery should be reconstructed at once by placing a short (4.0-cm) vein graft from the petrous to the supraclinoid ICA. This method has the theoretical advantage of immediately providing a large volume of blood; the disadvantage is carotid occlusion for a period of approximately 50 minutes (LN Sekhar, et al., unpublished data, 1985). Alternative methods of reconstruction include superficial temporal to middle cerebral artery anastomosis, or the use of a much longer vein graft from the external carotid artery to a major branch of the middle cerebral artery.

Management of Cranial Nerves. In addition to electrical stimulation to identify the cranial nerves at the beginning of the operation, periodic stimulation of the nerves during the operation and the observation of spontaneously generated EMG activity due to traction or heat are useful in the dissection and preservation of the cranial nerves. Even if an ophthalmoplegia occurs after an operation, a useful degree of function can be recovered if anatomical continuity of the nerves has been preserved. The abducens nerve is most likely to be injured during operations in the cavernous sinus. When such injury occurs, reconstruction by direct suturing or with a nerve graft may be worthwhile.

Management of Venous Bleeding. Bleeding from the venous plexus inside the cavernous sinus usually indicates the margin of the tumor in that area. Packing with Surgicel and gentle pressure applied over a cotton patty are adequate for control. Further evaluation of the head may also be utilized.

Prevention of CSF Leak. When the tumor extends into the sphenoid sinus, there is a danger of postoperative CSF leakage and meningitis. In these cases, it is preferable to remove the tumor from the sphenoid sinus at a first stage of the operation and to occlude the defect with vascularized tissue. The cavernous sinus tumor should be removed in a second stage 4 weeks later.

Operative Results
The cavernous sinus neoplasm was believed to be excised totally in six patients and subtotally in one. No patients suffered a stroke postoperatively. Three patients had cranial nerve injuries: one patient (Case 1) suffered temporary third, fourth, and sixth cranial nerve palsies, and the third division of the fifth cranial nerve was resected because of tumor invasion; another (Case 6) suffered a temporary abducens palsy and a permanent trigeminal nerve injury due to tumor invasion; and in the third (Case 2) a permanent injury to the third division of the fifth cranial nerve occurred inadvertently. Preexisting cranial nerve deficits resolved in three patients, including one with complete ophthalmoplegia and facial pain.

Radiation therapy was given after surgery to four patients. Postoperative intravenous or intra-arterial angiography was performed in four patients and revealed a patent ICA in all cases. The follow-up period is short (6 to 18 months); however, clinical examination and CT scanning have shown no evidence of tumor regrowth. We describe four of these cases in detail below.

Illustrative Case Reports

Case 1: Recurrent Meningioma

This 51-year-old woman was referred for management of a recurrent meningioma 4 years after an initial operation to remove a middle fossa tumor.

Examination. Trismus, fullness of the right side of the face and the nasopharynx, and diminished sensation in the trigeminal distribution were present. A CT scan revealed a very large tumor involving the petrous bone and clivus, retropharyngeal area, infratemporal fossa, sphenoid sinus, middle fossa, cavernous sinus, and ten- dorial notch area on the right side (Fig. 3). Cerebral angiography revealed that the neoplasm was quite vascular, predominantly supplied by the external carotid artery. A trial balloon-occlusion was well tolerated by the patient clinically, but cerebral blood flow was significantly reduced.

Operations. The tumor was resected in two stages. During the first operation, an infratemporal fossa approach was used, with resection of the mandibular condyle and mobilization of the infratemporal facial nerve. The neoplasm was totally removed from the infratemporal fossa, including the invaded muscles, the mandibular nerve, and a portion of the nasopharyngeal wall. The petrous ICA was encased by tumor involving the petroclival bone. The vertical segment of the petrous ICA was identified, and the entire petrous ICA was dissected free of tumor. The tumor was then removed from the basal cavernous sinus (inferior approach) by dissecting it away from the cavernous ICA and the abducens nerve (Fig. 4 left). The petroclival bone and the sphenoid sinus were also cleared of tumor. At the end of the operation, a vascularized rectus abdominis muscle flap was used to fill the infratemporal fossa, the
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FIG. 4. Exposure of the cavernous sinus in Case 1. The intracavernous internal carotid artery (ICA), the ophthalmic nerve (V1), the maxillary nerve (V2), the abducens nerve (VI), and the tumor (T) are exposed. Right: The second stage of the resection. Note the completely dissected oculomotor (III) and trochlear (IV) nerves, the tumor (T), and the pons (P).

sphenoid sinus, and the defect in the nasopharyngeal wall. Postoperatively, the patient had facial and abducens nerve palsy.

The second stage of the operation involved a frontotemporal approach to the lesion. Residual tumor was found in the upper cavernous sinus area, the dura overlying the trigeminal nerve in the middle fossa, the tentorial notch, and the clival area. Through a lateral and superior approach, the neoplasm was totally removed from the cavernous sinus. The third, fourth, and fifth cranial nerves and the second division of the trigeminal nerve were dissected from the tumor and preserved (Fig. 4 right). Two lacerations of the cavernous ICA were sutured with 8-0 nylon after temporary clipping of the petrous and supraclinoid ICA. The remaining intracranial tumor was also removed.

Postoperative Course. Postoperatively, the patient had a complete third and fourth cranial nerve paralysis in addition to her previous sixth nerve palsy, but otherwise had an uneventful recovery. A postoperative angiogram revealed the ICA to be patent and normal. On follow-up examination 1 year later, the third, fourth, and sixth cranial nerve palsies had completely recovered. Radiation therapy was given to the infratemporal fossa region as an adjunct to tumor resection. There is no evidence of tumor recurrence on recent CT scans.

Case 2: Chordoma

This 24-year-old man presented with a 4-year history of headaches, tingling around the eyes, and intermittent double vision. He had recently developed an abducens and oculomotor paresis. A CT scan showed a hyperdense lesion involving the left cavernous sinus and middle, posterior, and infratemporal fossae, which enhanced after administration of contrast material (Fig. 5). Cerebral angiography revealed a displacement of the petrous and cavernous ICA, but no tumor blush was apparent.

Operation. The tumor was approached through a left frontotemporal craniotomy, with monitoring of the third, sixth, and seventh cranial nerves. The temporal lobe was significantly elevated by the tumor and, after the sylvian fissure was split, it was merely held in place with a retractor. The supraclinoid ICA and the third cranial nerve were found to be displaced anteromedially by the tumor, which occupied the cavernous sinus and basal middle fossa and extended into the clival area medial to Meckel’s cave. After an incision in the lateral wall of the cavernous sinus, the trigeminal nerve and its branches were found to be displaced laterally by the tumor. A soft yellowish-red tumor was easily removed with suction, irrigation, and blunt microdissection. The sixth cranial nerve and the cavernous ICA were found.
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FIG. 6. Exposure of the intracavernous tumor after dural opening and the location of the intracavernous structures as seen after tumor removal in Case 2. ICA = internal carotid artery; MCA = middle cerebral artery; III, IV, V, VI, and VII = cranial nerves; F = frontal lobe; T = temporal lobe; FO = foramen ovale (markedly enlarged); D = dura; Tu = tumor.

to be displaced medially and downward (Fig. 6). The infratemporal fossa was entered through the enlarged foramen ovale and tumor was removed from it. After division of the tentorium, the portion of the tumor in the posterior fossa was removed. Tumor in the cavernous sinus and the middle and posterior fossae was thought to have been completely resected.

Postoperative Course. The patient has a permanent mandibular nerve palsy. The lesion was diagnosed as a chordoma. Proton-beam radiation therapy was administered and on follow-up review 9 months later the abducens and oculomotor palsies have resolved completely. Repeat CT scans have revealed no tumor in the cavernous sinus or the middle fossa, but a tumor remnant may remain in the infratemporal fossa.

Case 3: Invasive Pituitary Adenoma

This 76-year-old woman presented with a 4-year history of atypical trigeminal neuralgia involving all three divisions and the recent onset of drooping of the right eyelid.

Examination. The visual acuity in the right eye was reduced to finger counting, with a central scotoma. She had a complete paralysis of the third, fourth, and sixth cranial nerves and diminished sensation in all divisions of the trigeminal nerve. A CT scan revealed a mass involving the sphenoid, sellar, suprasellar, and parasellar areas (Fig. 7).

Operations. By a transsphenoidal approach, a yellowish friable tumor was removed from the sphenoid sinus, the sella, and the suprasellar area. The sphenoid sinus was packed with fat and fascia lata. The lesion was diagnosed as a nonsecretory pituitary adenoma. Postoperatively, the patient continued to have persistent facial pain and ophthalmoplegia and her vision was not improved. It was believed by the neuro-ophthalmology service that an extradural compression of the optic nerve was responsible for her visual problem. A further neurosurgical procedure was performed to relieve her pain and ophthalmoplegia, and to improve the chances of a cure of the tumor.

Ten days after the first operation, the tumor was approached again through a right frontotemporal craniotomy. The bone and dural canals of the optic nerve were completely unroofed. The tumor was found to be extruding from the superior surface of the cavernous sinus, and the third cranial nerve was humped and splayed over it as it entered the dura (Fig. 8 left). The lateral wall of the cavernous sinus was opened, and tumor was removed from within. The third nerve was decompressed by opening the dura of the lateral wall.

FIG. 7. Preoperative computerized tomography scan in Case 3. A tumor is seen involving the sphenoid sinus, sella, suprasellar area, and right cavernous sinus.
along its course. The superior surface of the cavernous sinus was then entered and further tumor resection was accomplished. At the beginning of the operation there was no response from the respective extraocular muscles upon electrical stimulation of the third and fourth cranial nerves, but after an incision was made in the lateral wall of the cavernous sinus some spontaneous activity was noted in the muscles supplied by them (Fig. 8 right).

Postoperative Course. This patient received postoperative radiation therapy. On follow-up examination 6 months later, visual acuity had improved to 20/70 and the facial pain was considerably reduced, requiring only an occasional analgesic. Except for a mild ptosis, she recovered normal extraocular muscle function. A CT scan obtained 8 months after the operation showed no evidence of tumor recurrence. Nine months after the operation, the patient developed septicemia from a urinary tract infection and died suddenly of a massive myocardial infarction. Permission for an autopsy could not be obtained.

Case 4: Chondrosarcoma

This 23-year-old man presented with a 2-year history of sixth nerve palsy. Investigation revealed a lesion occupying the petrous apex and the cavernous sinus areas (Fig. 9). The lesion had been biopsied at another institution and found to be a well-differentiated chondrosarcoma. The tumor was approached through a frontotemporal craniotomy after a partial resection of the temporal lobe tip. After dissection of the dura of its lateral wall, the cavernous sinus was entered between the fourth cranial nerve and the first division of the fifth, and between the first and second divisions of the fifth cranial nerve. A yellowish gelatinous tumor mass was found displacing the cavernous ICA anteromedially and the sixth cranial nerve laterally. A total resection of the tumor was accomplished.

On follow-up review 1½ years later, the patient's sixth nerve palsy had resolved and there is no CT evidence of tumor recurrence. This young man is attending college and functioning well.

Discussion

The present study demonstrates that total or subtotal resection of intracavernous neoplasms can be achieved with minimal morbidity. Careful preoperative evaluation, an adequate understanding of the anatomy of the cavernous sinus, readiness to deal with arterial injury, and the use of cranial nerve monitoring were considered important in achieving these results.
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<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Aneurysms</th>
<th>No. &amp; Type of Neoplasms</th>
<th>Approaches</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gordy, 1965</td>
<td>0</td>
<td>1 trigeminal neurinoma</td>
<td>lateral</td>
<td>good</td>
</tr>
<tr>
<td>Parkinson, 1965, and Parkinson &amp; West, 1982</td>
<td>12</td>
<td>0</td>
<td>lateral</td>
<td>1 death: details unavailable</td>
</tr>
<tr>
<td>Nakahara, et al., 1975</td>
<td>0</td>
<td>lateral</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>MacKay &amp; Hosobuchi, 1978</td>
<td>0</td>
<td>2 pituitary adenomas</td>
<td>lateral</td>
<td>1 good, 1 poor (1 III palsy)</td>
</tr>
<tr>
<td>Zozulia, et al., 1979</td>
<td>0</td>
<td>no. not given: meningiomas, pituitary adenomas</td>
<td>not given</td>
<td>not given</td>
</tr>
<tr>
<td>Johnston, 1979</td>
<td>0</td>
<td>lateral</td>
<td>fair</td>
<td></td>
</tr>
<tr>
<td>Unsdorl, et al., 1980</td>
<td>0</td>
<td>1 metastatic carcinoma (biopsy)</td>
<td>lateral &amp; superior</td>
<td>fair</td>
</tr>
<tr>
<td>Schubiger, et al., 1980</td>
<td>0</td>
<td>1 neurinoma (origin not identified)</td>
<td>lateral</td>
<td>good</td>
</tr>
<tr>
<td>Kline &amp; Galbraith, 1981</td>
<td>0</td>
<td>1 epidermoid</td>
<td>lateral</td>
<td>good</td>
</tr>
<tr>
<td>Hakuba, et al., 1982</td>
<td>6</td>
<td>4 meningiomas, 1 neurinoma, 1 teratoma, 3 pituitary adenomas, 2 chordomas</td>
<td>lateral (3), anterolateral (6), anteromedial (2), posterior (1), combined (2)</td>
<td>1 death, 1 hemiplegia, 3 cranial nerve palsies, 13 good</td>
</tr>
<tr>
<td>Dolenc, 1983</td>
<td>3</td>
<td>0</td>
<td>lateral (5), lateral &amp; superior (1), lateral, superior, &amp; inferior (1)</td>
<td>2 good, 1 fair†</td>
</tr>
<tr>
<td>Sekhar &amp; Møller, 1986</td>
<td>0</td>
<td>2 meningiomas, 1 neurinoma, 1 pituitary adenoma, 1 chordoma, 2 chondrosarcomas</td>
<td>lateral</td>
<td>6 good, 1 fair‡ (2 V3 palsies)</td>
</tr>
</tbody>
</table>

*Roman numerals denote cranial nerves.
† One patient died 3 months postoperatively as a result of infection after a good initial outcome.
‡ Died 8 months following the operation as a result of a myocardial infarction.

of operations inside the cavernous sinus for aneurysms and neoplasms are listed in Table 2. Reports of operations for carotid cavernous fistulas are not included.

Parkinson pioneered the operative approach to intracavernous lesions and reported on 31 lesions. He used a lateral approach to the cavernous sinus. Data concerning the completeness of tumor excision and long-term results were not available. Dolenc reported three cases of giant aneurysms managed by direct clipping or aneurysmorrhaphy. Although his approach to the cavernous sinus was lateral, it differed from Parkinson's technique in that it included a complete dissection of the cranial nerves in the lateral wall. Hakuba, et al., used four approaches during operations on six aneurysms and 13 neoplasms. The lateral approach was through Parkinson's triangle. Their anterolateral approach consisted of removing the anterior clinoid process and the wall of the optic nerve canal to expose the anterior intracavernous portion of the ICA. Their anteromedial approach was through the planum sphenoidale and the sphenoid sinus to reach the opposite cavernous sinus. Their posterior approach was an exposure of the petrous apex, without entering the cavernous sinus. The authors did not emphasize the preservation of cranial nerve function. Complications included death in one patient, stroke in one, loss of vision in one, and multiple other cranial nerve palsies in two.

Laws, et al., used a transtemporal, transsphenoidal approach to occlude a carotid cavernous fistula, with a balloon in the cervical ICA for proximal control. We do not recommend transsphenoidal approaches to the cavernous sinus because of inadequate exposure, poor proximal and distal control of the ICA, and the danger of CSF leakage.

The current options for managing a neoplasm of the cavernous sinus include: observation only, operative removal, and radiation therapy with or without operation. Until more data become available concerning the response to different therapeutic modalities, the decision should be individualized according to the patient's age and physiological condition, the pathology of the neoplasm, and its biological behavior. In a number of cases with recurrent cavernous meningiomas, involvement of the cavernous sinus has been the limiting factor for radical tumor resection, and thus the cause of recurrence. However, the biological behavior of meningiomas is variable. Recurrence may occur very quickly in some patients, while in others it may be delayed for years. Radiation therapy of intracavernous meningiomas has been shown to improve the symptoms but to cause no apparent change on CT. Thus, younger patients and those with recurrent meningiomas must be considered for a radical tumor resection with or without radiation therapy. Pituitary adenomas have been treated successfully in many cases by subtotal tumor resection and radiation therapy. However, it has been pointed out by MacKay and Hosobuchi that a major cause of recurrence of pituitary tumors is the residual intracavernous and extradural portion of the tumor. A radical operation in which intracavernous portions of the tumor are removed may therefore be indicated in patients with recurrent pituitary tumors.

In many patients with chordomas and chondrosarcomas of the cranial base, the combination of a radical
operative resection and postoperative radiation therapy gives the best long-term results.\textsuperscript{4,5,8,11,35,41} When these tumors involve the cavernous sinus, removal of tumor from within the sinus permits more complete resection. Reports on series of esthesioneuroblastomas and juvenile angiofibromas include evidence that involvement of the cavernous sinus is a limitation for radical tumor excision and impairs the eventual outcome.\textsuperscript{3,10,15,18,29,33}

The majority of adenoid cystic, acinar-cell, and squamous-cell carcinomas involving the cranial base and the cavernous sinus are currently managed by biopsy, irradiation, and chemotherapy and have a poor outcome. Removal of the cavernous sinus portion of the tumor may facilitate the total resection of the cranial base neoplasm and, in combination with radiation therapy, may improve patient survival.

A question that remains to be answered is whether treatment of cavernous sinus tumors by radical operation with or without radiation therapy is better than radiation therapy alone. Since radiation can induce sarcomas, cause temporal-lobe necrosis, and produce cranial nerve palsy, and since its effects on benign tumors are variable, radiotherapy should be avoided for benign tumors that can be totally excised. For malignant tumors, irradiation is more likely to be effective when the tumor cell mass is considerably reduced. Our experience and that of others should encourage neurosurgeons to be more aggressive in resecting the intracavernous extensions of neoplasms.

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