Long-term follow-up of meningiomas of the cavernous sinus after surgical treatment alone

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Object. The authors report on the long-term outcome in 100 consecutive patients with meningiomas arising from the cavernous sinus (CS) with compressive extension outside the CS. The treatment in all cases was surgery alone without adjuvant radiosurgery or radiotherapy. The aim of this study was to evaluate the percentage of patients in whom surgery alone was able to produce long-term tumor control.

Methods. All 100 patients harbored meningiomas with supra- and/or laterocavernous extension, and 27 had petroclival extension. Surgery was performed via frontopterionotemporal craniotomy associated with orbital and/or zygomatic osteotomy in 97 patients. Proximal control of the internal carotid artery at the foramen lacerum was undertaken in 65 patients; the paracarotid carotid segment was exposed extradurally at the space made by the anterior clinoideotomy in 81 patients. For the petroclival tumor extension, a second-stage surgery was performed via a presigmoid–retrolabyrinthine or retrosigmoid approach in 13 and 14 patients, respectively.

Results. The mortality rate was 5% and two patients had severe hemiplegic or aphasic sequelae. The creation or aggravation of disorders in vision, ocular motility, or trigeminal function occurred in 19, 29, and 24% of patients respectively, with a significantly higher rate of complications when resection was performed inside the CS (p < 0.05). Gross-total removal of both the extra- and intracavernous portions was achieved in 12 patients (Group 1), removal of the extracavernous portions with only a partial resection of the intracavernous portion in 28 patients (Group 2), and removal only of the extracavernous portions was performed in 60 patients (Group 3). The follow-up period ranged from 3 to 20 years (mean 8.3 years). There was no tumor recurrence in Group 1. In the 83 surviving patients in Groups 2 and 3 combined, the tumor remnant did not regrow in 72 patients (86.7%); regrowth was noted in 11 (13.3%).

Conclusions. The results suggest that there is no significant oncological benefit in performing surgery within the CS. Because entering the CS entails a significantly higher risk of complications, radiosurgical treatment should be reserved for remnants with secondary growth and clinical manifestations. (DOI: 10.3171/JNS-07/11/0937)

Key Words • cavernous sinus • long-term outcome • meningioma • recurrence • surgical removal

MENINGIOMAS originating in the CS are difficult to treat. Radical removal entails the risk of injury or occlusion of the ICA and almost always creates or aggravates cranial nerve deficits. Radiation therapy may not always prevent tumor growth, especially if the entire mass cannot be irradiated with sufficient doses, and it may damage the neighboring neurovascular structures. The optimal treatment for meningiomas of the CS remains controversial even in publications dealing with large numbers of cases. Some authors favor aggressive surgical removal, and others support radiosurgery, and still others prefer a combination of limited resection with adjuvant radiosurgery. In 1985 we began a prospective study in which we treated symptomatic CS meningiomas with compressive intracranial extracavernous extensions by attempting GTR of the tumoral extensions outside the CS, and removing as much of the tumor as possible within the CS if the lesion consistency was soft and neurovascular structures were not infiltrated. No adjuvant radiotherapy (external radiotherapy or stereotactic radiosurgery) was performed after surgery even in cases with a tumor remnant.

The aim of the study was to evaluate the long-term outcome in 100 consecutive cases of meningioma treated with surgery alone and followed up over a period of 3 to 20 years (mean 8.3 years). The percentage of patients affected with regrowth of the remnant was calculated. The purpose was to determine in how many patients systematic adjuvant stereotactic radiosurgery or radiosurgery would have been justified. We also considered whether neurological and ophthalmological complications were linked to an aggressive approach to the CS.

Abbreviations used in this paper: CS = cavernous sinus; CT = computed tomography; GKS = Gamma Knife surgery; GTR = gross-total resection; ICA = internal carotid artery; MR = magnetic resonance.
Clinical Material and Methods

Patient Population

This study included 100 consecutive patients who underwent surgery for CS meningiomas between 1985 and 2004. The meningiomas exerted a mass effect due to growth beyond the limits of the CS (Fig. 1A). Seventy-six patients were women and 24 were men (sex ratio 3.1:1), with ages ranging from 18 to 71 years (mean 54.1 years). The duration of symptoms from onset to surgical treatment ranged from 1 month to 10 years (mean 7.4 years). The clinical symptoms and signs on admission in most patients corresponded with the involvement of one or more cranial nerves. Forty-nine patients presented with visual acuity impairment. Exophthalmos was observed in 15 patients. Motor ocular disturbances were present in 58 patients (oculomotor, trochlear, and abducent nerve palsies in 33, 15, and 13 patients, respectively). These disturbances were responsible for diplopia that was intermittent in 35 patients, permanent but corrected with glasses in 13, and permanent and poorly corrected with glasses in 10 patients. Trigeminal disturbances were found in 35 patients, 17 of whom had neuralgic-type pain and 10 suffered dysesthesias, two of these with unbearable anesthesia dolorosa. Trophic corneal lesions were noted in two patients, and a masticatory deficit in eight. Thirteen patients with tumors extending to the petroclival region had auditory deficits due to eighth cranial nerve involvement, and three of these had additional facial palsy.

Tumor Classification

The meningiomatous nature of the tumor could be seen on imaging studies in 93 patients. In the other seven patients the images demonstrated atypical characteristics, and a percutaneous biopsy via the foramen ovale was performed. Thirty-two patients had a tumor extension beyond the CS lateral wall into the middle cerebral fossa, 12 had extensions beyond the CS superior wall into the suprasellar cistern, and 56 had both supra- and laterosellar extensions. Twenty-seven patients had an additional posterior extension into the petroclival region. According to our classification of extent of mass effect, two patients had Grade I involvement (occupation of the cisterns without parenchymal compression). In these patients, surgery was indicated to decompress the optic nerve because of worsening of visual acuity. Forty patients had Grade II involvement (occupation of the cisterns with moderate parenchymal compression and no shifting or reduction in size of the corresponding ventricle). In these patients, surgery was indicated to decompress the brain and free the cranial nerves and the circle of Willis arteries in the basal cisterns. Fifty-eight patients had a Grade III mass effect (complete involvement of the cisterns with major parenchymal compression, with shifting or reduction in the size of the corresponding ventricle). In patients with a Grade III mass effect, surgery was indicated mainly for brain decompression.

Imaging studies were used to assess the tumor’s involvement with the ICA. The meningiomas were classified according to the classification of Sekhar et al. Thirty-four meningiomas corresponded to Grade I, 20 to Grade II, and 46 to Grade III. No meningioma had Grade IV ICA involvement.

Selection Criteria

Inclusion criteria consisted of symptomatic meningiomas with extension beyond the CS and compression on the brain parenchyma and neighboring cisternal neurovascular structures. These tumors had one or both of the following topographical features: extension beyond the lateral wall of the CS into the middle cerebral fossa or extension above the superior wall of the CS into the suprasellar cistern (Fig. 1A). Tumors with extension beyond the posterior wall into the petroclival cistern were included only if accompanied by at least one of these two features. Only patients whose general health was considered good enough to undergo a long operation were included, and these patients had to sign an informed consent form stating their understanding of the potential risks of creating or aggravating visual deficits, motor ocular dysfunctions, and/or sensory disturbances in the trigeminal territory.

The excluded CS lesions were purely asymptomatic, discovered in patients referred for other symptomatic meningiomas. These lesions did not extend beyond the CS, or if they did, they extended only to the pituitary fossa or sphenoid sinus medially, or to the orbital apex anteriorly, or the pterygomaxillary fossa inferiorly. Excluded patients were treated conservatively in the absence of clinically observable growth, or underwent radiosurgery or conformational radiotherapy if the tumor appeared to grow.

Preoperative Investigation

Neurological, Ophthalmological, and Otolaryngological Examination. Patients were examined for exophthalmos, decreased visual acuity, motor ocular deficits, and trigeminal disturbances, and systematically underwent an ophthalmoscopy, a visual campimetry, and a corneal trophic state check. The otolaryngological examination included an evaluation of the cochlear, vestibular, and pharyngolaryngeal functions and signs of eventual serious otitis due to occlusion of the Eustachian tube.

Imaging Studies. Magnetic resonance imaging was performed to estimate the involvement of the adjacent cisterns and extent of parenchymal compression. The degree of tumor extension beyond the CS was evaluated by measuring the widest diameter of the extensions. The caliber and the degree of the ICA encasement at its intracavernous and supracavernous segments were evaluated, not only on MR imaging but also on MR angiography. Computed tomography scanning was also performed, with bone windows in very thin sections to delineate the fine skull base bone anatomy. Because of their intimate involvement in the surgical approach and procedure, the following structures were studied in detail: the sella turcica, sphenoid sinus, foramen ovale, foramen rotundum, intrapetrous carotid canal, foramen lacerum, and the anterior clinoid process and optic canal. Digital subtraction angiography was performed in all cases. A selective injection of the ipsilateral internal and external carotid arteries was undertaken to estimate their respective participation in tumor vascularization and to decide whether preoperative embolization would be justified. We also performed selective injection of the contralateral ICA with ipsilateral carotid compression at the neck to check the functionality of the anterior communicating artery, and injection of the vertebral arteries with ipsilateral
carotid compression to assess the functionality of the posterior communicating arteries. The venous phases of the digital subtraction angiogram were examined carefully for any predominance of venous drainage through the anterior or sylvian system or the inferior and posterior system of Labbé that would make the surgery more difficult.

Operative Technique

All surgeries were performed by the senior neurosurgeon (M.S.) (Fig. 1B) via a frontopterionotemporal craniotomy. The craniotomy was associated with an orbitozygomatic, orbital, or zygomatic osteotomy in 76, 19, and two patients, respectively, so as to widen the field of view and the working cone, and decrease brain retraction.

Surgical Exposure. A wide extradural exposure of the skull base was created in all patients, beginning at the middle fossa to visualize the foramen ovale (with the mandibular nerve) and the foramen rotundum (with the maxillary nerve), as well as the superior orbital fissure anteriorly (with the ophthalmic nerve and the motor ocular nerves) and the foramen rotundum (with the maxillary nerve), as well as the superior orbital fissure anteriorly (with the ophthalmic nerve and the motor ocular nerves). In 65 patients, the ICA was exposed at the posterior edge of the foramen lacerum by unroofing the intrapetrous horizontal portion of the carotid canal, this was to identify the ICA at its proximal segment before its entry into the parasellar space and to allow clamping if necessary. Then the anterior fossa was approached to reach the optic canal and expose the optic nerve by unroofing the bone canal. Eighty-one patients also underwent an extradural anterior clinoidectomy to free the optic nerve dural sheath completely and expose the paraclinoid portion of the ICA after its exit from the CS roof.

Such an extensive approach permits clear identification of the skull base structures and is supposed to achieve significant devascularization of the meningioma. In fact, this wide approach makes it possible to interrupt the arterial supply, not only from the middle meningeal artery that is coagulated, clipped, and divided at the exit from foramen spinosum, but also from the small arteries passing through the foramen ovale, the foramen rotundum, and the superior orbital fissure along the dural sheaths of the corresponding cranial nerves. It also seems that an anterior clinoidectomy contributes in interrupting the feeder vessels coming from the ophthalmic artery and its ethmoidal branches.

Tumor Removal. Tumor removal proceeded via an intradural approach. The first step was transsylvian, but with minimal opening of the arachnoid mater of the fissure thanks to the orbital osteotomy. Next, tumor dissection proceeded through the interoptico-carotid, interoptic, and/or retrocarotid triangles, depending on the particular extension of the tumor. The neurovascular structures to be respected were the anterior choroidal artery, the posterior communicating artery, and the oculomotor and trochlear nerves. The removal of the extracavernous portion of the tumor began at the lateral wall of the CS, following its superior wall, then proceeding posteriorly along the tentorial incisura, and through it to the upper part of the petroclival region (but not below the Dorello canal). The exploration of the Meckel cave was performed after opening its dural roof so that identification and dissection of the triangular plexus, the Gasserian ganglion, and the sensory division branches of the trigeminal root could be achieved. If the tumor was soft and only slightly infiltrative, removal within the CS was carefully attempted. It is very important to avoid injury to the intracavernous portion of the ICA, the third and fourth cranial nerves, the ophthalmic trigeminal branches situated within the two sheaths of the CS lateral wall, and the sixth cranial nerve inside the CS, lateral to the ICA.

Gross-total resection was performed on the extracavernous portion of the tumor arising from the lateral wall in 32 patients, the roof in 12 patients, and both regions in 56 patients. In 42 patients a meningiomatous fragment inside the Meckel cave was also removed. Surgery within the CS was attempted in only 40 patients, especially when the lateral wall of CS was dehiscent. The resection was deliberately partial when the tumor was of a hard consistency and/or invasive of the cranial nerves or the ICA. Within the CS, GTR was achieved in 12 patients in whom the tumor was soft and therefore considered cleavable.

After tumor removal, the resection cavity was packed with Surgicel (Johnson & Johnson) and adipose tissue harvested from the thigh to ensure hemostasis. In the last 63 patients of the series, a thin layer of fatty tissue was inserted between the intracavernous remnant of the tumor on one side and the surrounding brain as well as the neurovascular structures of the cisterns (the cranial nerves and arteries of the cavernous sinus).
the circle of Willis) on the other side (Fig. 1B). Adipose tissue was interposed to isolate the tumor remnant, under the hypothesis that such a barrier might decrease secondary angiogenesis from surrounding vessels, and consequently reduce the risk of tumor regrowth. The purpose was also to facilitate imaging during follow-up, and in the eventual need of any form of radiosurgical therapy to limit exposure of the adjacent brain and cranial nerves (especially the optic nerve) to radiation.

In the 27 patients with large petroclival tumor extensions, a second-stage operation was performed a few weeks to months later via a presigmoid retrolabyrinthine or retrosigmoid approach in 13 and 14 patients, respectively. To check for regrowth on CT. The patients’ conditions were considered worsened if surgery had created a new deficit or increased preexisting deficits, unchanged if the functions were preserved or the preexisting deficits had not worsened, and improved if the deficits present before surgery had resolved partially or totally (Table 1).

Then patients had an outpatient visit with CT scanning every 2 years to examine tumor control, even if no clinical signs had appeared. The CT examination included images obtained with and without iodine contrast, and thin jointed axial sections. The images were compared to earlier images by the same neuroradiological team to check the growth status of the tumor remnant. Recurrence was defined as growth with a mass effect on the neighboring cisterns and brain.

Statistical Analysis

Statistical analysis was performed using commercially available software (SPSS version 12, SPSS, Inc.). The analysis of variance test was used for comparison of parametric data with a normal distribution. Either a chi-square test or the Fisher exact test was used for nonparametric data. A probability value less than 0.05 was considered significant.

Results

Tumor Removal

The extent of tumor removal was evaluated using the operative record and the 3-month postoperative CT scan control. Gross-total removal of both the extra- and intracavernous portions of the tumor was achieved in 12 patients (Group 1). However it must be mentioned that of these 12 patients, three had an infiltration of the superior orbital fissure, four of the orbital apex, and five of the dura mater of the petroclival angle. Although the dural infiltration was left in place in these twelve patients, because the dura was coagulated—achieving a Simpson Grade III removal in this area—these patients were considered to have undergone GTR. Of the 88 other patients, 28 underwent complete removal of the supra- and/or laterosellar extracavernous portions with only partial resection of the intra-cavernous portion (Group 2). In these 28 cases the remnant was coagulated with a bipolar microforceps in an attempt to spare the neighboring cranial nerves and vascular structures. Sixty of the 88 patients had only extracavernous surgery with complete removal of the superior and lateral extracavernous portions; no attempt was made to resect the intracavernous portion (Group 3; Table 2).

The degree of removal in the 40 patients in whom the CS was entered depended on the grade of ICA involvement and is detailed in Table 3. It was possible to achieve GTR in eight (61.5%) of the 13 cases in which the carotid was only touched by the tumor, in three (50%) of the six cases in which the carotid was displaced, and in only one (4.7%) of the 21 cases with an encased ICA.

Postoperative Deaths and Complications

Five patients died within the first 3 months postoperatively, therefore the mortality rate was 5%. Neurological deficits (hemiplegia and/or aphasia)—three mild and two severe—remained as sequelae in five patients. Pituitary disturbances occurred in eight patients—transient in five and permanent in three.

At the 1-year follow-up examination, optic nerve function had worsened in 19 patients; of these, a preexisting deficit was worsened in nine and a new visual impairment was created in 10. Visual function was improved in 16 patients and remained unchanged in the 60 others (Table 1). Cranial nerve complications noted at the 1-year follow-up examination are detailed in Table 1.

There were significantly fewer complications involving the cranial nerves in Group 3 than in Group 2 and Group 1 (Table 2). Furthermore, the rate of improvement in cranial nerve function was significantly higher in Group 3 for all the cranial nerves (p = 0.042).

At the 1-year follow-up visit, the rate of postoperative visual deficits after the three types of resection were 18, 19, and 33% for Groups 3, 2, and 1, respectively. The differences among the groups were statistically significant (p = 0.04). For the oculomotor nerve, the rates were 29, 37, and 25% (p = 0.005); for the trochlear nerve, 9, 22, and 33% (p = 0.001); and for the abducens nerve, 13, 22, and 33% (p = 0.024) for Groups 3, 2, and 1, respectively.

At the latest follow-up depending on the patient the values were still significant for the optic nerve (p = 0.04) and the oculomotor nerve (p = 0.03) functions.

Tumor Recurrence

The follow-up ranged from 3 to 20 years (mean 8.3 years). None of the 12 patients with complete removal of both the extra- and intracavernous portions of the tumor

### TABLE 1

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Outcome Grade</th>
<th>Exophthalmos</th>
<th>Optic Nerve</th>
<th>CN III</th>
<th>CN IV</th>
<th>CN VI</th>
<th>CN V</th>
</tr>
</thead>
<tbody>
<tr>
<td>improved</td>
<td>12</td>
<td>16</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>unchanged</td>
<td>3</td>
<td>60</td>
<td>60</td>
<td>74</td>
<td>74</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>worsened</td>
<td>0</td>
<td>19</td>
<td>29</td>
<td>15</td>
<td>17</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

* See Clinical Material and Methods for explanation of outcomes. Abbreviation: CN = cranial nerve.
had a recurrence. In 72 (86.7%) of the 83 surviving patients with remnants inside the CS, the residual fragment remained clinically silent and without significant volumetric growth on imaging, whereas 11 (13.3%) had clinical tumor growth signs and/or a significant increase in mass effect on the adjacent brain parenchyma (Fig. 1C). Two of these 11 patients later had tumors with histological signs of anaplasia, and the nine others had benign tumors. In the two patients with anaplastic meningiomas, conformational radiotherapy was indicated; nine others underwent repeated operations to reduce tumor volume (achieving a Simpson Grade 3 resection) and received radiosurgical treatment on the potentially fertile remnant.

An actuarial curve, with a follow-up period of up to 20 years, was established for the whole series (Fig. 2). The curve shows that any eventual tumor growth was revealed between 3 and 9 years postsurgery, and that there was no tendency for recurrence after 9 years.

The tumor growth was then considered according to resection modality. In the group of 12 patients who underwent GTR of both the extra- and the intracavernous portions of the tumor (Group 1), no growth was observed during the follow-up period (mean follow-up 15.3 years, range 11–20 years). The patients in Group 2 underwent GTR of the extracavernous extensions and incomplete resection of the intracavernous portion, (27 surviving patients; mean follow-up 14.6 years, range 7–20 years), and those of Group 3 underwent resection limited to the extracavernous extensions (56 surviving patients; mean follow-up 6.9 years, range 3–20 years). Regrowth occurred in 11 patients as follows: five patients from Group 2 and six patients from Group 3, 13.25% of the 83 surviving patients. Although there were no patients with tumor regrowth in Group 1, the difference among the three groups was not statistically significant (p = 0.695).

**Discussion**

Despite recent advances in imaging and microsurgical and stereotactic radiosurgical techniques, the best treatment for CS meningiomas remains controversial. No single therapy has proven to be effective and totally safe in controlling volumetric growth. Many publications have included discussions of patients treated in various ways: microsurgical removal with systematic adjuvant radiation therapy, surgery followed by delayed radiation therapy in the eventuality of a large remnant or tumor growth, radiation therapy alone, or surgery alone.

There are few reports in the literature on patients treated with surgery alone.\(^1,5–7,9,32\) We therefore thought it useful to present the results of our prospective study in which patients underwent microsurgical removal of the tumor without any adjuvant radiation therapy, even when tumor remnants were left in place. The study aimed to establish the efficacy of surgery alone. In other words, we wanted to determine in what percentage of patients recurrence or tumor regrowth from a remnant would occur that would justify supplementary radiotherapy or radiosurgical treatment to control growth.

Tumor control was achieved in 88.4% of our 95 surviving patients. Because the follow-up duration varied from one patient to another—ranging between 3 and 20 years—an actuarial curve was established for a follow-up period of

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**TABLE 2**

*Postoperative outcome and extent of resection*

<table>
<thead>
<tr>
<th>Resection Type</th>
<th>No. of Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Growth</td>
</tr>
<tr>
<td>Group 1 EC + IC complete</td>
<td>0</td>
</tr>
<tr>
<td>(12 patients)</td>
<td></td>
</tr>
<tr>
<td>Group 2 EC + IC incomplete</td>
<td>5 (18)</td>
</tr>
<tr>
<td>(27 patients)</td>
<td></td>
</tr>
<tr>
<td>Group 3 EC complete</td>
<td>6 (11)</td>
</tr>
<tr>
<td>(56 patients)</td>
<td></td>
</tr>
</tbody>
</table>

* EC = extracavernous; IC = intracavernous.

**TABLE 3**

*Degree of tumor resection depending on the classification of the ICA involvement in the 40 patients in whom the CS was entered*

<table>
<thead>
<tr>
<th>ICA Involvement</th>
<th>Total</th>
<th>Complete Resection</th>
<th>Incomplete Resection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I</td>
<td>13 (32.5)</td>
<td>8 (61.5)</td>
<td>5 (38.5)</td>
</tr>
<tr>
<td>Grade II</td>
<td>6 (15)</td>
<td>3 (50)</td>
<td>3 (50)</td>
</tr>
<tr>
<td>Grade III</td>
<td>21 (52.5)</td>
<td>1 (4.7)</td>
<td>20 (95.2)</td>
</tr>
<tr>
<td>Total</td>
<td>40 (100)</td>
<td>12 (30)</td>
<td>28 (70)</td>
</tr>
</tbody>
</table>

* Grade I = carotid touched by tumor but not displaced; Grade II = carotid markedly displaced or encircled without narrowing; Grade III = carotid totally encased by tumor with some degree of narrowing; Grade IV = carotid totally occluded (not encountered in this series).

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Fig. 2. An actuarial curve of the patients without tumor regrowth at 20 years of follow-up.
up to 20 years. The curve shows no tendency for tumor recurrence 9 years after surgery. These data plead for not systematically prescribing adjuvant radiation therapy after surgery, even if tumor remnants are left inside the CS. The relatively low rate of secondary tumor growth can be at least partly explained by the tumor devascularization because of the wide extradural exposure, which deprives the tumor of a large amount of its arterial feeding vessels at the skull base. In considering tumor growth relative to the extent of resection, we have shown that there is no benefit to limiting surgery to the resection of the extracavernous extension alone (p = 0.69).

As shown in Table 2, the rates of loss of visual function and persistence of cranial nerve deficits at the 1-year follow-up examination were lower in Group 3 than in Group 2, and almost all were lower in Group 2 than in Group 1. The statistical analysis demonstrates a significantly higher rate of visual function impairment and cranial nerve deficits in the group of patients in whom surgery was attempted to resect the intracavernous portion, with a probability value of 0.04 for the visual function, and probability values ranging from 0.02 to 0.001 for cranial nerve function depending on the involved nerve. These results show an advantage to limiting surgery to the resection of the extracavernous extensions without entering the CS.

Literature Review

We performed a literature review to examine tumor growth control depending on the various therapeutic modalities used: surgery alone, surgery with adjuvant radiotherapy/radiosurgery, and radiosurgery alone. The search was performed for articles published between January 1980 and January 2005 as archived on PubMed. The following key words were used: cavernous sinus, parasellar lodge, central skull base, meningioma, radiosurgery, radiation therapy, microsurgery, and natural history. Only studies with a patient population of 30 or more and a mean follow-up period 24 months or longer were included (Tables 4–6).

In patients treated with surgery alone (Table 4), tumor control ranged from 86.85 to 90% with mean follow-up periods of 24 to 96 months depending on the series. These results are similar to ours. In our series most of the tumor regrowth occurred between 36 and 108 months after surgery.

In patients treated with surgery and adjuvant radiotherapy or radiosurgery (Table 5), tumor control ranged from 81 to 94.1%. The best rates were obtained by Maruyama and colleagues and Dufour et al. Maruyama and associates used radiosurgery in 40 patients and achieved a recurrence rate of 5.7% with a mean follow-up of 47 months; Dufour et al. used adjuvant radiotherapy in 31 patients and obtained a tumor recurrence rate of 6.5% with a mean follow-up of 73 months. The largest series was published by Goldsmith and colleagues, who treated 140 patients with adjuvant radiation therapy, and achieved a recurrence rate of 11% with a mean follow-up of 40 months. It is important to note that the growth control rates obtained with surgery followed by adjuvant radiation therapy or radiosurgery and with surgery alone are not significantly different.

Most of the studies of patients treated with radiosurgery included a significant number of patients who had previously undergone surgery (Table 6). Tumor control was obtained in 90.5 to 98% of patients depending on the series, with mean follow-ups ranging from 30.5 to 109.2 months. The study presented by Liscak et al. on 86 patients demonstrated a low rate of 2% volumetric growth after GKS with a mean follow-up of 36 months; the rate of cranial nerve complications was 9%. The study by Lee et al. on 159 patients treated with GKS (a mean follow-up 35 months) showed that growth of the remnant occurred in 6% of the patients, with a cranial nerve morbidity of 9%. In the series of 43 patients reported by Iwai et al., the mean follow-up was 49.4 months, with a 9.5% rate of volumetric growth after treatment. In the 85 patients treated with GKS in the study published by Kondziolka et al. (mean follow-up 109.2 months) tumor regrowth occurred in 7% of

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases</th>
<th>Treatment (mos)</th>
<th>Growth Control</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldsmith et al., 1994*</td>
<td>140</td>
<td>radiotherapy</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>Maguire et al., 1999</td>
<td>28</td>
<td>radiotherapy</td>
<td>41</td>
<td>19</td>
</tr>
<tr>
<td>Dufour et al., 2001</td>
<td>31</td>
<td>radiotherapy</td>
<td>73</td>
<td>6.5</td>
</tr>
<tr>
<td>Maruyama et al., 2004</td>
<td>40</td>
<td>radiosurgery</td>
<td>47</td>
<td>5.7</td>
</tr>
</tbody>
</table>

* The rate of complications was 3.6% for this series. There was no available data on complications or deaths for the other series.
the cases. Roche et al.\textsuperscript{14} reported a 5\% rate of volumetric growth after radiosurgical treatment in 80 patients with a mean follow-up of 30.5 months. These results in terms of tumor control and complications linked to radiosurgery are difficult to compare due to variability in follow-up length.

**Conclusions**

This study shows that a relatively high rate of tumor control can be achieved with surgery as the only treatment, even when tumor remnants are left in the CS. When tumor regrowth did occur, it was between 2 and 9 years after surgery, and the tumors that had an early recurrence (1–4 years after surgery) were those that were considered atypical on imaging.

In considering tumor growth as well as overall visual function and cranial nerve complications, it may be concluded that there is no advantage to resecting the intracavernous portion of the meningioma. In fact there was no statistically significant gain in tumor control (p = 0.695) in patients who underwent complete resection compared to those with incomplete resection, and the rate of complications was significantly higher when resection was performed inside the CS. Our results indicate that resection should be limited to the extra-cavernous extensions, and that early systematic adjuvant radiotherapy or radiosurgery should not be applied to the meningioma remnant except if the lesion is atypical. If tumor regrowth is noted at follow-up, then adjuvant radiotherapy or radiosurgery should be considered.

In summary, there is no advantage to resecting the portion of the tumor in the CS; this generates cranial nerve deficits and does not result in a significantly better long-term outcome. There are divergent views in the existing literature concerning the need for adjuvant therapy after surgery. Randomized studies should help resolve this problem.

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