A multidisciplinary team approach to skull base chordomas


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Object. A multidisciplinary team devised a protocol for long-term care of patients with skull base chordomas. In this study they describe their approach.

Methods. Forty-two patients presented between 1986 and 1998 and were treated by maximum surgical cytoreduction and photon radiation therapy. Tumor volume–doubling time determined on the basis of magnetic resonance imaging, immunostaining, and cell proliferation (Ki67 labeling index [LI]) studies indicated growth rates of individual chordomas. The best outlook was associated with the greatest extent of tumor removal achieved during the first operation. There were no deaths associated with patients who underwent first-time surgery, but there was a 7.1% mortality rate associated with those who underwent subsequent operations. Cerebrospinal fluid leaks, additional cranial nerve palsies, and pharyngeal wound problems were the most difficult management problems encountered after second and subsequent surgeries. The time interval between operations was usually between 2 years and 3 years after the first surgery; very few patients required a second surgery, with a quiescent period in excess of 5 years. Life-table 5- and 10-year survival rates were 77% and 69%, respectively.

Conclusions. The authors believe that this series of skull base chordomas provides new insights into the management of these lesions, particularly with regard to techniques that increase survival times and studies that aid in formulating prognoses.

Key Words • chordoma • skull base tumor • skull base chordoma • transoral approach • radiosurgery

Chordomas are rare primary bone tumors arising from remnants of the notochord at the two extreme ends of the vertebral axis. In this paper we concentrate on chordomas arising at the skull base, which have an incidence of 1 in 2 million and a prevalence of 1.21 in 10 million of the population. In this area the natural history of the disease has been studied. If the lesion remains untreated, Kamrin, et al., estimated that the afflicted person would live between 6 months and 24 months; in a later survey, Eriksson and colleagues gave an equally poor prognosis. This contrasts strikingly with the 5- and 10-year survival rates of 77% and 69%, respectively. The advent of MR imaging has tempered surgical optimism concerning operative reports claiming radical, total, or near-total resection; postoperative MR images rarely demonstrate total excision, despite new advances in surgical access to the clivus.

If the diagnosis can be confused and the extent of resec-
tion that surgery has achieved can be uncertain, determination of outcome is also confused. Although death as an end point is easily accepted, terms such as “local failure,” “locally controlled disease,” and “disease-free survival” cannot be used indiscriminately when analyzing the published literature. Factors associated with a poor prognosis include tumor volume ($> 70 \text{ cm}^3$), increasing age of the patient (possibly related to less radical surgery performed in elderly patients), and, possibly, female sex. Although some authors contend that morphological subclassification can be used to identify patients with better prognoses, for example, those harboring chondroid chordomas, others have disputed this. Our own group has investigated estimated tumor volume–doubling times and Ki67 LI scores and found them to be useful.

It is against this background that we have been prospectively collecting data since our original retrospective review. A treatment protocol has been developed to include maximum safe surgical cytoreduction and radiation therapy managed by a multidisciplinary team on a consecutive series of patients over a 12-year period. In this article we report the results.

**Clinical Material and Methods**

**Patient Population**

Forty-two patients were referred to our department between 1986 and 1998. The mean follow-up period for these patients was 4 years and 3 months (minimum 2 years, maximum 14 years, and median 3 years and 6 months). Survival records were calculated to August 1999. All patients recruited have been followed up with continuous updating of the database.

There were 28 male and 14 female patients. The age of patients at first diagnosis ranged from 6 to 66 years; the mean age at diagnosis was 58.1 years (median 42 years). Of the 42 patients, 21 had undergone previous treatment—surgery, radiotherapy, or a combination of both. All patients harbored a tumor of the skull base and craniovertebral junction.

**Pathological Diagnosis**

Only those patients who fulfilled the pathological criteria described by Holton, et al., were included in the study. Cellularity, pleomorphism, mitotic activity, apoptotic bodies, necrosis, and inflammatory cell infiltrate were graded. Immunostaining was used routinely and the Ki67 LI was used to calculate a measure of proliferation.

**Tumor Volume**

Preoperative and postoperative tumor volumes were calculated by examining adjacent MR imaging slices by using a freely available imaging software program (Image, version 1.61; National Institutes of Health, Bethesda, MD). Measurements of all involved slices were summed to provide tumor volumes. The first postoperative MR image used for calculations was obtained 3 months after surgery. Additional MR images were obtained at 6-month intervals for the first few years and, later, annually in survivors. The length of time required for the postoperatively observed tumor to double in volume was correlated with the lesion’s histological features, as described by Holton, et al.

We do not use the term “recurrence” because it implies regrowth of tumor after excision. Instead, we use the term “tumor progression” to denote an increase in tumor volume observed on MR images.

**Extent of Surgery**

The amount of cytoreduction achieved by surgery was assessed by comparing a preoperative MR image with a postoperative MR image obtained between 3 months and 6 months after surgery. “Complete excision” was defined as no postoperative evidence of remaining tumor, “radical excision” as removal of at least 90% of the tumor, “partial excision” as removal of between 50% and 90% of the tumor, and “biopsy” as removal of anything less than 50% of the tumor during surgery.

Duration of symptoms was judged to be the length of time symptoms were experienced prior to diagnosis.

Overall survival time was the length of time the patient survived following diagnosis. Using life-table analysis, we assessed length of survival for all 42 patients included in this study and then compared it with that given in our
original paper43 (Fig. 1 upper). Survival rates for the 21 patients who had not undergone previous surgery were divided into two subgroups: 1) patients who presented for the first time and underwent total or radical surgical removal of their tumor; and 2) patients who presented for the first time, underwent less than radical surgical removal of the tumor, and, consequently, also received radiation therapy (Fig. 1 lower).

“Operative death” was defined as death within 28 days following a surgical procedure.

Case Management Protocol

The overriding goal since 1986 has been the surgical removal of as much tumor tissue as possible by whichever operative route is the most direct. Patients referred to our facilities after having undergone primary surgery and/or radiotherapy elsewhere presented us with a management problem different from those who presented for the first time. Also, during the time of this prospective review, our radiotherapy protocol evolved into that currently in use, and it has been in use for the last 7 years. The protocol is given in Fig. 2.

In summary, surgery was conducted with the goal of maximum cytoreduction with the least collateral damage. The decision to proceed to radiotherapy was based on histopathological characteristics of specimens obtained at surgery18 and the residual tumor volume noted on the 3-month postoperative MR image. First-time patients with few mitotic figures and a Ki67 LI lower than 6% associated with a radical or better surgical removal of tumor were treated without radiotherapy. All others entered the radiotherapy protocol (Fig. 2). Any patient in the former group who required further surgery years later was also referred for radiotherapy.

All patients have been examined regularly by the team by using MR imaging. If tumor growth was detected, additional surgery was performed by the most direct surgical path for the particular type of progression; in some cases up to five procedures were performed for tumor progression during the 12-year period (Fig. 3).
the nasal septum before initiating open-door maxillotomy. These mucosal flaps, which are still attached to the cribiform plate and ethmoidal area and fed by a blood supply from that area, are then sutured to the edges of the surviving clival mucosa.

Prevention of CSF leak depends on the use of a lumbar drain, Gelfoam, fascia lata, and thrombin fibrin glue (Tissueal; Baxter Hyland Immuno, Vienna, Austria). We use a dermal fat graft obtained from the thigh, with the epidermis stripped off to allow blood supply to be established to the fat graft. In those patients in whom circumferential tumor surrounds the brainstem, the fat graft has another purpose. By using a slightly oversized graft the neuraxis is gently displaced dorsally out of the planned figure-eight linear accelerator fields. All this is held in by careful closure of the mucosa, performed using the nasal septal flaps as described, or lower down at the foramen magnum by using lateral releases or rotational flaps.

Management of Lower Cranial Nerve Palsy

Many of our patients presented with varying degrees of bulbar palsy; even those patients without bulbar palsy experienced some difficulty in swallowing during the immediate postoperative period. In all patients with a bulbar palsy, we performed a percutaneous epigastic gastrostomy and provided alimentation and fluid replacement by this route for as long as necessary, sometimes for months. During the early days of the study, before the percutaneous technique became available, we used a feeding pharyngostomy. All patients who underwent an open-door maxillotomy underwent a tracheostomy. The latter was only closed when patients could care for their airway and swallowing was adequate.

Cranioceaval Stability

In those patients with tumors that encircled the foramen magnum or in whom the occipital condyle was involved, stability had to be considered. In general terms, surgery for cytoreduction was considered separately; subsequently, long-term stability at the craniovertebral junction was

Results

Thirty-two of the patients harbored tumors in the clivus, and in 10 patients the lesion was located at the craniovertebral junction and extended into one or both occipital condyles. Tumors arising caudal to this were not included in this series.

Duration of Symptoms

The average time from onset of symptoms to diagnosis of disease was 9 months (median 6 months). In 71% of patients there was involvement of the lower cranial nerves (ninth–12th cranial nerves). In 15 patients (36%) the 12th cranial nerve was involved and in 13 (31%) the sixth and/or ninth and 10th nerves were involved. Only two patients displayed eighth cranial nerve deficits and no one exhibited facial weakness. Eight patients presented with some optic nerve involvement. Headache only was noted in 23% of patients and neckache was present in 33%. Approximately one third (29%) of the patients referred to us displayed long tract signs, a number well above the usual reported incidence. Fourteen percent of patients were found to have a clear disturbance of the hypothalamo–hypophyseal axis.

Previous Surgery and Radiotherapy

Thirty-three patients underwent ventral surgery, 19 of whom had not undergone surgery before and 14 of whom had undergone a previous surgical procedure. Eighteen patients had undergone a total of 28 surgical procedures before being referred to our department: lateral, transoral, and transsphenoidal approaches in two patients each; a posterior and frontal approach in one patient each; a combination of these approaches in six patients; a biopsy alone in three patients; and an unknown procedure in one patient.

Ten patients had received radiotherapy to the skull base; in three of these cases, curative surgery was not attempted and only radiotherapy was administered.

Neuroimaging Studies

All patients underwent MR imaging and CT scanning prior to surgery. A lobulated lesion was noted in most patients, with calcification occurring in 32% of patients. Minimal amounts of contrast enhancement were evident on most CT scans. On MR images the lesions predominantly displayed low signal intensity on T1-weighted sequences and high signal intensity on T2-weighted proton-density sequences. Gadolinium enhancement was variable. In one patient a metastatic spread developed during the period of observation, and in one patient there was drop metastasis down the dural sac into the sacral dura. In half of the patients there was a significant distortion of the brainstem and midbrain.

Tumor Volume and Tumor Volume–Doubling Time

Preoperative tumor volumes varied from 2.3 to 129
Skull base chordomas

**TABLE 1**

*Extent of surgery in patients with skull base chordomas*

<table>
<thead>
<tr>
<th>Tumor Removal</th>
<th>1st-Time Surgery</th>
<th>1st Surgery at Unit*</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>radical</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>subtotal</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>partial</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>total patients</td>
<td>24</td>
<td>18</td>
</tr>
</tbody>
</table>

* Previous surgery was performed elsewhere.

cm³, with a mean tumor volume of 40.8 cm³. The size of the tumor at presentation was not in itself a prognostic feature, except that the largest lesions had often invaded the skull base widely, which made surgical cytoreduction difficult and more likely to be performed again during subsequent operations.

Calculations of tumor volume–doubling time were confined to the 24 patients who presented for their first treatment at our department, because they were treated by the same surgical team, sharing a consistent goal and technique. With the exception of one patient whose tumor grew extremely fast—doubling its postoperative volume within 7 months—there was an exponential decrease in tumor volume–doubling time; most patients returned to the hospital between 2 years and 3 years after the first surgery with new signs and requiring further surgery.

The longer the time a lesion takes to double in size, the less likely the patient is to require surgery. When we compared tumor volume–doubling times with histopathological features of the tumors, particularly the Ki67 LI,18 we found a close relationship between these two factors, indicating that both provide evidence for the rates at which individual tumors grow (Fig. 4).

**Dural Penetration**

Of the 24 patients who presented before undergoing any surgery, the dura had been eroded or tumor was growing through it in six patients (25%). Among those 18 patients who had undergone surgery prior to referral, in 10 (56%) there was evidence of tumor penetrating the dura. This included eight patients who had undergone a transcranial–transdural approach to the lesion, which at the time may have been extradural, combined with those patients in whom there was dural penetration at the time of the second surgery.

**Subsequent Surgeries**

Of all 42 patients recruited into this study, 14 needed to undergo an additional 22 operative procedures. Nine patients required one, two patients two, one patient three, and two patients four more procedures after being recruited into the study.

**Extent of Resection**

Table 1 lists the extents of surgical resection achieved during first surgeries performed at our institution.

Following surgery in the 24 patients presenting for the first time, in one patient total resection was achieved; that patient did not undergo radiotherapy and remains asymptomatic 8 years and 6 months later. In 18 patients radical resection was achieved; seven of these patients did not undergo initial radiotherapy. The other nine patients as well as patients in whom subtotal resections were performed and patients who initially underwent surgery performed elsewhere were entered into the radiotherapy protocol.

**Outcomes of Surgery**

There were no surgical deaths in patients undergoing surgery for the first time. Among patients undergoing second and subsequent procedures, there was one postoperative death due to myocardial infarction (7.1% mortality rate). Overall, the surgical mortality rate for the whole patient group, based on the number of procedures performed in 42 patients over 12 years, is 4.2% (three deaths in 71 operative procedures). Four deaths lie outside the definition of surgical death: a massive pulmonary embolus in one patient, a massive intraventricular hemorrhage following open-door maxillotomy in a patient who had previously undergone a transfrontal approach elsewhere followed by radiotherapy, a patient who had presented in extremis and for whom little tumor could be removed due to fibrous tissue, and a patient who had undergone three previous operations and proton-beam radiotherapy. The last patient’s surviving vertebral artery was damaged at the time of open-door surgery and he required long-term ventilatory support. All these patients died within 4 months following surgery.

**Complications From Surgery**

Table 2 details complications observed in the study group, stratified according to whether the complication occurred after the initial or a subsequent surgery. One extremely unusual complication was a traumatic aneurysm of the maxillary artery, which occurred in a 55-year-old man who harbored a 10-cm³-wide tumor extending around his right occipital condyle. Fourteen days after the patient underwent open-door maxillotomy he displayed profuse epistaxis, which required emergency treatment by endovascular occlusion. Details of this case are provided elsewhere.42

**Interval to Subsequent Surgery**

There was a wide distribution in intervals to subsequent

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operations for regrowth of tumor: in some patients the tumor has not yet recurred, whereas in three patients additional surgery was required within 9 months after the first procedure.

The mode reoperation interval was between 24 months and 36 months; very few second operations took place 60 months after the first surgery. Those cases in which the shortest intervals between operations occurred also had the highest Ki67 LIs and the shortest tumor volume–doubling times on MR images, although it should be noted that we tended to delay further surgery until there were new symptoms.

Radiation Treatment

Since 1989 we have used photon radiosurgery in combination with conventional fractionated megavoltage photon irradiation. An initial dose of 50 Gy is administered by a modified linear accelerator system to the region of the original tumor volume, as delineated by viewing preoperative MR images. Subsequently, a booster dose of 10 to 15 Gy (minimum dose to tumor margin) is delivered to the postoperative residual lesion (as delineated by viewing postoperative MR images).

In line with our treatment protocol, 16 patients did not initially undergo postoperative radiotherapy; all others underwent radiation therapy following surgery at our institution, including those who had previously undergone radiotherapy prior to referral. Three of the original 16 later experienced tumor progression and underwent subsequent radiotherapy; none of these patients have died. The other 13 patients still have not undergone radiation treatment, and no tumor progression has been demonstrated on their control MR images.

None of the patients have experienced complications directly related to radiotherapy, although it has been noticed that, in those patients who had undergone previous radiotherapy, additional surgery in the pharynx was extremely difficult and wound closure was extraordinarily taxing.

Survival Times

Survival times for the two subgroups of patients who presented for their first surgery are illustrated in Fig. 1 lower. For patients in whom a radical or more extensive surgical removal of tumor was achieved and, according to our treatment protocol (Fig. 2), in whom initial radiotherapy was not given, the survival rate was 100% at 5 years and the same would be predicted for 10 years; three patients have subsequently died, although perhaps not due to their tumor. Of this subgroup, only one patient has died, although three (19%) have suffered tumor progression and have undergone further surgery and radiotherapy.

In the subgroup of patients who underwent less than radical surgical resection of their tumor and, therefore, received radiotherapy according to our treatment protocol (Fig. 2), the 5-year survival rate was 65%, with the greatest incidence of mortality occurring within the initial 40 months. The difference in survival between this subgroup and the subgroup of patients who received no radiation is not statistically significant.

The life-table survival analysis curve for all patients included in this study is presented in Fig. 1 upper. Lengths of survival observed in the whole group predict a 77% 5-year survival rate and a 69% 10-year survival rate. We have not found any sex bias in this group. On the whole, patients aged older than 50 years experienced faster tumor progression than those younger than 30 years.

We compared the survival rate of the combined first-time surgery subgroups undergoing this treatment protocol with the survival rate from our previous report, and the results are presented in Fig. 1 upper. The survival rate of patients presented in this report is 77% at 10 years, compared with a 10-year survival rate of 51% in our previous report.

Discussion

In 1857 Virchow described the incidental findings of a phylaisphorous tumor with prominent vacuoles in the clivus during a routine postmortem examination. In 1864 Klebs described the first symptomatic case, and it was Müller in 1858 who made the suggestion that these tumors arose from embryonic rests of the notochord. In 1894 Ribbert first used the term “chordoma” to emphasize the lesion’s origin. Over 100 years later this term has survived, but we believe that the wrong message has been imparted: a word ending in the suffix -oma suggests a
Skull base chordomas

TABLE 4
Comparison of surgical series of skull base chordomas*

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases</th>
<th>Type of Surgery</th>
<th>Overall Mortality</th>
<th>CSF Leak</th>
<th>Meningitis</th>
<th>1st Op</th>
<th>2nd &amp; 3rd Ops</th>
<th>Intradural Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gay, et al., 1995</td>
<td>46</td>
<td>34% subtemporal</td>
<td>5</td>
<td>20</td>
<td>10</td>
<td>67</td>
<td>17</td>
<td>60</td>
</tr>
<tr>
<td>Al-Mefty &amp; Borba, 1997</td>
<td>23</td>
<td>21% subfrontal</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>91</td>
<td>26</td>
<td>48</td>
</tr>
<tr>
<td>present study</td>
<td>42</td>
<td>50% ventral</td>
<td>4.3</td>
<td>21†</td>
<td>8</td>
<td>91</td>
<td>48</td>
<td>56</td>
</tr>
</tbody>
</table>

* Ex = extensive.
† At first operation.
‡ At reoperation.

relatively benign condition. This is clearly not the case, however, and for many patients harboring this lesion at the skull base, the disease is ultimately fatal. For the most part, the tumor is slowly growing, locally invasive, and, because of its difficult position and relationship to vital structures, it is relatively inaccessible to surgery. In addition, few centers in the world have accumulated a large experience with this tumor or have supported studies of it for any length of time.

There are now just short of 1000 cases of chordoma in the literature, with 70% of publications reporting 10 cases or less and only 10 publications reporting more than 30 cases. Most authors have been oncologists or radiation therapists/radiologists. In fact, Krähenbühl and Yaşargil have suggested that there has been selective reporting by surgeons because the results of surgery had been so poor. Only four publications have been authored by surgeons (Tables 3 and 4). All these surgeons have aimed at maximum surgical cytoreduction and, where this can be deduced from the publication (see the studies by Gay, et al., and Al-Mefty and Borba, as well as our own), a radical, near-total, or total cytoreduction has been possible in over 40% of first-time operations. The surgical approaches of these three teams are very different. Gay, et al., Al-Mefty and Borba, and Sekhar, et al., emphasize using a lateral approach, whereas we approach chordomas via a midline ventral transoral procedure. Surgeons have championed their individual approaches, yet the overall operative mortality rate has been the same, approximately 5% overall. In the two larger series, incidences of CSF leak and meningitis have been comparable (Table 4), despite the use of very different surgical management. Interestingly, the incidence of meningitis was just as high in studies conducted by authors who eschew transoral surgery; leakage of CSF into the mastoid air cells can be just as hazardous.

In terms of surgery, we may therefore conclude that the most important factor is the greatest amount of tumor removed during surgery; the route preferred by the individual surgical team may be less important. The expertise to achieve cytoreduction, however, must be at the highest level. That tumor volume reduction is important is implied in the literature. In the series conducted by Eriksson and colleagues, 14 patients harboring skull base tumors who did not undergo surgery were dead within 18 months. In cases in which biopsy alone was performed, there was a life expectancy of 1.5 years. In our opinion (Fig. 1), we now have enough information to show that, with few exceptions, those cases in which the greatest cytoreduction is achieved during the first surgery have the longest and best surgical outcomes. Our own figures and those of Gay, et al., illustrate that maximum cytoreduction can be achieved at the first surgery, with the fewest complications and the lowest incidence of operative deaths.

In this study, one surgeon and one oncologist formulated and followed a protocol on a prospective basis, in an attempt to reduce some of the variables that have flawed many studies published in the literature. Our current radiation therapy strategy is as follows: we aim to deliver a moderately high dose of conventionally fractionated radiation to the whole region (preoperatively measured volume) and, using current radiosurgical technology, deliver as high a boost dose to the postoperative residual lesion as is possible. One problem encountered in postoperative radiosurgical planning has been the position of the neuraxis, which in cases of many larger tumors is surrounded by the tumor bed. This point is emphasized by Hug and associates. In such patients, we believe there has been a major advantage in selecting midline ventral surgical for the effective removal of the midline bulk of tumor. To that procedure we have added a fat pad splint, which, in effect, displaces the brainstem and pons farther away from the high-dose radiosurgical target volume. We are convinced that the thoughtful cooperation of surgical and radiation therapy teams is an advance in the management of this disease.

The radiotherapy literature is poor, but early work has demonstrated that a high dose equivalent and conventionally fractionated photon radiotherapy produces temporary disease regressions. With the development of stereotactic mapping and sophisticated focal radiation therapy techniques (acquiring the name of radiosurgery), it has become possible to deliver higher radiation doses to a chordoma, with perceived outcome advantages. Using proton radiosurgery, several authors have been able to show tumor regression and a longer period to relapse. The most carefully documented focused-radiotherapy results have been those in cases in which proton beams (rather than stereotactically delivered photon beams as described here) have been used. For example, the Boston
group reported a 64% 5-year rate of local control of clival chordomas treated by surgery and proton-beam radiotherapy. Nonetheless, it is by no means proven that proton-beam therapy is superior to photon-beam therapy, when modern stereotactic and conformal radiotherapy techniques are used, as described in this paper. All have emphasized the margin of the high-dose area as that location most likely to house a relapse or further tumor growth, and the major limitation at the skull base is the sensitivity of the adjacent normal nervous system to the energy levels required. We have attempted to address both these issues in our current policy.

The team approach has been particularly useful in arriving at treatment decisions based on accurate histological diagnosis. Including chondrosarcomas into the chordoma group would certainly improve the apparent outcome statistics. Previous authors have used morphological criteria to describe the entity of chondroid chordoma in addition to chordoma and chondrosarcoma. This distinction was believed to be of prognostic significance, in which chondroid chordomas pursue a less aggressive course than classic chordomas. It has been stated that chondroid chordomas contain biphasic differentiation with areas of typical chordoma together with focal chondroid differentiation. The literature relating to the existence of chondroid chordoma, with particular reference to immunohistochemical studies seeking evidence of biphasic differentiation, has been reviewed recently. It was concluded that, if immunophenotype is used to confirm the presence of chondroid areas within chordomas, there is evidence to suggest that this occurs very rarely. In our experience in a specialized center for the treatment of skull base tumors, neither chondrosarcomas nor chordomas have been found to have areas of biphasic differentiation when examined using a panel of immunohistochemical markers. We therefore regard these lesions as representative of either chondrosarcoma or chordoma.

There is a wide variation in the growth rate of immunohistologically verified chordomas (Fig. 4); again the team approach has been useful in the identification of features that lead us to believe that a particular tumor will grow rapidly. The tumor volume–doubling time calculated by the neurosurgical team on the basis of postoperative MR images and the Ki67 LI determined from histopathological investigations have been used to identify tumors that are likely to regrow quickly and, with a few very rapidly growing exceptions, both observations will provide information on the likely rate of further tumor growth. Detailed comment on this is provided elsewhere. Practically, it means that patients with the most aggressive tumors present again within 24 months and, conversely, after 5 years postoperatively, the likelihood of further surgery is small. There have been no subsequent operations in symptomat ic patients in whom tumor volume–doubling times were long and the Ki67 LIs were not very high. We consider these measures as useful guides when considering prognosis.

The results of the overall survival analysis (Fig. 1 upper) show that the group as a whole is not much different from those originally reported by our team 7 years ago. Perhaps there will be a statistical separation beyond 10 years, but to date we have not been able to verify this. Those patients referred to our unit after already having undergone surgery have followed our original survival curve most closely. Those patients who underwent their first surgery at our unit are faring best, although in some progression of disease has been observed after 10 years. Patient age has been mentioned in the literature, but in this study we wonder if one factor is less resilience to surgery in older patients. Another is the finding of higher Ki67 LIs and slower doubling times in older patients. On this basis it could be postulated that chordomas grow more quickly in older people.

Conclusions

This sequential series of skull base chordomas treated by one multidisciplinary team has, we believe, provided new insights into the management of these lesions. Maximum surgical cytoreduction followed by photon radiosurgery in all patients harboring residual tumor may increase survival time. Tumor volume–doubling time and Ki67 LI reveal which tumors grow fastest and this may aid formation of a prognosis. Chordomas seem to grow faster in patients older than 50 years of age.

References

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