Definitive radiation therapy for chordoma and chondrosarcoma of base of skull and cervical spine

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Proton-beam radiation therapy has been developed for the treatment of chordomas or sarcomas of bone or soft tissue that abut the central nervous system. The authors report the results of treatment of 10 patients, six with chordoma, three with chondrosarcoma, and one with a neurofibrosarcoma. Local control has been achieved for all patients (with, however, one marginal failure) with a follow-up period ranging from 2 months to 6 years. High doses of radiation, up to 76 Cobalt Gray Equivalents (CGE), have been delivered without significant morbidity. In particular, no neurological sequelae have been observed.

KEY WORDS • radiation therapy • chordoma • chondrosarcoma • proton therapy • base of skull • cervical spine • bone tumor

Primary bone sarcomas and chordomas of the cervical spine and base of the skull present exceptionally complex problems of management by surgery or by radiation therapy. There are several reasons for this: 1) radical resection is nearly impossible; 2) high radiation doses are required for permanent control; and 3) the juxtaposition of tumor to the central nervous system (CNS: cervical cord or brain stem) means that the high doses required for tumor eradication are not technically feasible with conventional techniques because of the radiation sensitivity of those CNS structures.

Sarcomas of the cervical spine and base of the skull are uncommon, representing from 3% to 11% of the total incidence of primary sarcomas of bone in man. The most common varieties of sarcoma of bone in this region are osteosarcoma and chondrosarcoma, followed by fibrosarcoma. Osteosarcomas in the head are most frequently found in the mandible and maxilla. A few cases of primary osteosarcomas arising in the skull have been reported, but most are associated with preexisting Paget's disease or fibrous dysplasia, or are found in previously irradiated bone. Chondrosarcomas are also very uncommon in the base of the skull and cervical spine. Approximately 40% of chordomas arise in the sphenoid-occipital and cervical spine region. These tumors have a benign histological appearance, but are regionally invasive and thus carry a poor prognosis.

This paper is an account of our experience in the management of 10 patients who harbored chordomas or sarcomas involving bone or soft tissue that abutted the CNS.

Clinical Material and Methods

This series of 10 patients was treated with radical doses of radiation using a combination of high-energy x-rays (photon) and 160-MV proton beams, which required very precise positioning of the patient. The tumors were diagnosed histologically as chordomas in six patients, chondrosarcomas in three, and a neurofibrosarcoma in one. One tumor was in the C-5 vertebra, two were situated in the C-2 vertebral body, five involved the clivus and parasellar regions, one was in the intrasellar region, and one was in the petrous ridge.

Diagnostic evaluation, definition of the target volume, and delineation of adjacent critical structures were performed by a team of neurosurgeons, neuroradiologists, and radiation therapists. The diagnostic procedures involved computerized tomography (CT) scanning, often with polytome (thin-section pluridirectional tomography) metrizamide myelography. If the patient was to be treated in the horizontal position, the CT and polytome studies were performed with the patient in the immobilization device to be used during treatment. Details of the anatomic site, histopathology, radiation dose, and fractionation schedule are
### TABLE 1
Radiation therapy for chordoma and chondrosarcoma of the base of skull and cervical spine*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Site of Tumor</th>
<th>Pathology</th>
<th>Photon Therapy†</th>
<th>Proton Therapy†</th>
<th>Total Dose†</th>
<th>TDF</th>
<th>Radiation Reaction</th>
<th>Treatment-Related Neurological Damage</th>
<th>Follow-Up Status†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31, F</td>
<td>Lt petrous apex</td>
<td>chondrosarcoma</td>
<td>1 field: 21.3 Gy/11 F/15 D</td>
<td>1 field: 40 CGE/20 F/22 D (2-3 F/D)</td>
<td>65.3 CGE/31 F/45 D</td>
<td>116.4</td>
<td>erythema dry desquamation over entrance portal; slight erythema; Lt cheek</td>
<td>none</td>
<td>NED-74 mos</td>
</tr>
<tr>
<td>2</td>
<td>24, M</td>
<td>clivus</td>
<td>chondrosarcoma</td>
<td>2 fields: 34.2 Gy/18 F/27 D</td>
<td>3 fields: 28.7 CGE/15 F/26 D</td>
<td>65.7 CGE/34 F/114 D</td>
<td>97.3</td>
<td>epilation over posterior &amp; superior skull portals</td>
<td>none</td>
<td>NED-16 mos</td>
</tr>
<tr>
<td>3</td>
<td>55, F</td>
<td>C-2</td>
<td>chordoma</td>
<td>2 fields: 46.3 Gy/23 F/40 D</td>
<td>2 fields: 27.1 CGE/15 F/25 D (2 F/D)</td>
<td>76.2 CGE/38 F/124 D</td>
<td>116.3</td>
<td>mild dryness of mouth; occasional mild headaches</td>
<td>none</td>
<td>NED-52 mos</td>
</tr>
<tr>
<td>4</td>
<td>63, M</td>
<td>parasellar region</td>
<td>chordoma</td>
<td>3 fields: 39.1 Gy/22 F/29 D</td>
<td>1 field: 30.6 CGE/16 F/27 D</td>
<td>72.8 CGE/38 F/63 D</td>
<td>113.6</td>
<td>brisk erythema at proton portal; dryness &amp; erythema of external auditory canal</td>
<td>none</td>
<td>NED-26 mos</td>
</tr>
<tr>
<td>5</td>
<td>63, F</td>
<td>C-2</td>
<td>chordoma</td>
<td>2 fields: 34 Gy/17 F/27 D</td>
<td>3 fields: 38.2 CGE/20 F/35 D</td>
<td>76 CGE/37 F/69 D</td>
<td>120.9</td>
<td>slight dryness of mouth; loss of taste</td>
<td>none</td>
<td>NED-22 mos</td>
</tr>
<tr>
<td>6</td>
<td>47, F</td>
<td>clivus</td>
<td>chordoma</td>
<td>2 fields: 39.8 Gy/21 F/33 D</td>
<td>3 fields: 32.5 CGE/17 F/28 D</td>
<td>75.5 CGE/38 F/63 D</td>
<td>120.9</td>
<td>mucositis of soft palate &amp; upper pharynx</td>
<td>some cortical defect relating to memory &amp; word order</td>
<td>NED-5 mos</td>
</tr>
<tr>
<td>7</td>
<td>55, M</td>
<td>intrasellar region</td>
<td>chordoma</td>
<td>3 fields: 36 Gy/20 F/28 D</td>
<td>3 fields: 30.6 CGE/16 F/26 D</td>
<td>69.6 CGE/36 F/59 D</td>
<td>108.7</td>
<td>none</td>
<td>none</td>
<td>NED-8 mos</td>
</tr>
<tr>
<td>8</td>
<td>60, F</td>
<td>clivus &amp; sphenoid</td>
<td>chordoma</td>
<td>2 fields: 37.8 Gy/21 F/32 D</td>
<td>3 fields: 32.5 CGE/17 F/28 D</td>
<td>73.6 CGE/38 F/65 D</td>
<td>115.3</td>
<td>dryness of mouth; change in taste sense</td>
<td>none</td>
<td>NED-5 mos</td>
</tr>
<tr>
<td>9</td>
<td>55, F</td>
<td>C-5</td>
<td>neurofibrosarcoma</td>
<td>2 fields: 30 Gy/25 F/41 D</td>
<td>3 fields: 42 CGE/22 F/38 D</td>
<td>76.2 CGE/37 F/84 D</td>
<td>120.5</td>
<td>erythema of skin; large bulla, upper lateral field</td>
<td>none</td>
<td>Marg rec-2 mos</td>
</tr>
<tr>
<td>10</td>
<td>25, M</td>
<td>clivus</td>
<td>chondrosarcoma</td>
<td>2 fields: 39.6 Gy/22 F/31 D</td>
<td>3 fields: 32.5 CGE/17 F/35 D</td>
<td>75 CGE/39 F/87 D</td>
<td>115.3</td>
<td>epilation over irradiated areas</td>
<td>none</td>
<td>NED-4 mos</td>
</tr>
</tbody>
</table>

* Results of analysis in May, 1981. Gy = 1 Gray = 100 rads; CGE = cobalt Gray equivalent (dose in Gy x radiobiological effectiveness factor of 1.10); TDF = time-dose-fractionation factor. F/D = fractions/day. NED = no evidence of disease; Marg rec = marginal recurrence; DM = distant metastases.
† Treatment parameters are: dose/no. of fractions/overall time (days).
‡ The time indicated is time elapsed since the date of the first treatment.
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given in Table 1.* A brief history of several of these patients is given below.

Illustrative Cases

Case 1

This 31-year-old woman enjoyed good health until the spring of 1971, when she noticed hoarseness and some difficulty in swallowing. A paralyzed vocal cord was found on examination. Clinical and radiographic evaluation led to a diagnosis of tumor in the petrous ridge of the left temporal bone. A partial resection was performed, and a diagnosis of chondroma made. One year later, she complained of diplopia and inward turning of the left eye. Two and a half years after the onset of these systems, the petrous ridge was explored and a mastoidectomy and decompression of the petrous apex were performed at another hospital. Tumor extended to the lateral aspect of the sphenoid sinus, and there was questionable extension into the middle fossa and posteriorly as far as the dissection went. The patient was then referred to the Massachusetts General Hospital.

Examination. The abnormalities were confined to the head and neck region. She had paralysis of the left sixth nerve and left vocal cord, and evidence of involvement of the 12th nerve. Multiple polytome studies combined with a pneumoencephalogram showed an area of extensive destruction of the apex of the left petrous ridge, with loss of bone extending to the lateral margin of the foramen magnum. A small tumor nodule protruded from the petrous ridge into the posterior fossa. The tumor was judged to surround the jugular foramen. There was no clear evidence of extension into the sphenoid sinus or into the middle fossa. The tumor was read as a myxoid chondrosarcoma of low grade. There was no evidence of metastatic disease.

Treatment. The patient was treated with a combination of photon and proton beams. She received 21.3 Gy from a left lateral 42-MV x-ray beam, designed to cover the entirety of the involved tissues, but, unavoidably, also the entirety of the midbrain and brain stem. Treatment was then continued using a left posterior oblique 160-MV proton beam. For this, a special head cast and bite-block were made and fixed to the rigid holder, which could make fine adjustments of the head in three orthogonal directions. The field was shaped so as to include only those tissues thought to be invaded by tumor. The proton beam entered at an angle of 45°, and passed through the head to intersect the midportion of the clivus. A small lateral sector of the brain stem was included in the proton beam.

The dose distribution for the overall treatment is shown in Fig. 1 in the form of lines of equal dose superimposed upon a polytome film. The patient received 40 Gy from the protons, making the total radiation dose 65.3 CGE. (This dose was also given to the small sector of the brain stem included in the proton beam.) She tolerated this treatment well with only a modest skin reaction over the mastoid tip.

Posttreatment Course. There was prompt neurological improvement. By 6 weeks, the patient had regained partial function of the left sixth nerve, and the soft palate was retracting normally. By 15 months, she had slight further improvement of sixth nerve function, but some degree of diplopia persisted. At 6 years after treatment, there has been further slight improvement of the function of the eye; diplopia is limited to extreme lateral gaze. There is slight hypesthesia over the area supplied by the second division of the fifth nerve. The tongue protrudes almost in a straight line; there is good palatal retraction. The paralysis of the left vocal cord persists unaltered. On CT scanning, there is no evidence of tumor. Thus, the patient has had local control for 6 years, with no accompanying neurological sequelae associated with the radiation treatment.

* Doses are given in the standard international (SI) unit, the Gray (1 Gy = 100 rads). We estimate the biological effectiveness of protons to be 1.10 times that of cobalt 60 (60Co) radiation. Hence, we also give a statement of the "equivalent dose" in CGE (60Co Gray Equivalent). Hence, 10 Gy delivered by the proton beam would be 11 CGE.

FIG. 1. Case 1. Dose distribution achieved by the combination of a 42-MV left lateral x-ray beam and a posterior oblique (45°) 160-MV proton beam directed toward the lesion of the apex of the left petrous bone (shaded area). Only a very small left lateral sector of the brain stem is included in the high-dose region.
Case 3

This 55-year-old woman presented in November, 1975, with a 12-month history of neck pain. Radiographic evaluation revealed a lytic lesion in the anterior portion of the C-2 vertebral body. The remainder of her history and physical examination was noncontributory. She was subjected to a biopsy through a left lateral neck approach. Curettage of the body of C-2 was performed, and a light-purple gelatinous material was obtained. This was diagnosed as a chordoma. She was then referred to the Massachusetts General Hospital for consideration of proton therapy. Further evaluation showed that the lesion involved the right pedicle of C-2. The odontoid and left pedicle were judged to be free of disease on radiographic evaluation (Fig. 2). The posterior margin of the body of C-2 was intact as judged from the metrizamide myelogram, which showed no displacement of the contrast material.

This patient's problem was reviewed at the hospital's bone and soft-tissue sarcoma conference. Surgical treatment was judged to pose an unacceptable risk and a low likelihood of long-term control. Further, the risk of damage to the spinal cord by conventional photon therapy would so limit the radiation dose as to make it ineffective. The decision was made to develop a treatment plan based on combined proton and x-ray beam techniques and a surgical procedure.

Treatment. The first phase of treatment was with two MV x-ray fields covering the C1-3 vertebrae; the biopsy scar was also included, since there was concern about wound contamination because of the curettage procedure. In total, 46.3 Gy was given in 23 fractions over 40 days. She then had resection of the right pedicle of C-2, several iodine-125 seeds were inserted into the body of C-2, and the cervical spine was stabilized. Proton-beam treatment was then initiated using parallel opposed lateral fields. For this, the patient was treated in the supine position with a cast and head support for immobilization (Fig. 3). The supine position was selected so that the spinal cord would fall posteriorly from the vertebral body. A metrizamide myelogram demonstrated that the anterior surface of the cord was 4 mm from the posterior surface of the vertebral body when she was in the supine position.

The treatment portal covered the vertebral body of C-2, including the odontoid and a small portion of C-3 (Fig. 4). For the first component of the proton treatment, the 50% isodose curve was set at 2.25 mm posterior and at 5 mm anterior to the vertebral body. Treatments were given at 1.79 Gy per fraction and two fractions per proton-treatment day. After 17.9 Gy, the posterior margin was moved anteriorly 1 mm for one treatment and 2.25 mm for the final four treatments, so that, for these last treatments, the 50% isodose line was on the posterior margin of the vertebral body. In addition, for the last four treatments the odontoid process was excluded from the field. At the time this patient's treatment was planned, CT scanning was not available. In planning the penetration of the proton beams, therefore, we assumed a conservative high value of 1.4 for the density of the entire vertebral body. Hence, the beam may have “overshot” the vertebral body by as much as 2 cm. Had CT scan data been available, a proper compensating filter could have been used with consequent reduction in the volume of overshoot (Fig. 5).

The position of the patient was confirmed before
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Each treatment (repeated portal films and positioning were essential in order to have the patient in precisely the desired position). The positioning error was demonstrated to be less than 1 mm. The total dose was 76.2 CGE delivered over 124 days to the vertebral body (27.1 Gy by photon-beam technique and 46.3 Gy by photon-beam technique). Calculation of the dose to the cervical cord at various sites showed that the dose was 52.8 CGE at the most anterior portion of the cord and 45.5 CGE at midcord. Despite the fact that the patient received 76.2 CGE to the vertebral body, there was virtually no noticeable skin reaction over the entrance portals at the completion of treatment.

Posttreatment Course. The patient tolerated this treatment extremely well and is without complaints referable to the neck 4½ years after treatment. There is negligible change on visual examination and on palpation. Radiographically, however, the lesion has shown almost complete healing (Fig. 6).

Case 5

This 63-year-old woman became dysphagic in October, 1978, with a feeling of fullness in the throat. In January, 1979, her physician noticed a mass in the posterior pharyngeal wall. She had had some minor complaints of stiffness in the neck over the past 3 to 4 years; she was otherwise asymptomatic. A transoral biopsy was performed and a chordoma was diagnosed. Tomograms of the cervical spine revealed a lytic destructive defect of C-2 at the base of the odontoid process. There was no radiographic evidence of extension of the tumor through the posterior surface of the vertebral body. She was referred to the Massachusetts General Hospital for consideration of proton therapy.

Examination. Polytome metrizamide myelography

Fig. 3. Case 3. The patient is placed in the supine position in a partial posterior body cast with nose support, in preparation for treatment with parallel opposed left and right lateral 160-MV proton-beam therapy.

Fig. 4. Case 3. A portal film showing the coverage of the 160-MV proton-beam field. This is so positioned that the 50% isodose line is 2.25 mm posterior to the posterior body surface. For each treatment, the portal films were taken and the patient’s position was adjusted until the target volume was within 0.5 mm of the intended position.

Fig. 5. Case 3. Dose distribution achieved in this patient. The 90% line is shown in two positions, depending on the average density assumed for the vertebral body. The closest 90% isodose contours (solid line) conformed to those that would be required if the vertebral body were assumed to have a uniform density of 1.4 and the widest contours (broken line) if the density were assumed to be 1.0. For the worst assumption, the high-dose region does not extend to the subcutaneous tissue. The real isodose distribution was expected to lie at some intermediate position between the two sets of isodose contours.
and subsequent CT scans were performed. These demonstrated a destructive lesion of the body of C-2 with prominent extradural extension of the tumor into the spinal canal producing marked posterior displacement of the dura. The cervical cord was shifted posteriorly and to the left. There was no clear evidence of soft-tissue mass anterior to the vertebral body. The extent of the disease in the spinal canal is shown in Fig. 7. Further documentation of this mass is demonstrated in Fig. 8, which shows a CT section (taken after the polytome metrizamide myelogram) through the level of C-2. In this section, the destruction of the body of C-2 is not particularly evident, but there is good illustration of the posterior and lateral displacement of the dura and the cord. This patient’s problem was reviewed at the institutional conference on tumors of bone and soft tissue. The consensus was that treatment by radiation therapy, although extraordinarily difficult, should be attempted. The patient refused surgery, even for stabilization of the cervical vertebrae.

Treatment. We developed a treatment plan using the proton beam. Because of the proximity of the lesion to the cord, a high dose would inevitably be delivered to the anterior and the right anterolateral portion of the cord. The patient and her family were told that there might be serious neurological sequelae. Our proposed treatment was, however, based on the likelihood that the tolerance of the spinal cord to the high-dose radiation to one sector of the cord would be higher than for irradiation of the entire cross section of the cord. The patient, her family, and the referring physician readily accepted the risk of our proposed treatment.

The basic plan was to employ a pair of parallel opposed lateral proton beams and a single right posterior 160-MV proton beam to cover the disease demonstrated within the spinal canal, the bodies of C1–3, and the posterior pharyngeal wall. The dose aimed to the tumor mass was 76 CGE, to the pharyngeal wall was 63 CGE, and to the midportion of the cervical cord was less than 50 CGE. Because of its complexity and the time required to complete this treatment plan, we began therapy with parallel opposed 10-MV photon fields covering all the diseased area, even though this required coverage of the full cross section of the

Fig. 6. Case 3. Radiogram 4 years after completion of treatment. The subcutaneous tissues and skin showed very little change on examination.

Fig. 7. Case 5. Left: Polytome section through the midportion of the bodies of C-1 and C-2. Right: Polytome section through the lateral section of the same vertebrae. These views clearly demonstrate the marked posterior extension of the tumor into the spinal canal.
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cord. The dose for this component was 34 Gy (17 fractions over 27 days, 2 Gy per treatment day, two fields treated per day). After a week's delay, proton-beam therapy was started using right and left parallel opposed proton beams (one field treated per day) and then a right posterior proton beam. The lateral fields were 64 mm high; the posterior portal was 27 mm high and 12 mm wide. The use of a much shorter posterior field was based on the demonstration of posterior extension of tumor over a quite narrow range. The composite dose distribution of proton and photon beams is presented in Fig. 9. The dose at the anterior surface of the cord is estimated to be between 60 and 64 CGE and the dose at the midportion of the cord to be approximately 42 CGE. The lateral fields were treated with the patient supine, with her head supported in a mask and further immobilized by a bite block (the same position as employed for the CT scan). For treatment through the right posterior portal, the patient was sitting.

The positional error was determined to be less than 1 mm for the lateral fields. There was a small “hot spot” of 84 to 88 CGE (Fig. 9) due to the requirement that the right posterior beam have a range sufficient to result in a modest overshoot into the area covered by the opposed lateral fields. The quite high dose delivered to this extremely small region was not expected to cause a change in symptoms.

Posttreatment Course. The patient tolerated the treatment quite well. There was virtually no symptomatic pharyngeal reaction. Twenty-two months following treatment the patient is free of clinically evident neurological sequelae. She is feeling well and is without signs of progression of her tumor. At 14 months, there was radiographic evidence of healing of the vertebral body of C-2. We have not requested a follow-up metrizamide myelogram and hence are unable to comment on the size of the tumor.

We know of no technical approach with photon therapy that would permit delivery of a comparable dose to the tumor and spinal cord. With strengthened staffing and further development of the necessary treatment planning programs and techniques, we would be able to plan and implement such treatments promptly and hence eliminate the photon component. Had this been possible with this patient, the dose distribution to the spinal cord would have been more favorable.

Case 6

This 47-year-old woman went to her physician in March, 1979, complaining of double vision and difficulty in focusing on near objects. In August, 1977, she had a radical mastectomy and postoperative radiation therapy to the peripheral lymph nodes for an infiltrating adenocarcinoma of the breast without involvement of the axillary nodes. She did well until the presenting symptoms developed. The visual symptoms were accompanied by headaches, poor memory, and manifest anxiety.

Ophthalmological evaluation documented paresis of the sixth nerve and loss of visual acuity. Polytomograms demonstrated a large tumor mass in the region of the sella, with extensive involvement of the sphenoid sinus and destruction of its anterior margin (Fig. 10 left). On CT scanning, an enhancing mass, 4 cm in diameter, was revealed in the region of the sella; there was some calcification, bony sclerosis of the left sphenoid wing, and extension into the sphenoid sinus (Fig. 10 center and right).
**Examination.** Metrizamide polytomography followed by CT scanning demonstrated a large tumor mass that had destroyed the clivus and the sella turcica. There was erosion into the sphenoid sinus and posterior nasopharynx, suprasellar extension which did not directly abut on the chiasm, and extension posteriorly into the intrapetuncular cistern and pre-pontine cistern, producing compression and posterior displacement of the pons and upper medulla. There was no evidence of metastatic disease, and the patient was accepted for combined photon and proton radiation therapy.

**Treatment.** The treatment began in May, 1979, with 10-MV photon beams, using shaped right and left lateral parallel opposed fields, delivering a dose of 1.8 Gy per day with a total of 39.8 Gy to a target volume shown in Fig. 11. Proton treatments were then begun, delivered at 1.9 Gy per fraction, 4 fractions per week. Nine fractions were given through a superior portal and then eight fractions from right and left lateral portals. The proton beam was planned after extensive analysis of the extent of disease at each level throughout the affected volume. Compensating boluses were used for the superior and the right and left lateral portals. The total radiation dose was 72.3 Gy or 75.5 CGE. The proton portals were smaller and more tightly contoured than the photon portals (Fig. 11). The margin between the contrasting tumor volume and 90% isodose line was either 4 mm or 2 mm, depending upon the proximity of that margin to either the optic chiasm or the brain stem. The optic chiasm was not irradiated from the lateral field. During the last four treatments, the superior field was moved anteriorly by 1 mm and then a further 1 mm in order to increase the sparing of the brain stem.

In March, 1979, a transsphenoidal approach permitted partial removal of a tumor diagnosed as a chordoma. The patient was referred to the Massachusetts General Hospital for further evaluation and consideration of proton beam therapy. Since the surgery, her visual symptoms had disappeared; she was on maintenance prednisone and a visual field defect was documented in perimetry.
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Posttreatment Course. The patient is without clinical or radiographic evidence of progression of tumor 18 months after treatment. However, there has been minimal improvement in this patient’s memory. Repeat CT scan and polytomography show no tumor progression, and visual fields have returned to normal. She remains free of evident metastases from her breast cancer.

Discussion

The proposal that radiation therapy might be of benefit in the treatment of patients with chordoma of the base of the skull and cervical spine was suggested by the reports of Dahlin and MacCarty and Kamrin, et al. However, chordomas of the sphenoid-sella area and cervical vertebrae are rarely treated successfully. More recently, Heffelfinger, et al., reviewed 36 cases of non-chondroid chordoma in these regions; the mean survival times were 5.2, 4.8, 1.8, and 0.9 years, respectively, for radiation plus surgery, radiation, surgery, or no treatment. Firooznia, et al., reported that two of nine patients with such tumors were free of disease 2.5 and 6 years after treatment. Only one of 15 patients treated for sphenoid or vertebral chordoma at Memorial Hospital survived without evidence of disease. However, an occasional patient will survive a long time following biopsy and conventional radiation treatment or without treatment.

The failure rate for treatment of chondrosarcomas and osteogenic sarcomas of the cervical spine, the base of the skull region, or the calvaria is almost 100%. Arlen, et al., reported four failures in four patients with chondrosarcoma, and Caron, et al., reported failure of all of 11 patients with osteosarcoma of the skull.

Local control has been achieved without complication in all 10 patients reported here, with follow-up periods of up to 6 years. There was, however, one marginal failure (Case 9) due to our inability to appreciate the extent of disease. However, no in-field failures have been seen to date. These results are clear justification for continued study of this group of tumors. We have demonstrated the technical feasibility of using protons to administer quite high total doses of radiation to chordomas and chondrosarcomas of the cervical spine and base of the skull while achieving a rapid reduction in dose outside the defined target volume. We are very much aware that the follow-up period is short, especially for the purposes of judging tumor control; however, the absence of major neurological sequelae in this group of patients is significant.

In the future, we expect to realize further improvement in dose distribution. In most of these 10 patients, treatment had to be started on a photon unit because proton plans could not be worked out expeditiously. Planning proton therapy for these patients’ problems has taken several weeks with the technical facilities and manpower that were previously available to us.

With on-site availability of the CT scanner and VAX computer, employment of established computer programs for three-dimensional reconstruction of tumor volume and anatomy and for the design and fabrication of compensator filters, and with the effort of a strong clinical staff, we expect to complete treatment planning and institute treatment within 1 week. Hence, in future plans, photon beams will be employed only because of their physical characteristics, and not as a “holding” action until proton therapy can commence. As a result, we expect to be able to plan and deliver even better dose distributions than those achieved to date.

References


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