Surgical seeding of chordomas

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Object. Chordomas have a high propensity for local recurrence and progression, as well as for systemic and cerebrospinal fluid metastasis. The authors identified and analyzed a series of patients with chordomas, focusing on an underrecognized entity—surgical seeding.

Methods. In a retrospective analysis of 82 patients with chordomas treated over a 10-year period (1990–2000) the authors found six patients (7.3%) in whom surgical seeding had occurred. In five (83%) of these patients the primary tumor was located at the clivus. In one (17%) the tumor was present in the cervical region. There were two male (33%) and four female patients (67%) with a mean age of 34 years. The seeding sites, which were separate from the primary tumor, were located along the operative route or in the abdomen where fat was removed. The seeding was diagnosed 5 to 15 months after surgery (mean 12 months). One seeding site was present in five patients and 17 seeding sites were present in one patient. The involved tissues included mucosa, bone, dura, muscle, and fat. After resection, all seedings were documented histologically.

Conclusions. Seeding of chordomas occurs along the operative route and at distant locations where fat is harvested. Early diagnosis and aggressive surgical treatment are recommended. Based on the results of this study, it is suggested that surgical techniques, postoperative irradiation, the neuroradiological follow-up protocol, and even research on chordomas should be reevaluated.

KEY WORDS • chordoma • skull base • surgical seeding • tumor • cervical spine • clivus

Chordomas are rare, aggressive, slow-growing, invasive, and locally destructive tumors that arise from the notochordal remnants along the cerebrospinal axis. In half of the patients with chordomas, they occur in the sacrococcygeal region. Other sites are the sphenoccipital area (35%) and the upper cervical spine (15%). Males are affected more frequently than females, and radical resection and postoperative radiotherapy are well established as the treatment modalities. This tumor's propensity for local recurrence, direct extension from the primary site, and systemic and cerebrospinal fluid metastasis are well known. Metastasis most often occurs in young patients, those with sacrococcygeal or vertebral tumors, and those with atypical chordoma histological features. Predictably, patients with metastasis have a poor prognosis.^{1,3–13,15–25,27–36,38–40,42–50}

Surgical seeding of tumor cells along the operative route or at distant locations where fat is harvested is an underrecognized surgery-related complication in the treatment of chordomas. We found six patients in whom seeding of the tumor into tissues occurred separate from the primary tumor. In this article we focus on this underrecognized entity. We discuss the impact this phenomenon may have on future surgical and radiation treatments as well as pathology research. We also describe modifica-

tions of surgical technique that can prevent or at least minimize this problem.

CLINICAL MATERIAL AND METHODS

We retrospectively analyzed a series of patients with chordoma surgically treated or evaluated by the senior author (O.A.M.) over a 10-year period (September 1990–October 2000) in three institutions: the University of Mississippi Medical Center (1990), Loyola University Medical Center (1991–1993), and the University of Arkansas for Medical Sciences (1993–2000).

Of 82 patients with chordomas, 62 underwent surgery and 20 underwent only evaluation. The series was composed of 35 male (43%) and 47 female (57%) patients, ranging in age from 5 to 87 years (mean 40 years). The early part of this series has been described previously.^{1,6}

Of the 82 patients, surgical seeding of the tumor was documented in six (7.3%). We reviewed data obtained from each patient's medical chart, follow-up examinations, neuroradiological review, and histological analysis. For patients who could not be followed on a regular basis, we obtained medical, operative, imaging, and pathology reports, or we contacted the patients directly through phone interviews or questionnaires. Four of these patients

TABLE 1
Characteristics and outcome in six patients with surgical seeding of chordomas

Case No.	Age (yrs), Sex	Primary Tumor Site	Seeding Op Approach	Type of Radiation	Time Between Op & Diagnosis of Seeding (mos)	Seeding Site/Tissue	Mos Until Death After Last Op
1	29, F	clivus	transmaxillar	proton beam	15	maxillary sinus/bone, mucosa	8
2	51, F	bilat petroclivus, pterygoid plates	transnasal	proton beam	12	inferior nasal cavity, nasal septum, hard palate, upper & lower lips, tongue/bone, cartilage, mucosa	alive
3	52, M	clivus, dorsum sellae	transnasal	conventional	15	anterior nasal septum, hard palate, maxilla/bone, cartilage, mucosa	2
4	44, F	C3–6	anterolat to cervical spine	conventional	5	anterolat neck/muscle & subcutaneous tissue	alive
5	15, F	clivus	transoral	proton beam	10	abdominal wound/subcutaneous tissue, fat	8
6	14, F	clivus	petrosal	none	13	posterior petrous, retroauricular area/dura, tentorium, subcutaneous tissue	alive

were female (67%) and two were male (33%) and they ranged in age from 14 to 52 years (mean 34 years) (Table 1, Figs. 1–4).

RESULTS

In all six patients there was a classic histological picture of chordoma. In five patients (83%) the site of the primary tumor was the clivus. In the remaining patient (17%) it was the cervical spine. Five patients underwent radiotherapy (three proton beam and two conventional) after the initial surgery. All patients underwent multiple surgeries for the treatment of the primary tumor, recurrence, or seeding; the number of surgeries ranged from two to eight, with a mean of four. In each patient, seeding of the tumor occurred during the first surgery. In two patients, a chordoma was not considered in the differential diagnosis before the first surgery. The time between the primary surgery and the diagnosis of chordoma seeding ranged from 5 to 15 months (mean 12 months). Five patients had only one site of seeding, which occurred in various tissues: mucosa (nasal, sinus, oral, and labial), facial bones (vomer, hard palate, and maxilla), the cartilage, the petrous bone, the tentorium, the petrous dura, muscle, and subcutaneous tissues (abdomen and neck). One patient had 17 different seeding sites in the mucosa of the nose, lips, and tongue that were treated surgically as they appeared and were diagnosed.

Three patients died during the follow-up period. One died of a stroke 2 months after his last surgery. The other two patients died of local recurrence of the tumor at the primary site 8 months after their last surgery.

DISCUSSION

Local Tumor Recurrence and Progression

Both the use and combination of modern skull base surgical techniques have significantly improved the outcome of patients with skull base chordomas, clearly extending the boundaries of their treatment. At the same time, the use of these techniques has brought about certain contemporary developments and complications previously unknown. These techniques have allowed a radical tumor

resection rate of approximately 50%, a mortality rate of approximately 5%, and a major complication rate of approximately 10%. The 5-year recurrence-free interval in patients with a chordoma is approximately 76%. To achieve radical resection, multiple skull base approaches

Fig. 1. Case 1. *Upper Left:* Axial T₂-weighted magnetic resonance image obtained at initial presentation, demonstrating the hyperintense tumor (asterisk), which was resected in two stages (the transcondylar and the transmaxillary approach). *Upper Right:* Follow-up T₂-weighted magnetic resonance image obtained 15 months later, revealing the chordoma seeding in the left maxillary sinus, which was removed surgically. *Lower:* Photomicrograph showing the tumor (black asterisk) and the mucosa of the maxillary sinus (white asterisk). H & E, original magnification × 33.

Fig. 2. Case 2. Magnetic resonance images. *Upper:* Coronal T₁-weighted postcontrast image with fat suppression, demonstrating one of the patient's 17 chordoma seedings that occurred after initial surgery via the transnasal approach conducted at another institution. This seeding was located in the right inferior nasal cavum (*asterisk*). *Lower:* Axial T₂-weighted image revealing the hyperintense tumor (*asterisk*).

may need to be performed in as many as 50% of patients. Nonetheless, radical resection remains one of the most important prognostic factors in the treatment of chordomas in any location. The other important treatment modality and prognostic factor is postoperative radiotherapy. Proton-beam radiotherapy (or conventional radiotherapy as an alternative in patients with spinal lesions) in combination with radical surgery offers the best chance for long-term tumor control in patients with chordoma.^{1,2,6,15,17,26,30,33,37,41,47,50}

The most common failure in the treatment of skull base (78%) and spinal chordomas is local tumor recurrence or progression.^{1,2,6,17,30,50} If the tumor recurs, radical surgery and radiotherapy (if the patient is eligible) may be repeated. Another failure in the treatment of these challenging tumors, which may also be an initial presentation of the disease, is local extension of the tumor from the primary site. The most common sites of tumor extension in the skull base are the nasopharynx, maxilla, and the frontal sinus.^{5,21,31,35,39,48}

Metastasis of Chordomas

Chordomas metastasize in 3 to 48% of the patients harboring these lesions. Tumors in the sacrococcygeal and vertebral locations are more prone to metastasis and metastasis is more likely to occur in children younger than age 5 years than in older children. Atypical histological patterns are found in 86% of metastases, whereas classic

and chondroid patterns are found in 7% each. Most of the patients with metastatic disease die within a mean follow-up period of 40 months. In descending order of occurrence, the organs and tissues involved by metastasis include the lungs, lymph nodes, liver, bone, skin, muscle, peritoneum, heart, pleura, retroperitoneum, spleen, dura mater, kidney, and the adrenal glands.^{1,3–11,13,18,22–25,27,29,30,32,33,35,36,38,39,41–50} Markwalder, et al.,²⁹ have suggested that metastasis is more common with spinal rather than clival chordomas because most tumor cells reach the circulation by invading large veins. Chambers and Schwinn¹⁰ have suggested that irradiation may play some role in the genesis of metastasis, whereas surgery, length of survival, age, and sex do not.

Cerebrospinal fluid drop metastasis of skull base chordomas is rare, but several cases have been reported.^{13,25,33,40,42} Presumably, the tumor cells detach after the tumor penetrates the dura and dislodge distally along cerebrospinal fluid pathways.

Surgical Seeding of Chordoma

Although a few cases of “surgical pathway tumor recurrence” have been reported in the neuroradiological and radiotherapeutic literature,^{4,13,14,20} the seeding of chordomas as a surgery-related complication is an underrecognized entity. Austin, et al.,⁴ reported that among 141 patients with skull base and cervical chordomas treated with proton-beam irradiation, recurrent disease was demonstrated in 26. Of these 26 patients, recurrence along the surgical pathway, which was not part of the target volume, occurred in two (7.7%). Fagundes, et al.,¹³ noted that of 204 patients with skull base and cervical chordomas who underwent proton-beam irradiation, in 63 (31%) treatment failed. Of these 63 patients, in three the recurrence was present along the surgical pathways (neck, palate, and nasal cavity, respectively). All of these patients underwent surgical removal of these lesions, but two eventually died of local recurrence and local and distal tumor recurrence, respectively. Both of these teams published on series of patients that were collected at the same institution and thus these series may actually overlap. Hug, et al.,²¹ have reported that of 58 patients harboring chordomas and chondrosarcomas treated with proton beam irradiation, failure of treatment occurred in 10 (17%). In one of the 10 patients recurrence was demonstrated in the nasal cavity along the surgical pathway, which was outside the radiation field. Recently, Fischbein, et al.,¹⁴ reported three cases of clival chordoma “recurrence along the surgical pathway” occurring 4, 2, and 2 years postoperatively, respectively, all in the sinonasal cavity. The lesions in these patients were treated via the transsphenoidal, the sublabial transsphenoidal, and the transoral approach, respectively. The first two patients subsequently underwent proton-beam irradiation, which failed to include the surgical pathways in the treatment field. The authors stated that in these patients they could not distinguish between the two possible mechanisms of tumor recurrence along surgical pathways: direct surgical tumor implantation or hematogenous spread.

As our findings demonstrate, surgical seeding of chordomas is a consequence of the implantation of tumor along the surgical route or where fat is harvested. The rate

Fig. 3. Case 3. A: Axial postcontrast computerized tomography scan delineating the tumor recurrence at the clivus area (*asterisk*) and the tumor seeding in the inferior nasal cavum, nasal septum, and the hard palate (*asterisk*). The seeding occurred 15 months after surgery via the initial transnasal approach performed at another institution. We performed the transoral, transmaxillary approach and radically resected the tumor. B: Sagittal reformatted postcontrast computerized tomography scan. Note the recurrent clival tumor (*asterisk*) and chordoma seeding (*asterisk*) penetrating the hard palate (*arrows*). C: Postcontrast coronal reformatted computerized tomography scan revealing the extent of chordoma seeding (*asterisk*). D: Photomicrograph obtained after the surgery of the tumor seeding. Note the nasal mucosa (*white asterisk*) and the chordoma (*black asterisk*). E: Photomicrograph obtained after the same surgery demonstrating the bone of the hard palate (*white asterisk*) and the tumor (*black asterisk*). H & E, original magnification $\times 33$.

of chordoma seeding in this series was 7.3%. In all six patients, the seeding sites were separate from the initial tumor site, and all tumor seedings were confirmed histologically after their removal. A certain interval seems necessary between the time of surgery, when the seeding occurs, and the actual growth of a symptomatic mass. In our study, this period ranged from 5 to 15 months (mean 12 months). We hypothesize that this time is necessary for the tumor cells to adjust to a new environment, overcome the local and systemic defense mechanisms, and finally grow large enough to induce symptoms.

As analysis of data from this and other series^{4,13,14,20} indicates, radiotherapy, regardless of whether proton-beam or conventional radiation is used, does not routinely target the surgical route. One may speculate that this plan of treatment facilitates tumor growth. Undoubtedly, the planning and techniques used for radiotherapy in patients with chordomas should be reevaluated.

Despite the fact that the classic histological forms of chordoma without atypical features were demonstrated in all six patients, the chordoma cells were not selective for the new host tissue or the location. "Good" tissues for tumor growth included bone (vomer, maxilla, hard palate, and petrous pyramid), the mucosa (oral, nasal, tongue, and labial), the tentorium, the petrous dura, subcutaneous fat and muscles in the neck, and subcutaneous fat in the abdomen. Chordomas metastasize nonselectively to almost any organ or tissue. This combination of metastasis and seeding should inspire new pathological studies in which investigators assess the cultivation of chordoma cells and the development of new culture lines. The results of such

studies could shed light on the molecular, biochemical, cellular, and tissue levels that pertain to the invasive nature of chordomas. Additional studies could then be conducted to test the effects of different chemotherapeutic agents on this tumor. Finally, surgeons should rethink the graft techniques routinely used in skull base approaches to chordomas including fat, muscle, or bone.

With regard to prognosis, the results obtained in this and other series^{4,13,14,20} paradoxically indicate that the surgical seeding of chordoma per se does not contribute to the final, dismal outcome of most patients. Instead, these findings were better indicators of the aggressive behavior of the tumor in every patient and a harbinger of recurrence and progression at the initial site. These factors ultimately caused death in almost half of the patients in this series. On the other hand, early diagnosis and radical removal of all the tumors in our patients may have prevented seeding from becoming a more unfavorable prognostic factor.

On follow-up imaging, the surgical route must be routinely scrutinized for a recurrent tumor for this purpose. Magnetic resonance T_2 -weighted images are particularly useful. Until proven otherwise, a hyperintense lesion demonstrated along the surgical route on a T_2 -weighted image should be considered tumor seeding, not a benign postoperative change, a nasal cyst, or a polyp.

Finally, but most important, the surgical techniques and approaches used to remove chordomas must be tailored to meet new findings. During preoperative planning, the surgeon should consider that a clival tumor may actually be a chordoma. In fact, in two patients in this series, the surgeons performing the initial "seeding" operations did not

Fig. 4. Case 6. *Left:* Sagittal T₁-weighted magnetic resonance image revealing the clival chordoma (asterisk) that had been resected via a two-stage procedure (via transoral and transcondylar approach) at another institution. *Center:* Coronal postcontrast T₁-weighted magnetic resonance image demonstrating the contrast-enhancing tumor (asterisk). At that time fat had been harvested from the abdomen to serve as a graft. *Right:* The patient presented to us with local tumor recurrence as well as pain and swelling at the site at which fat was harvested. We resected the recurrent clival tumor and also explored the abdominal harvest site. To our surprise, a chordoma seeding was found. This photomicrograph of a specimen was obtained after exploration of earlier fat harvest site and removal of the tumor. Note the abdominal fat (black asterisk) and the chordoma (white asterisk). H & E, original magnification $\times 33$.

suspect chordoma in the preoperative differential diagnosis. We have modified our operative techniques based on the lessons learned in this series. After the approach is completed but before we remove the tumor, we coat the walls of the operative tunnel with fibrin glue and large cotton patties. At the end of surgery, we carefully remove the cotton patties and the fibrin glue. Grafts are then introduced into the tumor-free area (after gross-total resection has been achieved). Before closure, all contaminated drapes and towels are replaced, and a clean set of instruments and new gloves are used in the closure procedure. We also use a clean set of instruments and new gloves and drapes when harvesting fat from the abdomen. In general, all instruments that come in contact with the tumor are considered contaminated. If seeding of the chordoma is diagnosed during the follow-up examination, it is treated aggressively and radically, as is any recurrence at the primary site or metastasis. As the results of this study suggest, no particular surgical approach is predisposed to seeding. Rather, surgical seeding appears to be caused by contaminated instruments.

CONCLUSIONS

The seeding of a chordoma may occur along the operative route or at a distant site at which fat is harvested. The surgical techniques used to remove chordomas should be modified to prevent or minimize the risk of this complication. If seeding occurs, early diagnosis and aggressive surgical treatment are recommended. Because chordoma seeding may occur in the tissues along the operative route, this area should be included in the postoperative radiation field. Furthermore, on follow-up magnetic resonance im-

aging the operative route should be scrutinized for possible seeding. Chordomas seem to be able to grow on any tissue, a fact of great importance in chordoma research.

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References

1. Al-Mefty O, Borba LA: Skull base chordomas: a management challenge. *J Neurosurg* **86**:182–189, 1997
2. Ammirati M, Bernardo A: Management of skull base chordoma. *Crit Rev Neurosurg* **9**:63–69, 1999
3. Ariel IM, Verdu C: Chordoma: an analysis of twenty cases treated over a twenty-year span. *J Surg Oncol* **7**:27–44, 1975
4. Austin JP, Urie MM, Cardenosa G, et al: Probable causes of recurrence in patients with chordoma and chondrosarcoma of the base of skull and cervical spine. *Int J Radiat Oncol Biol Phys* **25**:439–444, 1993
5. Berdal P, Myhre E: Cranial chordomas involving the paranasal sinuses. *J Laryngol Otol* **78**:906–919, 1964
6. Borba LA, Al-Mefty O, Mrak RE, et al: Cranial chordomas in children and adolescents. *J Neurosurg* **84**:584–591, 1996
7. Brooks LJ, Afshani E, Hidalgo C, et al: Clivus chordoma with pulmonary metastases appearing as a failure to thrive. *Am J Dis Child* **135**:713–715, 1981
8. Campbell WM, McDonald TJ, Unni KK, et al: Nasal and paranasal presentations of chordomas. *Laryngoscope* **90**:612–618, 1980
9. Chalmers J, Coulson WF: A metastasizing chordoma. *J Bone Joint Surg (Br)* **42**:556–559, 1960
10. Chambers PW, Schwinn CP: Chordoma. A clinicopathologic study of metastasis. *Am J Clin Pathol* **72**:765–776, 1979

11. Chetty R, Levin CV, Kalan MR: Chordoma: a 20 year clinicopathologic review of the experience at Groote Schuur Hospital, Cape Town. **J Surg Oncol** 46:261–264, 1991
12. Congdon CC: Benign and malignant chordomas. A clinico-anatomical study of twenty-two cases. **Am J Pathol** 28:793–821, 1952
13. Fagundes MA, Hug EB, Liebsch NJ, et al: Radiation therapy for chordomas of the base of skull and cervical spine: patterns of failure and outcome after relapse. **Int J Radiat Oncol Biol Phys** 33:579–584, 1995
14. Fischbein NJ, Kaplan MJ, Holliday RA, et al: Recurrence of clival chordoma along the surgical pathway. **AJNR** 21:578–583, 2000
15. Forsyth PA, Cascino TL, Shaw EG, et al: Intracranial chordomas: a clinicopathological and prognostic study of 51 cases. **J Neurosurg** 78:741–747, 1993
16. Fox JE, Batsakis JG, Owano LR: Unusual manifestation of chordoma. A report of two cases. **J Bone Joint Surg (Am)** 50:1618–1628, 1969
17. Gay E, Sekhar LN, Rubinstein E, et al: Chordomas and chondrosarcomas of the cranial base: results and follow-up of 60 patients. **Neurosurgery** 36:887–897, 1995
18. Graf L: Sacrococcygeal chordoma with metastases. **Arch Pathol** 37:136–139, 1944
19. Heffelfinger MJ, Dahlin DC, MacCarty CS, et al: Chordomas and cartilaginous tumors at the skull base. **Cancer** 32:410–420, 1973
20. Higinbotham NL, Phillips RF, Farr HW, et al: Chordoma. Thirty-five-year study at Memorial Hospital. **Cancer** 20:1841–1850, 1967
21. Hug EB, Loredó LN, Slater JD, et al: Proton radiation therapy for chordomas and chondrosarcomas of the skull base. **J Neurosurg** 91:432–439, 1999
22. Kamrin RP, Potanos JN, Pool JL: An evaluation of the diagnosis and treatment of chordoma. **J Neurol Neurosurg Psychiatry** 27:157–165, 1964
23. Kaneko Y, Sato Y, Iwaki T, et al: Chordoma in early childhood: a clinicopathological study. **Neurosurgery** 29:442–446, 1991
24. Keisch ME, Garcia DM, Shibuya RB: Retrospective long-term follow-up analysis in 21 patients with chordomas of various sites treated at a single institution. **J Neurosurg** 75:374–377, 1991
25. Krol G, Sze G, Arbit E, et al: Intradural metastases of chordoma. **AJNR** 10:193–195, 1989
26. Lanzino G, Sekhar LN, Hirsch WL, et al: Chordomas and chondrosarcomas involving the cavernous sinus: review of surgical treatment and outcome in 31 patients. **Surg Neurol** 40:359–371, 1993
27. Lybeert ML, Meerwaldt JH: Chordoma. Report on treatment results in eighteen cases. **Acta Radiol Oncol** 25:41–43, 1986
28. Mabrey RE: Chordoma: a study of 150 cases. **Am J Cancer** 25:501–517, 1935
29. Markwalder TM, Markwalder RV, Robert JL, et al: Metastatic chordoma. **Surg Neurol** 12:473–478, 1979
30. Menezes AH, Gantz BJ, Traynelis VC, et al: Cranial base chordomas. **Clin Neurosurg** 44:491–509, 1997
31. Ormerod R: Clinical records. A case of chordoma presenting in the nasopharynx. **J Laryngol Otol** 74:245–254, 1960
32. Peramezza C, Cellini A, Berardi P, et al: Chordoma with multiple skin metastasis. **Dermatology** 186:266–268, 1993
33. Raffel C, Wright DC, Gutin PH, et al: Cranial chordomas: clinical presentation and results of operative and radiation therapy in twenty-six patients. **Neurosurgery** 17:703–710, 1985
34. Rich TA, Schiller A, Suit HD, et al: Clinical and pathologic review of 48 cases of chordomas. **Cancer** 56:182–187, 1985
35. Richter HJ, Batsakis JG, Boles R: Chordomas: nasopharyngeal presentation and atypical long survival. **Ann Otol Rhinol Laryngol** 84:327–332, 1975
36. Sassin JF, Chutorian AM: Intracranial chordoma in children. **Arch Neurol** 17:89–93, 1967
37. Sen CN, Sekhar LN, Schramm VL, et al: Chordoma and chondrosarcoma of the cranial base: an 8-year experience. **Neurosurgery** 25:931–941, 1989
38. Sibley RK, Day DL, Dehner LP, et al: Metastasizing chordoma in early childhood: a pathological and immunohistochemical study with review of literature. **Pediatr Pathol** 7:287–301, 1987
39. Singh W, Kaur A: Nasopharyngeal chordoma presenting with metastases. **J Laryngol Otol** 101:1198–1202, 1987
40. Stough DR, Hartzog JT, Fisher RG: Unusual intradural spinal metastasis of a cranial chordoma. Case report. **J Neurosurg** 34:560–562, 1971
41. Sundaresan N, Galicich JH, Chu FC, et al: Spinal chordomas. **J Neurosurg** 50:312–319, 1979
42. Uggowitz MM, Kugler C, Groell R, et al: Drop metastases in a patient with chondroid chordoma of the clivus. **Neuroradiology** 41:504–507, 1999
43. Volpe R, Mazabraud A: A clinicopathologic review of 25 cases of chordoma (a pleomorphic and metastasizing neoplasm). **Am J Surg Pathol** 7:161–170, 1983
44. Wang CC, James AE: Chordoma: brief review of the literature and report of a case with widespread metastases. **Cancer** 22:162–167, 1968
45. Whitaker RH, Cast IP: Prolonged survival in a case of sacrococcygeal chordoma with metastases. **Br J Surg** 56:392–395, 1969
46. Willis RA: Sacral chordoma with widespread metastases. **J Pathol Bacteriol** 33:1035–1043, 1930
47. Wold LE, Laws ER Jr: Cranial chordomas in children and young adults. **J Neurosurg** 59:1043–1047, 1983
48. Wright D: Nasopharyngeal and cervical chordoma—some aspects of their development and treatment. **J Laryngol Otol** 81:1337–1355, 1967
49. Yarom R, Horn Y: Sacrococcygeal chordoma with unusual metastases. **Cancer** 25:659–662, 1970
50. York JE, Kaczaraj A, Abi-Said D, et al: Sacral chordoma: 40-year experience at a major center. **Neurosurgery** 44:74–80, 1999

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