Chordoma is a rare malignant bone tumor that arises from ectopic rests of notochordal tissue.43 Restricted to the axial skeleton, it has a predilection for the sacrum (50%), skull base (35%), and the mobile segments of the spine (15%).4,24,33,39 Sacral chordoma occurs almost twice as frequently in men compared with women and is uncommon in individuals younger than 40 years of age.2,37 Chordomas are typically slow growing but locally aggressive. Significant extracompartmental growth is often seen by the time of diagnosis. Most sacral chordomas present as surgical Stage IB14 with anterior extension into the pelvis.5,11,35 The tumor often displaces but does not invade the rectum, because the tough periosteum and presacral fascia resist the transgression of disease.35 Metastasis is usually a late event.9,24

Sacral chordomas are relatively rare, locally invasive, malignant neoplasms. Although metastasis is infrequent at presentation, the prognosis for patients with chordoma of the sacrum is reported to be poor and attributable in most cases to intralesional resection. The value of adjuvant treatment is uncertain, and resection remains the primary mode of treatment. Chordomas are difficult to excise completely, but recent improvements in imaging and surgical techniques have allowed surgeons to perform more frequently en bloc sacral resections with wide surgical margins. The technical challenges of such operations, and the functional costs for the patient (with respect to anorectal and urogenital dysfunction) are significantly increased when the tumor involves high sacral levels. The authors review the clinical presentation and natural history of sacral chordoma and discuss the current treatment techniques and outcomes.

**Current management of sacral chordoma**

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Chordoma is a rare malignant bone tumor that arises from ectopic rests of notochordal tissue.43 Restricted to the axial skeleton, it has a predilection for the sacrum (50%), skull base (35%), and the mobile segments of the spine (15%).4,24,33,39 Sacral chordoma occurs almost twice as frequently in men compared with women and is uncommon in individuals younger than 40 years of age.2,37 Chordomas are typically slow growing but locally aggressive. Significant extracompartmental growth is often seen by the time of diagnosis. Most sacral chordomas present as surgical Stage IB14 with anterior extension into the pelvis.5,11,35 The tumor often displaces but does not invade the rectum, because the tough periosteum and presacral fascia resist the transgression of disease.35 Metastasis is usually a late event.9,24

The relative rarity and slow growth of these tumors account for why most large clinical studies over many years have been based on cases collected involving varied treatments.24,33,45 Authors of early studies9,45 reported very high local recurrence rates for sacral chordoma treated with traditional surgical debulking and radiotherapy. These patients were condemned to progressive deterioration and pain from continued tumor growth, deteriorating neurological function, pressure sores, and infection. Local recurrence of sacral chordoma is associated with a 21-fold increased risk of tumor-related death.4

Techniques to allow the en bloc resection of sacral tumors, along with a wide margin of uninvolved tissue, were pioneered in the 1960s and 1970s.27,38 Local control of disease has significantly improved with the advent of more aggressive surgery;3,4,24,38 however, major sacral resections are associated with high morbidity rates. Sacrifice of the sacral nerve roots produces varying degrees of bladder, bowel, and sexual dysfunction.6,31,40 High sacral amputation may jeopardize lumbopelvic stability,23 and total sacrectomy requires stabilization of the dissociated lumbar spine and pelvis.17,23

The purpose of this article is to review the clinicopathological manifestations of sacral chordoma and to discuss the current surgical and adjuvant treatment options for this condition.

**BIological behavior**

Although the biological activity of chordomas may be highly variable,4 most conventional chordomas are slow growing. Chordomas show various degrees of histological atypia; however, the relationship between histological features and biological behavior remains controversial.30

In an analysis of 39 cases of chordoma of the sacrum and mobile segments of the spine, Bergh, et al.,4 found that the presence of microscopic tumor necrosis and/or evidence of high proliferative activity (> 5% of cells staining positive for Ki-67) were adverse prognostic factors: the former was correlated with local recurrence and
the latter with metastasis. Other morphological features (cellularity, pleomorphism, number of spindled cells, predominance of physaliphorous compared with epithelioid tumor cells, mitotic rate) did not correlate with the clinical course.

Berven, et al., performed flow cytometry analysis on 23 chordomas of the lumbar spine and sacrum. The DNA pattern (aneuploid compared with diploid) was not associated with local recurrence or survival.

Dedifferentiated chordoma is a very rare variant of chordoma that is clinicopathologically analogous to dedifferentiated chondrosarcoma. The sarcomatous component of dedifferentiated chordoma may demonstrate more aggressive biological behavior and has a higher propensity to metastasize.

**CLINICAL PRESENTATION**

The presenting symptom in the vast majority of patients is local pain. Approximately one third of patients also have radiculopathy due to irritation of the sciatic nerve or iliolumbar trunk. The nonspecific nature of these symptoms often accounts for a delay in the diagnosis. Lytic sacral disease on plain radiographs may be missed, and routine CT and MR imaging studies frequently fail to reveal the sacrum below S-2. Unfortunately, the true diagnosis is often not realized until late in the course of illness, when bladder or bowel function is compromised, or when a mass is palpable on rectal or gynecological examination.

The mean duration of symptoms in a recent review ranged from 4 to 24 months (mean 14 months).

**RADIOLOGICAL EVALUATION**

Attributable to their notochordal origin, sacral chordomas usually arise in the midline and involve at least S-4 and S-5. The appearance on CT scans usually consists of lytic bone destruction in addition to a disproportionately large presacral mass. Calcification is present in 30 to 70% of cases. On T₁-weighted MR images, chordomas are frequently seen as iso- or slightly hypointense compared with muscle; they appear hyperintense on T₂-weighted MR images. Unlike most bone tumors, chordomas may show reduced uptake or normal distribution of radioisotope on bone scanning.

**BIOPSY SAMPLING**

The differential diagnosis of sacral tumors is extensive and includes metastasis, giant cell tumor, and chondrosarcoma. A biopsy procedure should therefore be performed in almost all cases. The minimally invasive nature of fine-needle aspiration biopsy seems to be the most oncologically sound. The cytomorphological features of chordoma allow accurate diagnosis by using this technique.

We believe that the surgeon who performs the definitive tumor resection should perform the biopsy or direct the choice of biopsy procedure. Poorly planned incisional biopsies or incomplete debulking operations prior to referral to a major tumor center have been shown to increase the risk of local recurrence and metastasis.

A cardinal error in the management of patients with sacral tumors is a transrectal or transvaginal biopsy, a procedure that violates the containing membranes of presacral fascia and perirectum. The rectum or vagina may become seeded with tumor cells, thus making it necessary to resect these organs at the time of operation.

**SURGERY**

Local recurrence is the most important predictor of mortality in patients with chordoma and local recurrence is clearly related to the extent of initial resection; therefore, wide en bloc excision of tumor without contamination of the surgical wound was 28%. For patients in whom the tumor capsule was entered at surgery, the recurrence rate was 64%. York, et al., also demonstrated a statistically significant difference in the time from surgery to local recurrence between patients who underwent radical resection and those who underwent subtotal excision (2.27 years compared with 8 months). Bergh, et al., showed that local recurrence was significantly associated with an increased risk of metastasis and tumor-related death.

En bloc sacral resection below the sacroiliac joint (the S-3 level) is a relatively straightforward procedure performed via a combined posterior–transperineal exposure. Tensionless wound closure may necessitate mobilization of soft-tissue flaps, but generally can be achieved without resorting to more elaborate reconstructive measures.

Sacrectomy above S-3, which includes a portion of the sacroiliac joint, is technically much more difficult. Although simultaneous dorsal and ventral exposures have been described, in our hands the lateral positioning makes neither exposure optimal for chordoma, which is predominantly a midline lesion.

The techniques of sacrectomy, popularized by Stener and Gunterberg, are well established. Total sacrectomy for chordomas involving S-1 has only been performed in a few instances. These technically demanding procedures require multidisciplinary (neurosurgery, surgical oncology, plastic surgery) involvement. Use of the transpelvic vertical rectus abdominis myocutaneous flap for the reconstruction of large sacral defects has significantly reduced problems with wound breakdown.

**Functional and Biomechanical Considerations**

There are several detailed studies in which the functional aspects of sacral amputations, which can be quite disabling, are addressed. Patients with amputations distal to S-3 generally have limited deficits, with preservation of sphincter function in the majority and some reduced perineal sensation. Sexual ability may also be inhibited. The highest variability in functional results is seen for transverse resections of S2–3 (including removal of one to all four roots of S2–3). There is seldom any relevant motor deficit; however, many patients have saddle anesthesia and a significant reduction in sphincter control. Sectioning of the S-1 roots may result in clinically rele-
vant motor deficits (walking with external support), and almost uniformly results in total loss of sphincter control and sexual ability. Unilateral resection of sacral roots leads to unilateral deficits in strength and sensitivity; however, sphincter control may be either preserved or only partially compromised.\textsuperscript{19,40} No matter the level of resection, damage to the lumbosacral trunks or sciatic nerves may cause serious postoperative motor and sensory deficits.

Gunterberg, et al.,\textsuperscript{20} studied cadaveric pelvises to evaluate pelvic strength after major amputations of the sacrum. If one third of the sacroiliac joint and the associated ligamentous structures were resected, the pelvic ring was weakened by approximately 30%. Resections between S-1 and S-2 caused loss of stability in approximately 50%. In all of these experiments, the load to failure far exceeded physiological loads. They concluded that weight bearing was safe for patients after sacral resection, as long as 50% or more of the sacroiliac joint (corresponding to at least the upper half of the S-1 segment) remained intact.

The problem of fatigue fractures as a complication of high sacral amputation appears to be limited. Bergh, et al.,\textsuperscript{4} found that only six of 18 patients with high sacral amputations (through or above the S1–2 disc) developed fractures, and only one of them had permanently disabling pain.

Total sacrectomy results in complete dissociation of the spine and pelvis and requires specialized surgical stabilization techniques to preserve mechanical support and allow satisfactory walking ability (Fig. 1a–e).\textsuperscript{17,23}

**Local Recurrence**

Even after an apparently total en bloc resection of sacral chordoma, local recurrence of disease is not a rare event.\textsuperscript{22} Cheng, et al.,\textsuperscript{11} demonstrated statistically significant differences in local recurrence-free survival rates among three groups of patients classified according to the location of tumor: lumbar region, S1–2, and S3–coccyx. They concluded that the most proximal extent of tumor involvement was a strong predictor of recurrence. We believe that determination of the level of planned sacrectomy must include careful inspection of the sacrospinal canal on preoperative MR imaging. It is not enough to simply base the level of sacral amputation one segment beyond the edge of bone involvement, because chordomas may ascend into the spinal canal above this level. Violation of the spinal canal tumor margin, heralded simply by observation of the tumor within the canal during resection, is probably one of the most common reasons for recurrence after an attempted en bloc resection.

Yonemoto, et al.,\textsuperscript{44} reported that local recurrences may be due to residual chordoma infiltrating the gluteal muscles. They stressed the importance of precise preoperative MR imaging assessment of the dorsal musculature and suggested that for complete tumor removal, a radical wide posterior margin of the gluteal muscles should be obtained.

Ishii, et al.,\textsuperscript{22} analyzed the locations of initial recurrences after total en bloc S2–3 resection for sacral chordomas located below S-3. In all patients, the primary re-
currences were located at either side of the lateral portion of the remaining sacrum. Because the conventional S2–3 sacrectomy does not disrupt the sacroiliac articulations, lumbopelvic stability is preserved. Avoidance of these lateral portions of the sacrum may result in a marginal or intralresional resection.

ADJUVANT TREATMENT

The value of radiotherapy as primary or adjuvant treatment for chordoma has been debated.1,3,8,10,16,35 Supplementary radiotherapy is a useful adjunct to surgical care but is not sufficient as stand-alone therapy.3,35,43 In a clinical series spanning 40 years, York, et al.,43 reported that the addition of radiotherapy significantly prolonged the disease-free interval for patients undergoing subtotal resection (2.12 years compared with 8 months). Others have suggested that radiotherapy is of limited value in most cases.4

Catton, et al.,8 found no difference between conventional or hyperfractionated radiotherapy regimens for chordoma, with respect to both the degree or duration of symptomatic response and the progression-free survival. They also showed no survival advantage for patients receiving radiation doses greater than 50 Gy compared with those receiving doses less than 50 Gy.

Samson, et al.,19 have suggested that the use of preoperative or postoperative irradiation might permit the surgeon to perform a marginal resection in the case of high sacral tumors, allowing the preservation of nerve roots. We strongly believe that the surgeon should not hesitate to sacrifice sacral nerve roots at the time of surgery, if it is necessary to obtain an en bloc resection. Otherwise, continued tumor growth or local recurrence will lead to even more severe neurological dysfunction.

Results with brachytherapy techniques for recurrent sacral chordoma have been reported in small numbers of patients.25 The place of newer methods of radiation delivery, such as charged-particle irradiation56 and high linear energy transfer therapy7 are yet to be determined.

Chemotherapy has been of little value in the management of these tumors.3,45 In the few clinical series in which chemotherapy was used, it was usually administered late in the course of the disease. A recent study of chordomas treated with radiotherapy and the radiosensitizing agent razoxane indicated promising results.32

CONCLUSIONS

Study of the natural history of sacral chordomas and their response to treatment has been hampered by the low incidence and slow growth of these tumors. During the last 40 years, tremendous advances in the fields of diagnostic imaging, surgery, and radiotherapy have taken place. This has yielded a heterogeneous group of patients, but has not obscured the salient fact that patients who undergo wide en bloc resection fare better than those who undergo intralresional resections.3,4,11,24,35,36,39,44,45 Subtotal resection followed by radiotherapy is a poor treatment option for most patients, because they inevitably suffer multiple, symptomatic, local recurrences before succumbing to metastatic disease or other comorbid conditions.4,11,25

A distressing finding, which is becoming more prevalent in the literature, is that local recurrence of chordoma is not terribly uncommon after an apparently en bloc resection.22,44,45 The technical challenges of total en bloc sacral amputations and total sacrectomy should not be underestimated. The functional consequences for the patient should be clearly discussed preoperatively.

Innovative treatment strategies are currently needed for sacral chordoma. Given the rarity of the disease, it is not feasible to perform Phase III trials. Alternatively, large academic centers should develop treatment guidelines so that treatment efficacy and outcomes can be better assessed.

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References


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