Conversion of high sacral to midsacral amputation via S-2 nerve preservation during partial S-2 sacrectomy for chordoma

Technical note

RAHIV SAIGAL, M.D., PH.D.,1 DANIEL C. LU, M.D., PH.D.,2 DONNA Y. DENG, M.D., M.S.,2 AND DEAN CHOU, M.D.1

Departments of 1Neurological Surgery and 3Urological Surgery, University of California, San Francisco; and 1Department of Neurological Surgery, University of California, Los Angeles, California

Chordomas of the sacrum require en bloc resection to reduce the risk of recurrence, but this may sacrifice nerves vital to bladder, bowel, and sexual function. High, mid-, and low sacral amputations have been previously classified based on nerve root sacrifice, not bony amputation. Sacrifice of the S-2 nerves or those above results in a high sacral amputation, but preserving the S-2 nerves converts it into a midsacral amputation. Preservation of the S-2 nerves has been shown to improve functional outcome, despite the bony osteotomy being unchanged. Thus, keeping the same bony amputation while preserving the S-2 nerve roots may allow for improved functional outcome while still achieving the same goal of oncological resection. Preservation of the S-2 nerves may be particularly difficult during amputation at the S-2 pedicle or above, and the authors describe their technique for preserving the S-2 nerves during partial sacrectomy at or just above the S-2 pedicle. Four cases of sacral chordoma resections are presented to illustrate the technique.

(https://thejns.org/doi/abs/10.3171/2014.1.SPINE12652)

**KEY WORDS** • sacrectomy • midsacral • high sacral • sacrum • amputation • chordoma • en bloc • nerve preservation • nerve sparing • oncology

Chordomas are rare, slow-growing malignant tumors of notochordal origin, most frequently located in the sacrococcygeal region.24 Although their incidence is only 1 per 2 million, chordomas are the most frequently occurring primary vertebral column tumor.12 Sacral chordomas can prove challenging because of their large size at the time of diagnosis, their high rate of recurrence when subtotally resected, and their involvement of nerve roots that control bowel, bladder, and sexual function. Gross-total, en bloc resection has been established as the primary means of controlling local recurrence.6,14 Subtotal or intralesional resection is less than ideal, resulting in disease-free intervals as short as 8 months (as compared with 2.3 years when radical resection is performed)32 and a 64% recurrence rate (as compared with 28% when gross-total resection is performed).19 With appropriate surgical treatment, however, the overall survival is 84%–88% at 5 years and 49%–64% at 10 years; disease-free survival can be 61% at 5 years and 24% at 10 years.3,4

To achieve an en bloc gross-total resection with either wide or marginal margins, sacral nerve roots oftentimes must be sacrificed. Fourney et al. have described a classification system that bases the type of sacral amputation on the level at which the nerve root is sacrificed, not on the level of the osteotomy.14 Low sacral amputation is defined as sacrifice of at least one S-4 nerve root and below; midsacral amputation is defined as sacrifice of at least one S-3 nerve root and below; and high sacral amputation is defined as sacrifice of at least one S-2 nerve root and below.14 Thus, preservation or sacrifice of the proximal-most nerve roots can significantly affect the morbidity associated with
the procedure. Many times, the osteotomy must be done at the level of or even above the level of the exiting nerve root to achieve a wide margin. However, if there is no tumor at this level (based on preoperative imaging), the nerves at the osteotomy level can potentially be preserved.

As a general rule, the lower the sacral amputation, the more likely bowel and bladder function will be maintained. Clinical studies have demonstrated that if all S2–5 sacral nerves are sacrificed, abnormal bowel and bladder function ensues in all patients.27,30 However, if the S-2 nerves can be preserved, approximately 25% of patients will maintain bladder function and 40% will maintain bowel function, even with S3–5 nerve roots sacrificed.50 Thus, preservation of the S-2 nerve roots, and converting a high sacral amputation to a midsacral amputation, can result in improvement in quality of life in some patients.

Although there have been published reports in the literature on total or partial sacrectomy for chordoma, there is a paucity of technical detail on preservation of nerve roots at the proximal-most level. We describe our technique for preserving the proximal-most nerve by illustrating 4 cases of S-2 sacral amputations in which we preserved both S-2 nerve roots, converting high sacral amputations into midsacral amputations. The technique is best suited for patients with high sacral chordomas involving the S-2 vertebral body, but not the S1–2 disc and not involving the S-2 pedicles. These patients require a sacral amputation at S1–2, yet do not have tumor at the S1–2 disc or dorsally at the S-2 pedicles. As long as the tumor does not violate the S-2 pedicle, it is feasible to try to preserve the S-2 nerves; however, if the tumor involves the S-2 pedicle, it is not possible to save the S-2 nerves without tumor transgression.

Methods

Patients

The Committee on Human Research at University of California, San Francisco, approved all methods in this study. We retrospectively reviewed electronic clinical records, imaging studies, and outcomes of 4 patients in whom the senior author performed partial sacrectomy at S-2 for chordoma from 2005 to 2008. Chart review included preoperative clinical assessment, operative notes, inpatient progress notes, discharge summaries, and outpatient follow-up notes. There were 3 male patients and 1 female patient who ranged in age from 56 to 65 years. All patients were followed up in clinic for more than 2 years. Table 1 provides a summary of clinical data.

Surgical Technique

Preservation of the sacral nerves during midsacral amputation involves mobilizing the nerves from the dorsal aspect of the sacrum to the ventral lateral aspect and removal of the S-2 pedicle. This allows the S-2 nerve roots to be displaced rostrally, effectively performing the osteotomy below the S-2 nerve roots even though the bony cut is placed at the pedicle or above. This technique can be accomplished with a combination of precisely placed osteotomies, appropriate bone removal, and mobilization of the nerves.

The anterior approach performed by our colorectal surgery colleagues involves a standard midline laparotomy and dissection of the rectum off the anterior sacrum and tumor. After the mesorectum is dissected ventrally, a small Silastic sheet is placed to define the ventral border. The vessels coming off the internal iliac vessels and the middle sacral vessels are left intact. These vessels are approached posteriorly and ligated via a posterior approach. The angle of the sacrum and the sacral promontory make it difficult to isolate and ligate the vessels from an anterior approach.

After careful planning with preoperative imaging, the posterior osteotomy sites are planned. Precise preoperative planning with T2-weighted MR images, CT scans, and T1-weighted Gd-enhanced MR images is critical for achieving a wide marginal resection at the sacrum. In our 4 cases, the chordomas all came up to S-2 vertebral body but not into the pedicle. Thus, we planned our osteotomies at the S-2 pedicle in each case for wide bony margins, with the intent to preserve the S-2 nerves. These osteotomies are the traditional osteotomies from the foramens to the sciatic notch (see Fig. 1C). In all 4 cases, the S-2 nerves were successfully preserved. The lateral margins were determined using the axial MR images, and the skin removal was determined by the biopsy site. This width between the lateral margins is then translated into the width of the surgical resection.

After anterior dissection of the sacral chordoma (staged or immediately preceding the posterior approach), the patient is turned prone onto the Wilson frame. Preop-

---

**TABLE 1: Demographic information of patients undergoing S-2 sacral amputation**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Extent of Resection</th>
<th>Last Follow-Up (yrs)</th>
<th>Bladder Control</th>
<th>Bowel Control</th>
<th>Sexual Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56, M</td>
<td>GTR</td>
<td>6</td>
<td>able to void 20–25% bladder volume prior to MVA</td>
<td>constipation, obstipation, treated w/ flexible sigmoidoscopy</td>
<td>erection, ejaculation intact</td>
</tr>
<tr>
<td>2</td>
<td>61, M</td>
<td>GTR</td>
<td>3</td>
<td>controls urination w/ intermittent dribble</td>
<td>controls defecation w/ occasional incontinence</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>58, M</td>
<td>GTR</td>
<td>3</td>
<td>unable to urinate, self-catheterizes</td>
<td>90% control of defecation</td>
<td>erection, ejaculation 50% compared to pre-op</td>
</tr>
<tr>
<td>4</td>
<td>65, F</td>
<td>GTR</td>
<td>3</td>
<td>urinary incontinence, catheterizes</td>
<td>intermittent incontinence</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

* GTR = gross-total resection; MVA = motor vehicle accident.
Conversion of a sacral amputation by S-2 nerve preservation

Operative fluoroscopy is used to localize the level. The tumor and sacrum can be palpated to ensure a wide lateral margin is achieved. A wide margin is achieved at the bony osteotomy site, but a marginal margin is achieved between the tumor and the mesorectum. An elliptical skin incision is planned through which to remove the biopsy tract. The paraspinous muscles at L-5 and S-1 are dissected using monopolar cautery. An intraoperative radiograph is taken to again localize the level. Dissection lateral to the bony sacrum is performed. The gluteal muscles lateral to the sacrum are dissected bluntly and then divided.

The first step is to perform wide laminectomies over the planned osteotomy for the sacral amputation (Fig. 1A and B). In our 4 cases of S-2 sacral amputation, the laminectomy was performed over the S-2 pedicle, identifying both S-2 nerve roots and the distal sacral nerves (Fig. 1).
1C). Multiple confirmatory radiographs are taken to ensure the S-2 pedicle is clearly identified. The distal nerves are then ligated and amputated (Fig. 1C–E). We use two 0-silk sutures to doubly tie off the distal nerves.

After ligation of the distal nerves, the course of the S-2 nerves is followed from the dorsal aspect of the sacrum to the ventral aspect of the sacrum. This is achieved with wide laminectomies over the S-2 nerves, identifying the nerves as they course medial to the pedicle and following them until they course lateral to the sacrum (Fig. 1C–E). As the nerves course laterally and inferiorly, extreme care must be taken to clearly follow the S-2 nerves as cephalad and lateral as possible to avoid, at this point, visualizing any chordoma tumor. As they course distally, the S-2 nerves have multiple branches, as well as ligamentous and vascular attachments to the sacrum. These must each be clearly identified and ligated sharply to allow proper dorsal rotation of the distal sacrum from the S-2 nerves. The edge of the sacrum and chordoma can be palpated, and dissection of the S-2 nerves should be carried out lateral to the edge of the chordoma. The chordoma itself is not seen as this point, but it can be manually palpated through the soft tissue.

The lateral osteotomies that are made are essentially the traditional osteotomies from the foramen to the sciatic notch. However, there is an additional cut that is made to move the S-2 nerve laterally and rostrally. This piece of bone is removed laterally, and it allows the osteotomy to be performed at the S1–2 disc space, yet still permits the S-2 nerve roots to be mobilized laterally and rostrally. This is illustrated in Fig. 1C with the small piece of bone that is shown with a curve arrow for removal. In addition, the main osteotomy is performed at the S1–2 disc space, above the S-2 pedicle. Thus, the lateral osteotomies are performed through the traditional landmarks, but the midline cephalad-caudal osteotomy is done proximal to the S-2 pedicle at the S1–2 disc space.

After the S-2 nerves are dissected lateral to the edge of the chordoma, the S-2 pedicles are amputated to mobilize the S-2 nerves in the cephalad direction (Fig. 1C and D). Because preoperative planning confirmed no tumor within the S-2 pedicles, these pedicles can be removed piecemeal. This should still be well cephalad to the tumor based on the preoperative MR images. After the S-2 pedicles are removed flush to the sacrum, the lateral attachment of the sacrum to the ilium prevents dorsal rotation of the chordoma. Again, because of confirmation that no tumor has violated this region, the lateral aspect of the sacrum can be divided, just lateral to the S-2 pedicle and the S1–2 disc. We use a high-speed matchstick-type bur or a sagittal saw to perform this step. The medial portion of the sacrum is separated from the lateral portion of the sacrum attached to the ilium at S-2. This separation needs to be planned using preoperative imaging; the cut needs to be cephalad to the tumor at this level. Given that this osteotomy is performed cephalad above the chordoma, it should be well clear of the tumor laterally as well.

The main sacral amputation osteotomy is subsequently planned. The osteotomy is planned at the S1–2 disc space or at the S-2 pedicle. This is confirmed by using multiple lateral radiographs. The S-2 nerves are protected, and because the S-2 pedicles are now gone, the nerves can be gently retracted laterally and cephalad. The osteotomy can then be performed using either a sagittal saw or a matchstick-type bur. Extreme care must be taken to ensure that the angle of the osteotomy is parallel with the S1–2 disc space and not into the S1 vertebral body (Fig. 1C and D). Significant bony bleeding will be encountered, and this can be slowed with Gelfoam powder and thrombin slurry. The ventral mesorectum protects vital structures from the sagittal saw or bur.

The sacrum is now dissected laterally, eventually amputating the sacrospinous and sacrotuberous ligaments. Once these ligaments have been amputated, the distal portion of the sacrum loosens significantly, and it can be rotated dorsally, away from the S-2 nerves (Fig. 1D). The S-2 nerves at this point should be gently retracted cephalad, which gives clearance for the remainder of the sacrum to rotate past the nerves. This maneuver is what allows for the S-2 nerve preservation while removing the sacrum at the S-2 pedicle. The ano-coccygeal ligament and mesorectum are identified and dissected. The specimen can then be removed en bloc while preserving the proximal nerves (Video 1).

**Video 1.** Intraoperative video demonstrating the technique of S-2 nerve root preservation during S1–2 sacral amputation. Copyright Dean Chou. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

### Case Reports

**Case 1**

A 56-year-old man presented with a 6-month history of perianal pain, especially when defeating. Imaging revealed a large sacral mass, and examination of a needle biopsy specimen showed a chordoma (Fig. 2). The patient underwent an S-2 sacral amputation for resection of his sacral chordoma with preservation of bilateral S-2 nerve roots via anterior-posterior surgery (Figs. 3 and 4). Postoperatively, the patient had Grade 5/5 strength in the bilateral lower extremities and intact gluteal sensation. He initially did well, but 2 months after discharge, he presented to clinic with a pathological S-1 fracture. He underwent open reduction and internal fixation of sacral fracture with image-guided placement of sacral screws.

The patient was initially unable to void and used clean intermittent catheterization, but he improved to be able to void 20%–25% of bladder volume until becoming involved in a motor vehicle accident. He had postoperative constipation and required intermittent disimpaction. He had worsening of preoperative erectile dysfunction, but did achieve erection with the aid of medication and had intact ejaculation. His last follow-up was 6 years postoperatively, and he was disease free.

**Case 2**

This 61-year-old man presented with a 2-year history of low-back pain and difficulty urinating. Imaging revealed a sacral mass, and examination of a preoperative biopsy sample confirmed a diagnosis of chordoma. The patient underwent anterior-posterior surgery and S-2 sacral amputation with bilateral S-2 nerve root preservation.
He progressed well postoperatively, but he continued to suffer urinary retention and some fecal incontinence. On clinical follow-up 3 years after surgery, he stated that he could control most of his urination, although he sometimes dribbled. He could urinate without a catheter. He had bowel control but had occasional incontinence. He had no sexual function.

Case 3

A 58-year-old man presented with a several-month history of sacral pain. Imaging revealed a sacral mass, and he underwent an open biopsy performed by a general surgeon at an outside hospital. The patient was referred to our institution for definitive management after the diagnosis was established. He underwent en bloc tumor resection, S-2 sacrectomy with preservation of S-2 nerve roots, and ligation of distal nerve roots. Postoperatively, he had an areflexic bladder but could control stool.

On outpatient follow-up 3 years later, he was pain free. He had bladder sensation, but was unable to void urine without a catheter. He had bowel sensation and 90% bowel control function, but he did have intermittent bowel incontinence. He had sexual function with the aid of medication, and he could achieve ejaculation. He rated sexual function as approximately 50% of his presurgery baseline.

Case 4

A 65-year-old woman presented with a 9-year history of coccydynia, which increased in the months preceding admission. Computed tomography scans of the abdomen and pelvis revealed an 11-cm sacral mass that caused bony destruction extending into the gluteus. Chordoma was diagnosed by core needle biopsy. The patient underwent an anterior-posterior S-2 sacral amputation for resection of the sacral chordoma with bilateral S-2 nerve root preservation.

Of note, the patient had significant fecal incontinence prior to the surgery that persisted postoperatively. Her muscle strength was Grade 5/5. She was readmitted 3 months after surgery for a right sacroiliac joint enterocolcal osteomyelitis and ultimately discharged to home on intravenous ampicillin, with no need for surgical debridement.

Video urodynamic studies 11 and 16 months after surgery revealed intrinsic sphincter deficiency and significant stress incontinence, without detrusor overactivity. The patient required diapers for stool incontinence and catheterization for urinary incontinence. At her last clinical follow-up examination 3 years after surgery, she still experienced saddle anesthesia and postoperative incontinence.
Radical margins include the entire compartment of tumor origin. For soft-tissue sarcomas of the thigh, wider resections correlate with decreased recurrent rate: 50% for marginal (2 of 4 patients), 25% for wide (3 of 12 patients), and 4% for radical (1 of 24). These resections are all marginal resections because the tumor capsule is ultimately dissected away from the mesorectum. We advocate a wide dissection dorsally, rostrally, and laterally so as not to violate the tumor; however, without resecting the rectum, a wide margin is not possible ventrally. Preservation of S-2, at minimum, is generally considered necessary for maintaining some control of bowel, bladder, and sexual functions. Gunterberg and colleagues have noted that unilateral sacral root transection does not have significant functional consequences. A single unilateral S-2 nerve root may be sufficient for weak voluntary contraction of the external anal sphincter but not enough to cause an effective anal closure. Both sensation of rectal contents and reflexive contraction of the external anal sphincter with rectal distension require at least one functional S-3 root, but patients can live normal lives even in the absence of this. In a case series of 8 patients, Fujimura and colleagues found similar results. They showed that bilateral preservation of the S-2 nerve roots allowed for sufficient urinary, bowel, and sexual functions to maintain activities of daily living, while bilateral S-3 nerve root preservation was necessary for normal physiological function.

In a series of 22 patients with sacral tumors, Sar and Erlap reported postoperative deficits with varying levels of nerve sacrifice. All patients with total sacrectomies (that is, bilateral loss of S1–5 nerve roots) suffered permanent bowel and bladder dysfunction. Of 4 patients with subtotal sacrectomy involving preservation of S-1 and S-2 nerve roots bilaterally and the S-3 nerve root unilaterally, 2 patients suffered temporary urinary incontinence, resolving several months postoperative. Another patient with bilateral S-1 and S-2 nerve root preservation but sacrifice of all lower roots suffered only temporary urinary and fecal incontinence as well. In a similar study, Samson et al. showed that of 7 patients with spared bilateral S-2 nerve roots had normal bowel function and 4 of 7 had normal bladder function. In those with spared bilateral S-3 nerve roots, 4 of 5 had normal bowel and bladder function. However, in 4 patients in whom S-2 nerve roots were sacrificed, none had normal bowel and bladder function.

In a large retrospective case series of sacral resection for tumor, Todd et al. indicated that normal bowel and bowel function was not maintained in any patients when only S-1 nerve roots were preserved. Preservation of S-2 nerve roots led to normal bladder function in 25% and normal bowel function in 40%. If one S-3 root was spared, these results improved to 60% for bladder control and 67% for normal bowel control. When both S-3 roots were preserved, there was further improvement to 69% and 100% for normal bladder and bowel function, respectively. Bowel and bladder function in most patients with unilateral sacral nerve root sacrifice was normal: 89% retained bladder control and 87% bowel control.

In a series of 28 consecutive patients with chordoma treated between 1977 and 2000, Baratti et al. provided fur-

Discussion

Posterior transsacral approaches have long been described, dating back to Kraske’s 1885 description for removal of mid rectal tumors. The Kraske approach involves removal of the coccyx and part of the sacrum via division of the gluteal muscle insertions; the sacrotuberous and sacrospinous ligaments; and the lower sacral nerves. The procedure we have described relates to the classic Kraske procedure in the division of surrounding ligamentous insertions, but it was adapted for primary tumors involving the high sacrum. Although we do ultimately perform the Kraske approach, the order in which the steps are done is a little different. We first dissect the rostral portion and then finish with the caudal portion. This is because the osteotomies are done using a sagittal saw to allow the S-2 nerves to be left in the patient once the tumor is removed. The amount of tension the S-2 nerves can withstand is identified, and the cuts along the sacrum are made based on this. This is the reason that we first make the cephalad cuts, rotate the sacrum out, and then perform the Kraske approach after the distal sacrum is somewhat mobilized.

Enneking classically divided surgical resection into 1 of 4 types: intrallesional, marginal, wide, or radical, defined by their surgical margins. Margins of intrallesional resections include the neoplastic part of the tumor. Marginal margins contain the reactive tissue surrounding the tumor. Wide margins incorporate only healthy tissue.

Fig. 4. Case 1. Intraoperative photograph demonstrating preservation of bilateral S-2 nerve roots.
Conversion of a sacral amputation by S-2 nerve preservation

er the importance of the pelvic and paravertebral sympathetic nerves in S-2–4 nerves. In a 2005 series on sacrectomy for chordoma and other tu-
mours, Guo et al. found 25% bowel incontinence with intact bilateral S-3 nerve roots, 37.5% bowel incontinence with unilateral S-3 resection, and 75% bowel inconti-
nence with bilateral S-3 resection.6 However, interpretation of these results is confounded by the different types of tumor pathology (chordomas were not exclusively stud-
ed) and lack of mention of preoperative neurological status or follow-up time. The follow-up period is especially

important since bowel or bladder incontinence may be transient, as mentioned above. In a series of 30 patients

treated with sacrectomy for chordoma, Bergh et al. found that 80% of those with sacrifice of S-2 and caudal roots

had major bowel problems and 95% had major bladder problems.4 In patients with preserved S-2 roots bilateral-
ly, 50% had major bowel problems and 80% had major bladder problems. None of those with bilateral preserve-

ation of S-3 nerve roots suffered bowel problems.4

Bowel and bladder control are mediated by 3 sets of peripheral nerves involving the parasympathetic, sympa-
thetic, and somatic nervous systems. Pelvic parasympa-
thetic nerves arise at the sacral level of the spinal cord, in
the intermediolateral gray matter of S2–4.2,37 They promote

urination by contracting the bladder detrusor muscle and

relaxing the internal urethral sphincter. Similarly, they

promote defecation by control of colonic motility past the

plesic flexure, rectoanl smooth muscle contraction, and

relaxation of the internal anal sphincter.

Sympathetic nerves, located in the intermediolateral
cell column of T11–L1, control complementary functions.

Sympathetic outflow from the rostral lumbar spinal cord

provides noradrenergic excitatory and inhibitory input to

the bladder and urethra.7 Activation of sympathetic nerves

induces relaxation of the bladder body and contraction of

the bladder outlet and urethra, which leads to urine storage

in the bladder. The peripheral sympathetic pathways follow

a complex route that passes through the sympathetic chain
ganglia to the inferior mesenteric ganglia and then through the

hypogastric nerves to the pelvic ganglia.20

Voluntary control is mediated through the somatic

motor neurons in the sacral spinal cord. Onuf’s sphincter

motor nucleus, in the latter anterior horns of S2–4, is

responsible for contraction of the external urethral and

anal sphincter during the storage phase.29 More medially

located motor neurons in S2–4 innervate the pelvic floor

muscles.

Afferent axons in the pelvic, hypogastric, and pu-
dental nerves transmit information from the lower urin-
ary tract to the lumbosacral spinal cord.9 The primary

afferent neurons of the pelvic and pudendal nerves are

contained in sacral dorsal root ganglia. The central ax-

ons of the dorsal root ganglion neurons carry the sensory

information from the lower urinary tract to second-order

neurons in the spinal cord.32

Synergistic neural circuits play an important role in

bowel and bladder function and partially rely on sensory

afferents at S2–4. For example, the urinary sphincter must

relax before detrusor contraction occurs to allow for flow

and hence emptying of the bladder. Lesions above the

sacral micturition center can lead to detrusor overactivity

(overactive bladder) or detrusor-sphincter dysynergia.5

The sacral nerves are also important for the control of

sexual function. Sensation during sexual arousal passes

through the S2–4 afferents. Parasympathetic nerves in

S2–4 innervate Bartholin’s gland, lubricating the opening

of the vagina. Both parasympathetic nerves in S2–4 and

sympathetic nerves in T12–L2 cause erection in men with

some degree of individual variation in their relative con-

tribution. Sympathetic nerves in T12–L2 contract prox-

dal smooth muscle, while Onuf’s nucleus and somatic

motor neurons in S2–4 innervate distal striated muscle in

the passage of semen during ejaculation.5

An en bloc removal of chordoma with wide resec-
tions increases the disease-free interval.6,7,14,32 In a sys-

tematic multicenter review of 63 articles, Boriani et al. summarized the relevant data.7 The quality of the initial

resection was found to be critical to local tumor control,

regardless of whether patients underwent high-dose irra-

diation postoperatively.7 Of 153 chordoma patients, 100% of

patients with palliative debulking, 78% with intrale-

sional resections, 26% with marginal resections, and 25%

with wide resections went on to have a recurrence. Thus,

wide resections led to the best control, but still had a sig-

nificant failure rate.7

In one of the larger single-center spinal chordoma

series, Boriani et al. showed that only patients in the mar-

gin-free en bloc resection group had disease-free survival

of more than 5 years.6 In a study of 27 patients treated for

sacral chordoma from 1954 to 1994, York et al. argued

that time to recurrence is an appropriate metric for judg-

ing treatment.32 They reported an 8-month disease-free

interval for subtotal resection compared with 2.3 years

for radical resection. In addition, conventional radiation

therapy added more than 17 months to the disease-free

interval for subtotal resection.32

Yamazaki et al. found that open biopsy or partial

resection increased the risk of recurrence.8 In the study

by Baratti et al., all patients without clean margins and

no postoperative radiation therapy had disease progres-
sion; however, only 55% of those with clear margins had

disease progression. Of note, only 50% of those with in-
adquate margins but who underwent postoperative irra-
diation had disease progression, a finding that shows the

importance of postoperative radiotherapy when complete

resection is not possible.3 In the study by Bergh et al., 81%

(13 of 16) of patients had recurrence after intralesional

surgery, whereas only 17% (4 of 23) of chordoma patients

had recurrence when the resection involved wide margins.
Seventy-four percent of those with wide surgical margins were disease free at a mean follow-up of 6.4 years.\(^4\)

With regard to our study, its main emphasis was to serve as a technical note and not necessarily a long-term outcome report. The small number of patients (n = 4) is simply insufficient to make any broad statements about a disease-free survival interval after chordoma treatment. However, our 25% rate of maintaining bowel and bladder function with S-2 preservation is consistent with other studies. Rao et al. have described the technique for sacral amputation below S-3.\(^6\) However, their technical note detailed the sacral amputation technique and not nerve preservation per se. Our technical note focuses on the technique of preserving the S-2 nerve roots while still performing a sacral amputation at S-2. The goal of such nerve preservation is to decrease the morbidity of an S-2 amputation and convert it from a high to a midsacral amputation. The concept of following the nerve from a dorsal aspect to a ventrolateral aspect, allowing for the dorsal rotation of the sacrum, may be the most difficult to grasp, given the rarity of these procedures. Hopefully, with the video, illustrations, and intraoperative photographs, this paper can help illustrate the technical nuances of nerve preservation while still performing the osteotomy at the site of nerve root exit.

Conclusions

If the need to achieve a wide surgical margin requires an S-2 sacral amputation, the S-2 nerve roots can be preserved if preoperative imaging shows no chordoma at the level of the pedicle. Preserving the S-2 nerve roots converts the operation from a high sacral to a midsacral amputation and hopefully decreases the morbidity of partial sacrectomy for chordoma.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Chou. Acquisition of data: Chou. Analysis and interpretation of data: Chou, Saigal, Deng. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chou. Statistical analysis: Saigal. Administrative/technical/material support: Chou, Saigal. Study supervision: Chou.

References

Conversion of a sacral amputation by S-2 nerve preservation


Supplemental online information:

Address correspondence to: Dean Chou, M.D., Department of Neurological Surgery, University of California, San Francisco, 505 Parnassus Ave., Box 0112, San Francisco, CA 94143-0112. email: choud@neurosurg.ucsf.edu.