Posterior-Only Approach for En Bloc Sacrectomy: Clinical Outcomes in 36 Consecutive Patients

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Received, October 27, 2011.
Accepted, April 11, 2012.
Published Online, May 7, 2012.

BACKGROUND: En bloc resection of primary sacral tumors has a demonstrated survival benefit. Total and high sacral amputations are traditionally performed by using a staged anterior and subsequent posterior approach. However, we have found that en bloc resection and biomechanical reconstruction of the spinal column is possible from a posterior-only approach in many cases.

OBJECTIVE: To assess our series of posterior-only sacrectomies, emphasizing postoperative complications and overall surgical and oncologic outcome.

METHODS: Sixty-nine consecutive patients underwent sacral resections for tumor at our institution between 2004 and 2009. Medical records of all patients were reviewed, and patients were excluded if they had an intentional intralesional resection, hemipelvectomy, or a previous operation. The records of the resulting 36 consecutive patients who underwent primary posterior-only en bloc sacral resections were retrospectively reviewed.

RESULTS: Of the posterior-only patients, all underwent midline posterior approaches for en bloc sacral resection. Sacral amputation was defined by the by sacral root preservation: total (2 cases), high (8 cases), middle (9 cases), low (12 cases), and distal (5 cases). Chordoma was the most common tumor type (30 cases), and surgical margins were marginal in 34 cases and contaminated in 2. Overall, there were 13 complications, including 9 wound infections/revisions. The extent of sacrectomy, and thus the extent of roots sacrificed, correlated with functional outcome.

CONCLUSION: It may be possible to perform a posterior-only approach to en bloc sacral resections/reconstructions in patients with tumors that do not extend beyond the lumbosacral junction or invade the bowel requiring bowel resection and diversion.

KEY WORDS: Chordoma, En bloc resection, Posterior-only approach, Sacrectomy

Neurosurgery 71:357–364, 2012 DOI: 10.1227/NEU.0b013e31825d01d4 www.neurosurgery-online.com

En bloc resection of primary sacral tumors has a demonstrated long-term disease-free survival benefit.[1-11] The most important predictor of local recurrence and survival in chordomas and chondrosarcomas, which are the most common malignant primary sacral tumors, is a negative surgical margin.[1,2,5,12-15] Locally invasive and prone to late metastases, these tumors are resistant to conventional radiation[16-18] and chemotherapy.[16,17,19] Aggressive en bloc resection with negative margins, a technique pioneered by Roy-Camille for musculoskeletal tumors, offers the best option with longer progression-free survival than intralesional resection for these aggressive tumors.[1,2,20]

ABBREVIATIONS: GLM, gluteus maximus myocutaneous; **LOS,** length of stay; **MPNST,** malignant peripheral nerve sheath tumor; **NED,** no evidence of disease; **XRT,** external beam radiation

Traditionally, en bloc total and high sacrectomies have been performed by using a combined anterior and posterior approach. The anterior approach allows the surgeon to dissect the rectum and internal iliac vessels away from the anterior surface of the sacrum. It also allows a rectus flap to be harvested for closure of the anticipated surgical defect. The posterior approach is then used to remove the tumor and address iatrogenic instability. However, including the anterior component of the procedure necessitates a separate procedure, abdominal incision, and access surgeon. Additionally, devascularizing the surrounding

tissues by tying off the iliac vessels may result in eventual wound complications.

Recently, the posterior-only approach to sacrectomy, including high and total, has been adopted by our institution.[21] There are 3 factors that preclude attempting a posterior-only approach: tumor invasion of the rectum requiring rectal diversion and resection; tumor extending caudally above the L5S1 disc space making posterior-only osteotomies difficult; and involvement of the iliac vessels. This report reviews the data from our surgical series of all en bloc sacrectomies performed through a posterior-only approach at our institution.

CLINICAL MATERIALS AND METHODS

With institutional review board approval, the Johns Hopkins University Hospital database was searched for patients having undergone posterior en bloc sacrectomy. All operations were performed by senior surgeons (Z.L.G. and J.P.W.). Retrospective data on preoperative patient characteristics, tumor, imaging, and functional outcome were collected via comprehensive chart review.

Preoperative demographic, tumor, and treatment data were collected. This included disease extent, type of diagnostic biopsy procedure, and preoperative treatment including radiation and chemotherapy. Preoperative imaging, including plain radiographs, computed tomography, and magnetic resonance imaging (MRI), was recorded. Preoperative evaluation including history, physical and neurologic examination, and functional status was documented. Pre- and postoperative functional status was assessed by using the modified Biagini scale (Table 1).[2,22]

Surgical data included level of bone resection, number and level of nerve roots sacrificed, surgical margins, estimated blood loss, total operative time, method of lumbosacral stabilization (if required), and method of closure. For assessment of stabilization requirements, level of bony resection was noted. However, because the functional consequences of nerve root sacrifice outweigh the consequences of bony osteotomy level, sacral amputation is classified based on the level of highest root sacrificed, as defined by Fourney et al (Table 2).[2]

The posterior approach to en bloc sacral resections and reconstruction has been described elsewhere.[2,23] In brief, the technique involves a midline posterior approach coupled with bilateral iliac osteotomies and midline osteotomy or discectomy and transperineal dissection, allowing delivery of the en bloc sacral specimen. In total sacrectomies, in which the S1 body is disrupted, lumbopelvic reconstruction is also required.[24-26]

In all cases, an attempt was made to deliver the specimen "en bloc": in 1 piece without disrupting the tumor and with a margin of healthy surrounding tissue.[27] Margins were defined by intraoperative findings demonstrating known violation, pathologic findings, and histology. Margins were defined as wide, if there was a margin of unviolated healthy tissue around the tumor; marginal, if the surgeon dissected along the reactive tissue or "pseudocapsule" surrounding the tumor and there was no evidence of capsular breach on pathologic examination of the specimen; or contaminated, if at any point the pseudocapsule was violated, the dissection became intralesional, or tumor contents were spilled. Wide margins are not possible if the tumor invades the sacral canal or the prerectal space, because critical structures would be sacrificed.

Patient outcomes, postoperative course, and length of stay (LOS) were recorded. This included neurologic and functional status as described above. Additionally, early (within 30 days of surgery) and late (greater than 30 days from surgery) complications were recorded and characterized as major (those that prolonged LOS) or minor (did not significantly alter LOS). Patients were evaluated at 1, 3, 6, and 12 months and every 6 months thereafter, with spinopelvic imaging every 3 to 6 months.

Spearman rank correlation was used to determine the statistical dependence between functional sacrectomy classification and estimated blood loss, length of procedure, and LOS. Spearman rank correlation was also calculated for LOS and rostral osteotomy site. A Kaplan-Meier survival curve was generated to visually represent patient attrition despite lack of valid comparison population.

RESULTS

Patient Population

Patients were identified who underwent primary posterior-only en bloc sacral resections at Johns Hopkins University Hospital between 2004 and 2009. During this period, 67 consecutive patients underwent sacral resections for tumor. Medical records of all 67 patients were reviewed. Patients were excluded from this study if they had an intentional intralesional resection (12), had

TABLE 1. Classification of Neurological Function After Resection of the Sacrum[a]

Function	Score	Description
Motor	0	Normal or mild deficit not requiring the help of external support for motion and common activities
	1	Deficits requiring the help of external support for walking and common activities
	2	Deficits that make walking impossible
Bladder	0	Normal
	1	Feels stimulus to micturate and has limited continence at varying times and quantities of urine and/or has increase in postmicturition vesicle residual and/or urinary loss in conditions of stress
	2	Does not feel stimulus to micturate and/or is completely incontinent
Bowel	0	Normal
	1	Feels stimulus to defecate and is incontinent when feces are soft or under stress
	2	Does not feel stimulus to defecate and/or is completely incontinent

[a]Adapted from Biagini, Ruggieri, Mercuri et al, 1997 and Fourney et al.[2] Pre- and postoperative functional status was assessed by using the modified Biagini scale.[2,22]

TABLE 2. Classification of en Bloc Sacral Tumor Resections[a,b]

Sacrectomy Type	Nerve Roots Sacrificed	Lumbopelvic Reconstruction	Flap Closure
Total	Bilateral S1 and below	LPF	VRAM
	Bilateral or unilateral L5		
High	Bilateral S2 and below	None	VRAM
	Unilateral S1 and S2 and below		
Middle	Bilateral S3 and below	None	Local
Low	Bilateral S4 and below	None	Local
Distal	S4 and above preserved	None	Local

[a]LPF, lumbopelvic flap; VRAM, vertical rectus abdominis myocutaneous.
[b]Adapted from Fourney et al.[2]

a combined anterior-posterior approach (8), hemipelvectomy (5), were previously operated on (5), or were aborted because of difficulties with anesthetic induction (1). The records of the resulting 36 consecutive patients who underwent primary posterior-only en bloc sacral resections were retrospectively reviewed.

The average patient age of the study population was 50.3 (range, 12-83), and 18 patients were male (50%) and 18 were female (Table 3). Preoperative diagnosis was made by fine-needle biopsy in 32 cases (89%), open biopsy in 3 cases (8%), and imaging alone in the final case of epidermoid. The most frequent tumor type was chordoma (n = 30; 81%) followed by osteoblastoma (n = 2), sarcoma (n = 1), epidermoid (n = 1), hemangioma (n = 1), and malignant peripheral nerve sheath tumor (MPNST; n = 1).

Four patients were treated preoperatively. Two patients underwent external beam radiation (XRT; osteoblastoma, sarcoma), and 1 patient underwent proton beam radiotherapy (chordoma). One patient underwent preoperative embolization for hemangioma. No patient underwent preoperative chemotherapy.

TABLE 3. Demographic Data[a]

Variable	Number (n = 36)
Sex	
Male	18
Female	18
Age, y	50.6 (range, 12-83)
Male	43.3 (range, 12-63)
Female	57.8 (range, 24-83)
Preoperative diagnostic test	
None	1
Fine-needle biopsy	32
Open biopsy	3
Diagnosis	
Chordoma	30
Osteoblastoma	2
Sacroma	1
Hemangioma	1
MPNST	1
Epidermoid	1
Preoperative treatment	
External bean radiation	2
Proton beam radiation	1
Chemotherapy	0
Angiographic embolization	1
Comorbidities	
Cardiac (hypertension)	4
Other cancer diagnosis	4
Diabetes	2
Rheumatologic disease	2
Respiratory	1

[a]MPNST, malignant peripheral nerve sheath tumor.

Surgical Approach

During the past 8 years, 36 patients underwent posterior-only midline sacral amputations for tumor including 1 patient who had a unilateral excision of the sacroiliac joint. As defined by Fourney et al, sacrectomies are classified by the highest level of root sacrificed, and thus provide an estimate of functional status (Table 2). Thus, in this series, the surgical classification of the 36 patients that underwent en bloc sacrectomy was 2 total, 8 high, 9 middle, 12 low, and 5 distal. Of the 6 nonchordoma patients, 2 underwent high sacrectomy (osteoblastoma and MPNST), 3 underwent low sacrectomy (osteoblastoma, sarcoma, and hemangioma), and 1 underwent distal sacrectomy (epidermoid). Surgical margins were marginal in 34 and contaminated in 2.

However, this functional definition of sacrectomy type does not directly correlate with osteotomy level, because uninvolved roots may be preserved below the bone resection level. Thus, of the 36 patients in the series, 4 had osteotomies at the L5S1 level necessitating lumbopelvic reconstruction. This was accomplished by using an L3 to iliac construct and allograft femur reconstruction of the pelvic ring as outlined in our previous article.[21] The remaining patients received ostomies at the S1S2 junction (9), S2S3 junction (17), S3S4 junction (3), and below S4 (3). Complex wound closures and management of wound complications were usually undertaken in collaboration with plastic surgery.

Surgical Outcome

Length of procedure was significantly associated with more rostral sacrectomy classification based on nerve root sacrifice (Spearman rank order correlation coefficient: 0.561; $P = .001$). Estimated blood loss was also significantly associated with more rostral sacrectomy classification (Spearman rank order correlation coefficient: 0.753; $P < .001$).

Of the 36 patients, 13 (36%) experienced perioperative complications (Table 4). One patient had a major intraoperative complication during total sacrectomy because of a bowel injury, resulting in multiple wound revisions for infection and percutaneous endoscopic gastrostomy tube placement for nutritional support during the lengthy recovery period. Most complications (77%) revealed themselves within 30 days, with only 3 late complications, all of which were wound related. Nine patients had wound-related complications (25%). Seven (19.4%) required

wound revision or washout, including 4 of the 10 patients who underwent total or high sacrectomies (40%).

Overall, outcome based on modified Biagini score (Table 1) is outlined in Table 5. Ambulatory function was preserved in 95% of patients, with 1 patient requiring an assist device following high sacrectomy, and 1 patient was nonambulatory following a complicated recovery after total sacrectomy. Bowel and bladder function was correlated with nerve root sacrifice as expected, with 2 patients maintaining normal continence following total or high sacrectomies. Following surgery, overall pain medication requirements also lessened.

Length of stay was significantly associated with the extent of surgery as based on rostral osteotomy location (Spearman rank order correlation coefficient: 0.58; $P < .001$) and functional classification (Spearman rank order correlation coefficient: 0.56; $P < .001$). At time of dismissal, 1 patient was discharged to a short-term nursing facility (total sacrectomy), 18 were discharged to a rehabilitation unit (7 high, 8 mid, 2 low), and 17 were discharged to home (1 total, 1 high, 1 mid, 10 low, 1 distal).

Long-term Disease-Based Outcome

One patient with chordoma was lost to follow-up after discharge from the hospital and a second patient with epidermoid was not followed up. For the remaining 34 patients, average follow-up was 47.3 months (range, 12-86 months). Of these remaining patients, one died of his MPNST at 25 months. Average follow-up for patients alive with evidence of disease was 52.0 months (range, 12-86 months). This includes 1 patient who had a complicated hospital course following total sacrectomy for chordoma, who developed a local recurrence and elected palliative care at 12 months. Average follow-up for patients with no evidence of disease was 38.4 months (range, 12-83 months). Of the 30 patients with chordoma, the median follow-up was 45 months (range, 12-83), with a median time to recurrence in 6 patients of 23.3 months (range, 2-70). One patient died of disease at 19 months. Of note, of the patients with contaminated surgical margins (chordoma), one developed scalp metastases 24 months after surgery, and the other had no evidence of disease at 41 months following chemotherapy and radiation. All patients who had open biopsies before en bloc resection for chordoma had recurrences, in all cases locally and, in 1 case, distantly. Excluding patients who underwent open biopsy, median follow-up was 43 months (range, 12-83) and median recurrence was 27 months (range, 9-70; n = 3).

Postoperatively, 11 patients underwent adjuvant therapy. One patient with chordoma had adjuvant chemotherapy and had no evidence of disease (NED) at 50 months. Ten patients had adjuvant radiation therapy, including 6 who underwent proton beam (chordoma) and 4 who underwent XRT (3 chordoma, 1 MPNST). Of the 6 who underwent proton beam therapy, 4 had no NED, and 2 were alive with disease, including 1 with distant metastases. Of the 4 patients with adjuvant XRT, 2 had NED and 1 had local recurrence of chordoma. The final patient, also treated with chemotherapy as noted above, died of MPNST.

DISCUSSION

The first en bloc sacrectomy was described in 1952.[28] However, aside from mention in a few small series and case reports,[10,29,30] the technique did not gain a following until Tomita published a article outlining the technique of total en bloc sacrectomy.[31] Traditionally, total and high sacrectomies have been performed via combined anterior-posterior approach, although many institutions perform middle, low, and distal sacrectomies through a posterior-only approach. The advantage to the combined technique is that it allows excellent control of the rectum and vasculature anterior to the sacrum, and can be used to obtain a vascularized rectus abdominus or omental flap to aid in closure during the second, posterior stage. However, this approach has the added morbidity of a laparotomy. Our institution has preferred to extend the indications for the posterior-only approach to all en bloc sacrectomies with an anterior osteotomy at or below the L5S1 disc space and without tumor invading the rectum or anterior vasculature.

The primary goal of any en bloc resection is the removal of the tumor in 1 unviolated piece. Thus, the reduced morbidity of a posterior-only approach to en bloc sacrectomy is only a valid accomplishment if tumor margins can truly be preserved. It is

TABLE 4. Complications[a]

Sacrectomy Type	Total, n (%)	Early (<30 d), n (%)	Late (>30 d), n (%)	Minor, n (%)	Major, n (%)	Wound, n (%)	Other
Total (n = 2)	1 (50)	1 (50)			1 (50)	1 (50)	DVT (1), PEG (1)
High (n = 8)	5 (65)	4 (50)	1 (12)	2 (25)	3 (36)	3 (36)	UE DVT (1), hypoNa (1)
Middle (n = 9)	4 (44)	3 (33)	1 (11)	2 (22)	2 (22)	2 (22)	UTI (1), ileus (1)
Low (n = 12)	2 (17)	1 (9)	1 (9)		2 (17)	2 (17)	
Distal (n = 5)	1 (20)	1 (20)		1 (20)		1 (20)	Wound vac
All (n = 36)	**13 (36)**	**10 (28)**	**3 (9)**	**5 (14)**	**8 (22)**	**9 (25)**	

[a]DVT, deep vein thrombosis; PEG, percutaneous endoscopic gastrostomy; UE, upper extremity; hypoNa, hyponatremia; wound vac, wound vacuum-assisted closure; UTI, urinary tract infection.

TABLE 5. Pre- and Postoperative Neurological Functional Outcome Based on Modified Biagini Score[a]

	Total (n = 2), n (%)		High (n = 8), n (%)		Middle (n = 9), n (%)		Low (n = 12), n (%)[b]		Distal (n = 5), n (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ambulation										
0 (normal/mild)	2 (100)	1 (50)	8 (100)	7 (88)	9 (100)	9 (100)	12 (100)	11 (100)	5 (100)	5 (100)
1 (needs device)				1 (12)						
2 (no ambulation)		1 (50)								
Bladder function										
0 (normal)			2 (25)		6 (67)	3 (33)	11 (92)	7 (64)	4 (80)	4 (80)
1 (mild-moderate)	2 (100)		5 (63)	1 (12)	2 (22)	4 (45)	1 (12)	4 (36)		
2 (incontinent)		2 (100)	1 (12)	7 (88)	1 (11)	2 (22)				
Bowel function										
0 (normal)			2 (25)		6 (67)	4 (45)	11 (92)	9 (82)	4 (80)	5 (100)
1 (mild-moderate)	2 (100)		5 (63)	1 (12)	2 (22)	3 (33)	1 (12)	2 (18)		
2 (incontinent)		2 (100)	1 (11)	7 (88)	1 (11)	2 (22)			1 (20)	
Pain										
None		1 (50)	1 (12)	6 (75)		5 (56)	3 (25)	9 (82)	1 (20)	4 (80)
Requires NSAIDs			5 (63)		3 (33)	1 (11)	3 (25)	2 (12)		
requires narcotics	2 (100)	1 (50)	2 (25)	2 (25)	6 (67)	3 (33)	6 (50)		4 (80)	1 (20)

[a]NSAIDs, nonsteroidal anti-inflammatory drugs.
[b]One patient lost to follow-up.

accepted that the optimum treatment for prolonged survival, delayed time to recurrence, and possible cure of sacral chordoma is en bloc resection.[1-11] Because the patients in our series underwent posterior-only en bloc sacrectomies for a wide range of tumor pathologies, each with its own natural history, comparison with other studies with regard to overall survival and tumor recurrence is difficult. However, 30 of these patients had chordoma, the most common and well-studied primary sacral tumor. Thus, the efficacy of the posterior en bloc technique is best explored studying this subset of patients.

Unfortunately, because these are rare tumors, most patient series have small numbers of patients. A large study of en bloc sacrectomy that included 27 patients (including 16 chordomas) was published by the senior surgeon of this article, and contains a mix of posterior-only and anterior-posterior resections. Based on the method of closure, 3 combined anterior/posterior approach cases were reported, all of whom developed recurrence, including 1 patient who died of his disease. Of the 13 posterior-only patients, 5 developed recurrence (38%), including one with distant metastasis.[2] More recently, in a series of 6 previously unoperated sacral chordoma patients operated on by using a combined approach with negative margins, none developed a recurrence, including 3 that were followed for over 5 years.[23] In comparison with these approaches, of the 30 chordoma patients in our series, 6 (20%) developed recurrence or distant metastases. Attrition due to follow-up and recurrence are represented by a Kaplan-Meier curve (Table 6 and Figure).[32] Thus, despite approaching the tumor from a posterior-only trajectory, the long-term outcome of these patients has not been compromised. Longer-term data are required for definitive survival comparisons, and our study is limited by the fact that only 5 patients were followed beyond 2 years owing to their more recent surgeries.

In some studies, the data become murky, because studies span an era in which formal en bloc resection was not in favor, and the surgical goal was to obtain negative tissue margins. Although some studies include en bloc resections, this is not uniform across these series. The largest of "negative margin series" demonstrated a 54% recurrence rate in 28 patients who underwent "radical" tumor resection, although margins in this case were not fully defined.[15] Another study of chordoma resection included 21 patients treated with "adequate" margins, although this did not specify an en bloc technique. Of these 21 patients, one developed local recurrence. It was noted that neither approach (17 combined, 4 posterior-only), nor extent of sacrectomy affected recurrence or survival. No posterior-only sacrectomy was attempted for high or total sacrectomies.[12] Similarly, another study spanning 15 years demonstrated a 33% recurrence rate in 27 patients who underwent complete resection with "wide margins."[33] Finally, Hulen et al presented a series of 16 chordomas, all in S2 or above, resected through an anterior-posterior approach. Although the surgical

TABLE 6. Kaplan-Meier Time to Recurrence in Chordoma subset

	Time (months)						
	0	2	9	12	23	24	70
No. at risk	30	29	29	28	21	20	5
No. disease free	30	28	27	24	16	15	4
Estimated survival probability	1.0	.96	.92	.91	.89	.78	.67

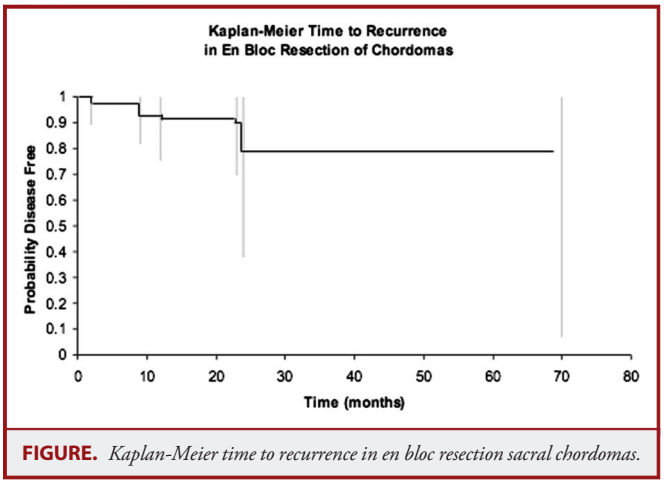

FIGURE. *Kaplan-Meier time to recurrence in en bloc resection sacral chordomas.*

technique is outlined, it is unclear if a true "en bloc" resection was performed, or if a piecemeal resection occurred with the goal of negative margins. In this series, 9 of the 16 patients developed recurrence or metastases, including all 3 patients with known contaminated margins, and 3 of the 4 patients with marginal margins.[13]

Although these studies underscore the need to achieve negative margins, a consistent definition of negative margins has been elusive in the sacrectomy literature. Enneking originally created a 4-level classification of surgical margins in musculoskeletal sarcomas: (1) intralesional: piecemeal debulking or curettage, (2) marginal: lesion shelled out leaving pseudocapsule or reactive zone, (3) wide: intracompartmental en bloc, and (4) radical: extracompartmental excision.[34] However, unlike musculoskeletal tumors in which major amputations are possible, critical structures including the rectum, cauda equina, and iliac vessels preclude more than a "marginal" resection by this definition. Thus, we have chosen to classify all margins as either "contaminated" (gross intraoperative violation of the specimen, or positive margins at pathologic analysis) or "marginal" (in which none of the preceding factors occurred). Because of the proximity of unresected critical structures, we do not feel that "wide" margins can truly be applied in en bloc sacrectomy procedures.

Tumor violation must not only be taken into account intraoperatively, but also during the preoperative period. It is important to note that all 3 patients with chordoma who underwent open biopsy developed recurrence. Although this is a small sample size, it is half of the patients with chordoma that ultimately had recurrent disease. Of the other 3 patients, one underwent an intralesional resection. The remaining 2 chordoma patients with recurrence were classified as en bloc resection with negative margins. Thus, of the 25 chordoma patients that underwent needle biopsy followed by en bloc resection with negative margins, 2 developed recurrence (8%). However, it is notable that the other patient with an intralesional resection has no evidence of disease at 41 months, having been treated postoperatively with XRT and chemotherapy. Two other patients developed recurrence, one of whom died of MPNST and one who was alive with recurrent osteoblastoma at 43 months. Thus, we feel strongly that physicians should not proceed beyond a needle-guided biopsy unless definitive management is offered if chordoma or other primary tumor is suspected. Additionally, it is wise to consider resection of the biopsy needle tract in the operative plan to avoid contamination.

Wound healing following en bloc resection of sacral tumors has proven challenging. Techniques for repairing the resultant soft tissue defects have included mesh,[35] omental mobilization,[36] myocutaneous flaps,[37] and vascularized free flaps.[38] With the use of a combined approach, a vertical rectus abdominis myocutaneous flap or omental flap can be harvested during the anterior approach and fixed into place following tumor resection at the close of the posterior approach. However, such techniques are not possible by using a posterior-only approach. In our practice, we have used a combination of human acellular dermal matrix and gluteus maximus myocutaneous (GLM) flaps to repair large defects, and local tissue to repair smaller defects.[39] The use of a GLM flap has been explored by other groups and has been advocated because of its proximity to the sacrum, robust blood supply, and large size.[40,41] Of note, by performing a posterior-only approach, the hypogastric and gluteal arteries are preserved, ensuring a robust blood supply to the GLM flap that may be compromised in the circumferential approach.

In this series of both GLM and local tissue closures, 25% of patients developed wound-related complications, including 19.4% that required revision surgery. Previously, we reported a wound revision rate of 14.7% in posterior incisions closed with GLM flaps[39]; however, this study includes 1 additional patient who underwent high sacrectomy and required a wound revision. Other studies have reported infection rates of up to 66.7% with a GLM flap.[41] The risk of infection increases substantially in patients who have previously undergone lumbosacral surgery. In a series in which 94% of patients were operated on from the posterior approach, but no reoperations were considered, the infection rate was 39%.[42] Other patient series in which the combined approach was used report infection rates ranging from 25% to 45%.[1,33,43] Finally, because of the posterior surgical site location, diverting colostomies have previously been advocated to protect the healing incision from fecal contamination in the postoperative period, especially in cases where bowel and bladder incontinence are expected because of anticipated sacral nerve root sacrifice. No patient in this series underwent preoperative or postoperative diversion. Although it is not possible to compare these patient cohorts directly, it appears that the posterior-only approach does not increase the risk of infection or wound complications.

Although the posterior-only approach allows the patient to avoid a laparotomy, access is more challenging to the structures anterior to the sacrum. Whereas tumor invasion into the presacral fascia, rectum, and iliac vessels precludes the use of the

posterior-only approach, we have found that we are able to safely dissect the tumor away from these structures if invasion has not occurred. Early in this series, 1 patient undergoing a total sacrectomy did have an intraoperative bowel injury and postoperative infection. This patient had a difficult postoperative course and was dismissed to a short-term nursing facility and ultimately elected to pursue palliative care.

Although this is the largest series of posterior-only sacrectomies, there are several limitations with this study. Overall study size and the lack of an anterior-posterior approach comparison cohort in this retrospective study make definitive conclusions impossible. However, the ability to successfully perform en bloc sacral tumor resections without undue morbidity from a posterior-only approach should warrant further study.

CONCLUSION

A posterior-only approach to en bloc sacral resections/reconstructions can be safely performed in patients with tumors that do not extend beyond the lumbosacral junction or invade the bowel, requiring bowel resection and diversion.

Disclosures

Dr Bydon is a research grant recipient for DePuy Spine; Dr Gokaslan has grant and research support from AO North America, AO Spine, NREF, DePuy, OREF, is a self-managed stock shareholder for US Spine and Spinal Kinetics, and has honoraria with AO Foundation, AANS, DePuy and NREF. The other authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

In this article, the authors undertake a retrospective review of their series of posterior-only sacral amputations for attempted en bloc resection of a neoplasm. Thirty-six patients were included in the analysis. The objective was to evaluate complications and overall surgical and oncologic outcome. The alternative surgical approach is a combined anterior and posterior approach typically in a staged fashion. Unfortunately, given the small numbers available (this being the largest series of posterior-only cases in the literature), a satisfactory comparison of these 2 techniques is unlikely. This article provides insight into the indications, expected morbidity, and feasibility of the posterior-only option. The article emphasizes the desire to achieve en bloc resection of these tumors (particularly chordomas) and that open biopsy or subtotal resection should be avoided. Maximum surgical management with or without previous needle biopsy is most desirable to reduce recurrence rate.

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This case series reports on 36 patients undergoing posterior-only en bloc sacrectomy for primary sacral tumor resection, the largest series to date. This approach, previously described by the authors (21), is advocated for a subset of patients to avoid the morbidity of an anterior approach. The authors have vast experience in surgical approach to these lesions to maximize resection and minimize morbidity. The value of this review is not only in demonstrating the efficacy and safety of the procedure, but in the call for a more uniform definition of surgical margins for primary bony tumors of the spine. The authors have aptly discussed the limitations, including the lack of a comparison group that limits the ability to make definitive conclusions. In today's environment of cost-effective treatment options, future study directions may include a comparative analysis utilizing standardized definitions.

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This article reports the currently largest series of patients (n = 36) who underwent a "posterior-only" surgical approach for attempted en bloc sacrectomy. The predominant tumor type was chordoma (30 patients), with a variety of malignant and benign histologies comprising the remaining 6 tumors. The authors demonstrate that a "posterior-only" approach for en bloc sacral resection is technically feasible, albeit with a significant complication rate (36%). The most predominant complication is poor wound healing or infection. Complication rate and ultimate neurologic function correlate, not surprisingly, with extent of sacral resection and the cephalad extent of sacral nerve roots sacrificed, respectively.

The authors point out that morbidity and outcome analysis comparing the "posterior-alone" and "combined" anterior-posterior sacrectomy approaches is difficult because of the relative novelty of these surgical approaches, scarcity of primary sacral tumors, and lack of reporting uniformity or completeness in the literature. However, the authors' data suggest that, in experienced hands, a "posterior-only" approach does not increase surgical morbidity or compromise tumor control.

Although this report represents an evolution of the surgical approach toward a difficult set of histologies located in a challenging anatomical setting, it also reconfirms what we already know: that if sacral chordoma is suspected, unnecessary tumor violation, be it by open biopsy or intentional intralesional surgery, predicts a less than optimal surgical outcome.

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