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ORIGINAL ARTICLE

Risk Factors for Blood Loss During Sacral Tumor Resection

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Abstract Extensive hemorrhage is a serious complication during sacral tumor resection. Identifying the risk factors predicting the possibility of extensive hemorrhage would be important to predict which patients would need large amounts of transfused blood intraoperatively and postoperatively and which patients would need blood control by vascular occlusion. We retrospectively reviewed 173 patients who underwent sacral tumor resection performed at our institute between 2003 and 2007. Patients with an estimated total blood loss greater than 3000 mL were classified as having a large amount of blood loss. Sixty-nine (39.88%) patients had blood loss greater than 3000 mL. Male gender, excessive tumor blood supply, tumors involving the S2 body and cephalad to the S2 body, tumor volume greater than 200 cm^3, aorta occlusion, surgical approach, reconstruction, and operative time were associated with a large amount of blood loss. Tumors cephalad to the S2-S3 disc space (odds ratio, 3.840), tumor volume greater than 200 cm^3 (odds ratio, 3.381), and excessive blood supply (odds ratio, 2.281) independently predicted a large amount of blood loss. Sacral tumors that invaded cephalad to the S2-S3 disc space with a volume greater than 200 cm^3 and an excessive blood supply were likely to have a large amount of blood loss during resection.
Level of Evidence: Level III, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Primary tumors of the sacrum are rare, accounting for 1% to 4.3% of all bone tumors [23]. Metastatic tumors that involve the sacrum are more common than primary lesions [21]. The sacrum also can be affected by tumors arising from a neural origin or adjacent locally invasive lesions. Most of the primary tumors of the sacrum are benign, aggressive lesions such as aneurysmal bone cysts, osteoblastomas, and giant cell tumors or low-grade malignancies such as chordomas [22]. Malignant lesions of the sacrum, including chondrosarcomas, osteosarcomas, myelomas, and Ewing's sarcomas, occur frequently [21].

Although some metastatic lesions are treated palliatively with radiation, most sacral tumors are relatively resistant to radiotherapy and chemotherapy [9, 10] and need surgical resection. En bloc resection with adequate margins is the only effective method to achieve long-term disease control or cure [3]. Because of the complex anatomy of the sacral region and the typically large tumor size at presentation, aggressive resections are technically difficult. Wound infections, neurologic deficits, blood loss, pelvic instability, and cerebrospinal fluid leakage are the main complications of sacrectomy [9, 21, 22, 25]. Among these complications, intraoperative and postoperative extensive hemorrhage is a major concern and may threaten the life of the patient and jeopardize the outcome of surgery.

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Each author certifies that his or her institution has approved the reporting of these cases and that all investigations were conducted in conformity with the ethical principles of research.

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Blood volume loss during sacral tumor resections varies from case to case. Among 29 reported cases with en bloc resections of sacral tumors, the median blood loss was 3.9 L (range, 0.1–37 L) [9]. In another study [16], the estimated blood loss of 10 procedures ranged between 400 and 7650 mL. Obviously, a wide variety of risk factors influence perioperative blood volume loss. For example, resection of massive sacral tumors always requires a longer operative time, most malignant neoplasms have an abundant blood vessel supply, and local recurrence or preoperative radiation distorts the normal anatomy; all of these factors may lead to a large amount of blood loss. The location of the tumor is another factor determining blood loss. In one study [6] of 27 sacral tumor resections, the median estimated blood loss was four times higher in the proximal sacral amputation group than in the distal amputation group. The results of several studies suggest preoperative arterial embolization and aortic balloon occlusion may reduce blood loss during surgery [4, 5], especially for sacral tumors [14, 26]; however, the indications for performing these procedures remain uncertain.

The purposes of this study, therefore, were to first ascertain the blood loss volume in sacral tumor surgery and then identify the relative and independent risk factors for a large amount of blood loss to help surgeons discriminate which patients would likely require more transfused blood and in whom hemorrhage control may be necessary preoperatively.

Materials and Methods

We retrospectively reviewed all 220 patients with sacral tumors who we treated surgically between June 2003 and October 2007. We reviewed the medical records (history, operative procedure) and histology slides. All patients had radiographic studies, including 32 patients who had CT alone, whereas others had MRI or both. Eight patients who had an unexpected main blood vessel injury during surgery and 39 patients with disseminated tumors caused by repeated local recurrence were excluded. These mainly were patients with chordomas who had three to four recurrences. These exclusions left 173 patients, 88 of whom were males and 85 were females. Patients ranged from 8 to 79 years of age with an average of 45.2 years. The diagnoses included 27 giant cell tumors, 20 neurofibromas or schwannomas, six teratomas, one aneurysmal bone cyst, 15 other benign tumors, 31 chordomas, seven neurofibrosarcomas, six chondrosarcomas, four osteosarcomas, four Ewing's sarcomas, five soft tissue sarcomas that involved pelvic bone, and 47 metastatic tumors (Table 1).

Table 1. Pathologic diagnoses and blood loss volumes of 173 patients with sacral tumors

Pathologic diagnosis	Number of patients	Blood loss volume (mL)			
		Minimum	Maximum	Mean	Standard deviation
Benign tumor	69	250	8020	2826.59	1880.61
Neurofibroma/schwannoma	20	700	7700	3094.50	1793.45
Teratoma	6	290	1750	898.33	618.40
Aneurysmal bone cyst	1	—	—	350	—
Giant cell tumor	27	350	8020	3741.85	1809.49
Other benign tumor	15	250	4200	1758.33	1274.10
Low-grade malignant tumor	31	500	6000	2597.42	1443.30
Chordoma	31	500	6000	2597.42	1443.30
High-grade malignant tumor	26	700	9900	3533.46	2198.86
Neurofibrosarcoma	7	2350	9900	4874.29	3103.67
Chondrosarcoma	6	1150	7170	3486.67	2087.84
Osteosarcoma	4	700	4720	2942.50	2006.46
Ewing's sarcoma	4	1400	4310.00	2452.50	1278.29
Liposarcoma	3	3400	4250.00	3733.33	453.67
Malignant fibrous histiocytoma	2	1500.00	2550.00	2025.00	742.46
Metastatic tumor	47	500	8700	2939.68	1793.44
Renal carcinoma	5	1350.00	6620.00	4208.00	2338.88
Multiple myeloma	4	1150.00	4730.00	3270.00	1679.66
Hepatocarcinoma	1	—	—	2600	—
Thyroid carcinoma	1	—	—	3260	—
Other metastatic tumors	36	500	8700	2727.36	1750.84

All the operations were performed by two senior surgeons (GW, RLY), using the following strategies. Routinely, the marginal resection or intralesional curettage for primary benign and metastatic sacral tumors is performed through a posterior approach. The exceptions are some neurofibromas and schwannomas with a large presacral mass needing combined approaches. For primary malignant tumors caudad to the disc space between S2 and S3, the posterior approach is sufficient for en bloc subtotal sacrectomy. When tumors involve S2 and above, two stages of combined anterior and posterior approaches are needed. First, the visceral and vascular structures are dissected through an anterior approach to prepare the ventral margin of the tumor and the distal portion of the abdominal aorta is mobilized and encircled with nylon tape for temporary occluding. Second, the tumor is removed from the posterior approach with a wide or marginal margin and then a spinal screw-rod system is applied for sacral iliac joint reconstruction. A balloon dilation catheter (BDC) is used to occlude the abdominal aorta in some patients undergoing the posterior approach to control hemorrhaging during surgery.

The total blood volume loss consisted of the estimated intraoperative blood loss and the drainage volume on the first day after surgery. The intraoperative blood loss volume was estimated by surgeons and anesthesiologists. It included the exact volume of suction and the estimated volume absorbed by gauze and dressings. The normal saline volume of lavage was subtracted from the suction volume. A volume greater than 3000 mL was defined as a large amount of blood loss.

Age, diagnoses, extent, location, and histologic grade of disease varied degrees of surgical resection and subsequent reconstructions in sacral tumor resestions [7]. These factors also may have influenced blood loss volume. Other potential risk factors for blood loss during sacral tumor resection were derived primarily from our experience and a review of the literature [1, 6, 9, 10, 14, 16, 17, 24, 26] and were patient surgical factors. The patient risk factors included age and gender, blood supply, location of the tumor, whether the patient had surgery or radiation therapy before the current surgery, and tumor volume. The surgical risk factors included the surgical approach, type of resection (en bloc resection or intralesional curettage), operative time, and whether the patient had any kind of temporary aorta occlusion and sacrum reconstruction.

One of us (XDT) estimated the length, width, and height of the tumor by MRI or CT. The tumor volume, which was calculated using the formula for a sphere [19], ranged from 4.49 to 2714.96 cm^3 (mean, 330.49 ± 371.80 cm^3). A tumor in which the volume was greater than 200 cm^3 was considered a large tumor. One of us (WG) classified the blood supply of the tumor as excessive (65 cases) or reduced (108 cases). Tumors with an excessive blood supply included all the primary high-grade malignant tumors, multiple myelomas and metastatic hepatocarcinomas, renal carcinomas, thyroid carcinomas and two benign tumors (giant cell tumors and aneurysmal bone cysts). These tumors usually were considered as having abundant vascularity [2, 13, 18, 20, 24]. The tumors with a reduced blood supply included other primary benign tumors and tumor-like lesions; they also included low-grade malignant and other metastatic tumors. The location of the sacral tumor was determined by the cephalad edge of the lesion. Sacral tumors involving the S2 body or cephalad to the S2 body were defined as high-level tumors, whereas tumors caudad to the disc space between S2 and S3 were low-level tumors.

The blood volume loss was analyzed as a categorical variable with 3000 mL as the cut point. To identify factors relating to a large amount of blood loss (greater than 3000 mL), we used chi square tests for univariate analysis tests. Fisher's exact test was used if the expected frequency in any one cell was less than five. To identify independent risk factors for a large amount of blood loss we included variables significant at the $p < 0.20$ level in the multivariate Cox model. All analyses were made using Statistical Package for the Social Sciences, Version 12.0 (SPSS, Inc, Chicago, IL).

Results

The overall estimated blood loss for 173 sacral tumor resections (Table 1) ranged from 250 to 9900 mL with a mean of 2922.49 ± 1844.93 mL. Sixty-nine (39.88%) patients had blood loss greater than 3000 mL. The mean blood loss volume in primary high-grade malignant tumors was 3533.46 ± 2198.86 mL, whereas in benign tumors, it was 2826.59 ± 1880.61 mL. The median operative time ranged from 50 to 495 minutes with a mean of 196.42 ± 69.25 minutes. Seventy-nine patients received BDC or surgical cross-clamping of the aorta.

In univariate analysis (Table 2), gender, tumor blood supply, tumor location, tumor volume, aorta occlusion, surgical approach, reconstruction, and operative time had an effect on blood loss. An anterior combined with posterior surgical approach ($p < 0.001$), tumor volume greater than 200 cm^3 ($p < 0.001$), abundant tumor blood supply ($p = 0.002$), reconstruction of the sacral iliac joint ($p = 0.007$), operative time longer than 3 hours ($p = 0.007$), and male gender ($p = 0.032$), were associated with a large amount of blood loss. High-level tumors that involved the S2 body and cephalad to the S2 body were more likely ($p < 0.001$) to have a large amount of blood loss than low-level tumors. Only four of 32 (12.5%) low-level tumors had blood loss

Table 2. Comparisons of risk factors for blood loss

Characteristics	Number of patients		p Value
	3000 mL or less blood loss (N = 104)	Greater than 3000 mL blood loss (N = 69)	
Age			0.506
Older than 40 years	58	42	
40 years or younger	46	27	
Gender			0.032
Male	46	42	
Female	58	27	
Blood supply			0.002
Excessive	29	35	
Less	75	34	
Location			< 0.001
Cephalad to S2	76	65	
Caudad to S2	28	4	
Recurrent tumor			0.752
Yes	22	16	
No	82	53	
Preoperative radiation			0.245
Yes	6	1	
No	98	68	
Tumor volume			< 0.001
Greater than 200 cm3	35	49	
200 cm^3 or less	69	20	
Aorta occlusion			0.008
Yes	39	40	
No	65	29	
Approach			< 0.001
Anterior and posterior	5	19	
Posterior	99	50	
Type of resection			0.249
En bloc	53	29	
Piecemeal	51	40	
Reconstruction			0.007
Yes	78	63	
No	26	6	
Operative time			0.001
Longer than 3 hours	21	48	
3 hours or less	59	45	

greater than 3000 mL compared with 46.1% (65 of 141) of the high-level tumors. Patients who had temporary aorta occlusion had a greater (p = 0.008) chance of excessive bleeding than patients who did not require occlusion. We observed no increased risk of a large amount of blood loss between patients older and younger than 40 years (a large amount of blood loss occurred in 42 of 100 patients older than 40 years compared with 27 of 73 patients younger than 40 years). Recurrent tumors and patients who received radiation before the current surgery had no effect on the amount of blood loss. There was no difference (p = 0.249) in blood loss between patients with an en bloc resection or piecemeal curettage.

Table 3. Independent risk factors

Characteristics	p Value	Odds ratio	95% confidence interval
Excessive blood supply	0.024	2.281	1.116–4.666
Location at or cephalad to S2	0.021	3.840	1.225–12.032
Tumor volume greater than 200 cm^3	0.001	3.381	1.629–7.020
Anterior and posterior approach	0.054	3.047	0.980–9.476

Tumor location (high-level) had the strongest independent association with a large amount of blood loss with an adjusted odds ratio of 3.840 after controlling for other variables in the model (Table 3). Other variables that remained independently associated with an increased risk of a large amount of blood loss included tumor volume greater than 200 cm^3 (odds ratio, 3.381) and an abundant blood supply (odds ratio, 2.281). The combined anterior and posterior surgical approach did not independently predict (p = 0.054) blood loss.

Discussion

Wide excision has been suggested for biologically aggressive benign and malignant sacral tumors [8, 9, 22, 25]. Total sacrectomy for high sacral tumors is a complex surgical procedure, which requires a combined anterior and posterior approach, dissection of the visceral and vascular structures, mobilization of the tumor, completion of the resection, and reconstruction. Although total en bloc sacrectomy is believed to be an effective method to improve local tumor control, it is associated with a high risk of complications, especially excessive blood loss. Brisk hemorrhage also is encountered during intralesional curettage for some benign sacral tumors [18]. The purpose of our study was to evaluate the blood loss volume and identify the relative and independent risk factors for a large amount of blood loss in sacral tumor surgery.

Our study has several important limitations. The retrospective nature of the study precluded complete analysis of some potentially important risk factors. For example, the speed and volume of blood transfusion, which were decided by different anesthesiologists, were difficult to compare without strict criteria. We only considered risk factors associated with the patient and surgery. We did not include other factors such as the patient's general

condition, blood clotting ability, or surgical stage of the tumor. Also not considered were different levels of surgical skill and determination of surgical margins which likely influence blood loss. Surgeon bias may have resulted in aortic occlusion being used in patients with bleeding tendencies, thus making it a major risk factor associated with a large amount of blood loss.

Although no study has focused specifically on hemorrhage during sacral tumor resection, extensive bleeding has been reported. In one study [25] of nine patients with total sacrectomies, the blood loss ranged between 4.5 and 17 L (mean, 6.3 L). In another report [8], three sacral tumor resections were performed with blood losses of 9250, 7500, and 9600 mL. In one larger-scale study of 29 patients who underwent partial or total sacrectomies [9], the median blood loss was 3.9 L and the maximum blood loss was 37 L. The overall estimated blood losses in patients in our study, which is similar to another study [6], ranged between 250 and 9900 mL (mean, 2922.49 $\pm$ 1844.93 mL). Sixty-nine (39.88%) patients had blood loss greater than 3000 mL. The options for blood management in orthopaedic surgery have been well established [12] but are not suitable for sacral tumor resections. Preoperative collected autologous blood [15] and BDC for aortic occlusion [14, 26] have been used successfully in sacral tumor resections, but the result is uncertain. According to our experience in this study, however, although BDC or surgical cross-clamping of the aorta was performed in 79 patients, more than half had blood loss greater than 3000 mL. Thus, the first and most important step in preventing a large amount of blood loss in sacral tumor resection is to be aware of the salient independent risk factors.

Location of the tumor cephalad to the S2-S3 disc was associated with the greatest independent risk (odds ratio, 3.840) for a large amount of blood loss. Generally, a tumor situated low on the sacrum can be removed easily using the posterior approach without neurologic deficits, whereas a tumor at a high level on the sacrum always requires a combined anterior and posterior surgical approach. Furthermore, the tumor will be difficult to excise without neurologic damage [23]. Blood loss in proximal sacral amputations was considerably greater than in distal amputations [19]; the elevated risk of bleeding was attributable in part to the exposure required for proximal resections resulting in the sacrifice of large veins that drain the epidural plexus, which exit at the S1 and S2 foramina. It was also a result of the large exposed bleeding bone and two-staged exposure required for these difficult resections. Our results indicated the S2-S3 disc space is a landmark for a large amount of blood loss. Internal fixation for an osseous defect reconstruction, which is needed only after a high-level sacral tumor resection [11], also may result in increased bleeding and although it was associated with a large amount of blood loss it did not independently predict blood loss.

Tumor volume greater than 200 cm^3 was another important independent risk factor associated with a 3.381-fold increased risk of a large amount of blood loss. Sacral tumors are difficult to diagnose at an early stage and may be far advanced at the time of presentation. Usually, the size of sacral tumors is often much greater in the sacrum than in other sites. In two studies [7, 24] of sacral tumors, the average tumor size was 10.5 x 8.5 x 6 cm and 7.8 x 6.3 x 4.8 cm, respectively, whereas the mean volume of tumors was only 95 cm^3 in another study involving giant cell tumors of the extremities [19]. The large sacral tumors always involve the upper portion of the sacrum and have a presacral mass adhered to or invading the pelvic visceral organs, both of which make surgical resection difficult and lead to increased bleeding.

The third independent risk factor for bleeding was the excessive blood supply, which is different in various tumors. Generally, malignant tumors are more likely to induce ingrowth of abnormal capillary vessels and arterioles than benign tumors, although in the sacrum area, the vascularity of some aggressive benign tumors such as giant cell tumors and aneurysmal bone cysts is even greater. In one study [24], the reported average blood loss of sacral giant cell tumors was 7.5 L. In another study [13] of resection of a sacral aneurysmal bone cyst, despite successful embolization, the replacement of 34 units of packed red blood cells was still necessary. In our study, the blood volume loss of giant cell tumors was similar to malignant tumors. Therefore, BDC or surgical cross-clamping of the aorta is now a standard procedure for sacral giant cell tumor resection at our institute.

Although the combined surgical approach did not independently predict blood loss, it was the only surgical factor with any tendency of risk and might have been significant with greater numbers. The surgical approach usually was determined on the basis of tumor characteristics. However, a combined approach requires complex surgical manipulation in the presacral area and more operative time than a posterior approach alone, both of which could lead to a large amount of blood loss. Additional sequential cases may clarify the effect of the combined approach on blood loss during sacral tumor resection.

Our data indicate blood volume loss during sacral tumor resection is influenced mainly by location of the tumor, tumor volume, and tumor blood supply. Sacral tumors that invade cephalad to the S2-S3 disc space have a volume greater than 200 cm^3 and an abundant blood supply are likely to have a large amount of blood loss. BDC or other blood vessel control should be considered for such patients.

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