Experience with wound complications after surgery for sacral tumors

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Abstract

Purpose The aim of this article is to summarize our experience in treating sacral wound complications after sacrectomy. We focus, in particular, on factors associated with wound complications, including surgical site infection (SSI) and wound dehiscence.

Methods The definition of SSI devised by Horgan et al. was applied. Wound dehiscence was defined as a wound showing breakdown in the absence of clinical signs meeting the diagnostic standard for SSI. Between September 1997 and August 2009, 387 patients with a sacral tumor underwent sacrectomy performed by the same team of surgeons and were followed up for ≥ 12 months. Potential risk factors were evaluated for univariate associations with SSI and wound complications. Multivariable conditional logistic regression was used to identify the combined effects of several risk factors.

Results Of the 387 wounds studied, 274 healed uneventfully, and 113 (29.2 %) broke down because of infection or dehiscence. Fifty-one (13.2 %) patients developed a postoperative SSI, and 62 (16.0 %) patients developed wound dehiscence. Gram-negative bacteria grew in 45 cultures (91.8 %) and included 38 cases of *Escherichia coli*. Previous radiation, rectum rupture, longer duration of surgery, and cerebrospinal fluid leakage were significantly associated with increased likelihood of developing an SSI. Previous radiation, rectum rupture, age <40 years, history of diabetes mellitus, maximum tumor

diameter ≥ 10 cm, and instrumentation used were risk factors for wound complications.

Conclusions The incidence of wound complications is not so high at a musculoskeletal tumor center with surgeons experienced in treating sacral tumors. Controlling for these risk factors when possible may improve clinical outcomes.

Keywords Sacrum · Tumor · Risk factors · Surgical site infection · Wound dehiscence · Surgery

Introduction

Most primary sacral malignancies respond poorly to radiation therapy and chemotherapy, and sacrectomy is still the main therapeutic modality for primary sacral tumors and some metastatic sacral tumors associated with refractory pain. The complicated regional anatomy makes sacral tumor resection a challenging and time-consuming operation. Tremendous and possibly fatal blood loss during the operation and wound complications are major factors that make sacral tumor resection challenging. The intra-abdominal aortic balloon is used frequently in our center and controls intraoperative blood loss in most cases. The risk factors for blood loss during sacral tumor resection at our center were discussed in 2008 by Tang et al. [1]. However, the incidence of wound complications, including surgical site infection (SSI), and wound dehiscence remains high [2]. Wound complications markedly complicate the postoperative course for patients.

The aim of this article is to present our experience in dealing with sacral wound complications after sacral tumor resection. We focus particularly on the factors associated with wound complications.

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Methods

Between September 1997 and August 2009, 397 patients with a sacral tumor underwent 519 tumor resection operations performed by the same team of surgeons who followed the same protocol during this period at our center. Some patients underwent more than one operation during this period because of local recurrence or internal fixation failure. For the patients who underwent more than one operation, only the data for the first tumor resection operation performed at our center were considered for further analyses. Three patients died of pulmonary embolism or hemorrhagic shock perioperatively, and seven patients died in the first year after the operation. The records of 387 surgeries were reviewed retrospectively, and all 387 cases were followed for at least 12 months postoperatively. The demographic data, pathology diagnosis of the tumor, technical details of surgery, aspects of the postoperative course, and microbiology were reviewed. The characteristics of SSIs and wound dehiscence were recorded.

Preoperative urethral catheterization and bowel preparation were performed in all patients. Prophylactic antibiotics were used preoperatively, and additional doses of antibiotics were given for operations lasting more than 4 h.

The patient was positioned in a prone or lateral decubitus position, and sacral resection was performed via an inverted “Y” incision or a two-way incision. An inverted “Y” incision is composed of a posterior midline incision in the lumbosacral region with the distal end at above the sacrococcygeal joint and two other incisions starting above the sacrococcygeal joint and running along the fibers of the gluteus maximus muscle. When one of the latter incisions could be spared, it is a two-way incision. The anterior approach was used occasionally, but no SSI or wound dehiscence was recorded for this procedure in our study. The details of the surgical procedure have been described [3]. A colostomy was not considered unless the tumor involved the rectum and part of the rectal wall had to be resected with the tumor, or a rectum rupture occurred postoperatively. The following principles for wound closure were observed at our center. The deep fascia was closed tightly. One or two silicon drainage tubes, Fr 24 or Fr 28, were inserted for wound drainage and were not removed until the daily drainage volume was <30 mL. Systemic antibiotics were used until the drainage tube was removed. The wound was well protected from contamination by feces. Sacrococcygeal pressure sores were avoided by all possible means. The characteristics of fluid drained from the wound were noted, and organism culture was performed if the wound drainage fluid became cloudy or the patient had a fever >38.5 °C.

Wound complications included SSI and wound dehiscence. The definition of SSI of Horgan et al. [4] was

applied in this review. Wound dehiscence was defined as a wound showing breakdown in the absence of clinical signs meeting the diagnostic standard for SSI.

Potential factors associated with SSI and wound complications (including SSI and wound dehiscence) were reviewed for each patient and included the following: age, sex, history of diabetes, preoperative serum albumin level, previous sacral tumor resection performed in another hospital, previous radiation of the lumbosacral area, maximum diameter and histopathological characteristics of the tumor, incision type (two-way approach vs. inverted Y incision), proximal segment of the sacrum resected, use of instrumentation, rectum rupture during or after the operation, intraoperative blood loss and special methods used to reduce intraoperative blood loss, duration of surgery, and cerebrospinal fluid (CSF) leakage after the operation.

To analyze the association between the diagnosis and SSI or wound complications, the 34 diagnoses in this study were combined into six categories: chordoma, giant cell tumor, neurological tumor (neurofibroma and schwannoma), metastatic disease (metastasis, multiple myeloma, and non-Hodgkin lymphoma), other primary malignancy (chondrosarcoma, malignant peripheral nerve sheath tumor, Ewing sarcoma, osteosarcoma, epithelioid angiosarcoma, malignant giant cell tumor, malignant fibrous histiocytoma, malignant teratoma, liposarcoma), and other benign lesion (all other benign lesions).

Biostatisticians at our institution performed the statistical analysis of the data collected. Data analyses were performed using the Statistical Package for the Social Sciences version 14.0 (SPSS; Chicago, IL, USA). All potential risk factors were evaluated for a univariate association with SSI and wound complication rates. The independent-sample *t* test was used to analyze continuous variables and χ^2 or Fisher's exact tests for categorical or discrete variables. Multivariable conditional logistic regression was used to identify the combined effect of several risk factors. All variables that had been identified previously in the literature, those with clinical and/or biological plausibility, and those with a univariate *p* value ≤ 0.20 , were considered for inclusion in the model. With use of a backward, stepwise procedure, variables that achieved a *p* value ≤ 0.10 remained in the final model. The results are reported as odds ratios (ORs) with 95 % confidence intervals (CIs) and *p* values. Two-sided *p* values <0.05 were considered significant.

Results

Clinical characteristics and description of risk factors

Among the 387 patients included in our study, 202 were men (52.2 %) and 185 were women (47.8 %). The average

Table 1 Histopathological diagnoses

Diagnosis	Frequency	Percent
Metastasis	90	23.3
Chordoma	78	20.2
Giant cell tumor	48	12.4
Neurofibroma	37	9.6
Chondrosarcoma	15	3.9
Schwannoma	14	3.6
Malignant peripheral nerve sheath tumor	11	2.8
Multiple myeloma	11	2.8
Ewing sarcoma	9	2.3
Teratoma	9	2.3
Epidermoid cyst	7	1.8
Osteosarcoma	7	1.8
Sacral canal cysts	7	1.8
Non-Hodgkin lymphoma	6	1.6
Malignant giant cell tumor	5	1.3
Osteblastoma	5	1.3
Aneurysmal bone cyst	4	1.0
Malignant fibrous histiocytoma	3	0.8
Osteochondroma	3	0.8
Dermoid cyst	2	0.5
Fibromatosis	2	0.5
Malignant teratoma	2	0.5
Eosinophilic granuloma	1	0.3
Epithelioid angiosarcoma	1	0.3
Granulocyte sarcoma	1	0.3
Gut-tail cyst	1	0.3
Inflammatory pseudotumor	1	0.3
Liposarcoma	1	0.3
Lymphangioma	1	0.3
Ossifying fibroma	1	0.3
Osteoma	1	0.3
Simple bone cyst	1	0.3
Smooth muscle tumor	1	0.3
Spinal meningioma	1	0.3
Total	387	100.0

age of the patients was 46.4 years (range 5–83 years). The histopathology diagnoses are summarized in Table 1. More than one-fifth of the histopathology diagnoses were metastasis, and about two-fifths were chordoma, giant cell tumor, or neurofibroma. No other tumor had a percentage >5 %. When combined into six categories, there were 78 chordomas, 49 giant cell tumors, 107 metastatic tumors, 51 neurological tumors, 48 other benign lesions, and 54 other primary malignant tumors in this study.

Thirteen (3.4 %) patients had a history of diabetes mellitus. Before undergoing the operation in our center, 95 (24.5 %) patients had undergone sacral tumor resection in another hospital, and 30 (7.8 %) patients had received

radiation therapy. One-hundred and fourteen (29.5 %) patients had a sacrococcygeal tumor with a maximum diameter ≥ 10 cm. An intra-abdominal aortic balloon, embolic occlusion of the internal iliac artery, or occlusion of the abdominal aorta with string were applied in 135 (34.9), 28 (7.2) and 20 (5.2 %) patients, respectively. A two-way incision was used in 69 (17.8 %) patients. S1, S2, and S3 were resected as the proximal sacral segment in 193 (49.9), 108 (27.9), and 86 (22.2 %) patients, respectively. Iliac–lumbar vertebral pedicle reconstruction was performed in 185 (47.8 %) patients. Rectum rupture occurred in 17 (4.4 %) patients during or after the operation. Colostomy was performed in 13 patients, and the other four were managed successfully by a one-stage repair. Thirty (7.8 %) patients experienced postoperative CSF leakage.

Rates and description of SSI and dehiscence

Of the 387 wounds studied, 274 healed uneventfully, and 113 (29.2 %) broke down because of infection or dehiscence.

Fifty-one (13.2 %) patients developed a postoperative SSI. Only four SSIs involved a superficial infection, and the other 47 were deep infections. The cultures were positive in 49 of the 51 (96.1 %) infected wounds. Thirteen SSIs were multimicrobial. The type and number of organisms identified from patients who developed an SSI are shown in Table 2. No culture grew fungus.

Surgical interventions including wound debridement and sufficient drainage were performed for all postoperative SSIs. Seventeen patients had a second debridement, and five had a third debridement before the wound healed. Regimens of culture-sensitive intravenous antibiotics were given for at least 3 weeks, and long-term suppressive oral antibiotics were administered to some patients as indicated by the surgeon. Among the 51 patients with a postoperative SSI, 29 underwent reconstruction. To control the infection, instrumentation was removed during debridement in nine patients.

Sixty-two (16.0 %) patients exhibited wound dehiscence. The wound dehiscence was caused by fat liquefaction in 21 patients, and the wound healed after drainage and a change of dressing. Forty-one patients experienced skin and subcutaneous necrosis caused by ischemia. The wound healed after surgical debridement, wide excision of the necrotic tissue, and repair of the skin and soft tissue defects using a gluteus maximus myocutaneous flap when necessary.

Risk factors for developing an SSI

Among the eight preoperative factors, age, sex, previous sacral tumor resection ($n = 95$) and histopathological diagnosis were not significantly associated with development of an SSI. Risk of developing infection increased

Table 2 Type and number of organisms identified from patients with SSIs

Types of organism	Number of infections in 49 patients (%)
Gram-negative organisms	45 (91.8)
<i>Escherichia coli</i>	38 (77.6)
<i>Acinetobacter baumannii</i>	4 (8.2)
<i>Klebsiella pneumoniae</i>	2 (4.1)
<i>Proteus vulgaris</i>	1 (2.0)
Gram-positive organisms	16 (32.7)
<i>Enterococcus faecalis</i>	6 (12.2)
<i>Staphylococcus aureus</i>	5 (10.2)
<i>Enterococcus faecium</i>	2 (4.1)
<i>Enterococcus durans</i>	1 (2.0)
<i>Staphylococcus hominis</i>	1 (2.0)
<i>Staphylococcus epidermidis</i>	1 (2.0)

significantly with previous radiation of the lumbosacral area (OR 4.42, 95 % CI 2.89–14.24, $p < 0.001$) and the maximum diameter of the tumor (≥ 10 cm) (OR 2.21, 95 % CI 1.21–4.04, $p = 0.010$). The nutrition status of the patients, as assessed by preoperative serum albumin level, was significantly associated with an increased risk of an SSI. The mean preoperative serum albumin level was 42.4 g/L in the non-SSIs group and 40.1 g/L in the SSI group ($p = 0.044$). Among the other risk factors, special methods used to reduce intraoperative blood loss, two-way incision ($n = 69$), proximal segment of the sacrum resected, use of instrumentation ($n = 185$), and intraoperative blood loss were not significantly associated with development of SSIs. Risk of developing infection increased significantly with rectum rupture (OR 28.40, 95 % CI 8.81–91.47, $p < 0.001$), longer duration of surgery ($p < 0.001$), and CSF leakage (OR 3.85, 95 % CI 1.69–8.80, $p = 0.003$). The data are summarized in Table 3.

Table 4 shows the results of the multivariate logistic regression analysis used to assess the association of risk factors for patients with SSIs after adjusting for other potential risk factors. Ten factors with a univariate p value ≤ 0.20 were considered for inclusion in the multivariate logistic regression analysis: history of diabetes mellitus, preoperative serum albumin level, previous sacral tumor resection ($p = 0.120$), previous radiation, maximal diameter (≥ 10 cm), instrumentation used ($p = 0.165$), rectum rupture, intraoperative blood loss ($p = 0.123$), duration of surgery, and CSF leakage. In the final model, previous radiation ($p = 0.016$), rectum rupture ($p < 0.001$), duration of surgery ($p = 0.045$), and CSF leakage ($p = 0.012$) were significant independent risk factors for the onset of SSI. Rectum rupture (OR 15.81; 95 % CI: 4.41–56.68) was

the strongest risk factor for SSI after adjusting for all other variables. Similarly, previous radiation (OR 3.28; 95 % CI 1.25–8.59) and CSF leakage (OR 3.30; 95 % CI 1.30–8.36) were also important risk factors and were associated with a threefold increased risk for the development of a postoperative SSI. The other factors did not meet significance in the final logistic regression model.

Risk factors for developing wound complications

Among the preoperative factors, sex, preoperative serum albumin level, and histopathological diagnosis were not significantly associated with development of wound complications. Risk of developing wound complications increased significantly with history of diabetes (OR 2.95, 95 % CI 0.97–8.98, $p = 0.062$), previous sacral tumor resection (OR 1.93, 95 % CI 1.19–3.14, $p = 0.008$), previous radiation (OR 3.56, 95 % CI 1.66–7.60, $p = 0.001$), and the maximum diameter of the tumor (≥ 10 cm) (OR 2.46, 95 % CI 1.55–3.92, $p < 0.001$). Younger age was associated with wound complications. The mean age was 41.8 years for the group with wound complications and 48.3 years for the patients without complications ($p < 0.001$). Among the other factors, two-way incision and intraoperative blood loss were not significantly associated with the development of wound complications. The risk of developing wound complications increased significantly with special methods used to reduce intraoperative blood loss ($p < 0.001$), resection at the S1 level ($p = 0.002$), use of instrumentation (OR 2.64, 95 % CI 1.68–4.16, $p < 0.001$), rectum rupture (OR 45.03, 95 % CI 5.89–344.08, $p < 0.001$), longer duration of surgery ($p < 0.001$), and CSF leakage (OR 2.28, 95 % CI 1.07–4.85, $p = 0.028$). Compared with no special blood control as the reference, wound complications increased with use of an intra-abdominal aorta balloon (OR 2.82, 95 % CI 1.74–4.57, $p < 0.001$), embolic occlusion of the internal iliac artery (OR 2.57, 95 % CI 1.12–5.91, $p < 0.001$), and occlusion of the abdominal aorta with string (OR 1.33, 95 % CI 0.45–3.86, $p < 0.001$). When compared with resection at the S1 level, wound complications decreased with S2 resected (OR 0.46, 95 % CI 0.26–0.78, $p = 0.002$) and S3 resected (OR 0.45, 95 % CI 0.25–0.81, $p = 0.002$). The data are summarized in Table 5.

Table 6 shows the results of the multivariate logistic regression analysis used to assess the association of risk factors for patients with wound complications after adjusting for all other potential risk factors. All 11 factors mentioned above with a univariate p value ≤ 0.20 were considered eligible for further analysis. In the final model, age (< 40 years) ($p < 0.001$), history of diabetes ($p = 0.041$), previous radiation ($p = 0.017$), maximum

Table 3 Univariate analysis via logistic regression analysis of surgical site infection

Potential risk factor	No surgical site infection (<i>n</i> = 336)	Surgical site infection acquired (<i>n</i> = 51)	Odds ratio (95 % confidence interval)	<i>p</i> value
Age*	46.4 ± 16.6	46.5 ± 16.9	–	0.965 [†]
Sex (male)	175 (52.1 %)	27 (52.9 %)	0.97 (0.54–1.74)	0.909 [†]
Diabetes mellitus	9 (2.7 %)	4 (7.8 %)	3.09 (0.92–10.44)	0.077 [§]
Albumin (preoperative)(g/L)*	42.4 ± 7.8	40.1 ± 5.7	–	0.044 [†]
Previous sacral tumor resection	78 (23.2 %)	17 (33.3 %)	1.65 (0.88–3.12)	0.120 [†]
Previous radiation	17 (5.1 %)	13 (25.5 %)	4.42 (2.89–14.24)	0.000 [§]
Maximal diameter (≥ 10 cm)	91 (27.1 %)	23 (45.1 %)	2.21 (1.21–4.04)	0.010 [†]
Histopathological diagnoses				0.759 [†]
Chordoma	65 (19.3 %)	13 (25.5 %)	Reference	
Giant cell tumor	43 (12.8 %)	6 (11.8 %)	0.70 (0.25–2.00)	
Metastatic lesion	94 (28.0 %)	13 (25.5 %)	0.69 (0.30–1.59)	
Neurological tumor	45 (13.4 %)	6 (11.8 %)	0.67 (0.24–1.89)	
Other benign lesion	44 (13.1 %)	4 (7.8 %)	0.46 (0.14–1.49)	
Other primary malignancy	45 (13.4 %)	9 (17.6 %)	1.00 (0.39–2.54)	
Blood control method				0.308 [†]
None	181 (53.9 %)	23 (45.1 %)	Reference	
Intra-abdominal aorta balloon	112 (33.3 %)	23 (45.1 %)	1.62 (0.87–3.02)	
Internal iliac artery embolism	24 (7.1 %)	4 (7.8 %)	1.31 (0.42–4.12)	
Abdominal aorta blocked by string	19 (5.7 %)	1 (2 %)	0.41 (0.05–3.24)	
Incision type (two way)	61 (18.2 %)	8 (15.7 %)	1.19 (0.53–2.66)	0.668 [†]
Proximal sacral segment resected				0.215 [†]
S1	167 (49.7 %)	26 (51.0 %)	Reference	
S2	90 (26.8 %)	18 (35.3 %)	1.29 (0.67–2.47)	
S3	79 (23.5 %)	7 (13.7 %)	0.57 (0.24–1.37)	
Instrumentation used	156 (46.4 %)	29 (56.9 %)	1.52 (0.84–2.76)	0.165 [†]
Rectum rupture	4 (1.2 %)	13 (25.5 %)	28.40 (8.81–91.47)	0.000 [§]
Intraoperative blood loss*	2727.4 ± 2109.1	3215.7 ± 2068.2	–	0.123 [†]
Duration of surgery (min)*	178.2 ± 68.3	227.9 ± 97.7	–	0.000 [†]
CSF leak	20 (6.0 %)	10 (19.6 %)	3.85 (1.69–8.801)	0.003 [§]

* The data are presented as the mean and standard deviation

[†] Significant at $\alpha = 0.05$ [§] Fisher's exact test**Table 4** Multivariate logistic regression analysis of risk factors for surgical site infection

	Adjusted odds ratio (95 % confidence interval)	<i>p</i> value
Previous radiation	3.28 (1.25–8.59)	0.016 [†]
Rectum rupture	15.81 (4.41–56.68)	0.000 [†]
Duration of surgery (per 30 min)	1.14 (1.00–1.29)	0.045 [†]
CSF leakage	3.30 (1.31–8.36)	0.012 [†]

[†] Significant at $\alpha = 0.05$

diameter of the tumor ($p = 0.037$), instrumentation used ($p < 0.001$), and rectum rupture ($p = 0.001$) were significant independent risk factors for the onset of wound complications. Rectum rupture (OR, 37.15; 95 % CI 4.59–300.60) remained the strongest risk factor for wound complications after adjusting for all other variables. History of diabetes (OR, 3.99; 95 % CI 1.06–15.02), previous radiation (OR, 3.19; 95 % CI 1.23–8.28), and instrumentation used (OR 3.03; 95 % CI 1.80–5.11) were also significant risk factors and were associated with a more than threefold increased risk for the development of

Table 5 Univariate analysis via logistic regression analysis of wound complications

Potential risk factor	No delayed healing (<i>n</i> = 274)	Delayed healing (<i>n</i> = 113)	Odds ratio (95 % confidence interval)	<i>p</i> value
Age*	48.3 ± 16.2	41.8 ± 16.8	–	0.000 [†]
Sex (male)	143 (52.2 %)	59 (52.2 %)	1.00 (0.64–1.55)	0.997 [†]
Diabetes mellitus	6 (2.2 %)	7 (6.2 %)	2.95 (0.97–8.98)	0.062 [§]
Albumin (preoperative) (g/L)*	42.8 ± 8.5	41.6 ± 5.3	–	0.329 [†]
Previous sacral tumor resection	57 (20.8 %)	38 (33.6 %)	1.93 (1.19–3.14)	0.008 [†]
Previous radiation	13 (4.7 %)	17 (15.0 %)	3.56 (1.66–7.60)	0.001 [†]
Maximal diameter (≥10 cm)	65 (23.7 %)	49 (43.4 %)	2.46 (1.55–3.92)	0.000 [†]
Histopathological diagnoses				0.403 [†]
Chordoma	55 (20.1 %)	23 (20.4 %)	Reference	
Giant cell tumor	32 (11.7 %)	17 (15.0 %)	1.27 (0.59–2.73)	
Metastatic lesion	78 (28.5 %)	29 (25.7 %)	0.89 (0.47–1.70)	
Neurological tumor	39 (14.2 %)	12 (10.6 %)	0.74 (0.33–1.65)	
Other benign lesion	37 (13.5 %)	11 (9.7 %)	0.71 (0.31–1.63)	
Other primary malignancy	33 (12.0 %)	21 (18.6 %)	1.51 (0.73–3.17)	
Blood control method				0.000 [†]
None	163 (59.5 %)	41 (36.3 %)	Reference	
Intra-abdominal aorta balloon	79 (28.8 %)	56 (49.6 %)	2.82 (1.74–4.57)	
Internal iliac artery embolism	17 (6.2 %)	11 (9.7 %)	2.57 (1.12–5.91)	
Abdominal aorta blocked by string	15 (5.5 %)	5 (4.4 %)	1.33 (0.46–3.86)	
Incision type (two way)	50 (18.2 %)	19 (16.8 %)	1.10 (0.62–1.97)	0.738 [†]
Proximal sacral segment resected				0.002 [†]
S1	121 (44.2 %)	72 (63.7 %)	Reference	
S2	85 (31.0 %)	23 (20.4 %)	0.46 (0.26–0.78)	
S3	68 (24.8 %)	18 (15.9 %)	0.45 (0.25–0.81)	
Instrumentation used	112 (40.9 %)	73 (64.6 %)	2.64 (1.68–4.16)	0.000 [†]
Rectum rupture	1 (0.4 %)	16 (14.2 %)	45.03 (5.89–344.08)	0.000 [§]
Intraoperative blood loss*	2759.1 ± 2068.3	2871.0 ± 2207.5	–	0.636 [†]
Duration of surgery (min)*	171.2 ± 60.7	217.5 ± 93.3	–	0.000 [†]
CSF leak	16 (5.8 %)	14 (12.4 %)	2.28 (1.07–4.85)	0.028 [†]

* The data are presented as the mean and the standard deviation

[†] Significant at $\alpha = 0.05$ [§] Fisher's exact test**Table 6** Multivariate logistic regression analysis of risk factors for wound complications

	Adjusted odds ratio (95 % confidence interval)	<i>p</i> value
Age (≥40 years)	0.393 (0.235–0.655)	0.000 [†]
Diabetes mellitus	3.990 (1.060–15.017)	0.041 [†]
Previous radiation	3.192 (1.230–8.284)	0.017 [†]
Maximum diameter (≥10 cm)	1.758 (1.034–2.988)	0.037 [†]
Instrumentation used	3.033 (1.800–5.111)	0.000 [†]
Rectum rupture	37.153 (4.592–300.598)	0.001 [†]
CSF leakage	1.874 (0.793–4.424)	0.152

[†] Significant at $\alpha = 0.05$

postoperative wound complications. CSF leakage and other factors did not meet significance in the final logistic regression model.

Discussion

This retrospective study is the first clinical study of a relatively large number of patients with sacral tumors to focus on wound complications including SSIs and wound dehiscence. Sacral procedures have had historically higher rates of infection than other spinal procedures [5–10]. Primary sacral tumors are rare, and experience with

postoperative wound complications of these tumors is, therefore, limited to observations on less than 80 patients [2, 11–18]. The postoperative infection rates were 8.3–39.1 %. The wound complication rate was 60.6 % [14]. In our study, 274 wounds healed uneventfully, whereas 113 wounds broke down because of infection or dehiscence, giving an SSI rate of 13.2 % and a dehiscence rate of 16.0 %. Thus, the wound complication rate is not so high at a musculoskeletal tumor center with surgeons experienced in treating sacral tumors. Practical tips for avoiding wound complications have been described in the methods section.

Dead cavity, proximity to the perineal region, poor blood supply, and neural atrophy may put patients with sacral tumors at high risk of wound complications. A huge dead cavity is often inevitable after sacral tumor resection because symptoms and signs of sacral tumors are often mild and nonspecific in the early stage and usually have a large volume at diagnosis. Computed tomography and magnetic resonance imaging showed that the dead cavity will be filled eventually by the rectum and scar tissue. In the short term, this dead cavity may be filled with hematoma. Although the posterior median incision or reversed “Y” incision can ensure sufficient exposure during tumor resection, the distal end of the incision is adjacent to the genitourinary and gastrointestinal structures. Poor blood supply to the skin flap can be caused by wide soft tissue stripping during tumor resection, embolic occlusion of the internal iliac artery to control intraoperative hemorrhage, or an SSI [19]. The dorsal ramus of the sacral nerves is usually sacrificed during the operation, and the resulting neural atrophy is also a negative factor for posterior median wound healing.

In a study of 678 patients undergoing spinal tumor (excluding sacral tumors), *Staphylococcus aureus* was the most commonly isolated organism ($n = 22$ of 65, 33 %) [10]. Ruggieri et al. [2] reported that the most frequent bacteria after sacrectomy were *Enterococcus* (23 %) and *E. coli* (20 %). In this study, Gram-negative organisms were cultured from 91.8 % of the infected sacral wounds, and most were *E. coli*. Because *E. coli* are believed to grow in the gastrointestinal tract, the proximity to the perineum may be one reason for the high SSI rate of sacral wounds.

The sacrum is a unique structure that connects the lumbar spine and pelvis, and although challenging, reconstruction after a sacrectomy is mandatory in some cases [20, 21]. Once postoperative SSI occurs, the decision whether to remove the instrumentation is a dilemma. In our study, instrumentation was not removed during debridement in most cases of SSI (20/29, 69 %), and these wounds healed well after debridement.

Wound complications represent a substantial increase in hospital stay, cost, and additional inherent risks of infection

treatment. One of the aims of our study was to define the significant factors that contribute to an increased incidence of wound complications. As in most studies, we selected SSI as the dependent variable [10, 13]. Wound dehiscence, which is also a major wound complication, also occurred frequently in this series of patients. Wound SSI and dehiscence are different complications, which we defined strictly in this study. However, we could not identify how many cases of SSIs were caused by wound dehiscence because wound dehiscence can develop into an SSI. Thus, wound complications including SSI and wound dehiscence were included as another dependent variable in our study. The univariate analyses identified seven independent variables as risk factors for the development of both SSI and wound complications: previous sacral tumor resection, previous radiation, maximum tumor diameter ≥ 10 cm, instrumentation used, rectum rupture, duration of surgery, and CSF leakage. In addition to these seven factors, low serum albumin was also a risk factor for an SSI, and age < 40 years, blood control method, and a proximal sacral segment resected were other risk factors for wound complications. The univariate analysis showed that most risk factors selected were the same for the two different dependent variables. One important point is that the inverted Y incision did not have a higher incidence of wound breakdown compared with the two-way incision.

In the multivariate logistic regression model, previous radiation and rectum rupture were significantly associated with an increased risk of developing both SSI and wound complications. A longer duration of surgery and CSF leakage were also risk factors for SSI only. Age < 40 years, history of diabetes mellitus, maximum diameter ≥ 10 cm, and instrumentation used were risk factors for wound complications. Late vascular changes after radiotherapy may adversely affect wound healing. Through the years, clinical experience has demonstrated a high incidence of wound complications after surgical incision through previously irradiated tissue [22–24]. Rectum rupture, a longer duration of surgery, and CSF leakage could potentiate infection from bacterial contamination. A history of diabetes mellitus is a well-known risk factor for problems with wound healing [25]. A maximum diameter ≥ 10 cm and instrumentation require wide soft tissue stripping and produced a huge dead space after sacrectomy, which may lead to a higher rate of wound complication. The result showing that age < 40 years has an adverse effect on sacral wound healing seems contrary to common sense. Estrella et al. [26] reported a higher rate of complications in the younger (< 54 years) patient group ($r = 0.516$; $p = 0.039$) in a retrospective descriptive study of sacral ulcer flap coverage. We could not identify the reason for the association between age < 40 years and a high wound complication rate. A prospective study of more cases may be able to answer this question.

All operations in our study followed the same protocol and were performed by the same team over a dozen years. No complex soft tissue reconstruction was applied, and the number of surgeons scrubbed in was always four in our study. We did not include the number of surgeons scrubbed in and complex soft tissue reconstruction in the analysis in this study. This was a retrospective study, and factors such as postoperative bowel and bladder dysfunction, and tumor resection margins were not recorded completely for all patients and were thus not analyzed.

Conclusion

The incidence of wound complications, including SSI and wound dehiscence, is not so high at a musculoskeletal tumor center with surgeons experienced in treating sacral tumors. Gram-negative organisms are the organisms isolated most frequently from infected wounds. Early debridement promises a good result, and instrumentation must be removed during debridement in only a small proportion of patients. Previous radiation, rectum rupture, longer duration of surgery, and CSF leakage are significantly associated with an increased likelihood of developing an SSI. Previous radiation, rectum rupture, age <40 years, history of diabetes mellitus, maximum diameter ≥ 10 cm, and instrumentation used are risk factors for wound complications. These risk factors should be considered when planning the operation and managing sacral wounds.

Conflict of interest None.

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