

What Are the Functional Outcomes After Total Sacrectomy Without Spinopelvic Reconstruction?

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Abstract

Background After total sacrectomy, many types of spinopelvic reconstruction have been described with good functional results. However, complications associated with reconstruction are not uncommon and usually result in further surgical interventions. Moreover, less is known about patient function after total sacrectomy without spinopelvic reconstruction, which may be indicated when malignant or aggressive benign bone and soft tissue tumors involved the entire sacrum.

Questions/purposes (1) What is the functional outcome and ambulatory status of patients after total sacrectomy

without spinopelvic reconstruction? (2) What is the walking ability and ambulatory status of patients when categorized by the location of the iliosacral resection relative to the sacroiliac joint? (3) What complications and reoperations occur after this procedure?

Methods Between 2008 and 2014, we performed 16 total sacrectomies without spinopelvic reconstructions for non-metastatic oncologic indications. All surviving patients had followup of at least 12 months, although two were lost to followup after that point (mean, 43 months; range, 12–66 months, among surviving patients). During this time period, we performed total sacrectomy without reconstruction for all patients with primary bone and soft tissue tumors (benign and malignant) involving the entire sacrum with no initial metastasis. The level of resection was the L5–S1 disc in 14 patients and L4–L5 disc in two patients. We classified the resection into two types based on the location of the iliosacral resection. Type I resections went medial to or through or lateral but close to the sacroiliac joint. Type II resections were far lateral (more than 3 cm from the posterior iliac spine) to the sacroiliac joint. Musculoskeletal Tumor Society (MSTS) scores, physical function assessments, and complications were gleaned from chart review performed by the treating surgeons (PK, BS). Video documentation of patients walking was obtained at followup in eight patients.

Results The mean overall MSTS scores was 17 (range, 5–27). Thirteen patients were able to walk, five without walking aids, two with a cane and sometimes without a walking aid, three with a cane, and three with a walker. Thirteen of 14 patients who had bilateral Type I resections or a Type I resection on one side and Type II on the contralateral side were able to walk, five without a walking aid, and had a mean MSTS score of 19 (range, 13–27). Two patients with bilateral Type II resection were only able to

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sit. Complications included wound dehiscences in 13 patients (which were treated with reoperation for drainage), sciatic nerve injury in seven patients, a torn ureter in one patient, and a rectal tear in one patient.

Conclusions Without spinopelvic reconstruction, most patients in this series who underwent total sacrectomy were able to walk. Good MSTTS scores could be expected in patients with bilateral Type I resections and patients with a Type I on one side and a Type II on the contralateral side. Total sacrectomy without spinopelvic reconstruction should be considered as a useful alternative to reconstructive surgery in patients who undergo Type I iliosacral resection on one or both sides.

Level of Evidence Level IV, therapeutic study.

Introduction

Total sacrectomy is an accepted treatment for aggressive tumors involving the entire sacrum. Because of the instability and discontinuity between the lumbar spine and pelvis, most surgeons perform spinopelvic reconstruction to facilitate early mobilization and better ambulation [1, 3, 5, 6, 10, 16, 18, 20, 23, 25, 28]. However, some surgeons prefer not to perform bony reconstructions after sacrectomy because some patients can ambulate and to avoid the risk of implant-related complications [11, 19, 21, 22]. We began using sacrectomy without spinopelvic reconstruction as the preferred method at our institute after treating a patient with an infected wound after spinopelvic resection; the patient was able to walk with minimal pain after we removed all implants [17].

Although a few other reports have evaluated total sacrectomy without spinopelvic reconstruction [11, 19, 21, 22, 24], these reports do not offer much detail on postoperative functional outcomes of these patients, especially with respect to the association between resection location and ultimate function. The purpose of this study is to provide video documentation (Supplemental materials are available with the online version of *CORR*®) of patients' ambulation after total sacrectomy without spinopelvic reconstruction.

We therefore asked: (1) What is the functional outcome and ambulatory status of patients after total sacrectomy without spinopelvic reconstruction? (2) What is the walking ability and ambulatory status of patients when categorized by the location of the iliosacral resection relative to the sacroiliac joint? (3) What complications and reoperations occur after this procedure?

Patients and Methods

A database of all musculoskeletal tumors at the Institute of Orthopedics, Lerdsin Hospital, Bangkok, Thailand, from

January 2008 to December 2014 was retrospectively reviewed. During that time, we performed 16 total sacrectomies without spinopelvic reconstructions for non-metastatic oncologic indications. All surviving patients had followup of at least 12 months, although two were lost to followup after that point (at 12 and 50 months after surgery). The mean followup of the whole group was 38 months (range, 5–66 months), and the mean followup on surviving patients was 43 months (range, 12–66 months). Nine patients were female and seven patients were male.

During this time period, we performed total sacrectomy without reconstruction for all patients with primary bone and soft tissue tumors (benign and malignant) involving the entire sacrum with no initial metastasis. We do not perform this operation in patients with metastatic disease involving the sacrum. Patients who underwent subtotal sacrectomy, total sacrectomy for pelvic tumors invading the sacrum, and patients who had a recurrent tumor were excluded from the study. All patients treated with total sacrectomy during the period in question were included, and we had followup of at least 12 months in all patients who survived that long. Patients who were treated at other hospitals before arriving at our center were excluded from this report.

All patients had plain radiographs, bone scans, MRIs, and CT scans of the chest and pelvis before the operation.

The diagnosis was chordoma in eight, chondrosarcoma in two, osteosarcoma in two, Ewing's sarcoma in one, high-grade liposarcoma in one, malignant peripheral nerve sheath tumor in one, and giant cell tumor in one (Table 1). Two patients were lost to followup at 12 and 50 months after the operation. The tumors were classified by the Enneking staging system [7]. There were 11 patients with Stage IB, four patients with Stage IIB, and one patient with benign Stage 3. Patients with high-grade sarcoma received neoadjuvant chemotherapy before the operation. The resections were performed at the L5–S1 disc in 14 patients and at the L4–L5 disc in two patients depending on the extent of the tumor.

The vertical resections of the sacrum were classified into two types based on the location of the iliosacral resection. A Type I resection went medial to or through or lateral but close to (less than 3 cm from the posterior iliac spine) the sacroiliac joint. Depending on tumor location and the angle of resection (which allowed us to remove the entire tumor with adequate margin), in our patients, the posterior sacroiliac joint was usually resected and sometimes the anterior sacroiliac joint could be preserved. A Type II resection went through the ilium far lateral to the sacroiliac joint (more than 3 cm from posterior iliac spine) (Fig. 1). There were 14 patients who had Type I resections (either unilaterally or bilaterally) and two patients had bilateral Type II resections.

Table 1. Demographic data of patients

Patient number	Sex/age (years)	Diagnosis	Stage	Resection level	Type of resection (right, left)	Size (cm)	Margin	Blood loss (mL)
1	F/74	Chordoma	IB	L5–S1	1, 1	10 × 7 × 7	Negative	1200
2	F/83	Chordoma	IB	L5–S1	1, 1	10 × 8 × 5	Closed	10,000
3	M/59	Chondrosarcoma	IB	L5–S1	1, 1	15 × 13 × 10	Positive	1600
4	F/66	Chordoma	IB	L5–S1	1, 1	8 × 7 × 6	Positive	1500
5	F/32	Chondrosarcoma	IB	L5–S1	1, 1	13 × 12 × 11	Negative	7000
6	M/74	Chordoma	IB	L5–S1	1, 1	8 × 6 × 4	Negative	2000
7	F/55	Osteosarcoma	IIB	L5–S1	1, 1	14 × 10 × 6	Negative	6000
8	M/14	Ewing sarcoma	IIB	L4–5	1, 1	16 × 10 × 7	Negative	10,000
9	M/31	Chordoma	IB	L5–S1	1, 1	20 × 17 × 16	Negative	11,000
10	F/60	Liposarcoma	IIB	L5–S1	1, 2	15 × 10 × 6	Negative	15,000
11	M/72	Chordoma	IB	L5–S1	1, 2	13 × 10 × 10	Closed	4000
12	M/76	Chordoma	IB	L5–S1	1, 2	17 × 16 × 12	Negative	4000
13	F/58	MPNST	IB	L5–S1	1, 2	14 × 13 × 13	Negative	8000
14	M/60	Chordoma	IB	L5–S1	2, 1	16 × 15 × 11	Negative	4000
15	F/22	Osteosarcoma	IIB	L4–5	2, 2	14 × 13 × 13	Closed	12,000
16	F/53	Giant cell tumor	3	L5–S1	2, 2	25 × 20 × 16	Positive	7000

F = female; M = male; MPNST = malignant peripheral nerve sheath tumor.

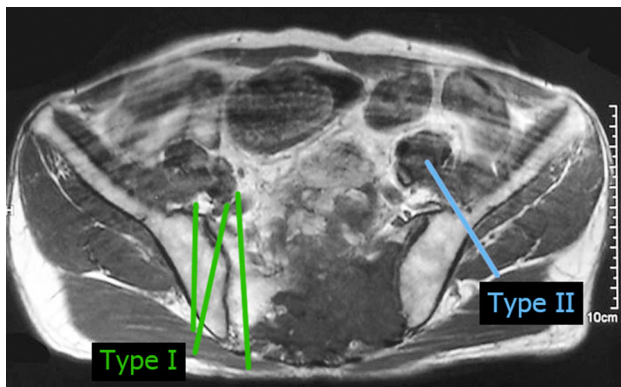


Fig. 1 Type of iliosacral resection: Type I resection is the resection that went medial to or through or lateral but close to (less than 3 cm from posterior iliac spine) the sacroiliac joint. Type II resection is resection through the ilium far lateral to the sacroiliac joint (more than 3 cm from posterior iliac spine)

Operative Technique

Preoperative embolization was performed in every patient 1 or 2 days before the operation. A sequential AP approach was used in eight patients and a posterior approach was used in eight patients. In general, we used the sequential AP approach in patients who had large tumors in which we thought access to internal iliac vessels was difficult by a posterior approach alone based on MRI findings. The technique is similar to the one described by Tomita and Tsuchiya [23].

For the anterior approach, we used a longitudinal midline incision from 5 cm above the umbilicus down to the lower

abdomen. Using a transperitoneal approach, we identified both ureters and cleared them off from the tumor and ligated both internal iliac arteries and veins and the middle sacral vessels. The rectum is mobilized off the tumor if possible. Then the disc of L5–S1 (or L4–L5) was exposed and partially removed. We used the anterior approach in patients who had large tumors and in most patients we were unable to identify the lumbosacral plexus or the sacroiliac joint. However, gauze was packed anterior to the tumor, which was intended to isolate the tumor from the rectum, ureters, and vessels and to use as landmarks for posterior osteotomies. A drain was placed and the abdominal incision was closed layer by layer. Then the patient was rolled to the prone position preparing for a posterior approach.

For the posterior approach, the midline longitudinal incision was used in nine patients and the three-limbed incision was used in seven patients depending on the extension of the tumor to the lateral aspect. The dissection is carried down just lateral to the sacrum to release the presacral fascia, the sacrotuberous ligaments, the sacrospinous ligaments, and the piriformis. Lower sacral nerve roots were also ligated and cut. Laminectomy was performed to identify the most caudal nerve roots to be preserved, which was already determined from the MRI. These roots were traced down to the sciatic nerves and were protected. The dural sac was ligated and divided below the preserved nerve roots. The disc of L5–S1 (or L4–L5) was identified and divided by using a sharp chisel to connect to that from the anterior approach surgery. Next, the iliac wings were exposed. The vertical osteotomies of

the sacrum were performed by using multiple sharp osteotomes at appropriate areas depending on the predetermined type of sacral resection as described earlier. The sacral tumor specimen now was mobilized from its surroundings. We then were able to rotate the specimen and dissect the anterior connective tissue, vessels, and rectum off. These osteotomies should be performed before dissecting the anterior soft tissue, especially when using the posterior approach only. While dissecting the anterior soft tissue off the tumor, blunt dissection is not recommended because it can cause much bleeding from vessels torn and when the torn vessels retract anteriorly, it is very difficult to identify and control. With completion of these procedures, the specimen was completely removed. Then bony and soft tissue margins of the specimens and the patient were inspected. Any questionable tumor contamination areas were resected.

Soft Tissue Reconstruction

Bony reconstruction and a flap were not used in all patients. Three to four negative pressure drains were placed. The remaining glutei on both sides were sutured together and most of the time, we were not able to completely cover the wound with those muscles because some part of muscles were resected with the tumor. Then subcutaneous tissue and skin were closed. Intravenous antibiotics were given for at least 10 days followed by oral antibiotics for 2 weeks.

Aftercare

The main problem after total sacrectomy without reconstruction was sacral pain. We initially managed this with patient-controlled anesthesia. Intravenous morphine was given before rolling patients to the side for hygiene and to prevent pressure sores. Isometric and isotonic exercises of the ankles, knees, and upper extremities in bed were recommended early to every patient. Then more progressive exercise in bed was instructed. When pain levels allowed, patients were encouraged to sit, stand, and walk as tolerated.

Two members of the surgical team (PK, BS) collected information from our musculoskeletal tumor database including demographics, resection level, margins, staging, method of reconstruction, intraoperative blood loss, functional outcome, motor level, walking ability, walking aids, bladder and bowel continence, and complications. Postoperative plain radiographs and three-dimensional CT scan of the pelvis were reviewed in regard to tumor recurrence, bony incorporation, and spinal column shifted down.

Video documentation was obtained at the followup clinic, ward, or at their house depending on patient convenience. Patients were instructed to walk according to their everyday routine. We were able to obtain videos in eight patients and a clinical picture in one patient who agreed to provide written consent for presentation and publication. Functional outcomes were measured at their recent followup using the revised Musculoskeletal Tumor Society (MSTS) Functional Score, which includes parameters of pain, function, emotional acceptance, need for external supports, walking ability, and gait [8]. Each variable scored range from 0 to 5; therefore, a maximum score for each patient was 30. Scores of 23 or greater were considered excellent, 15 to 22 were good, 8 to 14 were fair, and less than 8 were poor. Ambulatory status, walking aid use, and pain medication needed were also recorded using our questionnaire. In patients with disease progression, we used their best previous functional result and ambulatory status recorded in our patient profile instead.

Results

Function and Ambulatory Status After Total Sacrectomy

The mean MSTS score was 17 (range, 5–27 out of a possible 30, with higher scores representing better results). At the time of their last clinical evaluation, 13 of 16 patients walked; five patients used no walking aid, two also used no walking aid but sometimes needed a cane, three patients used a cane, and three patients needed a walker (Table 2). The last three patients were unable to walk; two patients were only able to lie down because of disease progression and one patient was able to sit or stand for a short time because of spinopelvic instability. Ten of 16 patients were able to ambulate independently and six patients of 16 became community ambulators and were able to walk for 1 hour or more with minimal pain.

Influence of Resection Location on Ambulatory Status

Thirteen of 14 patients who were treated with Type I resection on one or both sides were able to walk. The mean MSTS score among patients who walked was 19 (range, 13–27). For nine patients with bilateral Type I resection, five were able to walk without walking aids, four needed a walking aid and the mean MSTS score was 20 (range, 13–27). Among the five patients who had a Type I resection on one side and a Type II resection on the contralateral side, four were able to walk with a walking aid, and the mean MSTS score was 18 (range, 15–22). Radiographic findings

Table 2. Functional and oncologic outcome of patients

Patient number	Length of followup (months)	Status	Most caudal roots preserved (right/left)	Intact roots function (right/left)	Ambulatory status	Walking aids	AFO used	MSTS score	Complications	Pain medication needed	Video provided
1	18	CDF	S1/S1	S1/S1	Public, independent walking	None	No	20		None	
2	35	CDF	S1/S1	S1/S1	Household walking	Walker	No	13	Flexion contracture of knees	Nonnarcotic	
3	50	AWD	S1/S1	S1/S1	Public, independent walking	None	No	24	Recurrence	Narcotic	
4	63	CDF	S1/S1	S1/S1	Public, independent walking	None	No	20		None	
5	66	CDF	S1/S1	S1/S1	Public, independent walking	None	No	27		None	Yes
6	22	CDF	S1/S1	S1/S1	Public, independent walking	None/cane	No	24		Nonnarcotic	Yes
7	12	AWD	L5/L5	L5/L5	Household walking	Walker	No	15		Narcotic	Yes
8	22	DOD	L4/L4	L3/L3	Household walking	Cane	Yes	18	Sciatic nerve injury	Nonnarcotic	Yes
9	37	CDF	S1/L5	S1/L3	Public, independent walking	None	Yes	22	Ureter torn, Sciatic nerve injury	None	Yes
10	5	DOD	S1/S1	S1/S1	Only lie down	Bed bound	No	5	Internal iliac vein torn	Narcotic	
11	30	CDF	S1/L5	S1/L3	Public, independent walking	None/cane	No	15	Rectal torn, Sciatic nerve injury	None	Yes
12	51	CDF	S1/L5	S1/L3	Household walking	Walker	No	16	Sciatic nerve injury	Narcotic	Yes
13	61	CDF	S1/L5	S1/L3	Household walking	Cane	Yes	16	Ureter torn, Sciatic nerve injury	Nonnarcotic	Yes
14	61	CDF	S1/S1	S1/S1	Public walking with help	Cane	No	20		Nonnarcotic	
15	12	DOD	L5/L5	L3/L3	Lie down and sit	Wheelchair	Yes	11	Sciatic nerve injury	Narcotic	
16	60	CDF	L4/L4	L3/L3	Sit and short time stand	Wheelchair	No	12	Sciatic nerve injury	None	Yes

AFO = ankle-foot orthosis; MSTS = Musculoskeletal Tumor Society; CDF = continuous disease free; AWD = alive with disease; DOD = died of disease.

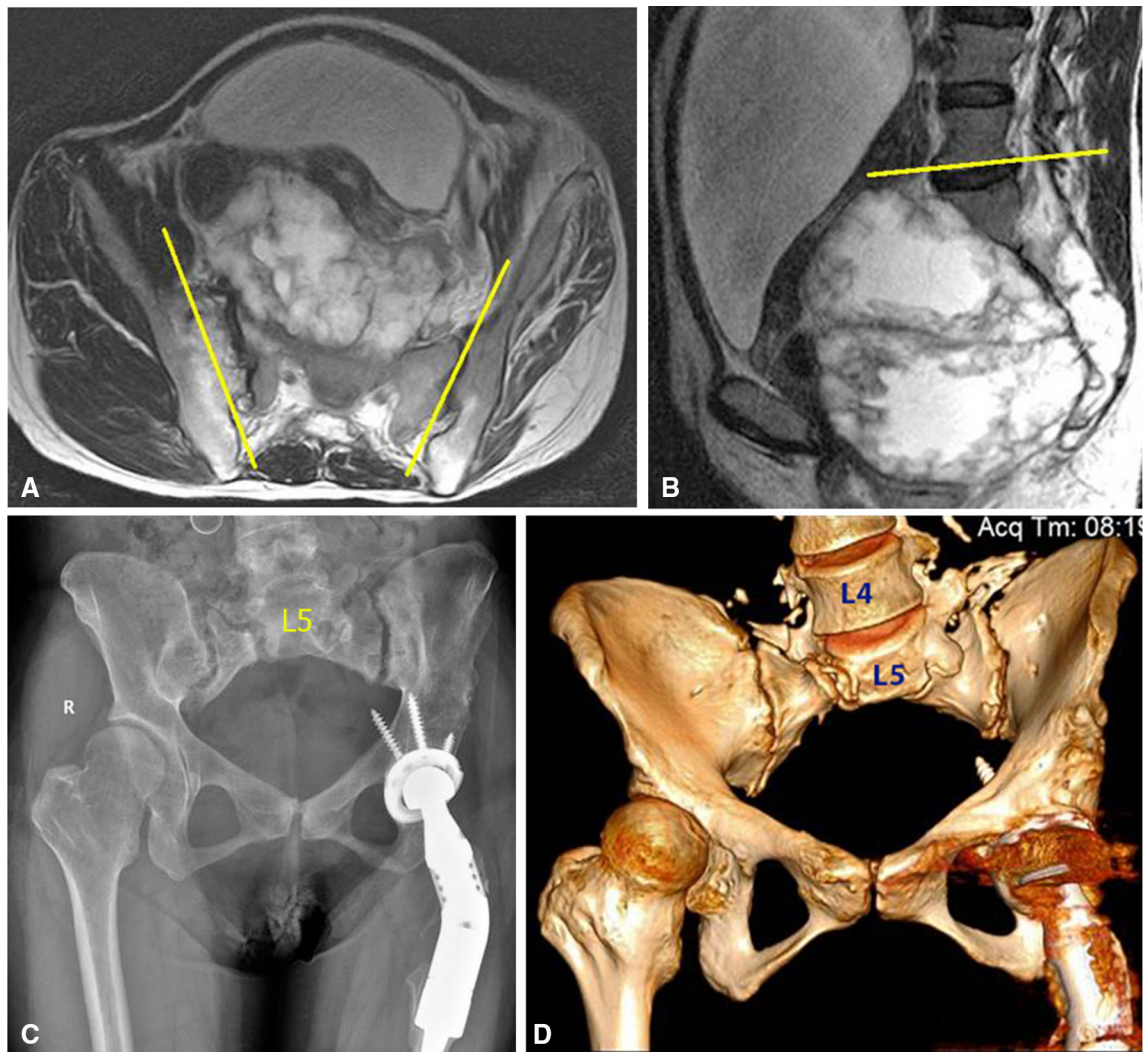


Fig. 2A–D A 32-year-old woman with chondrosarcoma of the sacrum and left proximal femur underwent total sacrectomy with bilateral Type I resection where part of the anterior sacroiliac joint remained and endoprosthesis reconstruction (Patient 5). (A) Axial and (B) sagittal MRI. The yellow line indicates planning lines of

resection. (C) Plain radiograph and (D) three-dimensional CT scan. At 5.5 years after the operation, the spinal column shifted down to the previous S1 or S2 level and their transverse processes fused with the remaining lateral sacrum

in patients who had bilateral Type I resections where part of the anterior sacroiliac joint was remained (Fig. 2), bilateral Type I resections where less part of the anterior sacroiliac joint was remained (Fig. 3), and a Type I resection on one side with a Type II resection of another side (Fig. 4) revealed the spinal column shifted down to the previous S1 or S2 level and their transverse processes fused or tended to fuse with the ilium or the remaining lateral sacrum.

Of nine patients who had bilateral Type I resections, eight patients underwent resection at the L5–S1 level and all L5 nerve roots were preserved. However, at the last followup, one patient was unable to perform dorsiflexion and plantar flexion of his ankle and needed to use ankle-

foot orthoses. One patient who underwent resection at the L4–L5 level was unable to dorsiflex and plantarflex both his ankles and used an ankle-foot orthosis. However, he was able to walk with a walker and later a cane until he had metastatic disease and died 22 months after surgery. Of five patients who had a Type I resection on one side and a Type II resection contralaterally, all underwent resection at the L5–S1 level and all L5 nerve roots were preserved. However, at the last followup, three patients were unable to perform dorsiflexion and plantar flexion of their ankles; one patient used an ankle-foot orthosis and the other two chose not to use them because they felt walking was easier without the orthosis.

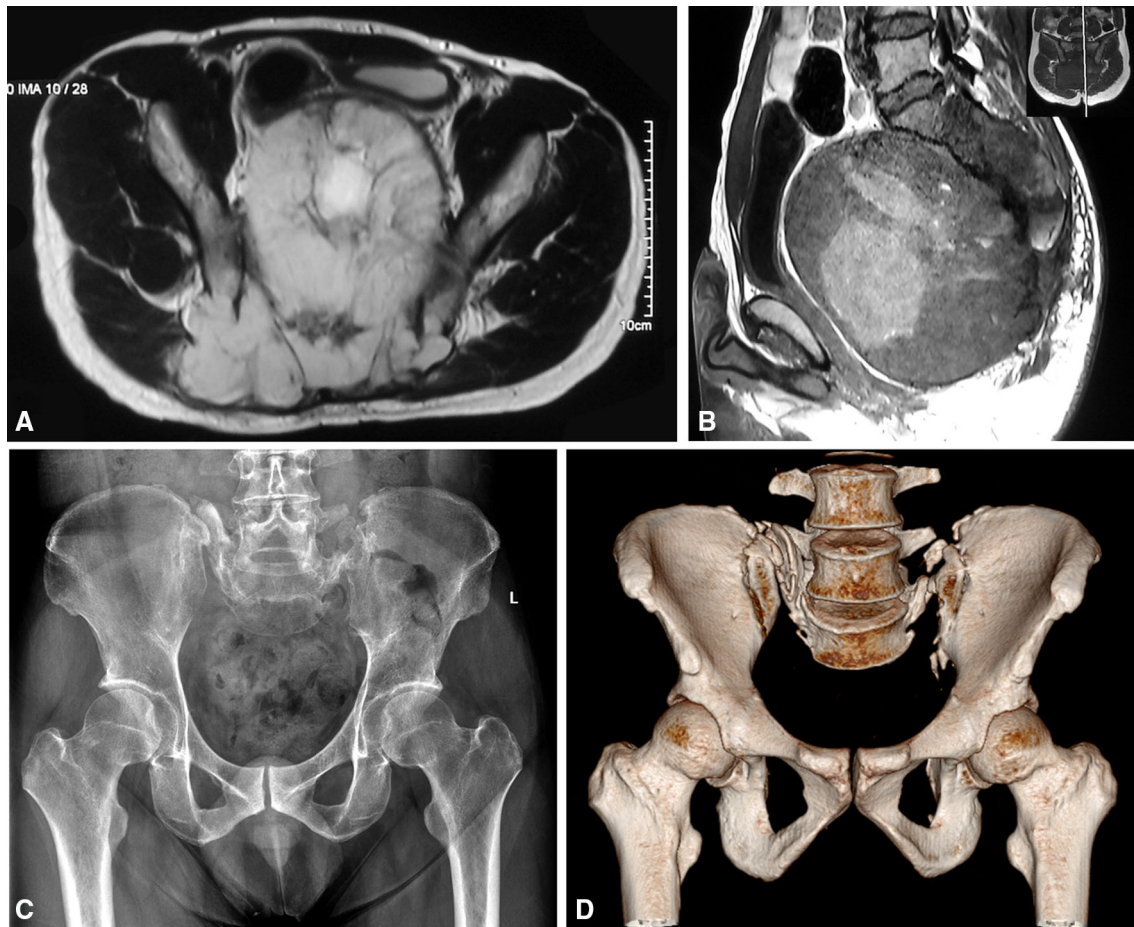


Fig. 3A–D A 31-year-old man with chordoma underwent total sacrectomy with bilateral Type I resection where less part of the anterior sacroiliac joint remained (Patient 10). **(A)** Axial and **(B)** sagittal MR images showed a large presacral mass involving S1 to S5.

The two patients with bilateral Type II resections were unable to walk. One patient with osteosarcoma had a resection at the L4–L5 level in which both L4 roots were kept intact and was unable to actively move her ankles and later died of disease at 12 months as a result of metastasis. The other patient with a large giant cell tumor underwent resection at L5–S1. Although both L4 roots were preserved at surgery, she was unable to actively move both ankles. She could sit for hours or stand for 5 minutes but not able to walk as a result of spinopelvic instability. Both patients had no pain and had MSTS scores of 11 and 12, respectively. Radiographic findings showed the spinal column shifted down and discontinued with both ilia (Fig. 5).

Complications and Reoperations

There were no perioperative death or systemic complications. Surgery-related complications included wound dehiscence in 13 of 16 patients. These patients underwent

(C) Plain radiograph and **(D)** three-dimensional CT scan. Three years after the operation, the spinal column shifted down to the pelvic area and their transverse processes closed but not fully fused to the ilia.

reoperations for drainage and vacuum-assisted closure; the ureter was torn in two patients and there was a rectal tear in one patient. Ten sciatic nerve injuries were noted in seven patients, two patients from bilateral Type I resection, three patients from Type I on one side and Type II on the other side, and two patients from bilateral Type II resection. The average estimated blood loss was 6520 mL (range, 1200–15,000 mL); the mean number of packed red cells transfused was 11 units (range, 3–23 units). Most patients were able to sit with back support within 4 to 6 weeks and sit without support at 8 to 10 weeks. The median time for patients to start walking with a walker was 4 months (range, 3–12 months). The average length of hospital stay was 90 days (range, 48–174 days).

Discussion

The main goal of any total sacrectomy is to completely remove aggressive tumor involving S1 and lower.

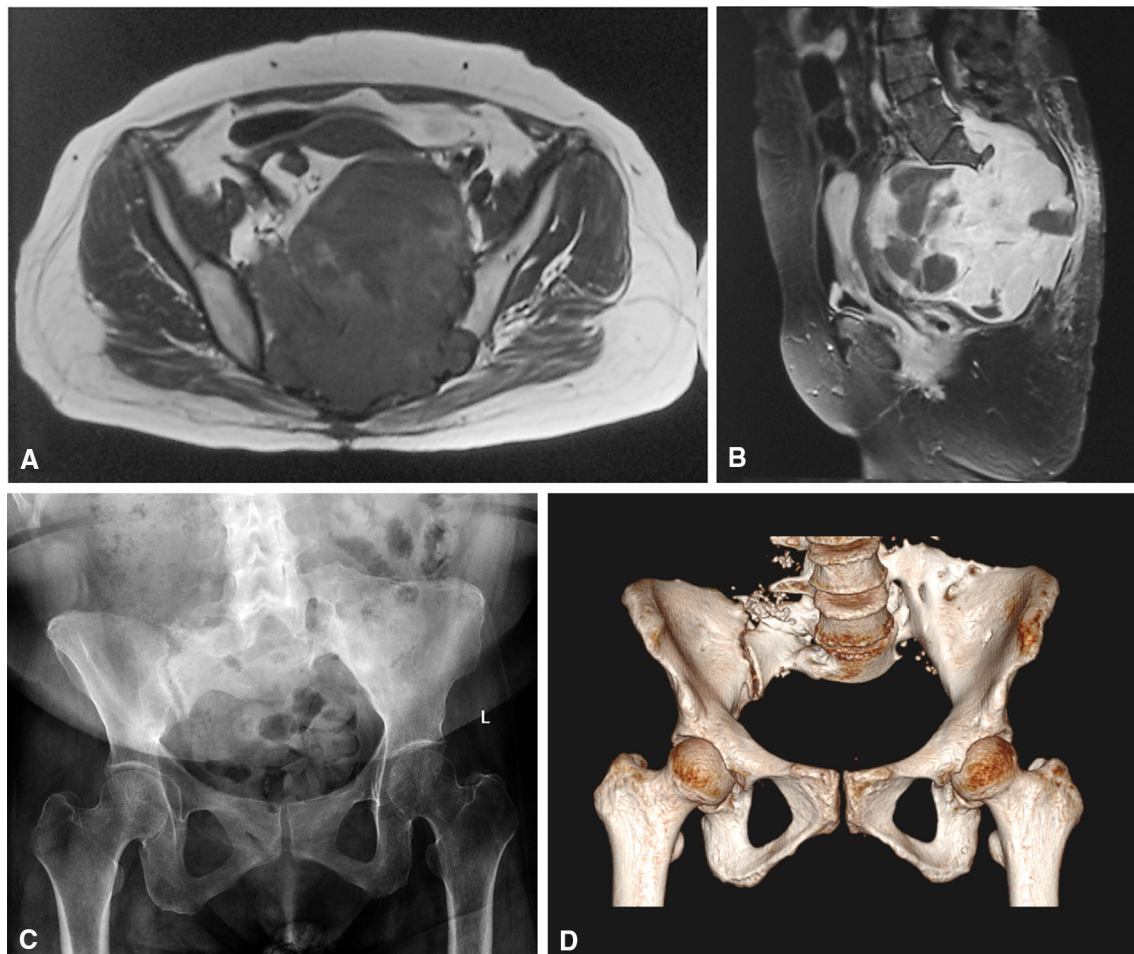


Fig. 4A–D A 58-year-old woman with malignant peripheral nerve sheath tumor involving the sacrum underwent total sacrectomy with Type I resection of the right and Type II resection of the left side (Patient 13). (A) Axial and (B) sagittal MR images showed a large

presacral tumor invaded the left sacroiliac joint. (C) Plain radiograph and (D) three-dimensional CT scan. Five years after the operation, the spinal column shifted down and fused with the ilium and the anterior sacroiliac joint.

Although this is a technically demanding procedure, and one that is associated with major complications, this procedure provides a disease-free survival benefit [4, 9, 13, 26]. After total sacrectomy, some have suggested that spinopelvic reconstruction should be performed because the instability between the lumbar spine and pelvis will cause problems with pain or mechanical kinking of blood vessels or viscera when carrying out simple movements such as moving from an upright to a supine position [6, 27]. However, from a systematic review by Bederman et al. [3], complications after spinopelvic reconstruction are common and only 24% to 44% of these patients were able to ambulate independently. Because of lower complication rates, other authors advocate sacrectomy without reconstruction [11, 19, 21, 22]; at least one study suggested little difference between patients who had a reconstruction and those who had not [24]. We previously reported a

satisfactory result of ambulatory status of a patient after total sacrectomy without spinopelvic reconstruction and thought that it was an appropriate method in selected patients [17]. Although others have evaluated total sacrectomy without spinopelvic reconstruction [11, 19, 21, 22, 24], those reports lacked detail on postoperative functional outcomes, especially with respect to resection location. We therefore sought to describe the functional outcome and ambulatory status of patients after total sacrectomy without spinopelvic reconstruction and to show video documentation of patients' ambulation.

There are several limitations with this study. First, although this is a large series of patients with total sacrectomy, our cohort is still small as a result of the rare nature of this procedure. Second, this is a retrospective study, which lacks a matched control group with patients who had bony reconstruction. Finally, we were not able to

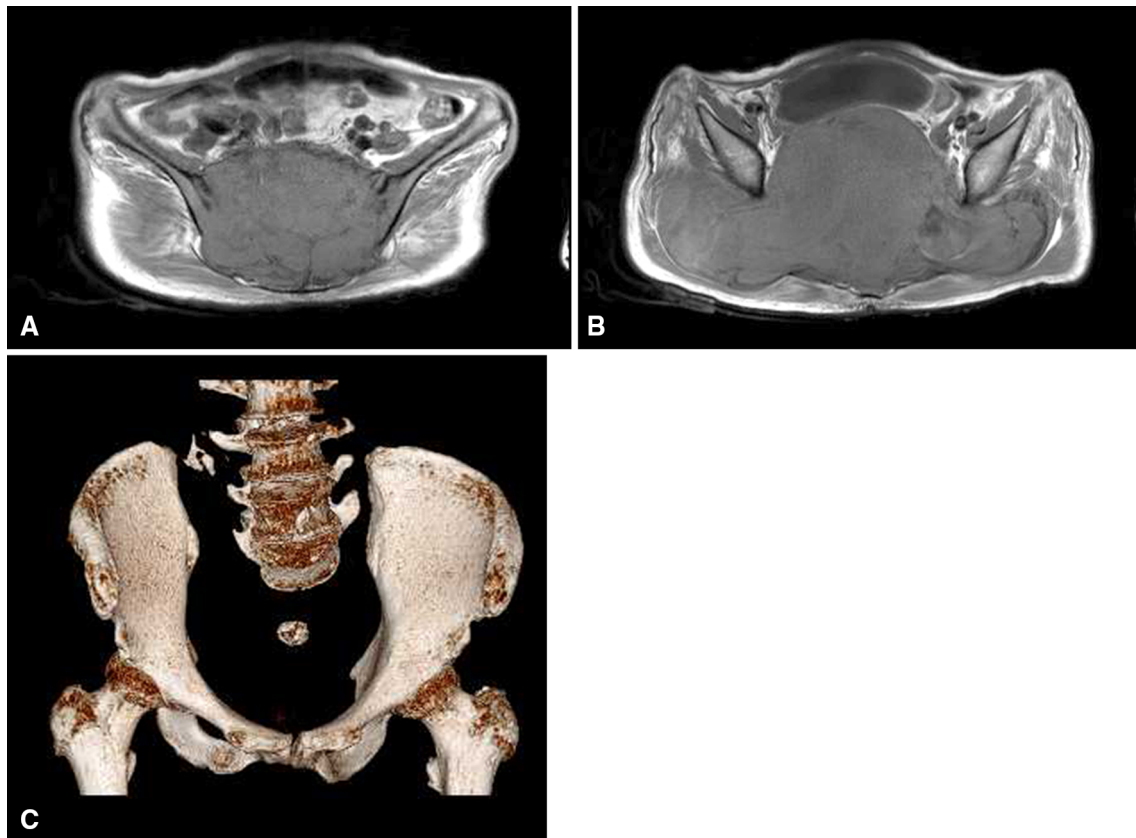


Fig. 5A–C A 53-year-old woman with a giant cell tumor underwent total sacrectomy with bilateral Type II resection (Patient 16). (A) Axial MR images at the S1 level and (B) axial MR images at the lower sacrum level showed a large tumor with extension far to both

lateral sides. (C) Three-dimensional CT scan 5 years after the operation showed the spinal column shifted down and discontinued with both ilia.

get video documentation from all patients, but we hope that this material will help readers get some idea of how patients who undergo total sacrectomy without bony reconstruction are able to walk. Two patients were lost to followup (although both had at least 1 year of followup); it is possible that those lost to followup have experienced a decrease in function and/or further surgery.

Few reports have analyzed functional outcome and ambulatory status in patients after total sacrectomy either with or without reconstruction. Some studies reported results for the whole patients and included both patients undergoing total sacrectomy and those undergoing partial sacrectomy, in whom functional results should be different [1, 21, 28]. For series of total sacrectomy with reconstruction [1–3, 5, 6, 12, 18, 20, 23–25, 28], the proportions of patients who were able to ambulate with walking aids varied widely (Table 3). Bederman et al. [3], in a systematic review of 43 patients with a mean age of 37 years old and mean followup of 33 months, found that 90% of patients were able to ambulate, 31% independently and 59% with help. Dickey et al. in a study of nine

patients (five with total sacrectomy) reported seven of nine patients were able to walk independently [6]. Tomita and Tsuchiya [23] reported three patients and all patients were able to walk, one with no walking aid, one with a cane, and one with an ankle-foot orthosis. However, in some case report or series, not many patients with reconstruction were not able to ambulate [2, 5, 12] or walk with a cane only in the house [25]. There are few studies regarding total sacrectomy without reconstruction (Table 4) and most patients were able to ambulate with a walker or cane [11, 19, 22]. In our series, 13 of 16 patients were able to walk and 10 of 16 patients were able to walk independently. These data are comparable to those series with spinopelvic reconstruction [3, 6, 18, 23, 24] and reflected that some spinopelvic stability could be obtained even without spinopelvic reconstruction. Observations from three-dimensional CT scan of patients in our supplement video demonstrated the lumbar spine shifted down and seated with the anterior sacroiliac joint or ilium. Solid fusion occurred in some patients and in those who had not had fusion, fibrotic scar that surrounded the

Table 3. Functional outcome details and complications for total sacrectomy with reconstruction

Study	Year	All sacrectomy patients (number)	Total sacrectomy patients (number)	Age (years)	Followup (months)	Functional outcome	Complications
Bederman et al. [3]	2014	43	43	37 (13–61)	33 (5–83)	35/39 (89.7%) able to ambulate	5/31 (16.1%) instrument failure
Guo et al. [10]	2013	9	9	33 (13–59)	19.7 (11–35)	Not reported	2/9 (22.2%) wound problem
Arkader et al. [1]	2012	8	(3 were total and 5 were partial sacrectomies)	14 (4–18)*	80 (54–204)*	MSTS score: 17.5 (5–25) (for all sacrectomy patients) 2/8 (25%) ambulate independently	4/8 (50%) deep infection
Asavamongkolkul et al. [2]	2012	21	3	Not reported	Not reported	5/8 (62.5%) used cane or crutches 1/8 (12.5%) wheelchair-bound Not reported	1/3 (33/3%) hardware failure
Clarke et al. [5]	2012	36	12	29–75*	7 years*	5/12 (41.7%) wheelchair-bound 12/12 (100%) could not walk without orthotics	8/22 (36.4%) wound complications
Hsieh et al. [12]	2009	20	2	50.6 (12–83)*	52 (12–86)*	32/33 (97%) able to ambulate (for 34 partial sacrectomy) 1/2 (50%) not able to ambulate	8/34 (34%) wound complications 1/2 (50%) wound-related complication
McLoughlin et al. [18]	2008	1	1	Not reported	Not reported	1/1 bed-bound	1/1 wound infection
Dickey et al. [6]	2005	9	1	57	More than 2 years	Pain-free ambulation	Not reported
Zileli et al. [28]	2003	11	5	39 (12–75)*	18 (7–42)*	7/9 (77.8%) independently walk	1/9 (11.1%) deep wound infection 1/9 (11.1%) instrument failure
						(5 patients with total, 3 patients with sagittal hemisacrectomy, and 1 patient with extended internal hemipelvectomy)	Not separately reported
			2	18	7 years	Walk with crutches	Not reported
			42	42	1 year	Not reported	Not reported

Table 3. continued

Study	Year	All sacrectomy patients (number)	Total sacrectomy patients (number)	Age (years)	Followup (months)	Functional outcome	Complications
Ohata et al. [20]	2004	1	1	13	5 years	Walk with crutches, ascend stairs	Not reported
Wuisman et al. [25]	2001	1	1	42	3 years	In house: walk with cane Outside: wheelchair	Superficial wound dehiscence
Wuisman et al. [24]	2000	9	4	28.5 (17–42)	69.5 (14–120)	MSTS score: 12 (7–18)	1/9 (11.1%) pelvic pain and instability 1/9 (11.1%) DVT No infection in 4 reconstruction patients)
Tomita and Tsuchiya [23]	1990	3	3	32	5 years 9 months	Walk without cane	Not reported
				36	2 years 9 months	Walk with cane but sometimes preferred wheelchair	Not reported
				72	10 months	Walk with ankle-foot orthosis	Not reported

* Number included patients in their whole series, which included patients with partial sacrectomy; MSTS = Musculoskeletal Tumor Society; DVT = deep vein thrombosis.

spinopelvic junction seemed to provide patients enough stability for ambulation.

Most patients with Type I resections were able to walk; patients who had bilateral Type I resections walked better and used fewer gait aids than those who had a Type I resection on one side and a Type II resection on the other. Two patients with bilateral Type II resection where a large portion of both iliac wings removed were not able to walk. We believe that when too much distance occurred between the lumbar spine and ilia, forming of the bony union or fibrotic scar would be difficult, which results in spinopelvic instability. Before our report, little has been reported on the relationship between iliosacral resection and ambulatory function. Our findings are comparable with those of Wuisman et al. [24], who classified posterior ilium resections into four levels based on the extent and angle of the resection and recommended bony reconstruction when removal of much of the iliac wing (Levels 3 and 4). Although their study did not give details of walking ability of patients in terms of type that they classified, we do agree that in patients who underwent larger resection of the ilium far lateral to the sacroiliac joint, spinopelvic reconstruction is necessary.

The most common complications after total sacrectomy without bony reconstruction in this study was wound dehiscence, which occurred in 13 patients. This could result from the fact that no flaps were used. The proportion of patients we observed with wound dehiscence was comparable to that observed by Ruggieri et al. in a series of 56 patients undergoing sacrectomy, including two who underwent total sacrectomy; a total of 66% of their patients had a wound dehiscence [21]. Deep wound infection in studies of total sacrectomy without reconstruction have occurred in 25% to 42% of patients [21, 24] and from 0% to more than 50% with reconstruction [3, 5, 6, 10, 12]. We observed no deep infections in our study, which may be explained by our aggressive approach to early reoperation for drainage and wound dehiscence and because we did not use implants or bone graft in our patients. Sciatic nerve injury was found in seven patients, generally in the setting of Type II resections. Traction or tension on the nerves, especially when bleeding was intense, could explain these injuries. Dissection and protection of nerve roots from the anterior approach might work for only small tumors. With a large tumor filling the whole true pelvis, nerve roots were pushed to the lateral aspect and identifying nerve roots was sometimes impossible. Careful protection of those nerves and intraoperative neurophysiological monitoring may be helpful for preventing injury to those nerve roots [14, 15].

Total sacrectomy without spinopelvic reconstruction may be considered as a useful alternative to reconstructive surgery in patients who undergo Type I iliosacral resection on one or both sides. Although disadvantages included longer rehabilitation and hospitalization, most patients in

Table 4. Functional outcome details and complications for total sacrectomy without reconstruction

Study	Year	Sacrectomy patients (number)	Total sacrectomy patients (number)	Age (years)	Followup (months)	Functional outcome	Complications
Ruggieri et al. [21]	2010	56	(37 patients underwent above S3 sacrectomies) (19 patients underwent below S3 sacrectomies)	55 (22–76)*	9.5 years (3–28)*	Not reported	37/56 (66%) wound dehiscence 24/56 (42.9%) infection 3/56 (5.4%) intraoperative death Not separately reported Neuropathic pain
Guo and Yadav [11]	2002	1	2	Not reported	Not reported	Standing for 30 minutes Ambulation 450 feet with walker (use corset)	
Wuisman et al. [24]	2000	9	5	57.4 (26–70)	48.4 (18–96)	MSTS score: 8 (1–14)	1/9 (11.1%) pelvic pain and instability 1/9 (11.1%) DVT
Simpson et al. [22]	1995	12	1	43	30	Walk few steps with cane, confined to wheelchair (for total sacrectomy patient)	2/5 (40%) deep infection
		5 patients: resection through S1		43.6 (21–66)*	38.2 (20–69)*	All walked independently outdoor (4 patients used a cane)	1/12 died (intraoperative) from massive hemorrhage
		3 patients: resection through S2					2/12 (16.6%) hematoma
		3 patients: resection of entire hemisacrectomy					1/12 (8.3%) delay wound healing 3/12 (25%) wound infection 1/12 acute renal failure 1/12 pulmonary embolism Not reported
Michel [19]	1990	1	1	27	2	Walk with only two ankle orthoses and two canes	Not reported
Kiatisevi et al. (current study)	2016	16	16	60 (14–83)	41 (12–66)	MSTS score: 17 (5–27)	1.3/16 (81.3%) wound dehiscence
						5/16 (31%) walked without a gait aid 5/16 (31%) walked with a cane 3/16 (18.8%) walked with a walker 1/16 (6.3%) wheelchair-bound 2/16 (12.5%) bed-bound 10/16 (63%) independently walk	No infection

* Number included patients in their whole series, which included patients with partial sacrectomy; MSTS = Musculoskeletal Tumor Society; DVT = deep vein thrombosis.

this small series were able to ambulate independently. Patients with bilateral Type II resection will have spinopelvic instability and we believe they should receive bony reconstructions, which may make it more likely that they will regain the ability to walk. Video documentation in this study demonstrates functional outcomes and walking ability of patients and could serve as a reference for further study. Future multicenter studies with more patients and studies comparing those treated with and without reconstruction might be useful to affirm our findings.

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