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Clinical results and quality of life after reconstruction following sacrectomy for primary bone malignancy

Juha Kiiski[a,b,*], **Hannu O Kuokkanen**[a], **Minna Kääriäinen**[b], **Ilkka S Kaartinen**[b,c], **Toni-Karri Pakarinen**[d], **Minna K Laitinen**[d,e]

[a] *Department of Plastic Surgery, Helsinki University Central Hospital, Helsinki, Finland*
[b] *Division of Plastic Surgery, Unit of Musculoskeletal Surgery, Tampere University Hospital, Tampere, Finland*
[c] *Department of Plastic and Reconstructive Surgery, Karolinska University Hospital, Stockholm, Sweden*
[d] *Division of Orthopaedics and Traumatology, Unit of Musculoskeletal Surgery, Tampere University Hospital, Tampere, Finland*
[e] *Department of Orthopaedics and Traumatology, Helsinki University Central Hospital, Helsinki, Finland*

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Summary *Background:* Sacrectomy is a rare and demanding surgical procedure that results in major soft tissue defects and spinopelvic discontinuity. No consensus is available on the optimal reconstruction algorithm. Therefore, the present study evaluated the results of sacrectomy reconstruction and its impact on patients' quality of life (QOL).
Methods: A retrospective chart review was conducted for 21 patients who underwent sacrectomy for a primary bone tumour. Patients were divided into groups based on the timing of reconstruction as follows: no reconstruction, immediate reconstruction or delayed reconstruction. QOL was measured using the EQ-5D instrument before and after surgery in patients treated in the intensive care unit.
Results: The mean patient age was 57 (range 22–81) years. The most common reconstruction was gluteal muscle flap (n = 9) and gluteal fasciocutaneous flap (n = 4). Four patients required free-tissue transfer, three latissimus dorsi flaps and one vascular fibula bone transfer. No free flap losses were noted. The need for unplanned re-operations did not differ between groups

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* Corresponding author at: Department of Plastic Surgery, Helsinki University Central Hospital, BO Box 266, 00029 Helsinki, Finland.
E-mail address: juha.kiiski@fimnet.fi (J. Kiiski).

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($p = 0.397$), and no significant differences were found for pre- and post-operative QOL or any of its dimensions.
Discussion: Free flap surgery is reliable for reconstructing the largest sacrectomy defects. Even in the most complex cases, surgery can be safely staged, and final reconstruction can be carried out within 1 week of resection surgery without increasing peri-operative complications. Sacrectomy does not have an immoderate effect on the measured QOL.

Introduction

The incidence of primary malignant sacral tumours is low, and these tumours often initially present with relatively mild and non-specific symptoms.[1] These tumours can progress to a large, advanced tumour. Depending on the histology, standard treatment in most cases is *en bloc* resection with or without adjuvant oncological treatment.[2,3] Advances in both medical imaging and surgical care have made most of these tumours resectable.

Hemi- and total sacrectomies result in complex bony and soft tissue defects with a possible disruption of the pelvic ring, spinopelvic discontinuity and inadequate soft tissue coverage. The reconstruction of these defects relies on the basic principles of surgical reconstruction as follows: providing spinopelvic stability, eliminating dead space and allowing tension-free wound closure. Because of the rarity of the sacrectomy procedure and the variability in reconstruction, no consensus has been reached on the optimal reconstruction method.[4] There is no concurrence on whether spinopelvic fixation is mandatory after a total sacrectomy[4]. The use of microvascular flaps for soft tissue or bone reconstruction is rare, probably because of the difficulties in finding proper donor vessels in this region.[4]

Previous studies of sacrectomy have focused on oncological outcome,[5,6] spinopelvic reconstruction[7] or soft tissue reconstruction;[8,9] however, only a limited number of studies have measured the effect of this complex and often disabling surgery on patient-reported outcome.[6,10,11] The present retrospective cohort study had two main objectives. The first was to evaluate whether the timing of the reconstruction affects surgical or oncological outcome. An urge for delaying tissue reconstruction emerged after an extremely complicated case was treated with prolonged sacrectomy. Previous studies of reconstruction after sacrectomy have not addressed the timing of reconstructive surgery in detail.[8,9,12] Second, we wanted to investigate the effect of this often mutilating surgery on patients' quality of life (QOL).

Methods

Selection criteria

Patients were identified from a prospectively maintained oncology database at Tampere University Hospital, Finland. The study was approved by the Institutional Review Board. All patients who underwent surgery for a primary bone tumour arising from the sacrum between 1 January 2008 and 30 June 2017 were included in the study. Patients with sacral metastasis, other malignancies affecting the sacrum (e.g. invasive rectal carcinoma), benign sacral lesions or bone biopsies (without intent for curative tumour resection) were excluded. Histology was confirmed in all patients by pre-operative biopsy. Pre-operative imaging studies were reviewed in a multidisciplinary team (MDT) meeting to determine the degree of tumour extension, nerve root involvement and surgical planning for both resection and reconstruction.

Variables and measurements

Data on patient demographics, surgical details, tumour characteristics, pre- or post-operative radiotherapy and/or chemotherapy and complications were collected from medical records. Complications were collected until death or the date last seen. Sacrectomies were classified as total sacrectomy, hemisacrectomy (sagittal osteotomy), partial sacrectomy (if part of the proximal sacrum could be saved) and extended sacrectomy (if lumbar vertebrae were resected *en bloc* with the tumour).[13] Patients were divided into three categories depending on the need for and timing of reconstruction. Patients who did not need soft tissue or spinopelvic reconstruction were classified as no reconstruction (NR). Patients who underwent soft tissue or bony reconstruction in a single stage operation were classified as immediate reconstruction (IR). Patients with planned staged resection and secondary reconstruction at a later date were classified as delayed reconstruction (DR).

The EQ-5D instrument was used to measure pre- and post-operative QOL. EQ-5D data were collected from a prospectively maintained intensive care unit (ICU) database on patients treated post-operatively in the ICU. Pre-operative data were recorded at the time of ICU admission. Post-operative EQ-5D data were collected at 6 months between 2008 and 2010 and at 12 months after 2010. The EQ-5D has been validated for measuring the health-related QOL of ICU patients[14] and comprises five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. All dimensions are graded from 1 to 3, with a lower grade meaning a better quality. These dimensions are combined into an EQ-5D index (range 0 to 1, with 1 representing a better quality).

Surgical technique

In partial sacrectomies, resection is performed solely by a posterior approach. In these cases, one or both of the S3

nerve roots can be preserved. In the posterior approach, the anterior aspect of the sacrum is mobilised with blunt dissection. Resection of both S3 nerve roots results in sphincter incontinence. Incontinence causes post-operative faecal contamination of the wound and, therefore, either temporary or permanent colostomy is favoured. If permanent colostomy was chosen, a combined anterior-posterior approach was used. This approach started with a laparotomy to mobilise the sigmoid colon anteriorly, thus leaving the posterior part of the colon untouched and lying on the sacrum. If temporary colostomy was chosen, colostomy was performed leaving the dissected distal sigmoid colon in place. The procedure then proceeded from the posterior part. Dissecting down to the deep musculature, an osteotomy was performed through the sacrum and the tumour removed *en bloc* with the sigmoid colon and anal canal.

In sacrectomies resulting in spinopelvic discontinuity, spinopelvic fixation was performed by a spine surgeon in collaboration with an orthopaedic oncologist. A plastic surgeon was responsible for soft tissue coverage and vascularised bone reconstruction. The soft tissue reconstruction was planned depending on defect size, available local tissue and gluteal vessel patency. For medium-sized defects, regional gluteal muscle or fasciocutaneous flaps were most commonly used. The perineal and posterior abdominal walls were reconstructed using either autologous tissue or synthetic mesh. In the case of delayed reconstruction, the skin was closed directly if possible, thus leaving a dead space behind with appropriately sized drains. In three patients in whom the skin could not be closed, negative pressure wound therapy (NPWT) was applied to cover the wound and possible fixation material (Figure 1a-f).

Follow-up

Routine follow-up included the re-evaluation of patients every 3 months for the first 2 years, at 6 month intervals for the next 3 years and then annually thereafter. A chest radiograph was obtained to identify possible dissemination of disease. Spine and pelvic radiographs were obtained from bony reconstructions to identify possible reconstruction failures. Magnetic resonance imaging (MRI) was obtained to identify possible local recurrence (LR).

Statistical analysis

Kaplan-Meier curves were constructed to assess patient survival. Categorical variables were compared between groups by chi-square test. Continuous variables were compared between groups by the Kruskal-Wallis test. Pre-operative and post-operative EQ-5D scores were tested by the Wilcoxon signed-rank test. All statistical analyses were performed using SPSS Statistics 24.0 (IBM Armonk, NY, USA). A p value of <0.05 was considered significant.

Results

A total of 21 patients with a mean age of 57 (range 22-81) years were operated on during the study period. Indication for sacrectomy was chordoma in 15 patients, chondrosarcoma in four patients and high-grade dedifferentiated sarcoma in two patients. The patient demographics and their tumour characteristics and treatments are provided in Table 1. Five patients did not require any soft tissue or bone reconstruction (NR), 11 underwent IR, and five had a planned DR (Table 2). The mean follow-up was 38 (range 0-108) months.

Seventeen patients had R0 resection, and four had R1 resection (two patients with S3/4 resection, one with hemisacrectomy and one with extended sacrectomy). Four patients (19%) had LR: two patients with primary R0 resection and two patients with R1 resection. The mean time to LR was 23 (range 5-48) months. Three of the LRs occurred in chordoma and one in high-grade dedifferentiated sarcoma. All the LRs occurred in soft tissue, no bony recurrences were noted. The treatment of LR was excision in one patient, palliation in one patient and radiotherapy followed by denosumab administration in one patient, and the details on further treatment were missing for one patient. Three patients died because of disease progression, and one patient had a fatal post-operative intracranial haemorrhage on the first post-operative day. The overall disease-specific survival was 83% at 1 year and remained the same at 5 years (Figure 2).

Resection size, length of hospital stay, surgical time and peri-operative blood loss differed significantly between the reconstruction groups (Table 2). No significant difference was found between the reconstruction groups regarding tumour histology, number of unplanned re-operations, surgical margins, LR or survival. Surgical details are presented in Table 3. All the patients in the NR group had partial sacrectomy distal to S3/4. Patients whose sacrectomies were distal to S1/2 or who underwent less extensive hemisacrectomies were reconstructed immediately. Nine of the 11 patients in the IR group had only soft tissue reconstruction and two had spinopelvic fixation and soft tissue reconstruction. Resection volumes exceeding 2000 cc^3 or soft tissue resections more than 20 cm in width were considered large and required a free flap reconstruction. Resections of smaller volumes and lengths were considered moderate. All extended sacrectomies, total sacrectomies and hemisacrectomies demanding microvascular tissue transfer were reconstructed in two stages. All patients in the DR group planned to have a secondary reconstruction within a week of the resection. This occurred in four patients; but one patient postponed reconstruction to 14 days after the primary surgery due to a complicated ICU period.

A total of 20 soft tissue flap reconstructions were performed in 16 patients. The most commonly used flaps were gluteal muscle flaps, followed by gluteal fasciocutaneous flaps. In three cases, a latissimus dorsi (LD) free flap was used when free tissue transfer was required (Table 4). Recipient vessels for microvascular transfer were end-to-end to a branch of the internal iliac vessel ($n=1$), end-to-side of the internal iliac vessel ($n=1$), gluteal perforator vessel ($n=1$) and a long saphenous vein arteriovenous loop from the groin ($n=1$).

A spinopelvic instrument reconstruction was performed using double iliac screw fixation combined with posterior lumbar segmental fixation. Bone reconstruction was performed using a non-vascularised autologous fibula in four patients, vascularised fibula in one patient and a tibia

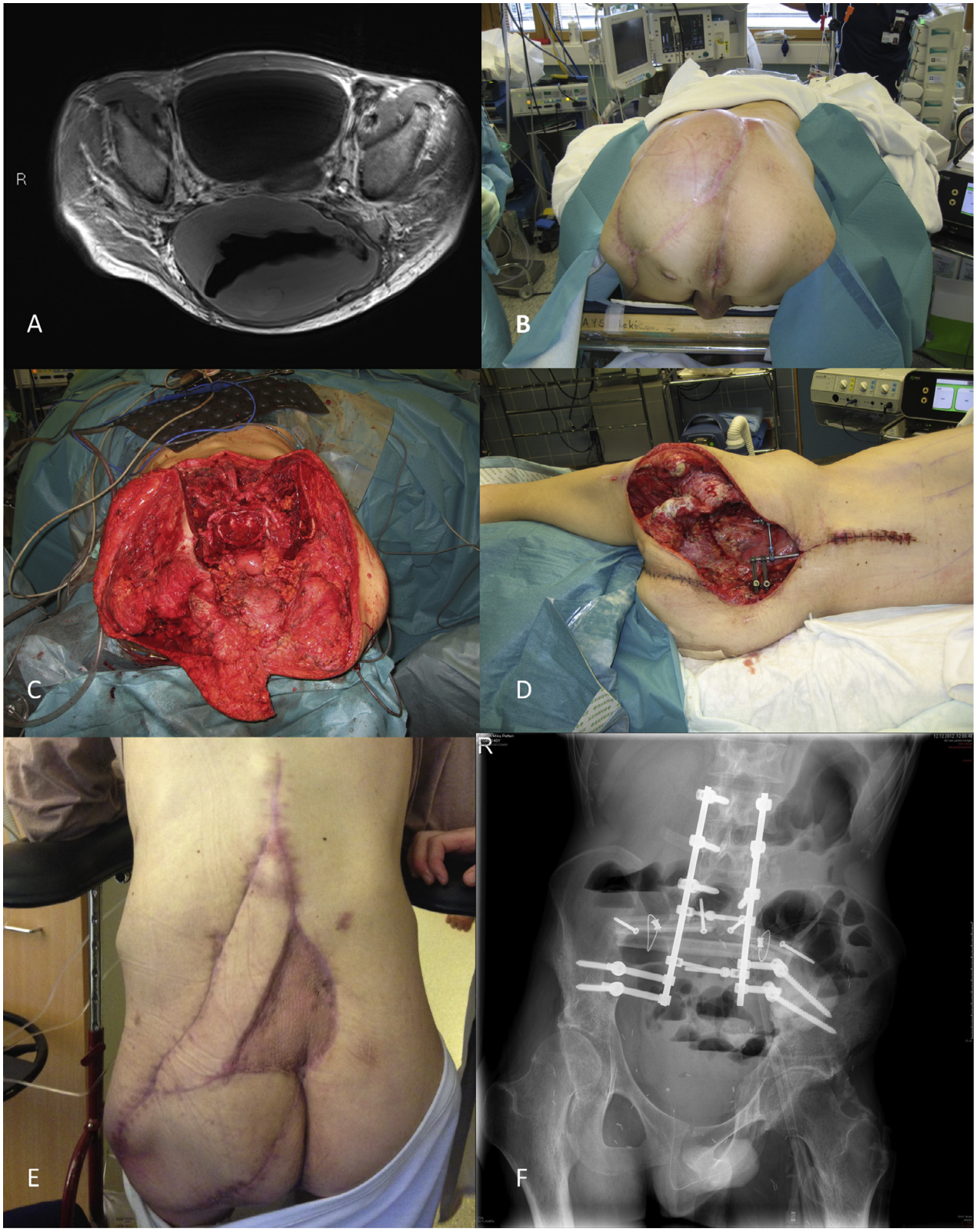

Figure 1 A. MRI of high-grade dedifferentiated sarcoma of the sacrum. B. Status after intra-lesional resection in another hospital before *en bloc* tumour resection. C. After *en bloc* resection of the L5 corpus, sacrum and medial parts of both ilea. Soft tissue resection extended inferior to the trochanter major of the right femur. D. Situation before reconstructive surgery after the removal of negative pressure wound therapy (NPWT). E. Healed LD free flap and pedicled vastus lateralis and ALT flap 1 month after wound healing and immediate rehabilitation. F. Post-operative radiograph.

Table 1 Surgical details of the patients. R0 = no ink on the margin, R1 = ink on the margin, IR = immediate reconstruction, NR = no reconstruction, DR = delayed reconstruction, VRAM flap = vertical rectus abdominis myocutaneous flap, LAP = lumbar artery perforator, LD = latissimus dorsi, NPWT = negative pressure wound therapy, ALT = anterolateral thigh, AKI = acute kidney injury, NSTEMI = non-ST elevation myocardial infarction, APR = abdominoperineal resection.

Patient	Age (years)/ gender	Histology	Resection	Resection margin	Timing of the reconstruction	Reconstruction	Length of the first operation (hh:mm)	Length of the secondary reconstruction, DR group (hh:mm)	Length of stay, total/ ICU (days)	Mesh	Complications	Peri-operative bleeding (ml)	Re-operations	Alive	Local recurrence	Follow-up (months)
1	48/F	Chordoma	S1/S2	R0	IR	Gluteal muscle flap and fasciocutaneous flap	8:05	-	14/1	Vypro	1. Ileus 2. Deep infection	3300	None	Y	N	108
2	56/F	Chordoma	S1/S2	R0	IR	Bilateral gluteus muscle flap	9:35	-	11/1	Parietex Compositum	Percutaneous seroma drainage	3500	None	Y	N	99
3	67/M	Chordoma	S1/S2	R0	IR	VRAM	15:40	-	43/7	Parietex Compositum (after VRAM flap loss)	1. AKI 2. Rhabdomyolysis 3. VRAM flap loss 4. NSTEMI 5. Wound dehiscence 6. Deep vein thrombosis 7. Deep infection	10,000	1. Bilateral gluteus musculocutaneous flap 2. Wound revision and direct closure	Y	N	36
4	64/M	Chordoma	Total	R0	DR	1. Spinopelvic fixation and NPWT 2. Free vascular fibula bone transfer and bilateral gluteus muscle flap	10:47	5:28	19/1	None	Mechanical complication of the spinopelvic fixation	3800	None	Y	N	78
5	23/M	HG sarcoma NOS	Hemisacrectomy	R1	DR	2. Pediceled LAP, distally based LD musculocutaneous flap and tibial allograft	10:40	6:32	22/1	Vypro	1. Deep vein thrombosis (pre-op) 2. Haematoma	5300	1. Haematoma evacuation	Y	N	72
6	74/M	Chordoma	S1/S2	R0	IR	Gluteal muscle flap	7:26	-	12/0	None	None	Unknown	None	Y	Y	60
7	65/M	Chondrosarcoma	Hemisacrectomy	R0	IR	Spinopelvic fixation, fibula autograft and bilateral gluteal muscle flap	8:25	-	25/1	Vypro	1. Iatrogenic contact burn 2. Wound dehiscence 3. Deep infection at 2 months	4000	1. Wound excision and direct closure 2. Wound debridement and direct closure 3. Wound debridement and NPWT	Y	N	49
8	22/M	HG sarcoma NOS	Extended	R1	DR	1. Spinopelvic fixation and NPWT 2. Pediceled vastus lateralis and ALT flap, microvascular LD flap and fibula bone autograft	13:19	7:10	53/15	None	1. *Candida albicans* septicaemia 2. Flap donor site wound dehiscence	3700	1. Wound debridement and direct closure	N	Y	8
9	57/F	Chordoma	S3/4	R0	NR	Direct closure	1:35	-	7/1	Prolene	None	200	None	Y	N	48
10	45/M	Chordoma	Total	R0	DR	1. Spinopelvic fixation 2. Microvascular LD flap and fibula autograft	12:28	8:18	60/7	Vicryl	1. Compartment syndrome 2. Deep infection	7000	1. Fasciotomy 2. Infection drainage 3. Removal of the spinopelvic fixation at 9 months	Y	N	49
11	81/M	Chordoma	S3/4	R1	IR	Regional fasciocutaneous flap	4:45	-	10/0	None	None	1700	None	N	Y	10
12	51/F	Chordoma	S3/4	R0	IR	Regional fasciocutaneous flap	5:45	-	11/1	Vypro	Deep infection	1700	None	Y	Y	36
13	69/F	Chordoma	S2/3	R0	IR	Bilateral gluteus muscle flap	4:51	-	14/1	Vypro	Anal incontinency	630	1. APR and colostomy at 2 months	Y	N	36
14	58/M	Chordoma	S1/2	R0	IR	Bilateral gluteus muscle flap	7:48	-	14/2	Vypro	None	3200	None	Y	N	34
15	63/M	Chondrosarcoma	Hemisacrectomy	R0	DR	1. Spinopelvic fixation, fibula autograft and NPWT 2. Microvascular LD flap	8:42	4:49	27/1	Optilene	None	3000	None	Y	N	24
16	58/M	Chondrosarcoma	Hemisacrectomy	R0	IR	Spinopelvic fixation, fibula autograft and bilateral gluteal muscle flap	9:55	-	3/2	Vypro	Brain haemorrhage	4000	1. Emergency craniotomy	N	N	0
17	63/F	Chondrosarcoma	Hemisacrectomy	R0	IR	Regional fasciocutaneous flap	7:20	-	16/1	Optilene	None	1900	None	Y	N	25
18	41/F	Chordoma	Coccyx	R0	NR	Direct closure	1:54	-	6/0	Vypro	None	100	None	Y	N	3
19	67/M	Chordoma	S3/4	R1	NR	Direct closure	2:41	-	7/0	None	None	555	None	Y	N	7
20	73/F	Chordoma	S3/4	R0	NR	Direct closure	2:39	-	30/0	None	Deep infection	910	1. Debridement	Y	N	1
21	41/F	Chordoma	S3/4	R0	NR	Direct closure	3:40	-	31/0	Prolene	Deep infection	500	1. Mesh removal and debridement 2. Debridement	Y	N	3

Table 2 Demographics and surgical details of the different reconstruction groups.

	No reconstruction (n = 5)	Immediate reconstruction (n = 11)	Delayed reconstruction (n = 5)	P-value*
Sex, F:M	4:1	5:6	0:5	0.043
Mean age (range)	55.8 (41-73)	62.7 (48-81)	43.4 (22-64)	0.164
Histology				0.061
Chordoma	5	8	2	
HG sarcoma NOS	0	0	2	
Chondrosarcoma	0	3	1	
Mean resection size, cm^3**	347.0 (88.4) n = 5	1252.3 (687.6) n = 9	2274.0 (2320.7) n = 2	0.007
Hospital stay, days	16.2 (13.1)	15.7 (10.5)	36.2 (18.9)	0.055
ICU stay, days	0 (0)	1.6 (1.9)	5.0 (6.1)	0.006
Surgical time, hh:mm				
Resection and immediate reconstruction	2:29 (0:48)	8:08 (3:01)	11:11 (1:47)	0.001
Delayed reconstruction surgery	-	-	6:27 (1:22)	
Peri-operative blood loss (ml)	453 (320)	3393 (2583)	4560 (1601)	0.004
Number of unplanned re-operations	0.60 (0.89)	0.64 (1.03)	1.20 (1.10)	0.397

Data are presented as mean (SD) unless otherwise noted. * Kruskal-Wallis and chi-square tests as appropriate. ** Four values were missing from the analysis.

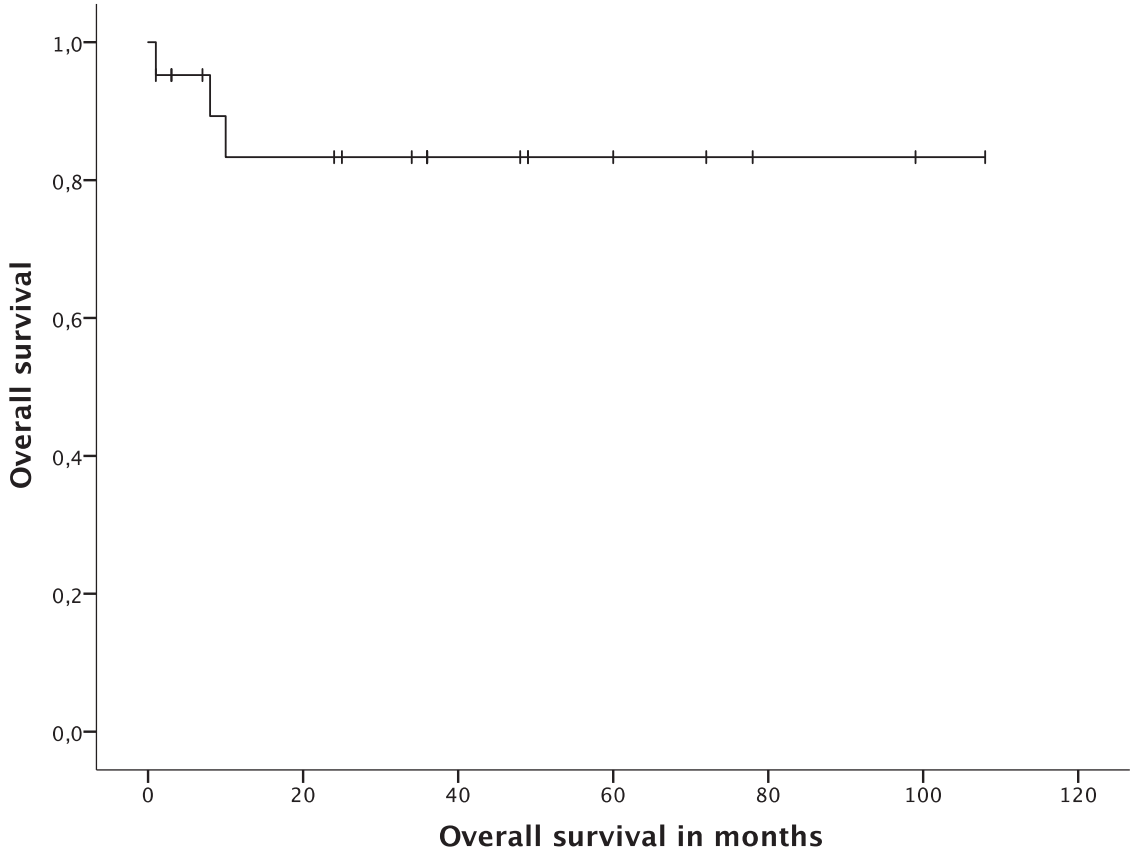

Figure 2 Kaplan-Meier curve of overall survival.

allograft in one patient. The bone graft was fixed to the host bone with additional cortical screws.

EQ-5D baseline data at ICU admission were available for 10 of the 14 patients treated in the ICU. Follow-up data were available for eight patients. Six of the 14 patients (43%) treated in the ICU had both pre-operative and post-operative EQ-5D data and were included in the analysis. No significant difference was found between the pre- and post-operative EQ-5D index or any of its dimensions (Table 5).

All complications during surgery, hospital stay and follow-up were recorded. Thirteen of the 21 patients (62%) had a total of 25 complications. The most common complication was post-operative infection (n = 8 patients), with

Table 3 Peri-operative details of the different reconstruction groups.

	No reconstruction	Immediate reconstruction	Delayed reconstruction	Total
Resection				
Extended	0	0	1	1
Total	0	0	2	2
Hemisacrectomy	0	3	2	3
S1/2 resection	0	5	0	5
S2/3 resection	0	1	0	1
S3/4 resection	4	2	0	6
Coccyx	1	0	0	1
Reconstruction				
Soft-tissue only	-	9	0	9
Spinopelvic fixation + auto/allograft bone + soft tissue flap	-	2	1	3
Spinopelvic fixation + vascular bone transfer + soft tissue flap	-	0	1	1
Spinopelvic fixation + autograft bone + soft tissue free flap with/without vascular bone flap	-	0	3	3
Mesh				
None	2	2	2	6
Absorbable	0	0	1	1
Semi-absorbable	1	7	1	9
Non-absorbable	2	2	1	5
Colostomy				
No colostomy	5	5	0	10
Loop sigmoideostomy	0	2	0	2
End sigmoideostomy	0	4	3	7

Table 4 Soft tissue flaps and vascular bone transfers in the immediate reconstruction (IR) and delayed reconstruction (DR) groups.

Flap	IR	DR
Gluteal muscle		
Unilateral	2	
Bilateral	6	1
Fasciocutaneous flap based on gluteal vessels	4	
VRAM	1	
LAP		1
LD free flap		3
Distally based LD		1
Vastus lateralis and ALT		1
Vascular fibula bone transfer		1
Total	13	8

VRAM flap = vertical rectus abdominis myocutaneous flap, LAP flap = lumbar artery perforator flap, LD flap = latissimus dorsi flap, ALT flap = anterolateral thigh flap

Table 5 EQ-5D index and dimensions for patients with full pre- and post-operative data.

	Pre-operative	Post-operative	P-value
EQ-5D index	0.81933	0.78933	0.600
Mobility	1.33	1.83	0.180
Self-care	1.00	1.33	0.157
Usual activities	1.17	1.50	0.317
Pain/discomfort	2.17	1.67	0.180
Anxiety/depression	1.17	1.00	0.317

five patients requiring surgical interventions to control the infection. Three patients had wound complications, two had venous thromboembolism and two required lower extremity fasciotomies due to compartment syndrome or rhabdomyolysis. Only one pedicled vertical rectus abdominis myocutaneous (VRAM) flap was lost. No other total or partial flap losses were noted in this study. All microvascular flaps survived completely.

Discussion

Algorithms have been proposed for the reconstruction of total[9,12] and partial sacrectomy defects[15], but they do not consider the duration of surgery or morbidity. Though these previous studies on reconstruction after sacrectomy provide useful steps for soft tissue coverage and bone reconstruction, they do not address the timing of reconstructive surgery in more detail. Sacral resection may result in heterogeneous bone and soft tissue defects depending on the size and location of the tumour. The factors that need to be addressed are the need for spinopelvic fixation due to pelvic instability, bone reconstruction, posterior abdominal wall reconstruction and the amount of soft tissue needed to fill the dead space and surface the defect. In such complicated cases, reconstruction requires expertise from many

different specialities[8,9]. The results of our study show that a planned two-stage reconstruction for the largest tumours is safe in a MDT setting and can be added to the reconstructive algorithm.

Interestingly, we did not have any LRs in bone; three of the LRs were in soft tissue and one was in the spinal canal. This emphasises the need for *en bloc* wide margin resection not only in bone but also in soft tissues[16]. An intraoperative computer navigation-assisted surgery can alleviate bone resection, but adequate soft tissue margins remain a challenge for orthopaedic oncologists[17]. The need for adequate soft tissue resection should not be limited by the reconstructive possibilities. The possibility of free flap or more complex reconstructions allows appropriate soft tissue resection without the hardship of a limited amount of local tissue.

The most commonly used flap for medium-sized defects in our series was a gluteal muscle flap. Later in the series, gluteal region fasciocutaneous flaps were also used. In most cases, part of the fasciocutaneous flap was de-epithelialised to fill the dead space. Our flap selection was in line with previous publications.[8,9,12,15] A major difference in our study from previous publications was the use of a VRAM flap. Pedicled VRAM has been widely used to reconstruct large perineal and sacral defects after sacrectomy.[8,9,12,15,18] Only one VRAM flap was used in our series; the flap was lost completely due to vascular compromise and multiple medical complications. For large defects in which regional gluteal muscle or a fasciocutaneous flap was insufficient, our primary flap choice was a microvascular LD flap. There are two main reasons for preferring an LD free flap over a VRAM flap. First, patients who underwent proximal, total or extended sacrectomy need a permanent colostomy; therefore, compromising the anterior abdominal wall integrity with flap harvest should be avoided. Although relatively rare, donor site bulging, abdominal hernias and infections are possible complications of VRAM flap use.[19] In addition to donor site problems, a reason for avoiding an abdominal flap was that the major reconstructions were carried out at a second stage. The use of an abdomen-based flap would not have been feasible in this setting because of the previous abdominal surgery performed in the week prior to the reconstruction. Using an LD free flap, delayed reconstruction can be carried out in the prone or decubitus position without changing the position during the reconstructive surgery. For most cases, there were sufficient local recipient vessels for microvascular anastomosis. In one case, we used a long saphenous loop as a recipient vessel for microvascular anastomosis, as local vessels were unusable.[20] In our series, the use of free flaps was successful, as we did not have vascular compromise, take-backs or partial or total flap losses with free flaps.

There was great variation in the reconstruction of the posterior abdominal wall in this study. For most patients, the posterior abdominal wall was reconstructed with either non-absorbable synthetic mesh or semi-absorbable mesh. The role of mesh in posterior abdominal wall reconstruction is controversial. Synthetic meshes have been used to reconstruct sacral integrity.[21] We had only one case of deep infection that required mesh removal after 1 month. No intestinal fistulae or other intestinal complications directly related to the mesh were noted in this study. A combination of a posterior approach, gluteal flaps and acellular human dermal matrix for sacrectomy defect reconstruction is favoured over synthetic mesh to overcome infectious complications.[9,22,23] Other authors have favoured soft tissue reconstruction for perineal and sacral defects.[24,25] However, no studies have directly compared synthetic mesh, biological mesh and flap only for the reconstruction of sacral defects.

Total sacrectomy, extended sacrectomy and hemisacrectomy cause instability and discontinuity between the spine and pelvis. In the literature, there are multiple choices for reconstruction to facilitate early mobilisation and better ambulation, and spinopelvic fixation using double iliac screw fixation combined with posterior lumbar segmental fixation is one of the most common procedures.[7] Without iliolumbar ligamentous stability or other biological support, spinopelvic fixation will eventually fail in good survivors; therefore, vascularised or non-vascularised bone reconstruction is recommended in addition to spinopelvic fixation. The question of whether a bone graft should be vascularised is controversial. When considering bone reconstruction, some authors advocate the use of vascularised bone transfer,[26,27] whereas others have reported similar or better results with non-vascularised grafts.[28–30] In our series, we used vascularised bone graft, especially at the beginning, but with increasing evidence of good results in the literature, we changed to non-vascularised grafts without any problems.

After an extremely complicated case of sacrectomy (patient number 3) with multiple complications due to poor intra-operative homeostasis, excessive blood loss and kidney failure, we wanted to examine the possibility of staging the reconstructive surgery in difficult cases. The benefit of this planned delayed reconstruction is to allow the patient to recover from the combined anterior-posterior approach and avoid a prolonged time in the Mecca position. Patient homeostasis and coagulative status can be optimised for reconstruction during the week, and reconstruction can be carried out safely. This approach enables patients to recover longer than in the previously described staged sacrectomy approach.[33] An additional indication for converting planned IR to DR is unexpected difficulty during the tumour resection or anaesthesia resulting in excessive blood loss, hypothermia or any other kind of disruption of the patient's homeostasis. In this scenario, the reconstruction will be converted to a planned delayed operation rather than risking any additional deterioration of the patient's condition. This would be comparable to damage control surgery in many other indications.[31,32] For patients in whom the skin cannot be closed in the primary operation, the wound is covered with dressing for NPWT during the recovery period. The NPWT is changed once in the operating room and the wound washed out. In very long and complicated extended sacrectomies requiring free flaps, this planned DR is recommended and should be openly introduced to the reconstruction algorithms.

Our current algorithm for sacrectomies and subsequent reconstruction is as follows:

(1) Partial sacrectomy distal to S3/4 level: Most of these patients can be managed with primary closure of the wound. In patients with more extensive soft tissue

resection, reconstruction can be performed with local flaps, either a gluteal muscle flap or local gluteal fasciocutaneous flap.
(2) Partial sacrectomy above S3/4 level: This results in moderate-sized soft tissue defects. These defects can be reconstructed immediately with local gluteal muscle or gluteal fasciocutaneous flaps. A mesh is used for perineal or posterior abdominal wall closure if needed.
(3) Sagittal hemisacrectomy with moderate-sized soft tissue defect: The defect can be reconstructed immediately with a posterior-only approach. Bone fixation is carried out with double iliac screw fixation combined with sacral or posterior lumbar segmental fixation and fibula autograft. The soft tissue defect is reconstructed with local pedicled flaps from the gluteal region.
(4) Sagittal hemisacrectomies with large volume tissue defect: A posterior approach is used. Bone fixation is performed and the wound closed directly or with NPWT. After 1 week, a free flap is used to reconstruct the soft tissue and/or bone defect in a second surgery. If no local donor vessels are available, a long saphenous vein arteriovenous loop is used.
(5) Total sacrectomy or partial sacrectomy with large volume defect requiring a free flap: The surgery is planned in two stages. A combined anterior-posterior approach is used for resection. In a total sacrectomy, spinopelvic fixation is performed and the wound closed directly or with NPWT. After 1 week, a free flap is used to reconstruct the soft tissue and/or bone defect in a second surgery.
(6) Patients with unexpected difficulties during tumour resection: In the case of an unexpected difficulty during tumour resection or anaesthesia resulting in excessive blood loss, hypothermia or any other kind of disruption of the patient's homeostasis, the surgery is performed in two stages.

No significant decline was found in the EQ-5D index or any of its five dimensions. There was a trend towards reducing pain and discomfort, but the difference was not significant. However, a limited number of patients treated in the ICU had both pre-operative and post-operative QOL data available, and the statistical analysis was not able to demonstrate any difference regarding the EQ-5D or its dimensions. Some studies have reported the functional status of patients who underwent sacrectomy using MSTS,[10] PROMIS[11] or other scoring systems,[6] but these studies lack pre-operative comparisons.

The major limitations of this study are clearly its retrospective nature and limited number of patients, thus limiting the statistical analysis. However, malignant primary bone tumours in the sacrum are rare, and resections performed due to other malignancies make the results more heterogeneous; therefore, these patients were excluded. The number of patients in this study, though low, is in line with earlier reports.[8] In addition, though the study is retrospective, the QOL data were recorded in the ICU database prospectively.

Conclusion

Free flap reconstruction is feasible for reconstructing large sacrectomy defects, and the saphenous arteriovenous loop is an alternative recipient site if local vessels are not available. In the most complex cases, surgery can be staged safely and final reconstruction carried out within 1 week after ablative surgery without increasing peri-operative complications. We recommend considering planned DR for very long and complicated sacrectomies. Patients tolerate the functional deficit caused by sacrectomy, and the surgery does not have an immoderate effect on the measured QOL.

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