

Risk Factors Associated with Reconstructive Complications Following Sacrectomy

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Background: Sacral pathology requiring partial or total sacrectomy is rare, and reconstructing the ensuing defects requires careful decision-making to minimize morbidity. The purpose of this study was to review the experience of a single institution with reconstructing large sacral defects, to identify risk factors for suboptimal outcomes.

Methods: A retrospective chart review was conducted of all patients who underwent sacrectomy over a 10-year period. Univariate analysis of differences in risk factors between patients with and without various postoperative complications was performed. Multivariate logistic regression was used to identify predictive variables.

Results: Twenty-eight patients were identified. The most common diagnosis leading to sacrectomy was chordoma (39%). Total sacrectomy was performed on 4 patients, whereas 24 patients underwent partial resection. Reconstructive modalities included 15 gluteal advancement flaps, 4 pedicled rectus abdominis myocutaneous flaps, and 9 paraspinous muscle or other flap types. There was an overall complication rate of 57.1% (n = 12) and a 28.6% (n = 8) incidence of major complications. There were significantly more flap-related complications in patients who underwent total sacrectomy ($P = 0.02$). Large defect size resulted in significantly more unplanned returns to the operating room ($P < 0.01$).

Conclusion: Consistent with other published series', the overall complication rate exceeded 50%. Defect volume and sacrectomy type were the strongest predictors of postoperative complications and return to the operating room, while reconstructive strategy showed limited power to predict patient outcomes. We recommend that patients anticipated to have large sacral defects should be appropriately counseled regarding the incidence of wound complications, regardless of reconstructive approach. (*Plast Reconstr Surg Glob Open* 2018;6:e2002; doi: 10.1097/GOX.0000000000002002; Published online 5 November 2018.)

INTRODUCTION

En bloc sacrectomy can be an effective treatment for sacral tumors, metastatic lesions, and conditions such as osteomyelitis.¹⁻⁵ However, partial or total removal of the sacrum results in extensive injury to surrounding bone and soft tissue, often requiring hardware for bony recon-

struction and soft-tissue coverage via pedicled or free flaps.⁶⁻⁹ Plastic surgeons face particularly challenging decisions in this setting, as wound closure is frequently complicated by radiation, compromised local vasculature, and inherent stress to the sacral region.¹⁰

Few studies have investigated the preferred method of soft-tissue reconstruction following sacrectomy. Gluteal advancement flaps, tunneled rectus myocutaneous flaps, and free tissue transfer are the most common reconstructive approaches following complex sacral injury.¹¹ Garvey et al.¹² compiled an algorithm to guide flap selection for sacral reconstruction based on the clinical outcomes of 50 patients who underwent partial sacrectomy at M.D. Anderson Cancer Center. Surgeons at the Mayo Clinic added to the relatively limited literature by reviewing their experience with postsacrectomy reconstruction, ultimately recommending gluteal advancement flaps for the man-

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agement of small defects and vertical rectus abdominis myocutaneous flaps (VRAM) for larger defects.^{13,14}

Given the paucity of available studies and limited number of institutions that treat these complex patients, a consensus on the optimal management of sacral defects has been elusive. Significant progress has been made in recent years with regard to operative techniques, yet reported complication rates are consistently high, up to 66% in some series.^{11,15,16} Compounding the difficulty of studying this population is the heterogeneity of resection defects. Partial sacrectomy can range from limited distal extirpation to wide exposure of pelvic bone, nerve roots, and rectum. Various strategies have been developed to address these situations, such as the use of acellular dermal matrix (ADM) to reconstruct the posterior abdominal wall, and the use of Mitek anchor sutures. While guidelines exist on how to select among reconstructive options, our understanding of the specific risk factors corresponding to postoperative morbidity remains limited. Correlating defect characteristics with reconstructive choices and ultimate patient outcomes would thus build upon prior insights into surgical decision making.

The purpose of our study was to describe our institution's experience treating patients who underwent sacral reconstruction following ablative surgery, with the aim of identifying predictive or protective factors for surgical complications. We reviewed reconstructive strategies used over a 10-year period, in the context of specific patient and disease characteristics, to elucidate which factors are associated with greatest morbidity in the immediate postoperative period.

MATERIALS AND METHODS

Following institutional review board approval, the medical records of all patients who underwent partial or total sacrectomy at the Keck Hospital of University of Southern California in Los Angeles, California between December 14, 2008, and March 16, 2018, were retrospectively reviewed. Patients who underwent sacrectomy at an external institution but received follow-up care at University of Southern California were excluded. Demographic variables were collected from the electronic health record and compiled using the Research Electronic Data Capture (REDCap) system.

Differences in risk factors between patients with and without various postoperative complications following partial or total sacrectomy at a single institution were assessed univariately by Fisher's exact test. Risk factors analyzed included age, body mass index greater than 30 kg/m², sex, presence of diabetes mellitus, hypertension, coronary artery disease, hyperlipidemia, hypothyroidism, history of abdominal surgery, chemotherapy, radiation, steroid use, prior tumor resection, presence of malignancy, size of defect, total sacrectomy versus partial, use of Mitek bone anchor sutures, use of ADM, concurrent procedure, ostomy creation, and flap type. ADM was used in conjunction with gluteal advancement flaps when additional posterior soft-tissue support was needed. When applied, the mesh was inset to remaining deep fascia laterally or to the pelvic

bone using bone anchor sutures. The combined volume of all specimens sent to pathology was used to quantify 3-dimensional defect size. Sizes were then differentiated as size 1 (<400 cm³), 2 (400–2,000 cm³), or 3 (>2,000 cm³), based on previously published cutoffs.¹²

Reconstructive approach was categorized as using gluteal, rectus, paraspinous, or other flap. Primary outcomes included development of seroma, hematoma, infection, abscess formation, wound dehiscence, and flap necrosis, during the first 30 days. These complications were looked at individually and also grouped into a larger category of major flap complications. This group excluded clinically insignificant wound issues that required no intervention, such as subcentimeter wound openings or seromas too small to drain. Other outcome variables were development of a sacral hernia, chronic pain, return to operating room (OR), extended hospital stay (defined as greater than 14 days between admission and discharge dates), and death within 1 month of surgery. Return to the OR was defined as an unplanned additional surgery secondary to a reconstruction-related complication, within the same admission. Complications were defined as major or minor using the Clavien-Dindo scale (Table 1). Minor complications met criteria for grade II–IIIa classification on this scale, allowing for management via pharmacologic treatment or minimally invasive procedures.¹⁷ In contrast, major complications were grade IIIb–V, involving intervention under general anesthesia and possible mortality.

Potential predictors of postoperative complications were subsequently identified by univariate logistic regression analysis. Based on a model entry criterion of $P < 0.25$, the analyzed set of variables included history of abdominal surgery, size, total sacrectomy versus partial, Mitek sutures, concurrent procedure, ostomy, and flap type. Because size 2 was not significantly different from size 1 and because of the limited number of parameters available in our small sample, sizes 1 and 2 were collapsed to one category. A multivariate model was then constructed to control for confounding variables. Tetrachoric/polychoric correlations were calculated to examine for associations among the risk factors, and separately for associations among the outcomes. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, N.C.).

Table 1. Clavien-Dindo Classification of Surgical Complications

Grade	Definition
I	Deviation from normal postoperative course without need for pharmacological treatment or surgical, radiological, or endoscopic intervention
II	Requiring pharmacological treatment, including transfusion or total parenteral nutrition
III	Requiring surgical, endoscopic, or radiological intervention
IIIa	Intervention not under general anesthesia
IIIb	Intervention under general anesthesia
IV	Life-threatening complication requiring management in intensive therapy unit
IVa	Single organ dysfunction
IVb	Multiorgan dysfunction
V	Death

Table 2. Patient and Disease Characteristics (n = 28)

Variables	Frequency (%)
Sex	
Male	16 (57.1)
Female	12 (42.9)
Diagnosis	
Chordoma	11 (39.3)
(Adeno)carcinoma	8 (28.6)
Nerve sheath tumor	5 (17.8)
Metastatic melanoma	1 (3.6)
Osteomyelitis	2 (7.1)
Chronic fracture	1 (3.6)
Sacrectomy type	
Partial	24 (85.7)
Total	4 (14.3)
Flap type	
Gluteal	15 (53.6)
Rectus	4 (14.3)
Other	4 (14.3)
None	5 (17.8)
Defect size	
Small (< 400 cm ³)	14 (50)
Moderate (400–2,000 cm ³)	9 (32.1)
Large (> 2,000 cm ³)	5 (17.9)
Outcome	
Complications (overall)	16 (57.1)
Complications (major)	8 (28.6)
Complications (minor)	11 (39.3)

RESULTS

Our review identified 28 patients including 20 with malignant sacral tumors and 8 with other pathologies requiring sacrectomy. Surgery was typically performed by a team of neurosurgeons, colorectal surgeons, and plastic surgeons. Postoperatively, patients were placed on fluidized air mattresses to minimize pressure on the surgical site. Patient characteristics and flap outcomes are outlined in Table 2. The most prevalent diagnosis was sacral chordoma (39.3%). Total sacrectomy was performed on 4 patients, while partial resection was performed on 24. Patient age at time of surgery ranged from 42 to 81 years old; mean age was 62 years. Average duration of hospital stay was 13.9 days.

Average defect volume was 1,230 cm³. There were 23 patients with small or moderate defect volumes, and 5 patients with large defects (volume greater than 2,000 cm³). For adequate oncologic resection, a posterior-only approach was used in 25 cases, whereas 3 patients required anterior and posterior access. Cases involving both anterior and posterior resection were staged over 2 days due to safety concerns of prolonged anesthesia and excessive blood loss. Mobilization of the rectum and colectomy was performed for patients with bowel involvement (n = 3). An en-bloc resection specimen comprising sacrum and rectum in a patient with invasive rectal cancer is shown in Figure 1. Reconstructive modalities included 15 gluteal advancement flaps, 4 pedicled VRAM flaps, and 9 paraspinous muscle or other flap types. Cases requiring a dual anterior-posterior approach were exclusively reconstructed with VRAM flaps, given large defect size and availability of access. Paraspinous flaps were only used for small defects that allowed adequate coverage with local muscle advancement. VRAM flap design and elevation followed conventional techniques. Gluteal VY advancement

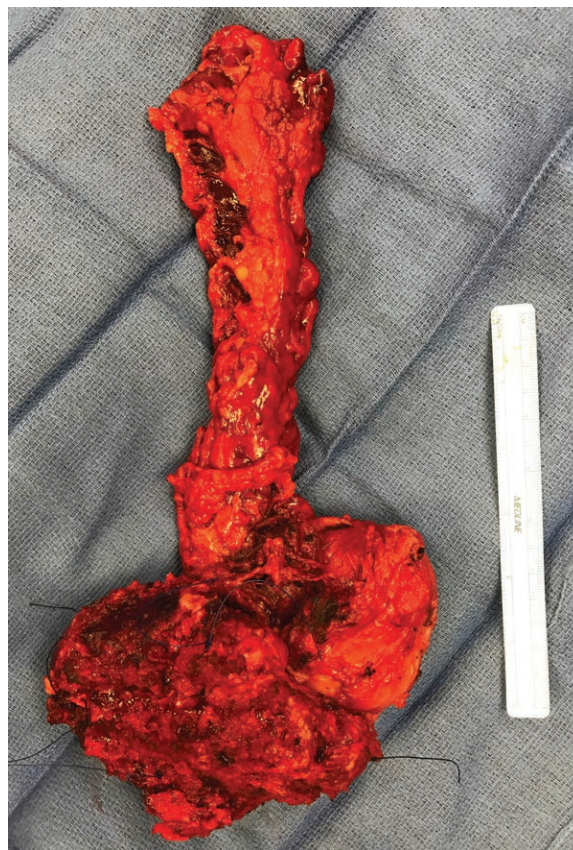


Fig. 1. Gross specimen following en bloc sacrectomy with resection of the sacrum and rectum, resulting in a 1,520 cm³ volume defect.

was performed by raising 2 myocutaneous flaps based on gluteal perforators, advancing the muscles toward the midline, and suturing each flap to its contralateral counterpart in layers. When necessary to obliterate all dead space, the medial aspect of the flap was de-epithelialized and inserted into the pelvic defect. Our reconstructive techniques are illustrated in Figures 2 and 3.

In the 30-day postoperative period, there was an overall complication rate of 57.1% (n = 12), and a 28.6% (n = 8) incidence of major complications. Minor complications met criteria for grade II–IIIa classification on the Clavien-Dindo scale, allowing for management via pharmacologic treatment or bedside procedures.¹⁷ In contrast, major complications were grade IIIb–V classification, requiring at minimum intervention under general anesthesia and in 1 case leading to patient death.

Results of the univariate analysis are shown in Tables 3 and 4. Outcomes with less than 5 patients/group were omitted due to insufficient power to detect associations. There were significantly more flap-related complications in total sacrectomy patients compared with partial sacrectomy, and in large-volume defects compared with small or moderate ($P < 0.05$). Compared with those without flap complications, patients who experienced flap complications had a significantly higher proportion of “sacrectomy total” (33.3% versus 0% for patients with and without flap complications, respectively; $P = 0.02$). Seven

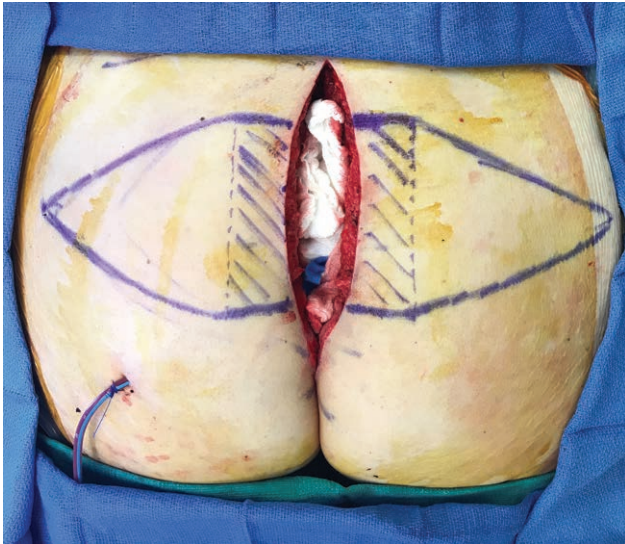


Fig. 2. Flap design for bilateral gluteal muscle-based V to Y advancement flaps, to cover a moderate sized defect (400–2,000 cm²).

patients (25%) underwent unplanned reoperation following reconstruction, and among patients with large volume defects, 80% required a return to the OR. Reasons for reoperation were postoperative bleeding, flap revision, hematoma evacuation, or incision and drainage.

ADM or mesh was used in 42.9% of patients. This biologic mesh was used in cases where the oncologic dissection significantly compromised posterior sacral support and patients were at high risk of herniation. Figure 4 demonstrates successful inset of porcine ADM into remnants of sacral ligaments and bone, before the advancement of bilateral gluteal flaps to close the wound bed. Only 1 patient demonstrated a sacral hernia postoperatively, where the rectum herniated into the wound due to loss of posterior support. Rectus abdominis myocutaneous flaps were associated with flap complications in all but one patient. History of prior abdominal surgery showed a trend

toward more postoperative flap complications but this did not reach statistical significance ($P < 0.15$). There were no patients with preexisting stomas; 10 patients (35.7%) underwent stoma creation at the time of reconstruction. Concurrent colostomy and/or ileostomy showed a notable trend toward higher rates of infection resulting in abscess ($P = 0.06$), return to the OR ($P = 0.06$), and extended hospital stay ($P = 0.10$); however, these findings were also not significant. No intraabdominal complications were reported.

Predictive variables identified by univariate analysis were then tested with a multivariate model. Correlation coefficients were calculated and reported for highly correlated variables, defined as ≥ 0.70 (Table 5). Due to the high degree of correlation observed between flap complication and OR return, only OR return was chosen for reporting in the multivariable regression. Defect size $>2,000$ cm² was identified by multivariate exact logistic regression to be an independent predictor of requiring reoperation. Patients with resection volumes greater than 2,000 cm³ were over 26 times more likely (95% confidence interval, 1.36–2194.10; $P = 0.02$) to return to the OR than patients with smaller volumes, where the confidence interval represents odds of OR return (Table 6).

DISCUSSION

Consistent with previously published literature on sacrectomy patient populations, our series of 28 sacral reconstruction patients demonstrated an overall complication rate exceeding 50%. However, the 28.7% incidence of major flap complications is lower than figures reported by other groups, varying between a 30% and 56% complication rate.^{12,18,19} Collaboration between the neurosurgery, plastic surgery, and colorectal teams at our institution over many years has allowed reconstructive surgeons to refine treatment approaches for this rare condition. Chordomas represent the most common neoplasm necessitating sacrectomy, both in the present study and in the general population, yet the incidence is only 0.1 per

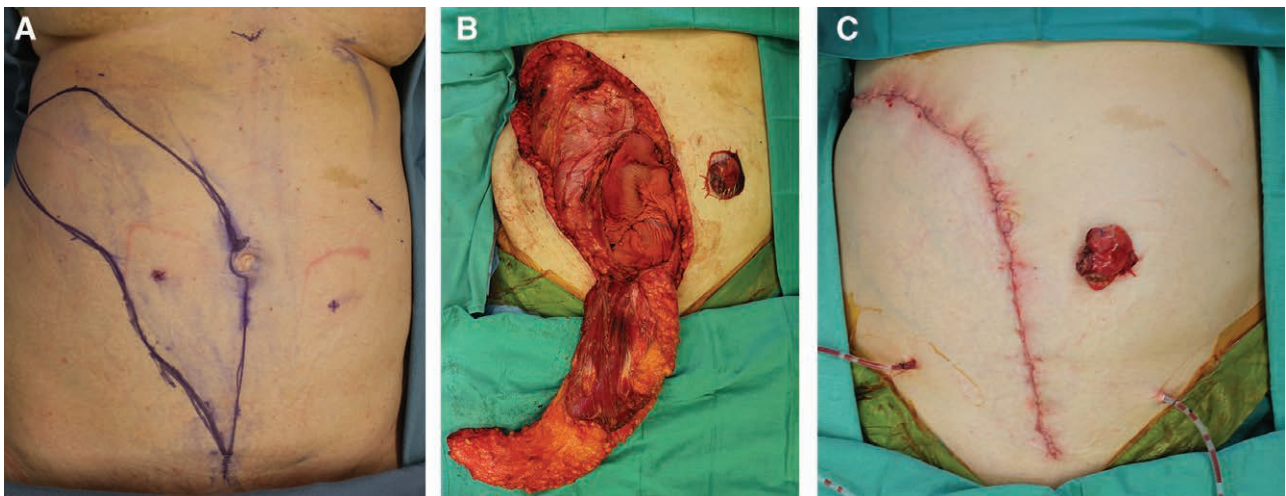


Fig. 3. A, Skin paddle design for a transpelvic pedicled VRAM flap. B, Flap elevation and identification of the deep inferior epigastric artery pedicle. C, Anterior abdominal wall after closure of the donor site and concurrent ostomy creation.

Table 3. Univariate Analysis of Perioperative Factors Associated with the Outcome of Flap Complication

Predictor, n (%)	Flap Complication, n (%)		P
	Yes (n = 12)	No (n = 16)	
BMI > 30 kg/m ²	3 (25.0)	4 (25.0)	1.00
Male sex	6 (50.0)	10 (62.5)	0.70
DM	2 (16.7)	3 (18.8)	1.00
HTN	5 (41.7)	8 (50.0)	0.72
CAD	1 (8.3)	1 (6.3)	1.00
HLD	4 (33.3)	5 (31.3)	1.00
Hypothyroidism	3 (25.0)	4 (25.0)	1.00
Hx of abd surgery	7 (58.3)	14 (87.5)	0.10
Chemotherapy	3 (25.0)	3 (18.8)	1.00
Radiation	1 (8.3)	5 (31.3)	0.20
Steroid use	4 (33.3)	4 (25.0)	0.69
Prior tumor resection	2 (16.7)	7 (43.8)	0.22
Malignant	8 (66.7)	12 (75.0)	0.69
Size			
1	3 (25.0)	11 (68.8)	0.05
2	5 (41.7)	4 (25.0)	
3	4 (33.3)	1 (6.3)	
Sacrectomy total	4 (33.3)	0	0.02
>50	11 (91.7)	16 (100.0)	0.43
>62	7 (58.3)	7 (43.8)	0.70
Mytec	3 (25.0)	2 (12.5)	0.62
ADM	7 (58.3)	5 (31.3)	0.25
Concurrent procedure	7 (58.3)	8 (50.0)	0.72
Ostomy	6 (50.0)	4 (25.0)	0.24
Flap type			
None	2 (16.7)	4 (25.0)	0.33
Gluteal	7 (58.3)	8 (50.0)	
Rectus	3 (25.0)	1 (6.3)	
Other	0	3 (18.8)	

BMI, body mass index. DM, diabetes mellitus. HTN, hypertension. HLD, hyperlipidemia. CAD, coronary artery disease.

Table 4. Perioperative Factors Associated with Return to the OR

Predictor, n (%)	OR Return, n (%)		P
	Yes (n = 7)	No (n = 21)	
Hx of abd surgery	3 (42.9)	18 (85.7)	0.04
Chemotherapy	2 (28.6)	4 (19.1)	0.62
Radiation	1 (14.3)	5 (23.8)	1.00
Steroid use	3 (42.9)	5 (23.8)	0.37
Prior tumor resection	1 (14.3)	8 (38.1)	0.37
Size			
1	1 (14.3)	13 (61.9)	0.01
2	2 (28.6)	7 (33.3)	
3	4 (57.1)	1 (4.8)	
Sacrectomy total	4 (57.1)	0	0.002
Concurrent procedure	6 (85.7)	9 (42.9)	0.08
Ostomy	5 (71.4)	5 (23.8)	0.06
Flap type			
None	1 (14.3)	5 (23.8)	0.11
Gluteal	3 (42.9)	12 (57.1)	
Rectus	3 (42.9)	1 (4.8)	
Other	0	3 (14.3)	

100,000 individuals.^{20,21} The limited number of cases and of institutions familiar with reconstruction make treatment algorithms ill-defined. Sacral tumors rarely metastasize, so radical resection can offer a potentially curative treatment. However, coverage of such wounds presents a daunting undertaking for the plastic surgeon, as local tissue is often irradiated and nearby vessels may be damaged during tumor extirpation. The presence of exposed hardware, proximity to the rectum, and daily stress on this area further compound the difficulty of postsacrectomy reconstruction.

Patients who underwent total sacrectomy experienced a significantly greater incidence of flap-related complications, such as hematoma, abscess, or dehiscence, and unplanned returns to the OR, compared with patients who required only partial resection. They also demonstrated longer hospital stays—a predictable sequela of complicated postoperative courses.

Notably, adjuvant radiotherapy was not shown to be associated with higher incidence of flap complications, which mirrors findings by other authors in a 54 patient series.¹³ Our data suggest that postoperative complications are primarily correlated with wound size, rather than with commonly assumed risk factors such as medical comorbidities or immunosuppression. Obesity, history of radiation, steroid use, and diabetes were not associated with flap complications; however, this may represent a type II error due to our small sample size. The limited patient population is a direct consequence of the rare nature of sacrectomy reconstruction, particularly outside of cancer centers. A meta-analysis with a greater number of patients could potentially identify factors that are indeed predictive of poorer outcomes. Regardless, our findings indicate that comorbid conditions should not play a larger role in surgical planning than a thorough consideration of the wound itself.

When we isolated independent predictors of need for reoperation, an outcome strongly correlated with flap complications, defect volume greater than 2,000 cm³ was associated with return to the OR. This is in contrast to the 2011 Garvey et al.¹² publication that demonstrated similar complication rates irrespective of defect volume. We find that larger extirpations demand more extensive dissection, leading to greater dead space, increased risk of injury to surrounding structures such as the iliac vessels or the rectum, and greater tension upon closure. These circumstances predictably increase the likelihood of wound breakdown and of postoperative complications requiring further surgery, which was the case in our data set. The importance of defect size therefore should not be underemphasized, and expected extent of resection should be assessed preoperatively to stratify particularly high-risk patients. A simple discussion with the spine team and review of imaging would provide key information to tailor patient expectations.

Regarding choice of flap, our findings indicate there are multiple reliable reconstructive options, with gluteal advancement flaps and transpelvic VRAMs being the most prevalent at this center. When the extent of tumor ablation or radiation fibrosis precludes the use of local flaps, rectus abdominis musculocutaneous flaps can provide an effective solution by bringing in remote healthy tissue. Rectus abdominis myocutaneous flaps were exclusively used for patients with defects greater than 2,000 cm³, as the additional bulk of this flap can fill the potential spaces created after significant soft tissue and skin resection. Gluteal advancement flaps were primarily applied for small and moderate defects. The observation that almost all VRAM patients experienced a major complication can likely be attributed to the use of these flaps for larger defects. Rectus abdominis flaps are among the best choices for recon-

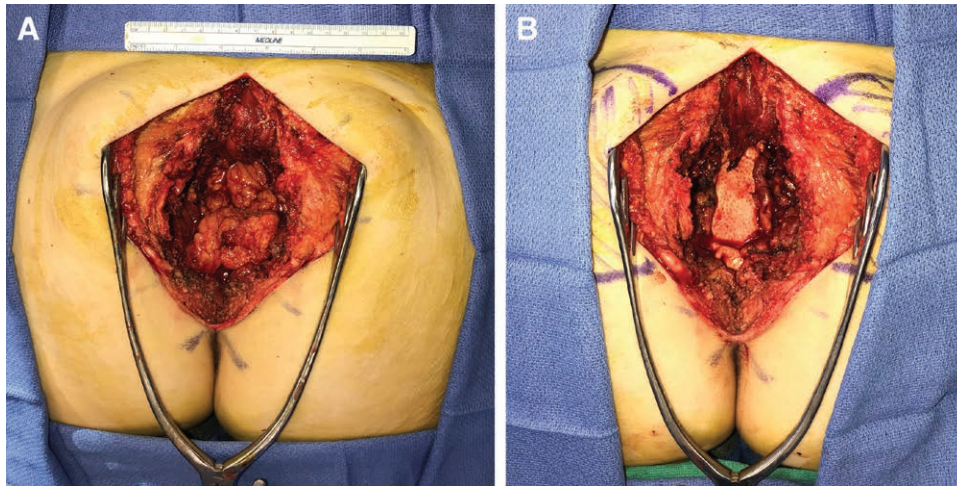


Fig. 4. A, Sacral defect after mobilization of omentum to cover exposed bowel. B, Inset of porcine ADM to lateral remnants of sacral ligaments and proximal bone, using bone anchor sutures. Defect closure was then achieved with bilateral gluteal advancement flaps.

Table 5. Correlation Analysis Between Outcome Variables

Type	Variable 1	Variable 2	r
Risk factors	Prior tumor resection	Sex	-0.70
	HLD	DM	0.75
	Sacrectomy total	Hx of abd surgery	-0.75
	Sacrectomy total	Size	0.87
	Ostomy	Size	0.88
Outcomes	Ostomy	Concurrent procedure	1.00
	Flap complication	Infection/abscess	1.00
	Flap complication	OR return	1.00
	OR return	Infection/abscess	0.84

HLD, hyperlipidemia.

Table 6. Multivariate Prediction Model for Return to the OR

Predictor	OR	95% CI		P
		Lower	Upper	
Size 3*	26.61	1.36	2,194.10	0.02
History of abdominal surgery†	0.09‡	0.0014	1.65	0.13

*Ref = size 1 or 2.

†Median unbiased estimate.

‡Ref = No history of surgery.

struction of a total sacrectomy defect, and thus were used more often in extensive sacrectomies. Since defect size is associated with a higher risk of complications, size becomes a confounding variable in the association between rectus myocutaneous flaps and subsequent morbidity. Furthermore, our study found no significant relationship between flap type and postoperative outcomes; however, it was likely underpowered to detect such correlations. Prior literature has established that defect volume is the key factor determining flap selection,^{12,13} and the present work indicates that defect volume is predictive of postoperative complications, thus an interesting question to explore in future prospective trials would be how the relationship between resection volume and postoperative outcomes is modified by reconstructive modality.

The identified trend toward higher rates of abscess formation if an ostomy was created at the time of reconstruction appears to be an expected consequence of violating the intestinal tract. Many sacrectomy patients ultimately receive stomas; however, the rationale differs based on individual pathology. Of the 10 cases in this series involving ostomies, 3 were performed for primary disease control, which necessarily creates a contaminated rather than clean-contaminated wound setting. An additional 3 were performed for temporary diversion to allow wound healing, and 4 were indicated due to high sacrectomies that sacrificed S2 roots and compromised bowel function. All VRAM reconstruction patients had concomitant ostomies, potentially exposing the elevated flap to gut bacteria and fecal contamination. By being cognizant of the increased risk of infection, reconstructive surgeons can take extra caution to irrigate thoroughly and optimize sterility, in addition to appropriate antibiotic prophylaxis.

Limitations of the present study include statistically small sample sizes, and only 7 patients who required reoperation, which limited the ability of our regression models to reach significance. Since polychoric correlation calculations determined that our main outcome variables were highly correlated, we were able to construct a multivariable predictive model for return to the OR, but we could not independently assess predictors for other outcomes. Data regarding chronic pain and ambulatory status were included in our chart review; however, our assessment of functional outcomes was limited by the lack of objective measures of motor strength or pain in clinic documentation. It would be particularly useful to look at gait disturbance in ambulatory patients who underwent reconstruction with gluteal muscle flaps. Additionally, the retrospective nature of our study makes it difficult to draw conclusions about causative relationships between perioperative variables and postoperative outcomes.

In summary, our experience suggests over half of patients are likely to experience wound-related complications within the first 30 days, and 1 in 4 may require

additional unplanned trips to the OR. These risks persist despite optimal reconstructive planning and choice of procedure. We set out to identify individuals most at-risk using multivariate statistical analysis to isolate the factors associated with suboptimal outcomes and determined that large defect size was predictive of major complications.

CONCLUSIONS

This is the largest series of sacrectomy reconstruction patients at one institution outside of dedicated cancer centers. The overall complication rate of patients undergoing soft-tissue reconstruction following partial or total sacrectomy exceeded 50% in this study. However, the incidence of major complications or unplanned return to the OR was under 30%. Sacrectomy type (partial versus total) and sacral defect volume were the strongest predictors of postoperative complications and return to the OR, while reconstructive strategy showed limited power to predict patient outcomes. We recommend that patients anticipated to have extensive sacral resections should be thoroughly counseled by their plastic surgeons regarding surgical morbidity.

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