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Effect of early mobilization on 30-day wound complications following sacral amputation for en bloc tumor resection

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OBJECTIVE Sacral amputations for en bloc resection of malignant spinal tumors are associated with significant morbidity, especially wound complications, and require complex plastic surgery reconstructions to achieve wound closure. In this study, the authors investigate wound healing related to early postoperative mobilization (≤ 3 days of bed rest) compared with delayed postoperative mobilization (> 3 days of bed rest). The primary outcome was 30-day postoperative wound complications.

METHODS This is a retrospective study of patients who underwent sacral amputation at a single institution with a single neurosurgeon between 2018 and 2023. Demographic information, comorbid conditions, pathological diagnosis, surgical characteristics, length of bed rest, and postoperative wound complications were collected for each patient. Univariate analysis followed by stepwise multivariable logistic regression was utilized to identify independent predictors of 30-day postoperative wound complications, defined as reoperation, infection, or dehiscence at the surgical site.

RESULTS Forty-three patients were included in the analysis. Thirty-one patients were placed on standard bed rest (> 3 days; mean 5.9 [SD 2.4] days), while 12 were mobilized early (≤ 3 days; mean 2.3 [SD 1.4] days). The overall wound complication rate was 37.2%. Of the patients with delayed mobilization, 15 (48.4%) experienced wound complications, while 1 (8.3%) with early mobilization experienced wound complications. On multivariable analysis, early mobilization was independently associated with reduced odds of 30-day wound complications (OR 0.035, 95% CI 0.002–0.689; p = 0.0275).

CONCLUSIONS These data show that early mobilization after sacral amputation is associated with a decreased incidence of wound complications compared with delayed mobilization. Further prospective studies investigating early mobilization after sacral amputation are warranted.

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KEYWORDS early mobilization; sacral amputation; wound complication; enhanced recovery after surgery; anatomy; oncology

Sacral amputations are complex procedures for en bloc resection of primary malignant tumors, such as chordomas, arising in the sacral and pelvic region.[1,2] En bloc resection with negative surgical margins decreases the risk of local recurrence, metastasis, and seeding, and has been associated with the highest probability of long-term tumor control and overall survival among patients with primary sacral malignancies.[3–7] Sacrectomies frequently necessitate the intentional sacrifice of neurovascular structures to achieve en bloc resection and are classified into low, middle, high, total, or hemisacral amputations based on the level of nerve root sacrifice.[8–10] As such, these procedures often require a multidisciplinary effort involving plastic, vascular, and orthopedic specialists in addition to neurosurgeons to manage tumor resection and sacral reconstruction.[11,12]

ABBREVIATIONS CCI = Charlson Comorbidity Index; EBL = estimated blood loss; LE = lower extremity; LOS = length of stay.

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Despite coordinated surgical efforts and improvements in operative techniques, sacral amputations are associated with high rates of postoperative complications.[13] Previous studies have reported a high incidence of infection, wound dehiscence, and delayed healing following sacral amputation.[14,15] Wound complications significantly impact hospital patient recovery and quality of life, and they often require rehospitalization and additional surgery.[16–18] Preventing wound complications remains a critical challenge for improving sacrectomy outcomes. To this end, mobilizing patients earlier and limiting bed rest has been shown in other surgical contexts to promote patient recovery postoperatively as part of the enhanced recovery after surgery initiative.[19,20] Here we present a retrospective cohort study comparing early postoperative mobilization (≤ 3 days of bed rest) and late mobilization (> 3 days of bed rest) with the primary outcome of 30-day wound complications (defined as reoperation, infection, or dehiscence at the surgical site).

Methods

Our institutional review board approved this study. We identified patients who underwent sacral amputation for primary malignancies at our tertiary academic center from 2018 to 2023. All resections were performed by the same neurosurgeon (J.P.W.), with closures performed by various plastic surgeons. Defect size was inferred from dimensions of surgical specimens measured intraoperatively after resection. Only patients with at least 30 days of postoperative follow-up were included. Variables, including demographics, medical and surgical history, surgical characteristics, preoperative and postoperative neurological function, and length of bed rest, were extracted and correlated with 30-day wound complications (defined as reoperation, infection, or dehiscence at the surgical site). Bilateral lower extremity (LE) strength, urinary continence, and bowel function were used to assess postoperative neurological status. Bilateral LE strength was averaged for each patient to approximate combined LE strength. Neurological assessments were recorded prior to surgery (baseline) and postoperatively on day 3 from the final stage of resection and closure (or day of discharge if discharged earlier than 3 days postoperatively). Patients were classified as being mobilized early if they were taken off bed rest ≤ 3 days postoperatively.

Statistical Analysis

Descriptive statistics for demographic, clinical, and outcome variables were calculated for the early and late mobilization groups as well as for the 30-day wound complications and no 30-day wound complications groups. Categorical variables are reported as frequencies with percentages, and continuous variables are reported as means with standard deviations. Fisher's exact test was used to compare categorical variables, and the Wilcoxon rank-sum test was used to compare continuous variables. The p values are reported for all univariate comparisons.

Stepwise multivariable logistic regression was performed to investigate independent predictors of 30-day wound complications. Continuous predictors were converted to categorical data to improve the interpretability of results. Individual predictors found to have a p value < 0.10 on univariate analysis were included in a Wald-based logistic regression to identify independent predictors. Adjusted odds ratios, 95% confidence intervals, and p values are reported. Structural equation modeling mediation analysis was conducted to investigate long length of stay (LOS) (> 7 days) as a mediator of the relationship between early mobilization and 30-day wound complications. Beta coefficients and p values are reported for variable relationships.

Statistical analysis was performed using Prism version 9.4.0 (GraphPad) and JMP Pro version 17 (SAS Institute Inc.). Statistical significance for all analyses was defined as a p value < 0.05 a priori.

Results

Cohort Characteristics

Forty-three patients met our inclusion criteria and were included in the analysis (Table 1). The yearly distribution of sacrectomies did not differ significantly between patients mobilized early and patients mobilized late (χ^2 = 8.97, p = 0.1100). The mean patient age at the surgery date was 48.8 (SD 15.6) years. Nineteen (44.2%) patients were female. The mean Charlson Comorbidity Index (CCI) score at the time of surgery was 3.2 (SD 1.1). Postoperative strength did not differ significantly for hip flexion (p = 0.7603), knee flexion (p > 0.9999), dorsiflexion (p = 0.5839), or plantar flexion (p = 0.4264) between the groups. Five (41.7%) early mobilization patients and 14 (45.2%) on standard bed rest experienced postoperative urinary retention during admission (p > 0.9999). One (8.3%) early mobilization patient and 1 (3.2%) patient on standard bed rest experienced transient postoperative fecal incontinence (p = 0.4850). Pathologically confirmed diagnoses included 31 (72.1%) chordomas, 6 (14.0%) osteosarcomas, 1 (2.3%) Ewing sarcoma, 1 (2.3%) pleomorphic sarcoma, 1 (2.3%) teratoma, 1 (2.3%) hemangiopericytoma, 1 (2.3%) benign notochordal tumor, and 1 (2.3%) tailgut cyst.

The types of amputation included 9 (20.9%) high, 6 (14.0%) middle, 19 (44.2%) low, 5 (11.6%) total, and 4 (9.3%) hemisacral amputations. Forty-one (95.3%) patients underwent complex closure procedures with plastic surgery. Of the 41 cases closed by plastic surgery, 35 (85.4%) were closed with a single flap. Of these, gluteal flap reconstructions were the most common with 22 (62.9%), followed by oblique and vertical rectus abdominal myocutaneous flaps with 9 (25.7%), paraspinous flaps with 3 (8.6%), and anteromedial thigh flaps with 1 (2.9%). Three patients had multiple flaps, including 2 (66.7%) combined gluteal and paraspinous flaps and 1 (33.3%) combined gluteal and lumbosacral flaps (Table 2).

Postoperatively, 12 (27.9%) patients were mobilized early, while 31 (72.1%) were placed on standard bed rest. Eleven (91.7%) early mobilization patients and 30 (96.8%) patients on standard bed rest were managed with Clinitron beds (p = 0.4850). Logrolling for transfers to protect the spinal column was utilized in 11 (91.7%) and 29 (93.5%) early and late mobilization patients, respectively (p > 0.9999). The mean length of bed rest for patients with

TABLE 1. Early mobilization versus late mobilization clinical characteristics

	Total (n = 43)	Early Mobilization (n = 12)	Late Mobilization (n = 31)	p Value
Patient demographics				
Age, yrs	48.8 (15.6)	42.6 (16.1)	51.2 (15.0)	0.1225
Female sex	19 (44.2)	7 (58.3)	12 (38.7)	0.3137
Clinical characteristics				
CCI	3.2 (1.1)	2.8 (0.9)	3.3 (1.2)	0.1744
BMI at surgery, kg/m^2	28.6 (5.8)	28.2 (7.5)	28.8 (5.1)	0.3862
ASA class				0.4766
II	12 (27.9)	5 (41.7)	7 (22.6)	
III	30 (69.8)	7 (58.3)	23 (74.2)	
IV	1 (2.3)	0 (0.0)	1 (3.2)	
Prior abdominal surgery	1 (2.3)	0 (0.0)	1 (3.2)	>0.9999
Steroid use w/in 30 days of surgery	4 (9.3)	1 (8.3)	3 (9.7)	>0.9999
Pathological diagnosis				0.1726
Benign notochordal tumor	1 (2.3)	1 (8.3)	0 (0.0)	
Chordoma	31 (72.1)	7 (58.3)	24 (77.4)	
Ewing sarcoma	1 (2.3)	1 (8.3)	0 (0.0)	
Hemangiopericytoma	1 (2.3)	0 (0.0)	1 (3.2)	
Osteosarcoma	6 (14.0)	2 (16.7)	4 (12.9)	
Pleomorphic sarcoma	1 (2.3)	0 (0.0)	1 (3.2)	
Tailgut cyst	1 (2.3)	1 (8.3)	0 (0.0)	
Teratoma	1 (2.3)	0 (0.0)	1 (3.2)	
Preop total RT	5 (11.6)	1 (8.3)	4 (12.9)	>0.9999
Preop RT	3 (7.0)	0 (0.0)	3 (9.7)	0.5478
Preop proton beam therapy	2 (4.7)	1 (8.3)	1 (3.2)	0.4850
Preop chemotherapy	1 (2.3)	1 (8.3)	0 (0.0)	0.2791
Preop bilat LE strength				
Hip flexion	5.0 (0.2)	5.0 (0.0)	5.0 (0.3)	>0.9999
Knee flexion	5.0 (0.1)	5.0 (0.0)	5.0 (0.1)	>0.9999
Dorsiflexion	4.9 (0.3)	4.9 (0.3)	4.9 (0.3)	>0.9999
Plantar flexion	4.9 (0.3)	4.9 (0.3)	4.9 (0.3)	>0.9999
Postop bilat LE strength				
Hip flexion	4.6 (0.9)	4.7 (1.0)	4.6 (0.8)	0.7603
Knee flexion	4.7 (0.7)	4.7 (1.0)	4.7 (0.6)	>0.9999
Dorsiflexion	4.5 (1.2)	4.6 (1.0)	4.4. (1.2)	0.5839
Plantar flexion	4.5 (1.2)	4.6 (1.0)	4.3 (1.3)	0.4264
Postop urinary retention	19 (44.2)	5 (41.7)	14 (45.2)	>0.9999
Postop fecal incontinence	2 (4.7)	1 (8.3)	1 (3.2)	0.4850
Postop Clinitron bed	41 (95.3)	11 (91.7)	30 (96.8)	0.4850
Postop logrolling technique	40 (93.0)	11 (91.7)	29 (93.5)	>0.9999
LOS, days	12.9 (11.7)	6.5 (3.1)	15.3 (12.8)	**0.0056**
Wound complication ≤30 days	16 (37.2)	1 (8.3)	15 (48.4)	**0.0171**
Nonwound complication ≤30 days*	10 (23.3)	2 (16.7)	8 (25.8)	0.6983

ASA = American Society of Anesthesiologists; RT = radiation therapy.
Values are given as number of patients (%) or mean (SD) unless otherwise indicated. Boldface type indicates statistical significance.
* Nonwound complications included bleeding, deep vein thrombosis, pulmonary embolism, pneumonia, hypotension, rectal perforation, and electrolyte imbalance.

early mobilization was 2.3 (SD 1.4) days, while the mean length for patients with delayed mobilization was 5.9 (SD 2.4) days. Of the 31 patients placed on standard bed rest, 15 (48.4%) experienced wound complications, while 1 (8.3%) patient with early mobilization experienced wound complications. Comparing pre- and intraoperative variables among patients mobilized early to those who were mobilized late, there were no significant differences be-

TABLE 2. Early mobilization versus late mobilization operative details

	Total (n = 43)	Early Mobilization (n = 12)	Late Mobilization (n = 31)	p Value
Sacral amputation type				0.5123
High	9 (20.9)	3 (25.0)	6 (19.4)	
Hemi	4 (9.3)	2 (16.7%)	2 (6.5)	
Low	19 (44.2)	6 (50.0)	13 (41.9)	
Mid	6 (14.0)	1 (8.3)	5 (16.1)	
Total	5 (11.6)	0 (0.0)	5 (16.1)	
Functional sacral amputation type				0.5059
High	7 (16.3)	2 (16.7)	5 (16.1)	
Hemi	2 (4.7)	1 (8.3)	1 (3.2)	
Low	18 (41.9)	6 (50.0)	12 (38.7)	
Mid	7 (16.3)	1 (8.3)	6 (19.4)	
Nerve sparing	4 (9.3)	2 (16.7)	2 (6.5)	
Total	5 (11.6)	0 (0.0)	5 (16.1)	
No. of sacral amputation stages				>0.9999
1	31 (72.1)	9 (75.0)	22 (71.0)	
2	10 (23.3)	3 (25.0)	7 (22.6)	
3	2 (4.7)	0 (0.0)	2 (6.5)	
Surgical approach				0.7199
Combined	14 (32.6)	3 (25.0)	11 (35.5)	
Posterior	29 (67.4)	9 (75.0)	20 (64.5)	
Defect area, cm^2	235.6 (174.6)	195.8 (180.7)	246.6 (174.6)	0.3464
Plastics closure	41 (95.3)	11 (91.7)	30 (96.8)	0.4850
Single flap type				0.2650
Anteromedial thigh	1 (2.3)	1 (8.3)	0 (0.0)	
Gluteal	22 (51.2)	5 (41.7)	17 (54.8)	
ORAM	4 (9.3)	0 (0.0)	4 (12.9)	
Paraspinous	3 (7.0)	1 (8.3)	2 (6.5)	
VRAM	5 (11.6)	1 (8.3)	4 (12.9)	
Combined flap type				NA
Gluteal & lumbosacral	1 (2.3)	0 (0.0)	1 (3.2)	
Gluteal & paraspinous	2 (4.7)	0 (0.0)	2 (6.5)	
Major vasculature ligated	8 (18.6)	2 (16.7)	6 (19.4)	>0.9999
Femur flap	1 (2.3)	1 (8.3)	0 (0.0)	0.2791
Fibula flap	1 (2.3)	0 (0.0)	1 (3.2)	>0.9999
Total EBL, mL	1003.5 (1339.2)	786.7 (1057.3)	1087.4 (1440.5)	0.2724

NA = not applicable; ORAM = oblique rectus abdominal myocutaneous; VRAM = vertical rectus abdominal myocutaneous.
Values are given as number of patients (%) or mean (SD) unless otherwise indicated.

tween the subgroups. Notably, pathological diagnosis (p = 0.1726), flap type (p = 0.2650), surgical defect area (p = 0.3464), and total estimated blood loss (EBL) (p = 0.2724) were insignificant. When assessing outcomes, patients who were mobilized early had significantly fewer 30-day wound complications (8.3% vs 48.4%, p = 0.0171), 30-day wound complications requiring surgery (0% vs 41.9%, p = 0.0081), readmissions within 30 days (0% vs 32.3%, p = 0.0403), and wound complications after 30 days (0% vs 32.3%, p = 0.0403). Additionally, patients mobilized early experienced a shorter LOS (6.5 [SD 3.1] days vs 15.3 [SD 12.8] days, p = 0.0056). The groups had no significant difference in recurrence rate, revision rate, or survival status.

Univariate Predictors of 30-Day Wound Complications

Within 30 days of surgery, 16 patients (37.2% of the total cohort) experienced wound complications, including 10 (62.5%) cases of infection and 8 (50.0%) cases of dehiscence. Of these patients, 13 (81.2%) required surgical intervention, including 10 (76.9%) debridement and washouts, 5 (38.5%) wound vacuum placements, and 3 (23.1%) surgical reclosures. Comparing patients without to those with 30-day wound complications, LOS > 7 days (48.1% vs 87.5%, p = 0.0021), early mobilization (40.7% vs 6.2%, p = 0.0171), EBL > 300 mL (37.0% vs 81.2%, p = 0.0103), pathological diagnosis of chordoma (81.5% vs 56.2%, p = 0.0920), low sacral amputation level (59.3% vs 18.8%,

TABLE 3. Univariate analysis and stepwise multivariable logistic regression evaluating independent predictors of 30-day wound complications following sacral amputation

	30-Day Wound Complications (n = 16)	No 30-Day Wound Complications (n = 27)	Univariate p Value	Adjusted OR	95% CI	LR p Value
LOS >7 days	14 (87.5)	13 (48.1)	**0.0021**	2.869	0.250–32.976	0.3976
Early mobilization	1 (6.2)	11 (40.7)	**0.0171**	0.035	0.002–0.689	**0.0275**
BMI >30 kg/m^2	6 (37.5)	12 (44.4)	0.7548			
EBL >300 mL	13 (81.2)	10 (37.0)	**0.0103**	2.983	0.377–23.607	0.3004
Pathological diagnosis: chordoma	9 (56.2)	22 (81.5)	**0.0920**	0.354	0.015–8.516	0.5223
Major vasculature ligated	6 (37.5)	2 (7.4)	**0.0369**	2.129	0.056–80.706	0.6837
Single stage	8 (50.0)	23 (85.2)	**0.0318**	0.494	0.039–6.288	0.5868
CCI ≥3	10 (62.5)	18 (66.7)	>0.9999			
Gluteal flap	5 (31.2)	17 (63.0)	**0.0094**	0.641	0.052–7.942	0.7292
Sacral amputation type: low	3 (18.8)	16 (59.3)	**0.0127**	0.688	0.066–7.202	0.7552
Age ≥50 yrs	8 (50.0)	17 (63.0)	0.5260			

LR = logistic regression.
Values are given as number of patients (%) unless otherwise indicated. Univariate predictors with a p value < 0.10 were included in the logistic regression. Certain predictor variables were excluded from stepwise multivariable logistic regression due to concerns of collinearity, perfect separation, or sparsity. Boldface type indicates statistical significance.

p = 0.0127), single-stage amputation (85.2% vs 50.0%, p = 0.0318), single flap type (63.0% vs 31.2%, p = 0.0094), and major vasculature ligation (7.4% vs 37.5%, p = 0.0369) were significantly different between the cohorts (Table 3).

Multivariable Predictors of 30-Day Wound Complications

Univariate predictor variables with a p value < 0.10 were included in the stepwise multivariable analysis (Table 3). Certain predictor variables were excluded from multivariable logistic regression due to concerns of collinearity, perfect separation, or sparsity. On multivariable analysis, only early mobilization was independently associated with reduced odds of 30-day wound complications (OR 0.035, 95% CI 0.002–0.689; p = 0.0275).

Mediation Analysis

Structural equation modeling was utilized to assess the direct and indirect effects of early mobilization on 30-day wound complications with prolonged LOS (> 7 days) examined as a potential mediator. On direct effect analysis, early mobilization was significantly associated with lower odds of 30-day wound complications ($\beta = -0.308$, p = 0.0398). The indirect effect of early mobilization on 30-day wound complications through prolonged LOS (> 7 days) was not statistically significant ($\beta = -0.093$, p = 0.1511).

Discussion

Sacral amputation remains a high-risk procedure associated with significant morbidity, namely postoperative wound complications.[2,21,22] The present study evaluated the impact of early mobilization on 30-day postoperative wound complications following sacral amputation. These results suggest that earlier mobilization, defined as bed rest for ≤ 3 days, is associated with significantly reduced odds of wound complications compared with prolonged periods of bed rest while controlling for EBL, comorbidities, surgical complexity, and pathologically confirmed diagnosis. The complexity of sacrectomies varies depending on amputation type (low, middle, high, total, or hemisacral) due to the level at which structures are resected (dictated by tumor extent).[8] Additionally, plastic surgeons commonly use flaps of varying complexity to achieve wound closure.[15,23–26] Importantly, we controlled for the varying complexity of cases, accounting for amputation and flap type, and found that early postoperative mobilization was correlated with a decreased risk of 30-day wound complications despite case complexity.

Surgical planning of resections is guided by the anatomical extent of tumor involvement on preoperative imaging. If eloquent neurovascular structures are involved and require ligation to achieve negative tumor margins, patients are counseled extensively regarding potential or expected surgery-related morbidity. Preoperative biopsy is obtained in all cases to confirm diagnosis. Additionally, CT scans of the chest, abdomen, and pelvis and/or positron emission tomography scans are often obtained preoperatively to guide surgical decision-making.

On the day of surgery, consent for surgery is obtained from patients, and their preoperative neurological baseline is evaluated. Intraoperatively, care is taken to prevent violation of the tumor capsule to achieve en bloc resection with negative tumor margins. Closure is then performed with assistance from the plastic surgery team. Postoperatively, patients are transferred to the neurosurgery intensive care unit for neurological and hematological monitoring. At the discretion of the plastic surgery team, most patients are placed on bed rest in a Clinitron bed for 2–5 days for air-fluidized pressure alleviation and facilitation of wound healing.[27] Once the patient is released from bed rest, physical therapists and occupational therapists work with the patient on bed mobility, functional transfers (via logrolling), functional ambulation, and strength for the remainder of the inpatient stay. Patients requiring additional therapies are discharged to acute inpatient rehabilitation centers for more intensive therapy at the recommendation of the physical therapist, occupational therapist, and physical medicine and rehabilitation physicians.

In other surgical contexts, early ambulation has been shown to promote postoperative recovery.[28–30] It is hypothesized that earlier muscle activation improves systemic circulation as wound healing begins postoperatively.[31–33] This increased blood flow reduces the risk of hypoxia and promotes the circulation of anti-inflammatory cytokines, accelerating wound healing.[34] Additionally, early mobilization may prevent the adverse effects of prolonged bed rest, such as thromboembolic events, pressure ulcers, and muscle deconditioning.[35] Recent studies evaluating wound healing after oncological resection of colorectal cancer and perineal reconstruction have similarly found that earlier postoperative mobilization is associated with a decreased risk of complications.[36]

The major limitation of this study is its retrospective nature and small cohort size. Future large-cohort, prospective, and randomized studies with sufficient power should be conducted to determine the incidence of wound complications following sacral amputation when removing patients from bed rest within 3 days of surgery. Additionally, the early mobilization group in this study had a younger mean age (although not statistically significant), which may have contributed to differences in wound healing. However, differences in wound healing attributed to age may be related to temporal delays in wound healing but not in overall quality.[37,38] Furthermore, exercise and activity improve wound healing in older cohorts in human and mice studies.[39,40] Finally, the mean age of both cohorts presented in this study is younger than that in previous studies evaluating the impact of aging on wound healing.[41,42] Prolonged LOS may play some role in the observed relationship between early mobilization and 30-day wound complications. Delayed mobilization likely contributes to longer hospitalizations, as coordination for discharge to inpatient rehabilitation cannot begin until therapy evaluations for patients have been completed. However, structural equation modeling validates the independent association between early mobilization and 30-day wound complications, indicating that LOS does not fully mediate the effect. The independent and potential compounding effect of LOS and postoperative wound healing is beyond the scope of this study but should be explored in future studies. Additionally, it is essential to consider additional aspects of postoperative recovery, including functional outcomes and pain management.[43–45] Optimizing recovery from sacral amputation involves not only minimizing wound complications but also improving long-term function and pain reduction. The impact of early mobilization on these factors remains an area for further investigation. Finally, it is important to recognize that the majority of our institutional cases of early postoperative mobilization were low or middle sacral amputations (7/12, 58.3%), with no patients undergoing total sacral amputation in the early mobilization group. Total sacral resection has been shown in the literature to have a significantly longer in-hospital LOS than low or middle sacral resection.[8] Furthermore, the literature has also reported impacts to ambulation following total or high sacral amputation, including postoperative weakness of foot plantar flexion and loss of gluteus maximus function, which can complicate the enactment of early mobilization protocols. Future research should seek to better characterize the patient population that may benefit the most from early ambulation measures.

Conclusions

In this study we found that early postoperative mobilization was correlated with decreased incidence of 30-day wound complications after sacrectomies for en bloc resection of primary malignancies. These preliminary findings suggest that implementing early mobilization protocols and reducing bed rest may improve postoperative healing in this high-risk patient population; however, future prospective studies are needed to validate these findings.

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Disclosures

Dr. Ko reported personal fees from Integra LifeSciences, Checkpoint Surgical, Neuraptive Therapeutics, and EDGe Surgical; and scientific advisory board membership for Mesh Suture outside the submitted work.

Author Contributions

Conception and design: Sadagopan, Du, Cach, Wolinsky. Acquisition of data: Sadagopan, Du, Sriram, Jain, Benato. Analysis and interpretation of data: Sadagopan, Chaliparambil, Du, Benato, Prasad, Cach. Drafting the article: Sadagopan, Chaliparambil, Du, Sriram, Prasad. Critically revising the article: Sadagopan, Du, Prasad, Cach, Alghoul, Ellis, Jordan, Ko, Galiano, Dumanian, Wolinsky. Reviewed submitted version of manuscript: Sadagopan, Chaliparambil, Du, Jain, Cach, Alghoul, Ellis, Jordan, Ko, Galiano, Dumanian, Wolinsky. Approved the final version of the manuscript on behalf of all authors: Sadagopan. Statistical analysis: Chaliparambil, Du, Prasad. Study supervision: Sadagopan, Wolinsky.

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