

Surgical Factors Associated with Prolonged Hospitalization after Reconstruction for Oncological Spine Surgery

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Background: Posterior trunk reconstruction is increasingly possible as a result of advances in spinal instrumentation, reconstructive approaches, and perioperative critical care. Extensive cases often require a muscle flap or complex closure to obliterate dead space. Postsurgical wound complications and subsequent reoperations can lead to neural injury, higher hospital costs, and longer hospitalizations. We aim to identify risk factors that are associated with increased length of stay (LOS) for patients receiving flaps to close a spinal defect.

Methods: A single institution, retrospective cohort study was performed on all patients from 2002 to 2014 who received a muscle flap to close a spine defect. Medical and perioperative variables that were significantly associated with LOS ($P < 0.05$) in univariate analysis were included in a stepwise regression model.

Results: A total of 288 cases were identified. Presence of instrumentation, preoperative chemotherapy, wound dehiscence, cerebrospinal fluid leak, partial/total flap loss, and medical morbidity occurrence were all independently associated with increased LOS in a combined multivariate model ($P < 0.02$ for each of the 6 variables). Importantly, Kaplan–Meier analysis demonstrated that postoperative wound dehiscence increased LOS by 12 days.

Conclusions: Spinal tumor resections often create large cavitory defects that necessitate the use of muscle flaps for closure. Patients who have received adjuvant chemotherapy require instrumentation, or those who develop specific wound-related or medical complications are at increased risk for prolonged hospitalization after spinal reconstruction. Thus, implementing measures to mitigate the occurrence of these adverse events will reduce costs and decrease the length of hospitalization. (*Plast Reconstr Surg Glob Open* 2017;5:e1271; doi: 10.1097/GOX.0000000000001271; Published online 7 April 2017.)

The 21st century has ushered in an era of unprecedented study and legislation focused on ballooning costs of health care. In the United States, inpatient admissions amounted to \$377.5 billion in 2012 with the highest costs associated with surgical stays according to the Healthcare Cost and Utilization Project (HCUP).¹ Although plastic surgery patients constitute a small percentage of the patients admitted to the hospital at any given time, those patients undergoing complex reconstructive

procedures are often utilizing extensive resources and can be among the sickest patients in the hospital. Patients undergoing posterior trunk reconstruction after spinal neoplasm resection are chief among this cohort. This population is at a high risk for wound complications because of the significant dead space resulting from a large resection and the high prevalence of adjuvant chemoradiation, use of hardware, and previous spinal surgeries, which diminish the capacity for wound healing and contribute to increased costs. Myocutaneous flaps offer a solution for complex spinal reconstructions by protecting neural elements, obliterating dead space, and promoting wound healing by inhibiting bacterial growth in contaminated wounds and increasing blood flow.^{2,3} However, relatively few studies have examined outcomes after immediate posterior trunk soft-tissue reconstruction or compared outcomes between immediate and delayed reconstruction.^{2,4,5}

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Received for publication January 12, 2017; accepted January 27, 2017.

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DOI: 10.1097/GOX.0000000000001271

Disclosure: The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.

Despite recent advances in complex muscle closures and perioperative critical care, these patients often still experience long postoperative hospital admissions.

Length of stay (LOS) has been extensively studied as a risk factor for many conditions. High-quality studies have shown that increasing LOS is associated with pneumonia, deep venous thrombosis (DVT), pulmonary embolism (PE), and “never events” such as pressure ulcers and catheter-based urinary tract infections (UTIs).^{6–8} Patients undergoing posterior trunk reconstruction after oncological surgery are at risk for similar complications from increased LOS, which may be magnified because of high rates of comorbidities and lack of mobility after large en bloc resections.⁹ Moreover, risk factors for increased LOS such as age, smoking, diabetes, malnutrition, obesity, preoperative hemoglobin level, and anesthesia duration are known to affect surgical patients in general.^{10–12} Crucially though there is very little known about predictors of increased LOS germane to this population. Whether there are preoperative medical characteristics, intraoperative conditions, or specific postoperative insults that uniquely affect these patients is unknown. Understanding specific risk factors will enable more accurate risk stratification and will help improve outcomes in the highest risk patients.

In an era of health-care reform with increased emphasis on quality of health care and minimization of postoperative complications, having a better understanding of the factors associated with worse outcomes and longer hospitalization after spine surgery is essential. In this study, we aimed to identify perioperative risk factors and postoperative complications that are associated with increased LOS for patients undergoing posterior trunk reconstruction. We hypothesized that patient comorbidities, the timing of reconstruction, and postoperative wound complications would be significantly associated with longer LOS. The specific aims of this study included analyzing how preexisting conditions, surgical variables, and largely preventable postoperative complications contribute to prolonged hospitalization in this patient population.

METHODS

Study Design and Subjects

This study was a retrospective review of subjects derived from a prospectively collected database and was approved by the Johns Hopkins Institutional Review Board. Included patients were seen at our institution and treated within the Department of Neurosurgery and the Department of Plastic and Reconstructive Surgery over a 12-year period (2002–2014). Enrolled patients satisfied the following inclusion criteria: (1) age 18 to 100 years at the time of surgery; (2) minimum of 6 months of follow-up after their initial operation; (3) complete electronic medical record; and (4) initial operation performed by a neurosurgeon, with soft-tissue reconstruction performed by a plastic surgeon.

Study Variables

The primary outcome variable in this study was the length of hospitalization. Collected predictor variables

included demographic variables (age, sex), medical variables [body mass index, diabetes, cardiovascular morbidities (hypertension, coronary artery disease, congestive heart failure, prior myocardial infarction, percutaneous coronary intervention, coronary artery bypass grafting), smoking status, chronic steroid/immunosuppression use], surgical variables (previous spine irradiation, previous spine surgery, flap type, location along the spine, and spinal hardware), and postoperative medical (DVT, PE, pneumonia, UTI, bacteremia, meningitis, small bowel obstruction) and wound-related [seroma, hematoma, infection, wound dehiscence, cerebrospinal fluid (CSF) leak] complications.

Data Collection, Management, and Analyses

Subjects were input into the database in a consecutive manner. Descriptive statistics were computed for the patient population. A *P* value of 0.05 was established as the threshold for statistical significance. Statistical computations were carried out using Stata/MP version 14.0 (Stata-Corp Inc.; College Station, Tex.).

LOS is well described in the literature to follow a highly nonnormal distribution with a long right-tail skew. Nonparametric methods (Mann–Whitney rank-sum/Kruskal–Wallis/Spearman correlation) were used to evaluate univariate predictors of LOS. Kaplan–Meier survival analysis (Cox proportional hazards model) was also used to measure variables correlated with a longer LOS. Goodness-of-fit tests were used to validate the overall models.

For regression and multivariate analysis, various distributions were evaluated. Zero-truncated negative binomial regression was found to produce the best model fit and is congruent with theoretical expectations for LOS (i.e., an over-dispersed nonzero Poisson count distribution). Stepwise regression evaluation was performed to develop the model with exclusion of collinear variables and maximization of model fit (as measured by AIC/BIC information criteria).

RESULTS

Demographics

A total of 288 cases in 258 patients were included in the study. The average age for the overall cohort was 52.6 ± 16.8 years, and 130 (50.4%) of the subjects were men. General demographic information is presented in Table 1. Surgical and postoperative course variables are presented in Table 2.

Medical and Surgical Variables: Univariate Analysis

Presence of spinal instrumentation during the neurosurgical and subsequent reconstructive surgeries was significantly associated with increased LOS ($P = 0.004$). The average LOS in patients without instrumentation was 13.68 (SD: 12.64) days, whereas the average LOS in patients with instrumentation was 19.85 (SD: 19.37) days. In cases involving tumor resection, the average tumor volume was 310.8 cm^3 . After log correction for nonnormality, tumor volume was still significantly associated with longer

Table 1. Patient Demographics

No. cases (no. patients)	288 (258)
Male/female	130 (50.4%)/128 (49.6%)
Average age, y	52.6±16.8
Current smoker	37 (12.8%)
Diabetes mellitus	49 (17.0%)
Cardiovascular morbidity	106 (36.8%)
Chronic immunosuppression/steroid use	35 (12.2%)
Preoperative spinal irradiation	102 (35.4%)
Preoperative chemotherapy	68 (23.6%)
Previous spine surgery	155 (53.8%)

Table 2. Surgical and Postoperative Variables

Spinal instrumentation	213 (74.0%)
Tumor location	
Cervical	40 (13.9%)
Cervicothoracic	37 (12.8%)
Thoracic	55 (19.1%)
Thoracolumbar	24 (8.3%)
Lumbosacral	129 (44.8%)
Three levels	3 (1.0%)
Spine etiology	
Soft-tissue sarcoma	19 (6.6%)
Chordoma	53 (18.4%)
Chondrosarcoma	7 (2.4%)
Osteosarcoma	6 (2.1%)
Metastatic lesion	65 (22.6%)
Nerve sheath tumor	2 (0.7%)
Giant cell tumor	6 (2.1%)
Hardware revision/fusion	82 (28.5%)
Benign lesion	34 (11.8%)
Chondroblastoma	2 (0.7%)
Osteoblastoma	3 (1.0%)
Ependymoma	6 (2.1%)
Meningioma	3 (1.0%)
Flap type	
Trapezius	25 (8.7%)
Latissimus dorsi	2 (0.7%)
Paraspinous	122 (42.4%)
Rectus abdominis	7 (2.4%)
Gluteus maximus	41 (14.2%)
Direct closure	21 (7.3%)
Platysmal	2 (0.7%)
Rhomboid	2 (0.7%)
Two back flaps	43 (14.9%)
Two other flaps	23 (8.0%)
Average LOS (standard error)	18.25 (1.06)
Average follow-up time in months (range)	7.7 (1–97)

hospitalization ($P = 0.008$). Preoperative chemotherapy was also associated with longer LOS ($P = 0.002$).

Postoperative Complications: Univariate Analysis

The LOS was significantly longer for patients who experienced a wound complication postoperatively ($P < 0.001$). Specifically, major wound complications that required reoperation ($P < 0.001$), wound dehiscence ($P = 0.002$), infection ($P < 0.001$), CSF leak ($P = 0.003$), and partial/total flap loss ($P = 0.025$) increased LOS, whereas the development of a hematoma and seroma did not significantly increase LOS. Postoperative medical morbidities also significantly increased LOS ($P < 0.001$); specifically, development of a DVT was associated with a longer LOS ($P = 0.005$). Significant variables with a P value < 0.05 in univariate analysis are ranked according to their influence on LOS in Table 3. Kaplan–Meier analysis showed that wound dehiscence postoperatively in-

Table 3. Univariate Analysis of Factors Significantly Associated with LOS

Variable	No. Cases	LOS (d)	P
Postoperative CSF leak			0.003
No	269	17.09	
Yes	19	34.63	
Medical morbidity			< 0.001
No	217	14.1	
Yes	71	30.92	
Flap loss (partial + total)			0.025
No	264	17.13	
Yes	24	30.58	
Major postoperative complication requiring reoperation			< 0.001
No	211	14.06	
Yes	77	29.71	
Infection			< 0.001
No	218	15.65	
Yes	70	26.33	
Postoperative wound dehiscence			0.002
No	238	16.59	
Yes	50	26.14	
History of chemotherapy within 5 y			0.002
No	220	16.17	
Yes	68	24.96	
Postoperative complication			< 0.001
No	158	13.2	
Yes	130	24.4	
DVT			0.005
No	244	17.23	
Yes	44	23.89	
Instrumentation present			0.004
No	75	13.68	
Yes	213	19.85	
Tumor volume			0.008

creased LOS by 12 days {median LOS, 11 [95% confidence interval (CI): 9–14] vs 23 (95% CI: 14–28)} (Fig. 1).

LOS and Complications: Multivariate Analysis

The multivariate model for preoperative factor prediction of increased LOS included presence of instrumentation ($P = 0.008$), preoperative chemotherapy ($P = 0.001$), and log-transformed tumor size ($P = 0.001$). The model for postoperative incident prediction of LOS consisted of medical morbidity occurrence ($P < 0.001$), wound dehiscence ($P = 0.02$), CSF leak ($P = 0.003$), and partial/total flap loss ($P = 0.02$). The final combined multivariate LOS model successfully included all of these factors except for tumor volume ($P < 0.02$ for each of the 6 variables).

DISCUSSION

The aim of this study was to identify factors associated with increased LOS for patients undergoing posterior trunk soft-tissue reconstruction. It was previously unknown which medical or surgical factors are most predictive of increased LOS in this vulnerable patient population. We aimed to describe independent predictors of LOS to better understand and mitigate risks after posterior trunk reconstruction.

The results of this study demonstrate that risk factors including presence of instrumentation, previous chemotherapy, and specific postoperative complications are associated with increased LOS. The only factor dropping out of the multivariate model was tumor volume. Thus,

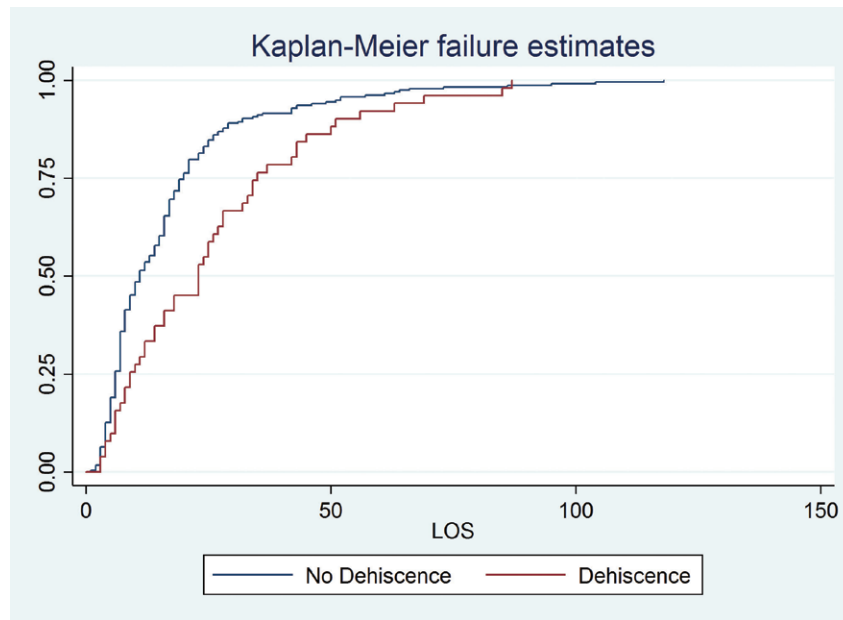


Fig. 1. Wound dehiscence and LOS. Wound dehiscence added 12 days, on average, to the postoperative LOS.

although tumor volume is still a possible factor potentiating prolonged hospitalization that requires future investigation, in our study, only presence of hardware and previous chemotherapy independently accounted for increased LOS in the preoperative model. Most importantly, postoperative wound breakdown was associated with a 12-day longer hospitalization. It has previously been shown that the use of prophylactic flaps helps minimize wound complications by increasing vascularity and obliterating the dead space after spine surgery.⁵ For example, the overall rate of CSF leak in patients undergoing spine surgery ranges from 5.5% to 21%, and in our series, the incidence with the use of flaps falls on the lower end of this range at 6.6%.¹³ Although future prospective studies would be needed to determine specific indications for prophylactic flaps, given that wound dehiscence and CSF leak significantly increase LOS, muscle flaps should be utilized whenever possible in high-risk patients undergoing posterior trunk surgery. Flaps are especially important in cases of multilevel en bloc tumor resections where there is an increased risk of complications due to the creation of a large defect. Although flap loss is also associated with increased LOS, this complication is uncommon. Total flap loss only occurred in 6 cases (2.1%) and partial flap loss occurred in 18 cases (6.3%) within 5 years of surgery. We therefore believe that the potential benefit that flaps provide in preventing wound complications and decreasing LOS outweighs the small risk of flap failure.

As more complex spine surgeries are made possible because of advances in instrumentation and reconstructive approaches, flaps will continue to play a larger role in covering large spinal defects to lessen the likelihood of complications.¹⁴ In patients undergoing extensive spinal tumor resection, wound complications can be particularly devastating because of the risk of exposed hardware or

neural structures. Subsequent reoperations and washouts potentiate the risk for hardware removal, which can cause long-term deformity and neural injury. Previous studies have reported the benefits of using muscle flaps in posterior trunk reconstructions. Cohen et al.⁵ reported a wound complication rate of 6.8% in patients who received a muscle flap to close a posterior trunk defect. Likewise, a study by Garvey et al.⁴ reported a major complication rate of 12% in a series of 52 patients who received an immediate flap after spinal tumor resection. These complication rates are substantially lower than rates ranging anywhere from 19% to 78% that are seen in patients undergoing complex spinal surgery without the use of flaps.^{15–17} Chang et al.² have examined the importance of spinal instrumentation and reported a lower rate of wound complications among patients with instrumentation when flaps were used prophylactically. Given that our study shows an association between presence of instrumentation and increased LOS and previous work has shown that flaps can decrease wound complications in these patients, local muscle flaps may be particularly beneficial for patients with instrumentation. Mericli et al.¹⁰ have previously identified smoking, malnutrition, obesity, thoracic defect location, and neoplasm as significant factors associated with LOS after paraspinous muscle flap reconstruction in a series of 92 patients. We add to this growing body of literature by reporting the association between medical and surgical variables and also postoperative complications and increased LOS.

Some of the factors that were implicated in increasing LOS in our multivariate model can be easily addressed in the postoperative period. Chief among these are medical complications, particularly DVT (39% of the medical complications in this study). Previous data have shown that chemoprophylaxis against DVT is safe and effective

for patients undergoing spine surgery.¹⁸ Commonly used agents include low-molecular-weight heparin, subcutaneous heparin, and intravenous heparin, among others.¹⁹ Despite the large body of evidence demonstrating the safety and effectiveness of these methods, a recent survey indicates that some spine surgeons do not employ DVT prophylaxis at all, even in cases of complex oncological resections.¹⁹ Beyond this, for surgeons who choose to order DVT prophylaxis medications, the timing of the first dose varies considerably, from immediately postoperatively to 96 hours later.²⁰ Heterogeneity is further demonstrated in the length of prescription of these medications, particularly in the setting of malignancy.^{19,21} This inconsistency in DVT prophylaxis very likely reflects the lack of high level of evidence studies to guide these decisions; however, the literature is very clear that pharmacological approaches to preventing DVT are safe, effective, and necessary. Our data are a call to action that for these patients, who are at very high risk for DVT formation due to nonmodifiable risk factors, DVT prophylaxis is essentially mandatory. This simple intervention can improve patient safety and significantly reduce LOS.

Similarly, we determined that wound dehiscence increases LOS by an average of 12 days. Typical postoperative interventions such as meticulous wound care by trained nursing staff, timely administration of antibiotics, routine skin assessment or monitoring devices for pressure sores, and negative pressure wound therapy can all be implemented to reduce the risk of dehiscence in patients undergoing spinal surgery.²² Even marginal decreases in local wound complications could have a major impact on the 12-day increase in LOS that our data demonstrate. Although the nonnormality of the data prohibited similar estimations of LOS increase for other specific complications, these data strongly encourage the participation of plastic surgeons early on in the care of these patients.

Our study has several limitations that warrant discussion. Because our study is retrospective, our ability to make causal conclusions regarding factors increasing LOS is limited. However, this is the largest study to date examining factors associated with LOS after posterior trunk reconstruction. Also, we did not assess readmission rates. Future studies are needed to examine whether similar factors are associated with reduced readmissions and whether efforts to lower LOS influence rates of readmissions. Finally, the nature of the LOS variable restricted our ability to produce quantitative estimates for the impact of certain complications on LOS. The data were amenable to this calculation for wound dehiscence, but we felt that we could not accurately produce similar estimates for the other complications identified. Despite this, actionable steps can still be taken to decrease the frequency of these complications and, thus, LOS. Moreover, future studies should continue our efforts and collect data adequate for these calculations.

CONCLUSIONS

Spine tumor resections often create large defects that necessitate the use of muscle flaps for closure. Specifi-

cally, patients who have received chemotherapy, require instrumentation, or experience wound dehiscence or a medical complication postoperatively are at increased risk for prolonged hospitalization after spinal reconstruction. Straightforward interventions can be implemented to reduce the risk of these costly complications.

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