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Reconstructive

Locoregional Flap Closure for High-risk Multilevel Spine Surgery

Jacob R. Rinkinen, MD*
Rachel E. Weitzman, MS*
Jason B. Clain, MD*
Jonathan Lans, MD†
John H. Shin, MD‡
Kyle R. Eberlin, MD*

Background: Postoperative wound complications pose a challenge to patients undergoing complex spine surgery. Long-term sequelae can be devastating including decreased quality of life, meningitis, prolonged hospital stay, and need for reoperation. Among high-risk patients, postoperative wound complications have been shown to approach 40% in the literature. The aim of this study was to identify predictive factors for postoperative complications following soft-tissue reconstruction after high-risk spine surgery with the hypothesis that it would result in significantly fewer postoperative wound complications.

Methods: A retrospective review of 67 consecutive spine operations at an academic, tertiary care center was performed, evaluating outcomes with a single plastic surgeon in conjunction with the spine surgery team. Data regarding patient demographics, perioperative risk variables, flap type, location of defect, and postoperative outcomes were obtained through retrospective chart review. Complications included soft-tissue complications and a number of reoperations. A bivariate analysis was used to identify predictors of postoperative complication. These data were compared to literature-reported averages.

Results: A total of 67 consecutive spinal reconstructive operations were included with a mean follow-up of 11.8 months. Thirty-seven patients (55.2%) underwent immediate reconstruction at the time of the index operation, and 30 (44.8%) underwent delayed reconstruction for secondary wound healing problems following the index operation (in which plastic surgery was not involved). The majority of both immediate (95%, n = 35) and delayed (100%, n = 30) patients was defined as high risk based on literature standards. Patients in this series demonstrated a 7.5% complication rate, compared to 18.7% complication rate in the literature. We did not find a difference between major wound complications in the immediate (8.1%) or delayed (6.7%) reconstructive setting ($P > 0.99$). There were no specific variables identified that predicted postoperative complications.

Conclusion: This study illustrates a postoperative complication rate of 7.5% among patients undergoing paraspinous or locoregional muscle flap closure by plastic surgery, which is significantly lower than that reported in contemporary literature for these high-risk patients. *(Plast Reconstr Surg Glob Open 2020;8:e2751; doi: 10.1097/GOX.0000000000002751; Published online 21 April 2020.)*

INTRODUCTION

Population-based rates of spinal surgeries in the United States have increased dramatically over the past 20 years.[1] Recent data indicate >60% increase in the number of elective lumbar spine operations over the last decade, with the greatest increase in spinal surgeries among patients who are 65 years old and older.[2] Moreover, aggregate hospital costs were shown to increase nearly 175%, exceeding $10 billion in 2015, with average costs for hospital admission being >$50,000 per patient.[2] The increasing rate in spinal procedures has been attributed to multiple factors, including advances in spine surgery technology (ie, improved materials), biosynthetic materials, progress in perioperative management, and improved adjuvant therapy allowing for increasing number of oncologic, surgical candidates.[3,4]

Consequently, a larger cohort of patients may benefit from complex spine surgery, which improves patients'

*From the *Division of Plastic and Reconstructive Surgery, Massachusetts General Hospital, Boston, Mass.; †Hand and Upper Extremity Service, Department of Orthopaedics, Massachusetts General Hospital, Boston, Mass.; and ‡Department of Neurosurgery, Massachusetts General Hospital, Boston, Mass.*

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overall quality of life and functional status. However, the average patient age has increased, leading to individuals with a greater number of comorbidities and higher risk of postoperative complications.[3] Known risk factors for poor wound healing include radiotherapy, malnutrition, previous spinal operation(s), previous infection, multilevel operations, lumbar–sacral involvement, and longer operation time.[5–10] Multiple risk factors may result in postoperative wound complications approaching 40%.[11–13] These patients are often subject to prolonged hospital stays, increased rate of reoperation, prolonged antibiotic requirements secondary to surgical site infection, hardware removal, diminished quality of life, and increased healthcare costs.[5,14,15] As a result, high-risk patients may benefit from immediate (ie, prophylactic) spinal reconstruction at the time of the index operation to limit the risk of postoperative complication, as the benefits in the high-risk patient have been well documented.[8,10,14,16] The aim of this study was to assess postoperative outcomes following complex spine closure at one major academic institution. Specifically, we aimed to (1) examine the utility of immediate reconstruction among high-risk patients and compare it with the current published literature on postoperative complication; (2) assess postoperative complication profile among patients with delayed paraspinous or other locoregional flap closure; and (3) identify predictors for postoperative complications following soft-tissue reconstruction after spinal surgery.

PATIENTS AND METHODS

After Institutional Review Board approval (protocol 2015P001837), a retrospective review was performed from September 2014 to October 2018 on 67 consecutive spinal procedures undergoing paraspinous or other locoregional flap closure by the senior author. A retrospective chart review was performed to collect information on patient demographics, preoperative risk factors [body mass index (BMI), smoking status, hypertension, diabetes, presence of paralysis, neoadjuvant radiotherapy, cerebral spinal fluid (CSF) leak, malnutrition (defined as albumin <3.5), preoperative hemoglobin, previous steroid therapy, previous spine surgery, and indication for surgery], and intraoperative factors, including number of intervertebral levels, type of flap closure, and timing of operation. We calculated the quantitative perioperative risk model score as previously described.[17] Analysis was divided into 2 cohorts comparing patients undergoing immediate reconstruction (plastic surgery closure performed at the time of the index spinal operation) or delayed reconstruction (patient developed wound complication from index operation and plastic surgery assistance requested for closure). Spinal wound algorithm at our institution is demonstrated in Figure 1.

Major wound complications were defined as any postoperative event requiring revision surgery (ie, deep infection, hardware removal, or wound dehiscence), and minor wound complications included any postoperative event that required intervention that was nonoperative (ie, superficial skin infections requiring antibiotics, bedside seroma drainage, and superficial wound dehiscence requiring dressing changes and healing by secondary intention). To identify the factors associated with complication, we combined both major and minor complications due to a overall low incidence of postoperative complication.

Literature Review

A search of the English literature was performed using PubMED and according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Fig. 2). The following MeSH terms were used to identify appropriate articles: spine/spinal with the "and" plastic surgery, reconstruction, fasciocutaneous flap, musculocutaneous flap, and flap. Studies in English were identified between the years of 2000 and 2019. Articles were eligible if they contained original clinical outcomes research of patients who underwent plastic surgery reconstruction/closure for spinal wound defects in either an immediate or delayed fashion (Fig. 2). The patient groups were separated into immediate versus delayed soft-tissue reconstruction. Studies reporting original data were included. Those excluded were review articles/meta-analysis, articles that did not stratify indications (immediate versus delayed), and articles that did not stratify complications (major versus minor). We recorded the incidence of major complications (defined above).

Statistical Analysis

Continuous variables were presented as median and interquartile range, and categorical variables were reported as frequency and percentage. We compared patient characteristics, treatment features, and complications between immediate and delayed soft-tissue reconstruction. We used a Student's t test for parametric explanatory variables (BMI and Risk Model Score), a Mann-Whitney U test for nonparametric continuous variables, and the Fisher's exact test for dichotomous and categorical variables. The association between explanatory variables and all postoperative complications was evaluated using a logistic regression. Additionally, we compared the overall complications' rate between this study and the literature identified in our literature review. A P value of <0.05 was set as statistically significant.

RESULTS

Sixty-seven consecutive patients met inclusion criteria. Thirty-seven (55.2%) patients underwent immediate reconstruction at the time of the index operation, and 30 (44.8%) underwent delayed reconstruction following the index operation. Thirty-five patients (94.5%) undergoing immediate reconstruction were defined as very high risk, whereas all 30 (100%) patients undergoing delayed reconstruction were defined as high risk.[14] The median perioperative risk score was 6.0 in the immediate group and 7.0 in the delayed cohort, which equates to 23%–32% risk of postoperative complication. Patient demographics and risk factors are summarized in Table 1.

In the immediate reconstruction cohort, the median age at the time of operation was 60.8 years, and there were

Immediate Soft Tissue Reconstruction of Spine defect	Delayed Soft Tissue Reconstruction of Spine defect
• Previous spine surgery with hardware complication • Oncologic resection • Neoadjuvant radiation or expected adjuvant radiation • Spinal deformity, kyphosis, or scoliosis reconstructive surgery • Revision spine surgery >6 levels • Severe malnutrition • Poor soft tissue quality	• Previous spinal instrumentation • Deep space abscess • Wound dehiscence • Previously radiated wound • Lumbar spine complication • Hardware involvement • CSF leak • Non-healing wound • Persistent seroma • Severe malnutrition

Fig. 1. Algorithm for spinal wounds.

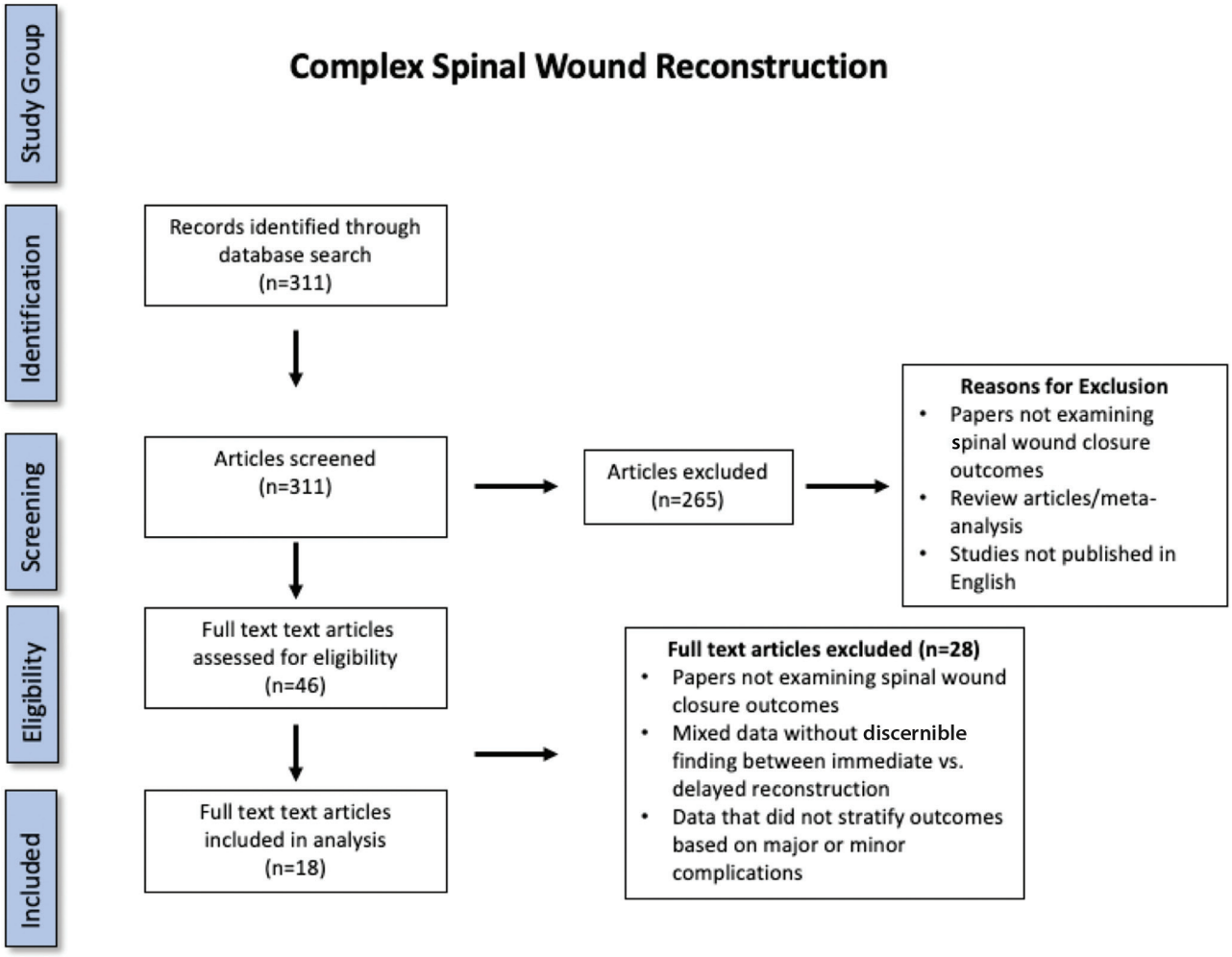


Fig. 2. Flow chart demonstrating systematic review of the literature for complex spine reconstruction.

14 (37.8%) men and 23 (62.1%) women. The median BMI was 26.1, and 8 patients (21.6%) were obese (BMI >30). Seventeen (45.9%) patients were smokers, 15 (43.2%) had hypertension, and 9 (24.3%) had diabetes. There were 4 (10.8%) paraplegic patients and 2 (5.4%) quadriplegic patients. Nineteen patients (51.3%) received neoadjuvant radiation therapy. Three (8.1%) had a dural tear that was recognized intraoperatively. The median hemoglobin level was 10.4. Nineteen (51.4%) patients were malnourished (defined as albumin <3.5), and 11 (29.7%) were receiving steroid therapy. Thirty patients (81.1%) had undergone a previous spinal operation in the past. Twenty-one patients (56.8%) underwent spinal reconstruction secondary to underlying spinal deformity.

Table 1. Preoperative Demographics Categorized by Immediate versus Delayed Reconstruction

Variable	Immediate (%)	Delayed (%)	*P*
No. (%)	37 (55.2)	30 (44.8)	
Age, median (IQR)	60.8 (52.0–67.4)	67.8 (62.3–70.7)	
Sex, n (%)			0.23
Men	14 (37.8)	16 (53.3)	
Women	23 (62.1)	14 (46.6)	
BMI, median (IQR)	26.1 (21.6–29.3)	25.5 (21.6–30.8)	0.83
BMI >30.0, n (%)	8 (21.6)	9 (30.0)	0.88
Tobacco use, n (%)	17 (45.9)	16 (53.3)	0.63
Hypertension, n (%)	16 (43.2)	20 (66.7)	0.084
Diabetic, n (%)	9 (24.3)	5 (16.7)	0.55
Paralysis, n (%)	6 (16.2)	2 (6.7)	0.28
Neoadjuvant radiation therapy, n (%)	19 (51.3)	15 (50.0)	>0.99
CSF leak, n (%)	3 (8.1)	8 (26.6)	0.053
Malnutrition (albumin <3.5), n (%)	19 (51.4)	20 (66.7)	0.23
Preoperative Hgb, median (IQR)	10.4 (8.8–11.2)	9.6 (8.4–10.8)	0.15
Steroid therapy, n (%)	11 (29.7)	8 (26.7)	>0.99
Previous spine surgery, n (%)	30 (81.1)	30 (100.0)	0.014
Oncologic resection, n (%)	21 (56.8)	16 (53.3)	0.81
Spinal deformity, n (%)	21 (56.8)	15 (50.0)	0.63
Quantitative perioperative risk model score, median (IQR)*	6.0 (5.5–8)	7.0 (6.0–9.0)	0.085

*n = 66 for quantitative perioperative risk model score.
Hgb, hemoglobin; IQR, interquartile range.

In the delayed reconstruction cohort, the median age was 67.8 years. Sixteen patients (53.3%) were men, and 14 (46.6%) were women. The median BMI was 25.5, and 9 patients (30.0%) were obese (BMI >30). Sixteen patients (53.3%) were smokers, 20 (66.7%) had hypertension, and 5 (16.7%) had diabetes. There were 2 (6.6%) paraplegic patients. Fifteen patients (50.0%) had received preoperative radiation. Eight patients (26.6%) had a CSF leak secondary to dural tear, 20 (66.7%) were malnourished, 8 (26.6%) were on steroids, and 30 (100%) had undergone previous spinal surgery. The average preoperative hemoglobin level was 9.7. Fifteen patients (50.0%) had underlying spinal deformity.

Operative characteristics are summarized in Table 2. In the immediate reconstruction cohort, there was a median of 6.0 spinal levels operated on, compared with 4.0 in the delayed cohort ($P = 0.002$). There were 1 (2.7%) cervical, 8 (21.6%) thoracic, 5 (13.5%) lumbar, 15 (40.5%) cervicothoracic, and 8 (21.6%) thoracolumbar defects in the immediate reconstruction group, compared with 4 (13.3%) cervical, 3 (10%) thoracic, 13 (43.3%) lumbar, 4 (13.3%) cervicothoracic, and 6 (20%) thoracolumbar defects in the delayed cohort. Overall, there was a significant difference in spinal level operated on when comparing immediate versus delayed reconstruction ($P = 0.007$). More specifically, the delayed group had a significantly higher number of operations involving the lumbar spine compared with immediate reconstruction (63.3% versus 35.1%; $P = 0.028$).

The most commonly utilized reconstruction was bilateral paraspinous advancement flaps: 30 (81%) in the immediate group and 18 (60%) in the delayed group. In the immediate group, there were 1 (2.7%) latissimus flap, 1 (2.7%) superior gluteal flap, 3 (8.1%) combined paraspinous and trapezius flaps, and 2 (5.4%) complex closures. In the delayed group, there were 2 (6.6%) latissimus flaps, 3 (10%) superior gluteal flaps, 1 (3.3%) combined paraspinous and trapezius flaps, and 6 (20%) complex closures.

Postoperative complications are summarized in Table 3. Overall, there were 5 (7.5%) major complications and 8 (11.9%) minor complications. There were 3 (8.1%) major complications in the immediate reconstruction cohort: 2 (5.4%) infections requiring operative washout and 1

Table 2. Operative Characteristics Categorized by Immediate versus Delayed Reconstruction

Variable	Immediate (%)	Delayed (%)	*P*
Instrumentation			
Spinal levels operated on, n (%)			0.007
Cervical	1 (2.7)	4 (13.3)	
Thoracic	8 (21.6)	3 (10.0)	
Lumbar	5 (13.5)	13 (43.3)	
Cervical + thoracic	15 (40.5)	4 (13.3)	
Thoracic + lumbar	8 (21.6)	6 (20.0)	
Lumbar versus other	13 (35.1)	19 (63.3)	0.028
Flap type, n (%)			0.14
Paraspinous	30 (81.0)	18 (60.0)	
Latissimus	1 (2.7)	2 (6.7)	
Superior gluteal	1 (2.7)	3 (10.0)	
Paraspinous + trapezius	3 (8.1)	1 (3.3)	
Complex closure	2 (5.4)	620	
Spinal levels operated on, median (IQR)	6.0 (4.0–8.0)	4.0 (2.0–5.0)	0.002
Case duration, median no. minutes (IQR)	405 (310–528)	103.5 (57–216)	<0.001

IQR, interquartile range.

Table 3. Postoperative Outcomes Categorized by Immediate Versus Delayed Reconstruction

Variable	Immediate (%)	Delayed (%)	*P*
Total complication, n (%)	7 (18.9)	6 (20.0)	>0.99
Major complication, n (%)	3 (8.1)	2 (6.7)	>0.99
Infection requiring return to operating room	2 (5.4)	1 (3.3)	
Hardware removal due to infection	0 (0)	1 (3.3)	
Wound dehiscence	1 (2.7)	0 (0)	
Minor complication, n (%)	4 (10.8)	4 (13.3)	>0.99
Superficial infection	2 (5.4)	1 (3.3)	
Seroma	2 (5.4)	1 (3.3)	
Superficial dehiscence	0 (0)	2 (6.6)	
Total hospital stay days, median (IQR)	9 (6–16)	10.5 (6–22)	0.50
Readmission secondary to spinal process, n (%)	7 (18.9)	4 (13.3)	0.74
Median duration of drains (d), median (IQR)	26 (19–34.5)	26 (20–35)	0.99

IQR, interquartile range.

Table 4. Logistic Regression Analysis on the Effect of Preoperative and Intraoperative Variables on Postoperative Complications

Variable	Adjusted OR (95% CI)	*P*
Age	1.01 (0.97–1.05)	0.58
Sex	1.57 (0.47–5.31)	0.47
BMI >30	1.40 (0.37–5.31)	0.62
Tobacco use	1.86 (0.54–6.41)	0.32
Hypertension	0.46 (0.13–1.60)	0.23
Diabetic	0.64 (0.12–3.27)	0.59
Paralysis	2.94 (0.60–14.34)	0.18
Neoadjuvant radiation therapy	1.72 (0.50–5.94)	0.39
CSF leak	0.91 (0.71–4.82)	0.91
Malnutrition (albumin <3.5)	1.19 (0.34–4.11)	0.79
Steroid therapy	1.79 (0.50–6.37)	0.89
Oncologic resection	2.09 (0.57–7.61)	0.26
Lumbar involvement	2.00 (0.58–6.91)	0.27
Preoperative risk model score >8	2.75 (0.74–10.21)	0.13
Preoperative Hgb	0.97 (0.70–1.33)	0.85
Spinal level operated on		
No. vertebral levels involved	0.96 (0.80–1.16)	0.70
Immediate versus delayed reconstruction	1.07 (0.32–3.61)	0.91
Case duration	1.00 (1.00–1.003)	0.61

Hgb, hemoglobin; OR, odds ratio.

(2.7%) wound dehiscence requiring flap readvancement without exposure of underlying hardware. In the delayed reconstruction group, there were 2 (6.6%) major complications: 1 (3.3%) infection requiring operative washout and 1 (3.3%) infection requiring hardware removal.

There were 4 (10.8%) minor complications in the immediate group: 2 (5.4%) superficial infections requiring antibiotics and 2 (5.4%) seromas requiring bedside drainage. There were 4 (13.3%) minor complications in the delayed cohort: 1 (3.3%) superficial infection, 1 (3.3%) seroma, and 2 (6.6%) superficial dehiscence requiring dressing changes. A total of 11 patients had a postoperative readmission. Differences between immediate and delayed reconstruction complication profile were not significant ($P > 0.99$). Similarly, there was no statistical difference in median total hospital stay (9 versus 10.5; $P = 0.50$), readmission secondary to spinal complication (7 versus 4; $P = 0.74$), or duration of drains (26 versus 26 days; $P = 0.99$) between immediate and delayed reconstruction, respectively. There were no factors associated with postoperative complication (Table 4).

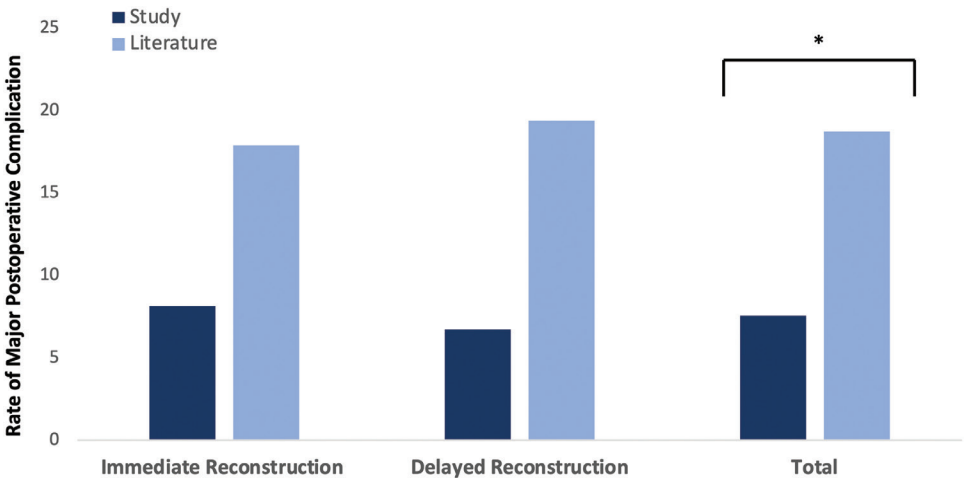
For the literature review, a total of 18 studies were identified using the MeSH terms stated in the Methods and relevant reference and bibliography search. Initial database search demonstrated 311 articles for potential review. Of these articles, 239 were excluded based on title. Seventy-two abstracts were reviewed, resulting in the exclusion of 26 additional articles. Forty-six articles were reviewed in their entirety. Ultimately, 18 articles met inclusion criteria (Fig. 2). A total of 820 patients were identified among these studies with an 18.7% rate of major complication (weighted by study size). When comparing our study cohort to the literature's total major complication rate, we found a significantly decreased rate of major complication (7.5% versus 18.7%; $P = 0.029$) (Table 5) (Fig. 3).

DISCUSSION

The role and timing of plastic surgery involvement for closure following complex spine operations have been debated. Few studies have examined the role of concomitant plastic surgery closure to prevent wound infection and breakdown among high-risk patients. Traditionally, plastic surgery intervention has been reserved for patients who developed wound complications following their index spinal surgery.[18–20] In the current study, we evaluated a total of 68 consecutive spinal operations involving plastic surgery closure with locoregional flaps. Of these cases, 30 patients underwent delayed spinal reconstruction, whereas 38 had primary reconstruction. Overall, 5 patients (7.4%) developed a major complication and 8 patients (11.9%) experienced a minor complication. Among patients undergoing delayed reconstruction, only 2 patients (6.7%) developed major postoperative complications. One patient developed deep surgical site infection that required hardware removal. In comparison to the literature, our study demonstrates >35% reduction in major complications compared to baseline control of 18.7%. With respect to minor complications, 4 patients (13.3%) developed minor wound complications which were treated conservatively with antibiotics, bedside aspiration of seroma, or wound care. All 4 patients went on to heal their wound without further complications.

A literature search over a 20-year period demonstrated a total of 17 studies that evaluated the traditional approach of delayed wound closure performed by plastic surgeons when complications arise from the initial operation. These studies comprised of 434 patients who developed postoperative wound complications following the index spinal operation. Complications included wound dehiscence, deep space infection, hardware exposure, and CSF leak. Following delayed plastic surgery intervention, 84 patients (19.4%) developed major postoperative complication requiring reoperation. Rates of postoperative complications ranged between 0.0% and 45%, with the majority of studies reporting >15% postoperative major complication rate.

Closure by plastic and reconstructive surgery typically involves locoregional muscle flaps to recruit well-vascularized tissue, which promotes improved wound healing and



Cohort	Immediate Reconstruction	Delayed Reconstruction	Total
Literature	17.9%	19.4%	18.7%
Study	8.1%	6.7%	7.5%
P-Value	0.17	0.14	0.03

Fig. 3. Comparison of our institution data with literature-reported averages for complex spine reconstruction.

fills dead space which is often seen following multilevel spinal instrumentation.[21] The benefits of such a multilayered muscle closure have been shown repeatedly in the literature with local muscle advancement having significantly decreased postoperative wound complications compared to delayed primary or secondary closure.[21,22] Wilhelmi et al[22] retrospectively examined 29 patients who developed spinal wound dehiscence. Ten patients received local muscle flap closure, whereas 19 patients were treated with delayed primary closure. The muscle flap patients had a 48% reduction in postoperative wound complications compared to delayed primary closure (20% versus 68%).[22]

Recent literature has examined the role of immediate reconstruction with locoregional muscle flaps at the time of the index operation to prevent future wound dehiscence, infection, or exposure of spinal instrumentation. Devulapalli et al[8] examined 259 patients who underwent oncologic spinal resection and soft-tissue reconstruction, the largest series in the literature. They reported a major complication rate of 22.1% (n = 64 cases). Subgroup analysis compared immediate versus delayed reconstruction to assess wound complications, unplanned reoperations, instrument removal, and mortality. Two hundred twenty-four patients underwent immediate reconstruction at the time of the index surgery versus 65 patients who underwent traditional delayed reconstruction after developing a wound complication. There was no significant difference in postoperative wound complication rates

Table 5. Literature Search of Plastic Surgery Spinal Closure Illustrating Major Postoperative Complications Categorized by Immediate versus Delayed Reconstruction

Study	Immediate Major Complication, n/N (%)	Delayed Major Complication, n/N (%)	Total Complication, n/N (%)
Wilhelmi et al[22]	NA	2/10 (20)	2/10 (20)
Akyurek et al[27]	NA	1/5 (20)	1/5 (20)
Chun et al[28]	0/2 (0)	0/3 (0)	0/5 (0)
Dumanian et al[9]	0/7 (0)	2/15 (13.3)	2/22 (9.1)
Meiners et al[29]	NA	3/14 (21.4)	3/14 (21.4)
Saint-Cyr et al[30]	0/7 (0)	0/2 (0)	—
Mitra et al[31]	NA	5/33 (15.2)	5/33 (15.2)
Vitaz et al[32]	NA	4/37 (10.8)	4/37 (10.8)
Hultman et al[33]	NA	2/25 (8.0)	2/25 (8.0)
Chang et al[6]	9/44 (20.5)	22/48 (45.8)	31/92 (33.7)
O'Shaughnessy et al[34]	NA	0/5 (0)	0/5 (0)
Garvey et al[10]	6/52 (11.5)	NA	6/52 (11.5)
Mericli et al[12]	NA	28/92 (30.4)	28/92 (30.4)
Mericli et al[35]	NA	0/14 (0)	0/14 (0)
De Weerd et al[7]	NA	1/9 (11.1)	1/9 (11.1)
Cohen et al[14]	0/50 (0)	3/52 (5.8)	3/102 (2.9)
Devulapalli et al[8]	54/224 (24.1)	10/65 (15.4)	64/289 (22.1)
Sambri et al[36]	NA	1/5 (20.0)	1/5 (20.0)
Total major complications	69/386 (17.9)	84/434 (19.4)	153/820 (18.7)

NA, not applicable.

between the groups (24.1% versus 15.4%; $P = 0.136$); however, patients who underwent immediate reconstruction had significantly lower rates of instrumentation removal, unplanned reoperations, and mortality compared to those who underwent delayed reconstruction.[8] Similar benefits of immediate reconstruction were shown by Garvey et al,[10] who showed a significant decrease in postoperative wound complications from 38% to 12% following a shift in approach to increased prophylactic soft-tissue coverage for high-risk spine surgery patients. Moreover, when comparing our study cohort to the literature average, patients in our immediate reconstruction group had an 8.1% rate of major postoperative complication, whereas the literature average demonstrated a 17.9% major complication rate. Minor complications occurred at a slightly higher rate with 4 patients (10.8%) developing postoperative wound complications that required nonoperative intervention (bedside seroma drainage and antibiotics for uncomplicated cellulitis). No patients required hardware removal following immediate reconstruction at the time of index surgery.

Although immediate reconstruction following spinal surgery has been shown to have favorable postoperative outcomes in high-risk spine patients,[10,14] it is likely that not all patients benefit from reconstruction at the time of the index operation. It is not known which patients pose a significant preoperative risk of developing complications, however, as the overall incidence of postoperative complications in spinal surgery is difficult to ascertain.[15,23,24] A 2010 meta-analysis by Nasser et al[4] examined data from 79,471 patients who underwent spine surgery without specialized closure or reconstruction. They reported an overall complication rate of 16.4% and found wound infection rates of 0%–17% reported in the literature. Complications for patients undergoing thoracolumbar procedures (20.4%) were significantly higher than patients undergoing cervical procedures (8.9%).[4] Similarly, Kasliwal et al[13] performed a systematic review of postoperative surgical site infections in instrumented spines and found an incidence of 0.7%–20%. Pull ter Gunne and Cohen[11] analyzed 3,174 patients who underwent orthopedic spinal surgery and found a 4.2% incidence of postoperative surgical site infections. Significant predictors of postoperative infection included previous surgical site infection, obesity, and diabetes. Similarly, in 2014, Keam et al[25] examined the postoperative wound complication rates in patients who underwent preoperative conventional or hypofractionated image-guided radiation therapy. They reported an overall complication rate of 14.5%, with 13.3% major complications (dehiscence and infection) and 1.2% minor complications (poor healing—not otherwise specified).[25]

Expanding upon these findings, Kimmell et al[17] developed a risk model in an effort to preoperatively stratify patients at high risk of developing complications. They examined 22,430 cases from the American College of Surgeons National Surgical Quality Improvement Project database. Their data examined all spinal operations, including both high-risk and low-risk patients. They reported an overall complication rate of 9.9%, with wound-related infections occurring in 2.2% of patients. The authors identified 20 risk factors associated with developing postoperative complications. They assigned 1 point to each factor and found a direct correlation with increasing preoperative score to developing complication. Patients with scores ≥5 developed complications at a rate of 18.5% and those with scores ≥12 had postoperative complications nearing 65%. Using this same risk model assessment, our patients had an average perioperative score of 7.0, which correlates to 23.3% risk of postoperative complication. Notably, the risk model by Kimmell et al[17] does not include the history of radiation, spinal instrumentation, or the location of procedure, which have been shown in multiple studies to be associated with postoperative wound complications. This analysis further supports the benefit of plastic surgery locoregional flap closure at the time of the index operation for patients who are preoperatively at an objective high risk of developing postoperative complications.

Review of the literature demonstrates multiple preoperative variables that increase risk of developing major wound complications. Garvey et al[10] examined 52 high-risk patients who underwent immediate reconstruction following oncologic spine surgery.[10] They defined high-risk patients as those with neoadjuvant or expected adjuvant radiation therapy, previous spine surgery, instrumentation, history of smoking, and medical comorbidities. Major complications occurred in 6 patients (12%), and minor complications were observed in nearly 50% of patients.[20] In our series, we also examine patients with substantial risk factors including smokers (47%), hypertension (51%), radiation history (49%), poor nutrition with albumin <3.5 (57%), chronic steroid therapy (27%), CSF leak (15%), and lumbar/lumbar–thoracic wound location (32%). Similar preoperative risk characteristics were observed in both cohorts in our study (immediate versus delayed reconstruction). Despite the frequency of preoperative risk factors among our cohort, we report an overall major complication rate of 7.5% and minor complication rate of 11.9%, which is significantly lower than the literature average for similar high-risk populations.

Multivariate analysis did not illustrate any significant perioperative variables predictive of major postoperative complications. This is most likely due to the low rate of major postoperative complications. However, multiple perioperative variables demonstrated an increased odds ratio of developing major postoperative complications that showed a trend toward significance. The strongest relationship occurred among patients with a preoperative risk model score of >8. Among these patients, there was a 2.5 times greater chance of developing a major postoperative complication compared to individuals with a score of 7 or less ($P = 0.13$). Other preoperative risk variables that showed a trend toward significance included paralysis, hypertension, and oncologic resection. Interestingly, the delayed reconstruction group had a significantly higher number of operations involving the lumbar spine compared to immediate reconstruction (63.3% versus 35.1%; $P = 0.028$). This finding correlates with previous work demonstrating the high surgical site morbidity associated with lumbar spinal resections. Daly et al[26] examined a case

series of 5 complex lumbar spine wounds requiring pedicled superior gluteal artery perforator (SGAP) flap reconstruction. Four out of the 5 patients underwent delayed SGAP reconstruction secondary to infection or CSF leak following the index operation. All of the delayed cases developed a postoperative complication including seroma, infection, or return to the operating room. Interestingly, the one patient who underwent primary SGAP reconstruction did not develop a postoperative complication.

Selection of high-risk patients for immediate reconstruction may be beneficial for wound-related outcomes. In our study cohort, we demonstrate an overall major complication rate of 7.5% which illustrates the value of using local muscle flaps for complex spinal operations. Moreover, we show a similarly low rate of major postoperative complication (8.1%) among high-risk patients undergoing immediate local flap closure which further supports the role of prophylactic flap closure in patients undergoing spinal surgery. We demonstrate multiple perioperative variables associated with increased odds ratio of developing major wound complication including increased perioperative risk score, hypertension, and oncologic resection. Furthermore, delayed reconstruction group had a significantly higher number of operations involving the lumbar spine compared to immediate reconstruction group suggesting higher complication profile among patients undergoing lumber surgery. Overall, this study adds further evidence to the use of prophylactic locoregional muscle flaps in high-risk patients and therapeutic flap closure in patients who developed wound complication following their index operation. It is limited by its retrospective nature and possibility for selection bias. Prospective studies, including randomized trials, are needed to fully understand which patients are at greatest risk of developing wound-related complications and wound benefit from undergoing prophylactic muscle flap closure.

CONCLUSIONS

The number of open spinal operations has increased dramatically over the last decade. Increasing patient age and number of medical comorbidities, postoperative wound complications have been shown to approach 40%. We present in this study the overall utility of plastic surgery closure following both immediate and delayed spinal surgery. We demonstrate a >50% reduction in major postoperative wound complications compared to the literature average (7.5% versus 18.7%). Moreover, we illustrate that immediate reconstruction can act as a preventative adjunct for high-risk patient cohorts undergoing extensive spinal surgery.

Kyle R. Eberlin, MD
Division of Plastic Surgery, Hand Surgery, and Peripheral Nerve Surgery
Massachusetts General Hospital
Wang 435, 15 Parkman Street
Boston, MA 02114
E-mail: keberlin@mgh.harvard.edu

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