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Predictors of 12-month reoperation after operative treatment of thoracolumbar burst fractures

Omar Zakieh[a], James F. Bathon[a,b], Naadir Jamal[b], Benjamin Wong[b], Derick Zhang[b], Akhil Rekulapelli[b], Logan Locascio[b], Curtis J. Bakle[b], Julian G. Lugo-Pico[a,c], Raymond J. Gardocki[a,c], Scott L. Zuckerman[a,c], Byron F. Stephens[a,c] Amir M. Abtahi[a,c,*]

Abstract

Background: Vertebral burst fractures can lead to a multitude of clinical issues, including pain, spinal deformity, neurological deficits, and a decreased quality of life. While current literature extensively covers risk factors associated with the failure of conservative treatment for burst fractures, there exists a relative paucity of data regarding risk factors for surgical treatment failures.

Objective: This study aimed to determine the predictors of reoperation among patients with vertebral burst fractures.

Methods: A retrospective cohort study was undertaken of patients undergoing surgical treatment of thoracic and lumbar vertebrae burst fractures from a single institution between 2010 and 2021. The primary outcome was reoperation within 12 months. Patients with less than 12 months of follow-up and without revision surgery were excluded. Multivariable regression models were performed controlling for age, body mass index, American Society of Anesthesiology (ASA) grade, and smoking status.

Results: Of 91 burst fracture patients included in this study, the mean age was 43.0 ± 17.9 and 60 (65.9%) were male. There were 27 (29.7%) patients who underwent reoperation within 12 months. Patients requiring reoperation had higher proportions of active smokers (44.4% *vs.* 23.4%, $p = 0.045$) and ASA grades 3 or 4 (81.5% *vs.* 50%, $p = 0.005$) than patients without reoperation. There was no difference in perioperative variables between the 2 cohorts. On multivariable regression, ASA grade of 3 or 4 (odds ratio = 3.934, 95% confidence interval = 1.169–13.235, $p = 0.027$) and smoking (odds ratio = 3.208, 95% confidence interval = 1.100–9.355, $p = 0.033$), with no impact of age or body mass index on the reoperation rate.

Conclusion: In our cohort of patients with vertebral burst fractures, smoking and ASA grades of 3 or 4 independently increased the odds of requiring reoperation. Smoking disrupts blood flow and oxygenation at the surgical site, impairing bone regeneration and wound healing. Higher ASA grades reflect more severe systemic health conditions, which can compromise postoperative recovery, leading to a higher likelihood of reoperation. These results can support surgeons in determining which burst fracture patients are at higher risk for reoperation and allow surgeons to provide more appropriate counseling and risk mitigation strategies.

Abbreviations: ASA = American Society of Anesthesiology, BMI = body mass index, OR = odds ratio.

Keywords: burst fracture, lumbar, reoperation, thoracic, thoracolumbar

1. Introduction

Vertebral burst fractures are traumatic injuries that are often the result of high-energy falls or motor vehicle trauma.[1] Flexion and axial loading of the spine induced by these traumatic injuries results in compressive forces that may result in compression or burst fractures with, disruption of posterior osseo-ligamentous structure, and retropulsion of bone into the spinal canal with compression of neurologic structures. Burst fractures account for roughly 15% of all spinal fractures, with most occurring around the thoracolumbar junction and midthoracic vertebra.[1,2] It is hypothesized that the thoracolumbar junction is particularly susceptible to injury due to its location

[a] Department of Orthopedic Surgery, Vanderbilt University Medical Center, Nashville, Tennessee, USA, [b] Vanderbilt University, School of Medicine, Nashville, Tennessee, USA, [c] Department of Neurological Surgery, Vanderbilt University Medical Center, Nashville, Tennessee, USA.

* Correspondence: Amir M. Abtahi, Department of Orthopedic Surgery, Vanderbilt University Medical Center, Medical Center East, South Tower, Suite 4200, Nashville, TN 37232-8774 (e-mail: amir.m.abtahi@vumc.org).

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between the rigid thoracic spine and the more mobile lumbar spine.[3] Additionally, the change in alignment from the kyphotic curvature of the thoracic spine to the lordotic curvature of the lumbar spine further contributes to its vulnerability.[4] Severe back pain is a common symptom, which can be followed by signs of neurologic compromise, such as paresthesia, motor deficits, and radicular pain. Patients without neurologic compromise or structural instability may be treated nonoperatively with physical rehabilitation and with or without orthotic support.[5] Risk factors for failure of nonoperative management in burst fractures have been well-studied, including advanced age and increased interpedicular distance.[6] In contrast, there remains a relative dearth of evidence for predictors of failure of operative management in thoracolumbar burst fractures. Studies in this population are often limited by poor postoperative follow-up.

Structurally unstable fractures and/or neurologic deficits are the most common indications for operative management.[7] The primary goal of surgical treatment in thoracolumbar burst fractures is spinal stabilization, with the addition of laminectomy/neural element decompression in selected cases with neurologic compromise.[8,9] While both combined anterior-posterior and posterior-only approaches have demonstrated improvements in patient outcomes and deformity correction, the choice of approach is nuanced and often driven by specific patient and injury factors.[9,10] While predictors of failure of operative management of burst fractures are not well-described, insights may be gleaned from reoperation risk factors in elective thoracolumbar surgeries, which is relatively more documented. Examples include osteoporosis, obesity, tobacco use and female sex.[11–13] In addition, to patient comorbidities, prior studies have identified other potential contributors to surgical failure in thoracolumbar burst fractures, including osteoporosis, surgical technique (e.g., navigating-assisted or percutaneous fixation), and the number of instrumented segments.[11–15] These factors may influence biomechanical stability and postoperative outcomes, and warrant further investigation.

Understanding predictors of reoperation in burst fracture patients allows surgeons to offer more nuanced patient counseling and establish more effective follow-up protocols. This approach ensures patients are better informed about their condition and potential outcomes, facilitating closer monitoring and timely interventions to mitigate the risk of reoperation. Among patients undergoing surgical treatment for thoracolumbar burst fractures, we sought to determine predictors of 12-month reoperation regarding (1) patient demographics, (2) clinical characteristics, and (3) perioperative variables.

2. Methods

2.1. Study Design

A retrospective cohort study was carried out at a single institution, identifying burst fracture patients from the trauma admissions database between 2010 and 2021, and utilizing data from their respective electronic medical records.

2.2. Patient Population

The inclusion criteria were: adult patients ≥ 18 years, undergoing posterior-approach only posterior fusion for all-level burst fracture of the thoracic and lumbar spine, and with at least 12 months follow-up. Patients who were treated nonsurgically, with the same level revision surgeries, and those with concomitant compression fractures were excluded. All surgeries were performed by board-certified spine surgeons at a single institution, though not by a single operative team.

2.3. Outcomes

The primary outcome was reoperation within 12 months of primary surgery. Basic demographics were compared between patients who did and did not undergo reoperation including age, gender, body mass index (BMI), comorbidities, smoking status, American Society of Anesthesiology (ASA) grade, insurance type, and prior spine surgery. Injury characteristics and perioperative variables were further assessed, including number and levels of vertebrae fractured, injury severity score, estimated blood loss, length of hospital stay, and incidence of postoperative complications. Data on fracture severity, kyphotic angle, and number of instrumented segments were not consistently available and thus not included in the analysis.

2.4. Statistical Analysis

Descriptive statistics and bivariate analysis were used to compare patients with and without reoperation within 12 months. Continuous variables were represented by mean and standard deviation, while categorical variables were presented as frequencies and percentages. The normal distribution and variance of continuous variables were evaluated using the Shapiro-Wilk test and F-test, respectively. Parametric data with equal variance were analyzed with a 2-tailed *t* test, while nonparametric data were compared with the Mann-Whitney test. Nominal data were assessed with χ^2 or Fisher's exact test. Reoperation within 12 months was considered a dichotomous categorical variable. A multivariable logistic regression model was constructed to include age, BMI, ASA grade, and smoking status. Statistical significance was considered at an alpha value < 0.05. Statistical analysis was performed using SPSS 22 (IBM, Armonk, NY).

3. Results

3.1. Patient Demographics and Injury Characteristics Data

A total of 329 consecutive patients were identified in the timeframe who underwent surgical treatment for vertebral burst fracture of the thoracic or lumbar

Table 1

Reasons for reoperation.

Reoperation reason	Total (*n* = 27)
Infection	9 (33.3%)
Hardware complication	6 (22.2%)
Nonunion	5 (18.5%)
Neurogenic Pain	3 (11.1%)
Wound dehiscence	2 (7.4%)
Hematoma Formation	2 (7.4%)

spine; however, only 91 had confirmed 12 months of follow-up for study inclusion, with a mean follow-up time of 1.8 years. The mean age was 43.0 ± 17.9 years, and 65.9% (60) were male. Reoperation within 12 months was observed in 27 patients, representing a reoperation rate of 29.7%. Reasons for reoperation included superficial and deep infection ($n = 9$, 33.3%), hardware complications ($n = 6$, 22.2%) nonunion ($n = 5$, 18.5%), neurogenic pain ($n = 3$, 11.1%), wound dehiscence ($n = 2$, 7.4%) and hematoma formation ($n = 2$, 7.4%) (Table 1).

Preoperatively, patients who required reoperation within 12 months had higher proportions of active smokers (44.4% *vs.* 23.4%, $p = 0.045$) and ASA grades 3 or 4 (81.5% *vs.* 50%, $p = 0.005$) than patients without reoperation. No difference was found between patients with and without 12-month reoperation with regards to age (46.7 ± 16.7*vs.*41.5 ± 18.3,$p = 0.205$),BMI(27.6 ± 3.6*vs.* 26.6 ± 5.6, $p = 0.406$), sex distribution (male: 74.1% *vs.* 62.5%, $p = 0.287$), comorbidities (none: 37.0% *vs.* 32.8%; one: 18.5% *vs.* 23.4%; 2 or more: 44.4% *vs.* 37.5%, $p = 0.845$), prior surgery (14.8% *vs.* 6.3%, $p = 0.187$) or insurance status (private: 48.1% *vs.* 43.8%; government: 37.0% *vs.* 43.8%; uninsured: 14.8% *vs.* 12.5%, $p = 0.834$) (Table 2).

Further there was no significant difference between patients with and without 12-month reoperation regarding injury severity score (21.30 ± 12.33 *vs.* 21.38 ± 11.92, $p = 0.977$), spinal cord injury (14.8% *vs.* 34.4%, $p = 0.059$), number of vertebrae (1.22 ± 0.58 *vs.* 1.14 ± 0.39, $p = 0.330$) or vertebral level (thoracic: 59.3% *vs.* 46.9%; lumbar: 40.7% *vs.* 53.1%, $p = 0.280$) fractured (Table 3).

3.2. Perioperative Variables

There was no significant difference between patients with and without 12-month reoperation with regards to estimated blood loss (431.67 ± 452.04 *vs.* 467.76 ± 551.13 mL, $p = 0.767$), whether a laminectomy was performed (51.9% *vs.* 40.6%, $p = 0.508$), incidence of postoperative complication (34.6% *vs.* 23.8%, $p = 0.296$), or length of stay (21.6 ± 43.4 *vs.* 10.9 ± 7.5days, $p = 0.059$) (Table 4).

3.3. Predictors of Reoperation Within 12 months

On multivariable regression controlling for age and BMI, ASA grade of 3 or 4 (odds ratio [OR] = 3.93, 95% confidence interval = 1.17–13.24, $p = 0.027$) and smoking (OR = 3.21, 95% confidence interval = 1.10–9.36, $p = 0.033$) were associated with increased odds of reoperation within 12 months, with no impact of age or BMI on the reoperation rate (Table 5).

4. Discussion

The current study aimed to characterize both the incidence and predictors of reoperation at the 12-month mark following surgical management of vertebral burst fractures. In our cohort of 91 patients with 12-month follow-up, 29.7% (27) had reoperation within 12 months of their primary surgery. The most common reasons for reoperation included infection, hardware complications, and nonunion. On multivariable regression analysis controlling for age and BMI, active smoking and higher ASA classification (grade 3 or 4) were found to have a significantly increased risk of reoperation within 12 months. There was no difference in other patient demographics,

Table 2

Patient demographics.

Variables	Total (*n* = 91)	No reoperation (*n* = 64)	Reoperation (*n* = 27)	*p*-value
Age, mean ± SD	43.0 ± 17.9	41.5 ± 18.3	46.7 ± 16.7	0.205
Gender: male, *n* (%)	60 (65.9%)	40 (62.5%)	20 (74.1%)	0.287
BMI, mean ± SD	26.92 ± 5.10	26.6 ± 5.6	27.6 ± 3.6	0.406
Comorbidities, *n* (%)				
0	31 (34.1%)	21 (32.8%)	10 (37.0%)	0.856
1	20 (22.0%)	15 (23.4%)	5 (18.5%)	
≥ 2	40 (44.0%)	24 (37.5%)	12 (44.4%)	
Smoker, *n* (%)	27 (29.7%)	15 (23.4%)	12 (44.4%)	**0.045**
ASA: 3+, *n* (%)*	54 (59.3%)	32 (50.0%)	22 (81.5%)	**0.005**
Insurance, *n* (%)				
Private	41 (45.1%)	28 (43.8%)	13 (48.1%)	0.834
Government	38 (41.8%)	28 (43.8%)	10 (37.0%)	
Uninsured	12 (13.2%)	8 (12.5%)	4 (14.8%)	
Prior spine surgery, *n* (%)	8 (8.8%)	4 (6.3%)	4 (14.8%)	0.187

ASA = American Society of Anesthesiology grade, BMI = body mass index.

*ASA data missing 2 patients.

Table 3

Injury characteristics.

Variables	Total (*n* = 91)	No reoperation (*n* = 64)	Reoperation (*n* = 27)	*p*-value
Number of vertebrae fractured, mean ± SD	1.16 ± 0.45	1.14 ± 0.39	1.22 ± 0.58	0.330
Level/s of vertebrae fractured, *n* (%)				
Thoracic	46 (50.5%)	30 (46.9%)	16 (59.3%)	0.280
Lumbar	45 (49.5%)	34 (53.1%)	11 (40.7%)	
Injury severity score, mean ± SD	21.35 ± 11.97	21.38 ± 11.92	21.30 ± 12.33	0.977
Spinal cord injury, *n* (%)	26 (28.6%)	22 (34.4%)	4 (14.8%)	0.059

Table 4

Perioperative variables.

Variables	Total (*n* = 91)	No reoperation (*n* = 64)	Reoperation (*n* = 27)	*p*-value
Laminectomy performed, *n* (%)	52 (57.1%)	26 (40.6%)	14 (51.9%)	0.508
Estimated blood loss (mL), mean ± SD	456.29 ± 519.27	467.76 ± 551.13	431.67 ± 452.04	0.767
Length hospital stay (days), mean ± SD	14.07 ± 24.65	10.91 ± 7.51	21.56 ± 43.40	0.059
Complications, *n* (%)	24 (27.0%)	15 (23.8%)	9 (34.6%)	0.296

Table 5

Univariate and multivariable logistic regression controlling for age and BMI.

Variables		Univariate		Multivariable	
Outcome variable	**Independent variable**	**OR (95% CI)**	***p*-value**	**OR (95% CI)**	***p*-value**
Reoperation	Smoking	2.61 (1.01–6.79)	**0.049**	3.21 (1.10–9.36)	**0.033**
	ASA grade 3+	4.40 (1.48–13.06)	**0.008**	3.93 (1.17–13.24)	**0.027**

Bold indicates a statistically signifncat *P*-value.ASA = American Society of Anesthesiology, BMI = body mass index, CI = confidence interval, OR = odds ratio.

clinical characteristics, and perioperative variables between patients with and without reoperation. These factors, higher ASA classification and smoking, may reflect underlying systemic vulnerability and impaired healing capacity, and should be considered in surgical planning and postoperative monitoring.

Our reoperation rate of 29.7% is comparable to the range reported within the literature. In a retrospective review of 22 operative patients with L3–L5 burst fracture, Seybold et al.[16] reported a 41% (9) reoperation rate. Conversely, An et al.[17] reported 2 of 13 (15.4%) surgically managed patients requiring reoperation. Little meaningful comparison can be drawn from these studies; however, given the relatively smaller cohorts and disparity in follow-up. Among 241 patients with an average follow-up of 18.7 months, Alimohammadi reported a reoperation rate of 14.1%; however, this study was limited to patients with short-segment posterior spinal fixation.[18] Similar to our findings, reasons for reoperation cited within the literature include hardware failure, pseudarthrosis, persistent back pain, and infection.[17,19–21] It is important to note that the observed reoperation rate of 29.7% is high, which may reflect the loss to follow-up amongst potentially eligible patients, the complexity of our followed patient population, variability in surgical technique, or differences in postoperative care protocols.

In the present study, the group of patients requiring reoperation had nearly double the proportion of active smokers compared with those not requiring reoperation. Smoking is a well-documented barrier to healing after surgery, as it hampers blood flow to injured tissue and contributes to other toxic metabolic effects from constituent chemicals such as nicotine, carbon monoxide, and hydrogen cyanide. Nicotine reduces the proliferation of red blood cells, fibroblasts, and macrophages, which are essential for wound healing. Moreover, carbon monoxide decreases the oxygen-carrying capacity of hemoglobin, while hydrogen cyanide impairs cellular respiration through inhibition of oxidative phosphorylation.[22,23] Smoking is particularly harmful to bony tissues not only through vascular insult but also by inhibiting osteoblast production and decreasing calcium absorption in the gut, which contribute to poorer bone healing.[24] Our finding is consistent with prior studies that aimed to characterize reoperation risk in spine surgery. Most notably, among 2293 patients undergoing adult spinal deformity surgery, smoking was associated with increased revision risk (OR = 1.37, $p = 0.002$).[25] Interestingly, Alimohammadi et al.[17] found no association between smoking and reoperation among thoracolumbar burst fracture patients treated with short-segment posterior fixation.

On multivariable regression, ASA class 3 or 4 was found to be a significant predictor of reoperation within 12 months. Findings from our cohort are echoed by Somani et al.[26] who reported ASA to be a significant risk factor (OR = 1.4) for 30-day reoperation among adult spinal

deformity patients. The ASA classification system is a scoring system from 1 to 5 that categorizes patients based on their overall health and any underlying medical conditions that could impact the risks associated with anesthesia and surgery.[27] Since the system's inception, ASA scores greater than 3 have been associated with increased reoperation risk across a variety of surgical subspecialties expanding the utility of this tool.[15,28] Our study's findings, in which the reoperation group had a 30% higher proportion of patients with ASA class 3 or higher, align closely with prior studies and suggest a need to monitor these patients for long-term complications in addition to immediate perioperative complications. Future prospective studies are warranted to evaluate the risk stratification abilities of the ASA classification in comparison to other systems that have shown promise in retrospective studies. A recent study of surgical outcomes in thoracolumbar fractures consisting of 66,904 patients from the NSQIP database found that a higher modified 5-item frailty index score was associated with higher overall complications and mortality, but the association of reoperation risk with this index has not yet been explored, nor is it routinely calculated clinically.[29]

Thoracolumbar burst fractures remain a challenging pathology for spine surgeons. Despite advances in operative management and techniques, a number of patients still endure long-term issues with pain, loss of function, and progressive deformity. Early identification of patients at risk of reoperation is critical to avoid adverse outcomes, ensure appropriate follow-up intervals, and improve patient experience. Multicenter studies with standardized outcome reporting are warranted in order to understand these predictors and develop the best possible treatment algorithms based on patient demographics and injury characteristics. One promising direction for such a study is validation of the ASA classification system and patient smoking status for predicting burst fracture reoperation risk and comparing it to other criteria, such as the 5-item frailty index score.[29]

Our study is not without limitations. Being a single-center study, the findings may not be generalizable to other institutions with different patient populations and treatment protocols. The follow-up duration of 12 months might not be sufficient to capture all relevant reoperations or complications, as some may manifest later. Furthermore, only 27.7% of eligible patients met the 12-month follow-up or without revision surgery criteria, which may introduce selection bias. Patients lost to follow-up may differ in clinical outcomes or risk profiles, potentially omitting those with successful outcomes and inflating the observed reoperation rate. Future studies should aim for more complete follow-up to reduce this bias. This may have also contributed to the small cohort size, though larger compared to other similar studies. Although several variables were controlled for, such as age, BMI, ASA grade, and smoking status, data on other potentially influential factors—such as fracture severity, kyphotic angle, number of instrumented segments, specific surgical techniques, surgeon experience, and postoperative care protocols—were not consistently available and therefore could not be included in the analysis. This limitation reduced the granularity of our findings and may have obscured additional predictors of mechanical failure or reoperation. It may also be valuable to assess the impact of individual comorbidities rather than relying solely on ASA grade as a composite measure, as this could offer more nuanced insight into patient vulnerability. Likewise, while our study focused on smoking and ASA grade, existing literature suggests that other variables—including osteoporosis, fixation method (e.g., navigation-assisted or percutaneous), and construct length—may also contribute to surgical failure.[11–15] These factors warrant further investigation in larger, multicenter studies with standardized data collection and outcome reporting. It is also important to note that functional outcomes such as VAS, ODI, or SF-36 were not available in the retrospective dataset, limiting correlation between reoperation with patient-reported outcome measures and represent an important area for future study. Finally, the reliance on self-reported smoking status could lead to reporting bias, as patients may underreport their smoking habits. Future studies should address these limitations by incorporating a prospective, multicenter design with larger sample sizes and longer follow-up periods to validate and expand upon our findings.

5. Conclusion

In a cohort of patients with thoracolumbar burst fractures, our study identified smoking and higher ASA grades (3 or 4) as independent predictors of reoperation within 12 months following surgical treatment. Smoking's detrimental effects on bone healing and wound repair, compounded by the systemic health complications reflected in higher ASA grades, significantly increase the likelihood of requiring additional surgical intervention. These findings highlight the need for targeted perioperative interventions, including smoking cessation programs and optimization of comorbid conditions, which may improve surgical outcomes. By addressing these modifiable risk factors in the postoperative period, healthcare providers can potentially reduce the incidence of reoperation and enhance the overall quality of life for patients undergoing surgery for vertebral burst fractures. These findings also aid in helping providers set preoperative expectations in patients with a higher risk of reoperation. Future research should focus on validating these findings in larger, multicenter studies to further elucidate the impact of these and other risk factors on surgical outcomes.

Acknowledgments

Not applicable.

Ethical statement

This study was in full compliance with the Vanderbilt IRB and appropriate guidelines were followed.

Conflicts of interest

AMA receives institutional research support from Stryker Spine. RJG is a consultant and teaching surgeon for *Joimax*, a consultant for *Arthrex*, a teaching surgeon and consultant with royalties for *Accelus*, and a consultant with royalties for *Spineology*. BFS receives institutional research funding from *Globus*, has received institutional research funding from *Stryker*, and is an Editoral Board Member for the research journal *Spine Research*. SLZ reports being an unaffiliated neurotrauma consultant for the *National Football League*. No other perceived conflict of interest by any of the listed authors.

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Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

Data collection: Omar Zakieh, Naadir Jamal, Derick Zhang, Akhil Rekulapelli, Logan Locascio, Curtis J. Bakle.
Interpretation of the analysis: Omar Zakieh, Naadir Jamal, Derick Zhang, Akhil Rekulapelli, Logan Locascio, Curtis J. Bakle, James F. Bathon.
Drafting of manuscript: Omar Zakieh, Naadir Jamal, Benjamin Wong, Derick Zhang, Akhil Rekulapelli, Logan Locascio, Curtis J. Bakle, James F. Bathon.
Formal data analysis: Benjamin Wong.
Editing of final manuscript: James F. Bathon.
Conceptualization: Julian G. Lugo-Pico, Raymond J. Gardocki, Scott L. Zuckerman, Byron F. Stephens, Amir M. Abtahi.
Review and editing of final manuscript: Julian G. Lugo-Pico, Raymond J. Gardocki, Scott L. Zuckerman, Byron F. Stephens, Amir M. Abtahi.

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