

# Cigarette smoking and complications in elective thoracolumbar fusions surgery: An analysis of 58,304 procedures

## ABSTRACT

**Study Design:** This was retrospective cohort study.

**Purpose:** The current investigation uses a large, multi-institutional dataset to compare short-term morbidity and mortality rates between current smokers and nonsmokers undergoing thoracolumbar fusion surgery.

**Overview of Literature:** The few studies that have addressed perioperative complications following thoracolumbar fusion surgeries are each derived from small cohorts from single institutions.

**Materials and Methods:** A retrospective study was conducted on thoracolumbar fusion patients in the American College of Surgeons National Surgical Quality Improvement Program database (2006–2016). The primary outcome compared the rates of overall morbidity, severe postoperative morbidity, infections, pneumonia, deep venous thrombosis (DVT), pulmonary embolism (PE), transfusions, and mortality in smokers and nonsmokers.

**Results:** A total of 57,677 patients were identified. 45,952 (78.8%) were nonsmokers and 12,352 (21.2%) smoked within 1 year of surgery. Smokers had fewer severe complications (1.6% vs. 2.0%,  $P = 0.014$ ) and decreased discharge to skilled nursing facilities (6.3% vs. 11.5%,  $P < 0.001$ ) compared to nonsmokers. They had lower incidences of transfusions (odds ratio [OR] = 0.9, confidence interval [CI] = 0.8–1.0,  $P = 0.009$ ) and DVT (OR = 0.7, CI = 0.5–0.9,  $P = 0.039$ ) as well as shorter length of stay (LOS) (OR = 0.9, CI = 0.9–0.99,  $P < 0.001$ ). They had a higher incidence of postoperative pneumonia (OR = 1.4, CI = 1.1–1.8,  $P = 0.002$ ). There was no difference in the remaining primary outcomes between smoking and nonsmoking cohorts.

**Conclusions:** There is a positive correlation between smoking and postoperative pneumonia after thoracolumbar fusion. The incidence of blood transfusions, DVT, and LOS was decreased in smokers. Early postoperative mortality, severe complications, discharge to subacute rehabilitation facilities, extubation failure, PE, SSI, and return to OR were not associated with smoking.

**Keywords:** National surgical quality improvement program, postoperative period, smokers, smoking, thoracolumbar fusion

## INTRODUCTION

With increased awareness of public health issues associated with tobacco smoking, 16.9% of adults in the United States admit to smoking.<sup>[1]</sup> Unfortunately, according to CDC estimates, 34.3 million adults still smoke cigarettes and this accounts for 480,000 deaths annually.<sup>[2]</sup> Several studies have reported increased complication rates in smokers after orthopedic and neurosurgical procedures including wound infection, systemic morbidities, and failure of fusions.<sup>[3,4]</sup> The results of prior studies on the association between

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cigarette smoking and postoperative complications have been conflicting. While some of these studies revealed increased 30-day readmission rates, SSI,<sup>[5-7]</sup> perioperative transfusion risks,<sup>[8]</sup> deep venous thrombosis (DVT),<sup>[5]</sup> and pulmonary complications,<sup>[9]</sup> others have not.<sup>[3,10-15]</sup> There are few studies explicitly addressing perioperative complications in smokers following thoracolumbar fusion surgeries, and the studies that do exist are most commonly derived from a small cohort of patients from a single institution.<sup>[3,4]</sup> The purpose of the current investigation was to compare short-term morbidity and mortality rates between current smokers and nonsmokers undergoing thoracolumbar fusion surgery using a large, multi-institutional national dataset.

## MATERIALS AND METHODS

### Study design and data source

We conducted a retrospective multi-center study of all patients who underwent elective thoracolumbar fusions using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2006 to 2016. The study was deemed exempt from review by the local institutional review board (2016–6862). Consent requirements were waived as ACS-NSQIP data are deidentified. Current Procedural Terminology codes for thoracic fusion, posterior lumbar fusion, and transforaminal lumbar interbody fusion (22,610, 22,612, 22,614, 22,630, 22,632, 22,633, 22,634) were used to identify patients who underwent those procedures. Patients with disseminated cancer, metastatic disease to the neural axis, or spinal epidural abscess as identified by the International Classification of Diseases (ICD) 9 (324.1) or ICD 10 codes (G06.1) were excluded from the analysis. Any patient with ventilator dependence prior to the operation was excluded. Subjects for whom important perioperative data such as age, sex, height, weight, preoperative laboratories, or functional status was not available were also excluded from the analysis. Two groups were identified as follows: smokers and nonsmokers using ACS-NSQIP variable for smoking within 1 year prior to surgery.

### Collected data

Demographic data collected included age, gender, preoperative functional status (dependent vs. independent), and body mass index (BMI). The American Society of Anesthesiologists (ASA) classification was reviewed and was separated into two categories: ASA of two or less, and equal to or greater than three. Data collected on medical comorbidities included diabetes, hypertension requiring medication, chronic obstructive pulmonary disease (COPD), congestive heart failure, chronic steroid use, and dialysis. Complications or morbidities examined included septic shock, myocardial

infarction, cardiac arrest, stroke, pulmonary embolism (PE), and delayed reintubation. Operative time and transfusion data were also collected. Laboratory data reviewed included hematocrit (Hct), presence of anemia, albumin, and white blood cell count. Anemia was defined as Hct <40% in males and <36% in females. We defined infection as a combination of deep or superficial wound infection and organ space infection. The primary outcome of the study compared the rates of overall morbidity, severe postoperative morbidity, infection, pneumonia, DVT, PE, transfusion, and mortality in smokers and nonsmokers.

### Statistical analysis

All statistical analysis was performed using STATA 13.0 (Stata Corp LLC, College Station, TX, USA). Descriptive statistics were used to describe the study population. Univariate analysis was used to analyze the differences between groups for demographic data, preoperative comorbidities, and laboratory values. Comparisons were made through Chi-squared tests, Fisher's exact test, or Student's *t*-tests as appropriate. Any factor with a *P* < 0.05 was then included in a regression model. Multivariate regression model was used to analyze the effect of smoking on various morbidities, mortality, and transfusions adjusted for other significant differences between the groups.

## RESULTS

A total of 57,677 patients from the 2006 to 2016 ACS-NSQIP data were identified who had undergone 58,304 cases. 45,952 (78.8%) cases involved nonsmokers and 12,352 (21.2%) included those who smoked within 1 year of their procedure. The two groups had statistically significant demographic differences in that the smokers were younger (53.6 years vs. 62.0 years), were more likely to be male (49.3% vs. 45.4%), had lower BMIs (29.7 vs. 30.9), and were less likely to have functional dependency (2.0% vs. 2.3%) [Table 1]. The smokers also had different physiologic and laboratory markers including lower rates of anemia (13.8% vs. 19.4%), diabetes (13.8% vs. 19.0%), hypertension (47.8% vs. 59.7%), and chronic steroid use (3.1% vs. 4.4%). The smokers did have a higher incidence of COPD compared to the nonsmokers (10.4% vs. 3.4%). Intraoperatively, smokers had slightly shorter operative times (3.5 h vs. 3.6 h), had slightly fewer average number of operative levels (1.5 vs. 1.6), and required fewer transfusions (10.8% vs. 14.5%). On univariate analysis their outcomes also differed as smokers had fewer severe complications (1.6% vs. 2.0%), decreased discharge rates to skilled nursing facilities (6.3% vs. 11.5%), and shorter length of stay (LOS) (3.5 days vs. 3.8 days) as compared to nonsmokers.

**Table 1: Comparison between the groups**

	Total	Non-smokers	Smokers	P
Number of cases	58,304	45,952 (78.8%)	12,352 (21.2%)	
Age (years)		62.0	53.6	<0.001*
Male (%)	46.2	45.4	49.3	<0.001*
Anemia (%)	18.2	19.4	13.8	<0.001*
Hypoalbuminemia (%)	2.0	1.9	2.2	0.022
Dependent functional status (%)	2.3	2.3	2.0	
Comorbidities				
Diabetes (%)	17.9	19.0	13.8	<0.001*
Hypertension (%)	57.2	59.7	47.8	<0.001*
COPD (%)	4.9	3.4	10.4	<0.001*
Heart failure (%)	0.2	0.2	0.3	0.661
Chronic steroid use (%)	4.1	4.4	3.1	<0.001*
Hemodialysis (%)	0.2	0.2	0.3	0.338
BMI		30.9	29.7	<0.001*
Operative time (mean hours)		3.6	3.5	<0.001*
ASA category of 3 or higher (%)	50.7	50.7	50.4	0.442
Average number of levels		1.6	1.5	<0.001*
Transfusions (%)	13.7	14.5	10.8	<0.001*
Complications (%)	6.7	6.9	6.0	<0.001*
Severe complications (%)	1.9	2.0	1.6	0.014*
Discharge to SNIF (%)	10.4	11.5	6.3	<0.001*
Length of stay (days)		3.8	3.5	<0.001*
Mortality (%)	0.2	0.2	0.2	0.809

\*shows the p value is significant at p=.05

**Table 2: Multivariate analysis of smoking effect on complications, transfusions, LOS, and discharge location**

	OR	95% CI	P
Complications	1.0	0.9-1.1	0.550
Transfusions	0.9	0.8-0.99	0.009*
Severe complications	1.1	0.9-1.3	0.164
LOS	0.9	0.9-0.99	<0.001*
Discharge to Subacute Rehab	1.0	0.9-1.1	0.562
Failure to be extubated	0.9	0.4-2.1	0.847
Pneumonia	1.4	1.1-1.8	0.002*
PE	0.9	0.6-1.2	0.314
DVT	0.7	0.5-0.99	0.039*
Infections	1.1	1.0-1.3	0.191
Return to the OR	1.0	0.9-1.1	0.709
Mortality	1.4	0.7-3.1	0.372

\*shows the p value is significant at p=.05

To control for the demographic differences between the two groups, multivariable logistic regression analysis was applied [Table 2]. Smokers had a lower incidence of transfusions (odds ratio [OR] = 0.9, confidence interval [CI] = 0.8–0.99, P = 0.009), DVTs (OR = 0.7, CI = 0.5–0.99, P = 0.039), and shorter LOS (OR = 0.9, CI = 0.9–0.99, P < 0.001). They did, however, have a higher incidence of postoperative pneumonia (OR = 1.4, CI = 1.1–1.8, P = 0.002).

There was no statistically significant difference in severe complications, discharge to subacute rehabilitation, failure to be extubated, PE, SSI, and return to the operating room

between smoking and nonsmoking cohorts. Mortality did not differ significantly between the two groups (P > 0.05).

## DISCUSSION

There is controversy regarding the association between cigarette smoking and complications following spine surgery. While some studies have reported increased 30-day mortality and incidences of SSI, DVT, and other complications, these have not been consistent conclusions seen across various analyses.<sup>[3,4,10-15]</sup>

SSI is widely believed to be associated with smoking.<sup>[16,17]</sup> Meng performed a meta-analysis of the association of smoking and SSI across 14 studies and reported that there is a slight increase in SSI in smokers (OR 1.17; 95% CI 1.03–1.32).<sup>[18]</sup> This study was heavily weighed by the results of Veeravagu *et al.*'s study that included 24,774 procedures, whereas the remaining 13 studies included in the meta-analysis compiled only 4488 procedures collectively.<sup>[6]</sup> With respect to smoking and SSI, after controlling for demographic differences in the present study, multivariate regression showed no statistical association between 30-day postoperative wound infection and smoking in patients who underwent thoracolumbar surgery. Studies by several other investigators have also failed to show a statistically significant increase in wound infection in smokers.<sup>[19-23]</sup> Furthermore, the present study includes

nearly twice as many procedures as those included in Meng's meta-analysis, and failed to show a significant association between smoking and early postoperative wound infection. This finding cannot however be extrapolated to have any implications regarding late wound infection in smokers.

While several authors have highlighted an increased risk of DVT associated with smoking,<sup>[3,24]</sup> this has not entirely borne out in the literature. This study reports a 30% decreased incidence of DVT (CI = 0.7, CI = 0.5–0.99,  $P = 0.039$ ) in smokers when compared to nonsmokers undergoing thoracolumbar fusion. There is some controversy in the literature regarding smoking and the incidence of postoperative DVT. Edmonds *et al.* performed a meta-analysis of 23 studies and stated that, “the role of cigarette smoking on the incidence of postoperative DVT is unclear” and “not conclusive.”<sup>[25]</sup> They further assert that the literature “suggest a nonsignificant protective trend for smokers against postoperative DVT.”<sup>[25]</sup> Their meta-analysis is in keeping with the data in this study. Regardless of statistical controls, the complex associations between smoking and other disease profiles are difficult to untangle when looking for specific and relatively rare complications such as DVTs. Further research specifically investigating the pathogenesis of DVTs in the postoperative period and the impact of smoking are warranted to better understand this topic. Despite this, the present study demonstrates that in this large cohort of patients who underwent thoracolumbar fusion there was no obvious association between smoking and DVT.

Smokers in the present study were less likely to receive allogeneic blood transfusions than their nonsmoking counterparts (OR = 0.9, CI = 0.8–0.99,  $P = 0.009$ ). There are conflicting reports in the literature on this topic. McCunniff *et al.*'s retrospective study of 559 lumbar decompression procedures (with or without fusion) at a single institution found a markedly increased risk of blood transfusion in smokers.<sup>[8]</sup> However, while the authors reported the OR and CI for blood transfusion in their population, they did not publish the actual number of patients receiving transfusion. Puvanesarajah *et al.* reported that smoking was a risk factor for blood transfusion in patients undergoing adult spinal deformity.<sup>[26]</sup> Conversely, Appaduray and Lo. and Zheng *et al.* found no association between transfusion and smoking in patients undergoing primary or revision posterior lumbar spinal fusion procedures.<sup>[12,27]</sup> In addition, Owens *et al.* could not find a relationship between the use of autologous cell saver and smoking in patients undergoing posterolateral lumbar fusion surgery.<sup>[15]</sup> All of these studies were small single institutional studies and perhaps underpowered to elucidate a definitive answer on this topic. The mechanism

by which smoking could lower the risk of transfusion is not understood. However, several studies suggest that current and recent smokers have higher Hct levels.<sup>[28-30]</sup> As a consequence, the typical Hct/hemoglobin thresholds for postoperative transfusion may not be reached in these patients as frequently. Another hypothesis for decreased postoperative transfusions in smokers suggests that smoking is proven to increase platelet activation and decrease the effect of antiplatelet medications like aspirin.<sup>[31-33]</sup> This effect could potentially result in less bleeding during and after surgery as well as quicker clotting of small capillary vessels. Further investigation into this topic could be beneficial to the understanding of blood loss and transfusions in spine surgery.

It would seem reasonable to assume that smoking is associated with significant pulmonary complications. Several authors have indeed found a correlation between smoking and postoperative pulmonary complications in patients undergoing lumbar fusions<sup>[9]</sup> and in adults undergoing spinal deformity surgery.<sup>[34]</sup> This relationship, however, has not been confirmed by all authors: Bohl *et al.* could not confirm the association between smoking and postoperative pneumonia and Jules-Elysee *et al.* did not find an association between smoking and the development of pulmonary radiographic abnormalities in patients undergoing anterior-posterior thoracic lumbar fusions.<sup>[15,35]</sup> This study indicates that there is a significant relationship between smoking and postoperative pneumonia (OR = 1.4, CI = 1.1–1.8,  $P = 0.002$ ) when controlling for confounding variables, although there was no significant relationship between smoking and failure to extubate in the operating room.

### Strengths and limitations

In utilizing the ACS-NSQIP database, this study was able to analyze a large, multi-institutional cohort of patients who underwent elective thoracolumbar fusion surgery over a decade and provided the necessary statistical power to evaluate the impact of rare occurrences on 30-day postoperative complications. ACS-NSQIP data are also collected prospectively and subject to audit regularly.<sup>[36]</sup> The ACS-NSQIP database is highly dependable database with low interobserver disagreement in data entry.<sup>[37]</sup>

This study does have several limitations. Selection bias is a possibility, as the ACS-NSQIP database tends to include patients from larger academic institutions.<sup>[37,38]</sup> The spine surgery literature strongly supports an association between smoking and nonunion or pseudoarthrosis after spine fusion surgery.<sup>[39,40]</sup> Unfortunately, the ACS-NSQIP database does not provide information on these two parameters and they could not be addressed in this manuscript. Finally, in this study



there was no way to quantify the longitudinal or cumulative effect of smoking on 30-day postoperative complications as ACS-NSQIP presented smoking as a binary yes-or-no answer choice.

## CONCLUSIONS

To the best of our knowledge, this is the largest study derived from a single multi-center national cohort addressing the short-term complications of cigarette smoking in patients undergoing thoracolumbar fusion procedures. While there is controversy regarding the association between cigarette smoking and postoperative complications, we were able to demonstrate a positive correlation between cigarette smoking and postoperative pneumonia. We also demonstrated a decreased incidence of blood transfusions, DVT, and LOS in smoker as compared to nonsmokers. Short-term mortality, complications, severe complications, discharge to subacute rehabilitation facilities, failure to be extubated, PE, SSI, and return to operating room were not associated with cigarette smoking in this cohort.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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