

The Impact of Smoking on Complication and Pseudoarthrosis Rates Following Single and Two-Level Posterolateral Fusion of The Lumbar Spine

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Abstract

Study design: Retrospective study.

Objective: To study the impact of smoking status on postoperative complications and pseudoarthrosis in adult patients undergoing posterolateral fusion (PLF) of the lumbar spine.

Summary of Background Data: Results of studies analyzing the impact of smoking on complication and pseudoarthrosis rates following spine surgery are conflicting.

Methods: A retrospective medical record review was performed to identify all adult patients who underwent single and two-level instrumented PLF without interbody

devices for degenerative spine disease in a 21-year period at a single institution. Patients were divided into smokers and non-smokers. The main outcome variables were development of at least one post-operative complication and development of pseudoarthrosis.

Results: A total of 281 patients underwent single or two-level PLF in the 21-year period. Of these, 231 (82.21%) patients were non-smokers and 50 (17.9%) smokers. For patients undergoing single-level PLF, complication rates in non-smokers (3.57%) vs. smokers (7.69%) were not significantly different ($P = 0.353$); pseudoarthrosis in non-smokers occurred in 9.82% of cases compared to 7.69% in the smoker's group ($P = 0.738$). Non-smokers undergoing two-level PLF had complication rates of 6.72%, compared to 4.17% in smokers ($P = 0.638$), but pseudoarthrosis rates were significantly higher in the smoker's group compared to non-smokers (29.17% vs. 10.92%; $P = 0.019$). Patients were followed-up for an average of 53.5 months.

Conclusion: The findings in the present study suggest that smoking has a significant impact on pseudoarthrosis rates following two-level PLF of the lumbar spine, but not necessarily on single-level PLF.

Key Words: lumbar; fusion; smoking; pseudoarthrosis; complications; surgery; posterolateral fusion; spine; outcomes;

Level of Evidence: 4

Mini-Abstract

The impact of smoking on complication and pseudoarthrosis rates after spinal surgery has been subject to research, but results are conflicting. In this study, only smokers undergoing two-level posterolateral fusion of the lumbar spine had significantly higher pseudoarthrosis rates when compared to non-smokers; smoking made no impact on single-level fusion.

Key Points

1. In the present study, complication rates between non-smokers and smokers following posterolateral fusion of the lumbar spine were not statistically different.
2. Smokers undergoing single-level posterolateral fusion of the lumbar spine do not have significantly higher pseudoarthrosis rates compared to non-smokers.
3. Pseudoarthrosis rates in smokers undergoing two-level posterolateral fusion of the lumbar spine are 29.17%, significantly higher than in non-smokers.
4. Smoking has a significant impact on pseudoarthrosis rates following two-level posterolateral fusion of the lumbar spine, but not necessarily on single-level posterolateral fusion.

Introduction

Tobacco smoking is a leading cause of morbidity and mortality worldwide, causing an estimated 200,000 deaths per year in the United States.¹ It is also associated with numerous chronic conditions, including coronary artery disease,² hypertension³, chronic obstructive pulmonary disease,⁴ cerebrovascular disease and others.

Additionally, both tobacco smoke and nicotine have been associated with unfavorable surgical outcomes, evidenced by increased rates of superficial and deep wound infections, sepsis, prolonged intubation, delayed wound healing, and others.⁵

The impact of smoking status on spine surgery has been subject to research, and although studies have shown an association between smoking and poor bone quality⁶ and higher rates of pseudoarthrosis^{7,8}, clinical studies have shown conflicting results⁹⁻¹³. On the other hand, few studies have assessed the relationship between smoking and perioperative complications following spine surgery, and results have also been inconsistent^{14,15}.

The purpose of this study is to examine the impact of smoking status on both postoperative complications and pseudoarthrosis, in adult patients undergoing single and two-level instrumented posterolateral fusions of the lumbar spine.

Methods

A retrospective medical record review from 1990 – 2011 was performed at our institution to identify all adult patients who underwent single or two-level instrumented posterolateral fusion (PLF) of the lumbar spine for the treatment of degenerative spine disease. Patients with additional placement of an interbody device and patients who underwent surgery for traumatic, neoplastic or infectious causes were excluded. Patients in which the fused segment crossed the thoraco-lumbar or lumbo-sacral joint were included.

Patient demographics such as age, co-morbidities (smoking status, coronary artery disease, diabetes, hypertension, obesity, osteoporosis, chronic obstructive pulmonary disease (COPD), and depression), pre-operative diagnosis and presenting symptoms

were collected and documented for all patients. Smoking status was assessed via a detailed review of medical records. For patients to be classified as non-smokers, they had to be either never-smokers or must have quit at least 1 year prior to surgery¹⁶. Intra- and perioperative data such as number of levels fused, use of BMP, autograft and allograft and estimated blood loss (EBL) were collected from operative notes. Length of stay, complications and development of pseudoarthrosis were assessed via follow-up clinical notes.

The main outcome variables were development of at least one post-operative complication and development of pseudoarthrosis. Post-operative complications were any of the following: wound infection, deep vein thrombosis (DVT), pulmonary embolism (PE), pneumonia, hematoma, wound dehiscence, myocardial infarction or death. Pseudoarthrosis was independently assessed by a radiologist. Pseudoarthrosis was assessed via a combination of X-rays and computed tomography (CT) scans. It was defined as any of the following: radiolucent lines within the fusion mass, excessive motion in flexion/extension X-rays, presence of bony lucency at the graft/vertebral body junction, screw loosening (halo sign) and/or absence of bridging bone.

Statistical analysis

Descriptive statistics were performed to compare the two groups (non-smokers and smokers) via Student's T-Test and Chi-squared test for continuous and non-continuous data, respectively. Data is presented as mean± standard deviation when applicable. A univariate analysis was performed to identify significant risk factors for the development of complications and pseudoarthrosis, and afterwards a multivariate logistic regression model was constructed to analyze outcomes in the form of adjusted

odds ratios (OR) and 95% Confidence Intervals (CI 95%). The multivariate analysis was adjusted for patient and operative characteristics. Sub-analyses were performed to independently assess complications and pseudoarthrosis based on number of levels fused. Statistical analyses were performed using STATA 12 (StataCorp LP, College Station, Texas). Statistical significance was set at $P < 0.05$.

Results

Demographics and Surgical Variables

A total of 281 patients who underwent PLF were identified, with 231 (82.21%) non-smokers and 50 (17.79%) smokers [Table 1]. The mean age of all patients was 58.91 ± 12.79 years, and 44.48% were males. A significantly higher number of patients in the smoker's group had depression (24.00% vs. 9.52%; $P = 0.004$) when compared to non-smokers. Pre-operative diagnoses did not differ between the two cohorts, and in terms of presenting symptoms there were no statistically significant differences. Intraoperative variables such as BMP, autograft and allograft use did not statistically differ between non-smokers and smokers [Table 2]. BMP use in the non-smokers group was 44.16%, compared to 56.00% in smokers ($P = 0.128$).

Outcomes

EBL in the non-smoker's group was on average 779.21 ± 685.21 mL and 600 ± 294.24 mL in the smoker's group ($P = 0.316$) [Table 3]. Length of stay in the non-smokers group was 5.48 ± 3.36 days and 6.12 ± 7.92 in the smoker's ($P = 0.791$). Complication rates were 5.19% in the non-smoker's group and 6.00% in smokers, but these differences did not reach statistical significance ($P = 0.818$). Specific complication rates did not differ between subgroups. Pseudoarthrosis occurred in 18%

of patients who smoked, compared to 10.39% in non-smokers ($P = 0.130$). Mean follow-up time for all patients was 53.47 ± 49.26 months (Range 6.1 – 239.5). Smokers who additionally received BMP had a pseudoarthrosis rate of 14.29%, compared to 22.73% in smokers who did not receive BMP ($P = 0.441$). This latter 22.73% pseudoarthrosis rate for smokers without BMP was not significantly different from the pseudoarthrosis rate of 16.28% in non-smokers without BMP ($P = 0.459$).

Univariate analyses revealed obesity to be the single significant risk factors of a post-operative complication (OR 4.72; 95% CI, 1.37 – 16.26; $P = 0.014$). On the other hand, there were no significant risk factors of pseudoarthrosis. Multivariate analyses indicated that patients who were smokers did not have significantly higher rates of post-operative complications (OR 1.03; 95% CI, 0.27 – 3.93; $P = 0.956$), or pseudoarthrosis (OR 1.89; 95% CI, 0.82 – 4.36; $P = 0.135$) when compared to non-current smokers.

Single-level Fusion Sub-Analysis

A total of 138 patients underwent single-level PLF, with 112 (81.16%) non-smokers and 26 (18.84%) smokers [Table 4]. Crude complication rates were 3.57% for non-smokers and 7.69% for smokers, and adjusted OR revealed no statistically significant difference (OR 1.92; 95% CI, 0.31 – 11.86; $P = 0.480$). Likewise, smokers did not have significantly higher rates of pseudoarthrosis (OR 0.84; 95% CI, 0.17 – 4.13; $P = 0.833$).

Two-level Fusion Sub-Analysis

One-hundred and forty three patients underwent two-level PLF, and 119 (83.22%) were non-smokers and 24 (16.78%) smokers [Table 5]. Complication rates were not

significantly different between groups ($P = 0.638$), but smokers had significantly higher rates of pseudoarthrosis (29.17%) compared to non-smokers (10.92%; $P = 0.019$).

Discussion

Despite extensive public health measures in the United States, more than 40 million Americans are current smokers, and 20% of deaths can be attributed to tobacco use.¹⁷ The impact of smoking status on surgical outcomes has been subject to extensive research, with results showing increased risks of perioperative cardiovascular, pulmonary and wound healing complications. These complications ultimately result in increased lengths of stay, intensive care unit admissions, revision surgeries and higher costs of care.⁵

Key Results

The overall complication rate in this study was reported as 5.34%, and pseudoarthrosis was reported in 11.74% of cases. Smokers had slightly higher rates of complications (6.00%) when compared to non-smokers (5.19%), but results were non-significant; the strongest risk factor for complication was obesity. On the other hand, pseudoarthrosis rates were not significantly different for patients undergoing single-level PLF [**Figure 1**], but smokers who underwent two-level PLF had almost a 30% rate of pseudoarthrosis, which was significantly higher than non-smokers.

Interpretation and generalizability

The findings in the present study suggest that smoking does not lead to significantly higher odds of postoperative complications, and smoking affects pseudoarthrosis rates for patients undergoing two-level PLF, but not necessarily single-level PLF. A recent

study published by Seicean et al. utilized the American College of Surgeons National Surgical Quality Improvement (NSQIP) database to analyze the impact of smoking on 30-day perioperative complications and mortality in 14,500 adults undergoing elective spine surgery. The study found a 2.8% minor complication rate in current smokers vs. 3.3% in non-smokers, and a 5.4% major complication rate in both cohorts; results were non-significant, and the authors concluded that smoking was unrelated to early perioperative morbidity.¹⁴ Similarly, our findings did not find any significant association with development a post-operative complication. However, a study by Dean et al. revealed that smoking negatively impacted lumbar fusion outcomes, evidenced by increased blood loss and transfusion requirements.¹⁵ In the present study, obesity was found to be the strongest independent risk factor for a complication, a finding consistent with previous results,¹⁸ indicating the overall higher risks to health when patients have increased body mass.

Compared to the link between smoking and complications, the association of smoking and pseudoarthrosis is even more vague.^{7,9,13,19} In the present study, pseudoarthrosis occurred in 11.74% of cases, similar to the 15% estimate in the literature for lumbar fusions.²⁰ Multivariate analyses revealed no overall significantly increased odds of pseudoarthrosis in patients who smoked, and sub-analyses only revealed a significant increase in two-level PLF. Brown et al. reported a 40% rate of pseudoarthrosis compared to only 8% in non-smokers in patients undergoing lumbar fusion.⁷

Similarly, Wetzel et al. found that smoking decreased the likelihood of achieving a solid arthrodesis in the lumbar spine, in a study of 24 patients.²¹ Lee et al. studied the effects of tobacco smoke on lumbar fusion in rabbits, and found that smoking delayed but did not prevent the fusion process.²² On the other hand, a recent study by Kalb et

al. analyzed 242 cases of anterior lumbar interbody fusion, finding no association between smoking and pseudoarthrosis.¹⁹

Another recent multi-center study by Luszczuk et al. analyzed 573 patients undergoing single-level ACDF with allograft and locked plates. Fusion rates were achieved in 91.6% of non-smokers, compared to 91.0% of smokers ($P = 0.867$).⁹ The authors concluded: “if patients are disinclined to stop smoking, it appears that the use of allograft with a locked plate produces acceptable fusion rates in single-level ACDF.”⁹ Similar to our results, smokers undergoing single-level PLF without an interbody device achieved a fusion rate of 92.31%, compared to 90.18% in non-smokers, without reaching statistical significance. Therefore, the findings suggest that this particular treatment modality may achieve acceptable fusion rates in patients who are reluctant to quit smoking.

Nevertheless, patients undergoing *two-level* PLF did have significantly higher rates of pseudoarthrosis, suggesting detrimental effects to bone arthrodesis caused by smoking. Tobacco smoke and nicotine have been shown to decrease osteoblast differentiation and neovascularization, which in turn lead to decreased bone quality.²³⁻²⁵ Furthermore, exposure to tobacco smoke has been linked to increased degeneration of vertebral bone and intervertebral discs.²⁶

Limitations

The foremost limitation of this study is its retrospective nature. More specific measures of smoking status such as pack-years could not be assessed, which could have given insight into the dose-effects of smoking on lumbar fusion outcomes. Additionally, the relatively smaller sample of smokers might result in a higher risk of type II error. An ideal study would be a prospective cohort study, where data

pertaining smoking status would be prospectively collected for the smoker and non-smoker's group and outcomes reported through time.

Conclusion

Smoking did not lead to significantly higher overall complication rates for patients undergoing one or two-level PLF in the present study. In smokers, single-level PLF has acceptable fusion rates, but in patients undergoing two-level PLF pseudoarthrosis rates are almost 30%. Patients should be cautioned against the detrimental effects of smoking in fusion rates following multi-level PLF of the lumbar spine.

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Figure Legends

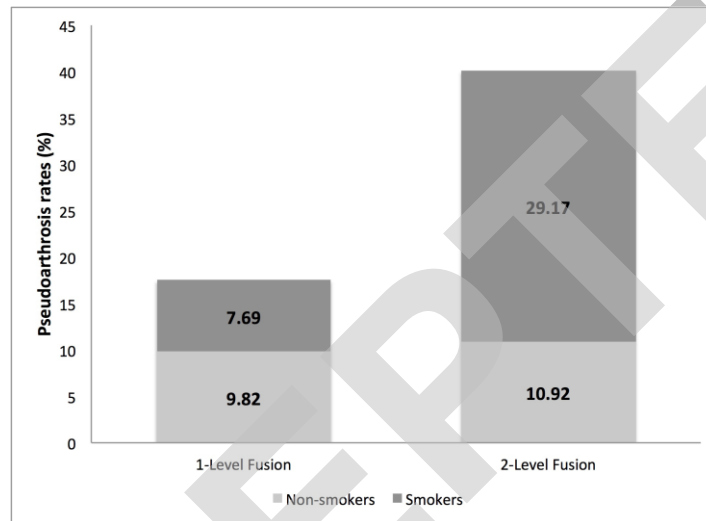


Figure 1: Pseudoarthrosis rates increased in direct proportion to number of levels. Smokers undergoing single-level PLF did not have significantly increased rates of pseudoarthrosis ($P = 0.738$), but smokers who underwent two-level PLF did have significantly higher rates ($P = 0.019$).

Table 1: Demographics of all patients undergoing PLF based on smoking status

Characteristic	Non-smoker	Smoker	<i>P</i> - value
No. Cases	231	50	
Age	58.88 ± 12.98	59.05 ± 55.63	0.533
Sex (male, %)	104 (45.02)	21 (42.00)	0.687
Comorbidities			
CAD	29 (12.55)	9 (18.00)	0.307
Diabetes	26 (11.26)	8 (16.00)	0.351
Hypertension	82 (35.50)	15 (30.00)	0.458
Osteoporosis	7 (3.03)	0 (0.00)	0.213
Obesity	17 (7.36)	6 (12.00)	0.278

COPD	1 (0.43)	0 (0.00)	0.641
Depression	22 (9.52)	12 (24.00)	0.004
Diagnosis			
Spinal stenosis	149 (64.50)	32 (64.00)	0.946
Spondylolisthesis	53 (22.94)	14 (28.00)	0.447
DDD	29 (12.55)	4 (8.00)	0.364
Presenting symptom			
Back pain	202 (87.45)	46 (92.00)	0.364
Radiculopathy	158 (68.40)	40 (80.00)	0.103
Motor deficit	29 (12.55)	8 (16.00)	0.514
Sensory deficit	29 (12.55)	10 (20.00)	0.167
Bowel/Bladder dysfunction	12 (5.19)	4 (8.00)	0.438

Boldface denotes statistically significant results.

Table 2: Intraoperative characteristics of all patients undergoing PLF based on smoking status

Characteristic	Non-smoker	Smoker	<i>P</i> - value
No. Cases	231	50	
BMP	102 (44.16)	28 (56.00)	0.128
Autograft	176 (76.19)	36 (72.00)	0.533
Allograft	122 (52.81)	27 (54.00)	0.879

Boldface denotes statistically significant results.

Table 3: Outcomes of all patients undergoing PLF based on smoking status

Characteristic	Non-smoker	Smoker	<i>P</i> - value
No. Cases	231	50	
Estimated Blood Loss (mean)	779.21 ± 685.21	600 ± 294.24	0.316
Length of Stay (mean)	5.48 ± 3.36	6.12 ± 7.92	0.791
Post-operative complication			
Overall rate	12 (5.19)	3 (6.00)	0.818
Wound infection	8 (3.46)	2 (4.00)	0.853
DVT	0 (0.00)	1 (2.00)	0.143
Pneumonia	1 (0.43)	1 (2.00)	0.232
Hematoma	2 (0.87)	0 (0.00)	0.509
Wound dehiscence	0 (0.00)	0 (0.00)	-
Myocardial Infarction	1 (0.43)	0 (0.00)	0.641
Death	0 (0.00)	0 (0.00)	-
Pseudoarthrosis	24 (10.39)	9 (18.00)	0.130
Symptoms at last follow-up			
Back pain	119 (51.52)	21 (42.00)	0.222
Radiculopathy	79 (34.20)	14 (28.00)	0.398
Motor deficit	13 (5.63)	5 (10.00)	0.252
Sensory deficit	13 (5.63)	4 (8.00)	0.524
Bowel/Bladder	4 (1.73)	3 (6.00)	0.079

dysfunction			
Follow-up (mean months)	54.03 ± 47.48	50.84 ± 38.55	0.339

Boldface denotes statistically significant results.

Table 4: Outcomes of all patients undergoing single-level PLF based on smoking status

Characteristic	Non-smoker	Smoker	<i>P</i> - value
No. Cases	112 (81.16)	26 (18.84)	
Complications			
Crude rate (%)	4 (3.57)	2 (7.69)	0.353
Odds Ratio	1.00 (Reference)	1.92; 95% CI, 0.31 – 11.86	0.480
Pseudoarthrosis			
Crude rate (%)	11 (9.82)	2 (7.69)	0.738
Odds Ratio ¹	1.00 (Reference)	0.84; 95% CI, 0.17 – 4.13	0.833

1. Adjusted odds ratio for patient characteristics

Table 5: Outcomes of all patients undergoing two-level PLF based on smoking status

Characteristic	Non-smoker	Smoker	<i>P</i> - value
No. Cases	119 (83.22)	24 (16.78)	
Complications			
Crude rate (%)	8 (6.72)	1 (4.17)	0.638
Odds Ratio	1.00 (Reference)	0.55; 95% CI, 0.06 – 4.76	0.593
Pseudoarthrosis			
Crude rate (%)	13 (10.92)	7 (29.17)	0.019
Odds Ratio ¹	1.00 (Reference)	3.97; 95% CI, 1.26 – 12.51	0.018

- Adjusted odds ratio for patient characteristics
- Boldface denotes statistically significant results