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Abstract

Study design: Retrospective comparative study.

Objective: Whereas smoking has been shown to affect the fusion rates for patients undergoing an anterior cervical discectomy and fusion (ACDF), the relationship between smoking and health-related quality of life outcome measurements after an ACDF is less clear. The purpose of this study was to evaluate whether smoking negatively affects patient outcomes after an ACDF for cervical degenerative pathology.

Methods: Patients with tumor, trauma, infection, and previous cervical spine surgery and those with less than a year of follow-up were excluded. Smoking status was assessed by self-reported smoking history. Patient outcomes, including Neck Disability Index, Short Form 12 Mental Component Score, Short Form 12 Physical Component Score (PCS-12), Visual Analogue Scale (VAS) arm pain, VAS neck pain, and pseudarthrosis rates were evaluated. Outcomes were compared between smoking groups using multiple linear and logistic regression, controlling for age, sex, and body mass index (BMI), among other factors. A *P* value <.05 was considered significant.

Results: A total of 264 patients were included, with a mean follow-up of 19.8 months, age of 53.1 years, and BMI of 29.6 kg/m². There were 43 current, 69 former, and 152 nonsmokers in the cohort. At baseline, nonsmokers had higher PCS-12 scores than current smokers (*P* = .010), lower VAS neck pain than current (*P* = .035) and former (*P* = .014) smokers, as well as lower VAS arm pain than former smokers (*P* = .006). Postoperatively, nonsmokers had higher PCS-12 scores than both current (*P* = .030) and former smokers (*P* = .035). Smoking status was not a significant predictor of change in patient outcome in multivariate analysis.

Conclusions: Whereas nonsmokers had higher function and lower pain than former or current smokers preoperatively, smoking status overall was not found to be an independent predictor of outcome scores after ACDF. This supports the notion that smoking status alone should not deter patients from undergoing ACDF for cervical degenerative pathology.

Keywords

anterior cervical discectomy and fusion, arm pain, neck disability index, neck pain, patient reported outcome measurements, Short Form-12 health survey, smoking, Visual Analogue Score

Introduction

Anterior cervical discectomy and fusion (ACDF) remains a mainstay in the treatment of degenerative disorders of the cervical spine, decompressing traversing nerve roots and restoring

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anatomical lordosis.¹ It has been well established in the literature that smoking has a negative impact on fusion rate, rate of adjacent segment disease, amount of dysphagia, and wound healing postoperatively.²⁻⁴ Given its major impact on microvascular circulation and pulmonary function, smoking cessation becomes a very important modifiable risk factor for improving the success rate following ACDF.

Whereas the increased risk of morbidity has been clearly established, the relationship of smoking and health-related quality of life (HRQOL) outcome measurements remains poorly delineated in patients undergoing ACDF. Epidemiological studies have demonstrated an overall decrease or loss of HRQOL years in smokers compared with nonsmokers.⁵ The association of smoking and decrease in HRQOL has been defined in the lumbar spine but has not been clearly established in the cervical spine.⁶⁻⁸ Jansson et al⁶ demonstrated that in patients undergoing a lumbar decompression for disc herniation, less improvement in HRQOL was seen in smokers compared with nonsmokers.

A successful patient selection algorithm for ACDF requires the identification of modifiable risk factors and their optimization preoperatively. Preoperative smoking cessation for patients undergoing ACDF leads to decreased pseudarthrosis, postoperative dysphagia, and wound complications. However, the relationship of smoking status, especially overall smoking history, and change in HRQOL after ACDF is poorly understood. The purpose of this study was to identify changes in HRQOL measures over time—or “treatment effect”—between active smokers, former smokers, and nonsmokers undergoing ACDF.

Methods

After institutional review board approval was obtained, a retrospective review of medical records was performed. The data was collected from fellowship-trained orthopaedic spine surgeons from January 1, 2015, until December 31, 2016, with all procedures performed at a single institution. Patients older than 18 years and with a diagnosis of cervical myelopathy, radiculopathy, or radiculomyelopathy who underwent an elective 1-5 level ACDF were included. Patients were sorted into 3 groups based on their self-reported smoking status: nonsmoker, former smoker, and current smoker. Patients younger than 18 years and those undergoing surgery for trauma, infection, metastatic disease, and revision surgery and those with less than 1 year of follow-up were excluded from the study.

Patient-reported scores, including the Neck Disability Index (NDI), Short Form 12 Physical Component Score (PCS-12), Short Form 12 Mental Component Score (MCS-12), and Visual Analogue Scale Neck (VAS Neck) and Arm (VAS Arm) pain scores were prospectively maintained and collected preoperatively and postoperatively up to the 1-year time point. Demographic data, including age, body mass index (BMI), smoking status, and gender was also recorded.

Analysis comparing pseudarthrosis rates between smoking groups was then conducted based on physician-reported diagnosis of clinical pseudarthrosis and measurements performed

on imaging from the institution’s Picture Archiving and Communication System (PACS, Siemens Magic Software, Munich Germany; precision of 0.1 mm). Because routine CT scans are not typically obtained postoperatively, the authors of this study used flexion and extension X-rays in PACS, excluding images taken before 6 months postoperatively. Criteria for radiographic pseudarthrosis were based on those described previously by Song et al,⁹ where a superjacent segment motion ≥ 4 mm and interspinous distance ≥ 1 between any of the fused vertebrae indicates presence of pseudarthrosis.⁹ The groups were also compared for differences in revision surgery rates.

Standard descriptive statistics, including mean and 95% CI, were used to analyze patient demographic data and outcomes for the entire cohort. Baseline differences between groups were compared using 1-way ANOVA and Bonferroni post hoc analysis. Recovery ratios (RRs) were calculated to compare improvements in each outcome between groups. The RR was calculated as follows: (Postoperative score – Preoperative score)/(Optimal score – Baseline score). Optimal scores for PCS-12 and MCS-12 were defined as 100, whereas those for NDI, VAS Neck pain, and VAS Arm pain were 0.¹⁰ The change in outcomes after surgery, pseudarthrosis parameters, and revision surgery between groups were compared using either linear or logistic regression analysis controlling for age, sex, BMI, months followed up, preoperative symptom duration, number of levels fused, graft type, preoperative diagnosis, American Society of Anesthesiologist physical status classification system, and Charlson Comorbidity Index. Pearson χ^2 analysis was used to determine any difference in revision surgery or pseudarthrosis rates with respect to smoking status. Binary logistic regression, controlling for age, sex, BMI, and so on, was used to determine whether smoking status was an independent predictor of revision surgery or pseudarthrosis. A *P* value $< .05$ was considered to be statistically significant. A power analysis for each preoperative and postoperative outcome was performed to determine whether the study was powered sufficiently to detect a difference equal to or greater than the appropriate minimum clinically important difference (MCID) between groups at a significance level of $\alpha < .05$ using the variance measured in our sample.¹¹ The following MCID values were used: NDI, 15 points; PCS-12, 8.1; MCS-12, 4.7; VAS Neck pain, 2.6; and VAS Arm pain, 4.1.^{12,13}

Results

A total of 264 patients were included in the study: 43 (16.3%) patients were identified as current smokers, 69 (26.1%) were former smokers, and 152 (57.6%) were nonsmokers in the cohort. There were 123 (46.6%) male and 141 (53.4%) female patients in the cohorts. The average follow-up for outcome scores was 19.8 [19.0, 20.6] months. The mean follow-up for radiographic measurements was 12.0 [1.4, 22.7] months. The mean age was 53 [52, 54] years, and the mean BMI was 29.6 kg/m² [28.8, 30.3]. There were a total of 61 one-level fusions (23%), 125 two-level fusions (47%), 65 three-level fusions (25%), 12 four-level fusions (5%), and 1 five-level

Table 1. Descriptive Statistics of Cohort by Smoking Status (n = 264).

	Overall (n = 264)	Never Smoker (n = 152)	Current Smoker (n = 43)	Former Smoker (n = 69)	P Value ^a
Age, mean [95% CI]	53 [52, 54]	52 [51, 54]	52 [49, 54]	56 [53, 58]	.089
Sex					.921
M, n (%)	123 (47%)	71 (47%)	21 (49%)	31 (45%)	
F, n (%)	141 (53%)	81 (53%)	22 (51%)	38 (55%)	
BMI, kg/m ² , mean [95% CI]	29.6 [28.8, 30.3]	29.2 [28.3, 30.1]	29.6 [27.7, 31.6]	30.3 [28.8, 31.8]	.487
Months follow-up, mean [95% CI]	19.8 [19.0, 20.6]	19.9 [18.8, 21.0]	18.5 [16.9, 20.1]	20.3 [18.9, 21.7]	.265
Symptom duration, n (%)					.784
<1 Month	18 (6.8%)	11 (7.2%)	2 (4.7%)	5 (7.2%)	
1-3 Months	41 (15.5%)	23 (15.1%)	5 (11.6%)	13 (18.8%)	
3-6 Months	46 (17.4%)	28 (18.4%)	4 (9.3%)	14 (20.3%)	
6 Months to 2 years	72 (27.3%)	41 (27.0%)	13 (30.2%)	18 (26.1%)	
2 Years+	87 (33.0%)	49 (31.3%)	19 (45.2%)	19 (27.6%)	
Number of levels fused, n (%)					.259
1	61 (23%)	35 (23%)	14 (33%)	12 (17%)	
2	125 (47%)	64 (42%)	20 (47%)	41 (59%)	
3	65 (25%)	45 (30%)	7 (16%)	13 (19%)	
4	12 (5%)	7 (5%)	2 (4%)	3 (4%)	
5	1 (<1%)	1 (<1%)	0 (0%)	0 (0%)	
Graft type, n (%)					.682
Allograft	243 (92.0%)	139 (91.4%)	41 (95.3%)	63 (91.3%)	
Iliac crest bone graft	21 (8.0%)	13 (8.6%)	2 (4.7%)	6 (8.7%)	
Diagnosis, n (%)					.604
Radiculopathy	122 (46.2%)	65 (42.8%)	23 (53.5%)	34 (49.3%)	
Myelopathy	64 (24.2%)	38 (31.1%)	11 (25.6%)	15 (21.7%)	
Myeloradiculopathy	78 (29.6%)	49 (26.1%)	9 (20.9%)	20 (29.0%)	
ASA, n (%)	n = 196	n = 12	n = 135	n = 49	.086
1	12 (6.1%)	10 (83.3%)	83 (61.5%)	28 (57.1%)	
2	135 (68.9%)	2 (16.7%)	15 (11.1%)	11 (22.4%)	
3	49 (25%)	0 (0%)	37 (27.4%)	10 (20.5%)	
4/5	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
CCI, n (%)	n = 199	n = 122	n = 29	n = 48	.092
0	27 (13.6%)	20 (16.4%)	4 (13.8%)	3 (6.3%)	
1	39 (19.6%)	25 (20.5%)	7 (24.1%)	7 (14.6%)	
2	60 (30.2%)	42 (34.4%)	6 (20.7%)	12 (25.0%)	
3	50 (25.1%)	23 (18.9%)	7 (24.1%)	20 (41.6%)	
4+	23 (11.5%)	12 (9.8%)	5 (17.3%)	6 (12.5%)	

Abbreviations: M, male; F, female; BMI, body mass index; ASA, American Society of Anesthesiologist physical status classification system; CCI, Charleston Comorbidity Index.

^aBaseline demographics were compared between groups with independent samples t-test, Pearson chi-square analysis, or Fisher's Exact test.

fusion (<1%). Baseline demographic data for patients in the cohort are given in Table 1.

HRQOL Outcome Measurements

At baseline, PCS-12 was significantly higher in the nonsmoker group than in the current smoker group, with a significant mean difference of 4.2 points ([0.8, 7.7], $P = .010$) between the groups. Additionally, VAS neck scores were significantly lower preoperatively for nonsmokers than both current and former smokers, with mean differences of -1.2 ($[-2.5, -0.1]$, $P = .035$) and -1.0 ($[-2.2, -0.2]$, $P = .014$) points, respectively. VAS arm pain scores were only significantly different between never and former smokers by a mean difference of -1.3 ($[-2.5, -0.3]$, $P = .006$) points. Neither MCS-12 nor NDI were found to significantly differ between smoking groups

at baseline (Table 2). Postoperatively, only PCS-12 was found to be significantly higher in nonsmokers than both current smokers and former smokers, with mean differences of 5.1 ([0.4, 9.8], $P = .030$) and 4.1 ([0.2, 8.0], $P = .035$) points, respectively. None of the other outcome scores significantly differed between the smoking groups at postoperative measurements (Table 2).

On multiple linear regression analysis, smoking status was found to not be a significant predictor of HRQOL changes after surgery for any of the outcome measures (Table 2). Other variables that came to significance included the following: greater follow-up (months) for NDI ($\beta = 0.468$ [0.078, 0.857]; $P = .019$), VAS Neck pain ($\beta = 0.084$ [0.028, 0.139]; $P = .003$), and VAS Arm pain ($\beta = 0.074$ [0.016, 0.132]; $P = .012$) and use of iliac crest bone graft for VAS arm pain ($\beta = 1.529$ [0.111, 2.948]; $P = .035$). When assessing

Table 2. Health-Related Quality-of-Life Outcome Measurement Comparisons Between Smoking Groups.

		Never Smoker (n = 152)	Current Smoker (n = 43)	Former Smoker (n = 69)	One-Way ANOVA, P Value	Multiple Linear Regression, P Value
PCS-12	Pre	34.6 [33.2, 35.9]	30.4 [28.0, 32.5]	32.0 [30.3, 33.8]	0.004 ^a	0.357
	Post	42.4 [40.6, 44.1]	37.3 [34.4, 41.1]	38.3 [35.7, 41.0]	0.006 ^a	
	RR	0.11 [0.09, 0.13]	0.09 [0.05, 0.13]	0.09 [0.05, 0.12]	0.455	
MCS-12	Pre	45.7 [43.8, 47.8]	44.1 [40.3, 47.8]	45.0 [42.4, 47.7]	0.720	0.160
	Post	50.2 [48.4, 52.0]	49.2 [45.7, 52.7]	46.7 [43.8, 49.6]	0.137	
	RR	0.04 [0.0, 0.08]	0.04 [-0.04, 0.13]	0.01 [-0.05, 0.06]	0.573	
NDI	Pre	40.1 [36.8, 43.3]	46.5 [41.4, 51.5]	45.2 [40.7, 50.0]	0.035 ^b	0.324
	Post	23.4 [19.7, 26.8]	30.0 [22.7, 36.4]	28.4 [23.0, 33.7]	0.105	
	RR	0.37 [0.27, 0.47]	0.34 [0.18, 0.49]	0.38 [0.28, 0.48]	0.919	
VAS Neck	Pre	5.2 [4.7, 5.7]	6.4 [5.6, 7.2]	6.2 [5.5, 6.8]	0.003 ^a	0.832
	Post	3.0 [2.6, 3.5]	3.6 [2.7, 4.6]	3.2 [2.4, 3.8]	0.349	
	RR	0.41 [0.31, 0.52]	0.40 [0.26, 0.54]	0.46 [0.30, 0.62]	0.860	
VAS Arm	Pre	4.7 [4.1, 5.2]	5.6 [4.7, 6.6]	6.0 [5.3, 6.6]	0.006 ^a	0.489
	Post	2.6 [2.1, 3.1]	2.7 [1.9, 3.5]	3.2 [2.5, 3.9]	0.290	
	RR	0.51 [0.37, 0.64]	0.51 [0.37, 0.65]	0.48 [0.37, 0.60]	0.966	

Abbreviations: PCS-12, Short Form 12 Physical Component Score; MCS-12, Short Form 12 Mental Component Score; NDI, Neck Disability Index; VAS, Visual Analogue Scale; RR, recovery ratio.

^aIndicates statistical significance.

^bBonferroni post hoc analysis revealed no significant differences between smoking groups.

Table 3. Pseudarthrosis/Revision Surgery Rates and Smoking Status Among Smoking Groups.

	Overall (n = 264)	Never Smoker (n = 152)	Current Smoker (n = 43)	Former Smoker (n = 69)	Pearson χ^2 or Fisher Exact Test, P Value	Binary Logistic Regression, P Value
Clinical diagnosis of pseudarthrosis?						
Yes, n (%)	23 (8.7%)	12 (7.9%)	2 (4.7%)	9 (13.0%)	.266	.152
No, n (%)	241 (91.3%)	140 (92.1%)	41 (95.3%)	60 (87.0%)		
Radiographic criteria of pseudarthrosis?	(n = 150)	(n = 87)	(n = 26)	(n = 37)		
Yes, n (%)	21 (14.0%)	14 (16.1%)	1 (3.8%)	6 (16.2%)	.260	.802
No, n (%)	129 (86.0%)	73 (83.9%)	25 (96.2%)	31 (83.8%)		
Revision surgery?						
Yes, n (%)	22 (8.3%)	15 (9.9%)	3 (7.0%)	4 (5.8%)	.562	.196
No, n (%)	242 (91.7%)	137 (90.1%)	40 (93.0%)	65 (94.2%)		

RR for each outcome, all groups noted similar amounts of improvement from baseline (Table 2).

Pseudarthrosis/Revision Surgery and Smoking Status

There were a total of 23 patients (8.71%) with a clinical diagnosis of pseudarthrosis. Of these, 12 were in the nonsmoker group (52.2%), 2 were in the current smoker group (8.7%), and 9 were in the former smoker group (39.1%); however, these differences were not statistically significant ($P = .266$). Based on the criteria used by Song et al,⁹ 21 of 150 patients (14.0%) had radiographic evidence of pseudarthrosis. There were 14 patients in the nonsmoking group (16.1%), 1 patient in the current smoking group (3.8%), and 6 patients in the former smoking group (16.2%), with no significant differences between groups ($P = .260$). Using binary logistic regression, smoking status was not a significant predictor of clinical pseudarthrosis ($P = .152$) or radiographic pseudarthrosis

($P = .802$). There was no significant difference between groups with regard to revision rates ($P = .562$), with 15 nonsmokers (9.9%), 3 current smokers (7.0%), and 4 former smokers (5.8%) undergoing revision surgery. Binary logistic regression did not identify smoking status as a significant predictor of revision surgery ($P = .196$; Table 3). Based on results of the post hoc power analysis, preoperative and postoperative outcome comparisons were sufficiently powered (Power = 0.99).

Discussion

In this study, the major aim was to determine the effect of smoking status on the HRQOL outcomes after an ACDF. Despite the well-known increase in general morbidity following ACDF and its relationship to fusion status, the effect of smoking on HRQOL outcome measurements is not as well studied.¹¹⁻¹⁵ HRQOL outcomes may be used as a proxy for overall well-being for patients receiving various types of spine

surgery, including ACDF.¹⁴⁻¹⁶ Both surgeons and patients must be cognizant of the potential associated risks of smoking prior to performing ACDF.

In the current study, nonsmokers exhibited higher baseline PCS-12 scores than the current smoker group, with a mean difference of 4.3 points ([0.8, 7.7], $P = .010$). This group was also found to have higher postoperative PCS-12 scores than both the current and former smoking groups, with mean differences of 5.1 ([0.4, 9.8], $P = .030$) and 4.1 ([0.2, 8.0], $P = .035$) points, respectively. The nonsmoking group also had lower baseline VAS neck pain scores than both the current and former smoking group, with mean differences of -1.3 ($[-2.5, -0.1]$, $P = .035$) and -1.2 ($[-2.2, -0.2]$, $P = .014$), respectively, and lower baseline VAS arm pain scores than the former smoking group by a mean difference of -1.4 ($[-2.5, -0.3]$, $P = .006$) points. VAS neck and arm pain scores were not significantly different between groups at postoperative measurements. Additionally, neither NDI nor MCS-12 scores were significantly different between groups at baseline or during postoperative measurements. Finally, both linear regression and RR analyses indicated no significant change in treatment effect between groups for any of the outcome measures examined.

Whereas nonsmokers reported less disability at baseline in terms of PCS-12 and VAS arm and neck scores, they had similar pain scores and a similar improvement in RR as the other groups postoperatively. In addition, smoking status was not found to be a significant predictor of change in treatment effect for any of the included outcome measures. These results suggest that all patients may benefit to a similar degree when undergoing ACDF, regardless of smoking status. However, it is not clear to what degree smoking cessation will actually improve baseline scores in those who smoke. Moreover, the fact that the current study found no significant differences in treatment effect over time between smoking groups suggests that insurance companies need not deny coverage to smokers who require ACDF to address degenerative cervical symptoms, especially those who do not quit using tobacco 6 weeks prior to surgery.¹⁷

Current literature regarding smoking status on cervical surgery show conflicting evidence. Davis et al¹⁸ conducted a prospective study comparing nonunion rates in patients undergoing ACDF and cervical disc replacement. They identified that at 48 months of follow-up, nonsmokers had a greater improvement in NDI, VAS for neck pain, SF-12 MCS, and SF-12 PCS compared with smokers.¹⁸ In a study evaluating multiple surgical techniques for patients with cervical myelopathy, Tetreault et al¹⁹ reported that nonsmokers were more likely to experience improvement in the modified Japanese Orthopedic Association score outcomes than smokers at the 1-year postoperative mark. Similarly, although they did not use HRQOL outcome metrics, Eubanks et al²⁰ and Hilibrand et al² reported worse outcomes after cervical spine surgery in smokers than nonsmokers.³ These findings are different from this study's findings and suggest that more studies are needed to determine the relationship between smoking and patient outcomes for ACDF.

Although this current study was not designed to look at pseudarthrosis rates, clinical and radiographic data was used to analyze the cohort. Radiographic measurements described by Song et al⁹ were used to determine the presence of a radiographic pseudarthrosis, with an overall rate of 14.0% in the cohort with no significant difference between groups ($P = .260$). Binary logistic regression found that smoking status was not a significant predictor of clinical ($P = .152$) or radiographic ($P = .802$) pseudarthrosis. This is consistent with current literature analyzing pseudarthrosis after ACDF that shows conflicting evidence.^{2,7,8,16,20-25} In a prospective study, An et al²¹ compared the use of allograft-demineralized bone matrix composite versus autograft for treatment of 77 patients undergoing ACDF and found no significant difference in the fusion rate of smokers (52.9%) and nonsmokers (72.1%; $P = .13$).²¹ Two other retrospective studies by Lau et al²³ and Luszczuk et al²⁴ found no significant differences in nonunion rates between nonsmokers and smokers ($P = .163$ and $P = .867$, respectively) who underwent anterior cervical surgery. Conversely, Lee et al¹⁶ identified smoking, female gender, and the number of fusion segments as independent risk factors for reoperation in patients undergoing ACDF. Similarly, in the study by Bishop et al,²² smokers were found to have an increased delayed union rate at 12 months based on radiological measurements than nonsmokers (60% for smokers vs 21% for nonsmokers). In addition, Hilibrand et al² also found that smokers had significantly lower fusion rates compared with nonsmokers (smokers: 62%; nonsmokers: 81%; $P < .02$).

Several limitations for this current study exist, including its retrospective nature, which can lead to potential observer and/or reporting bias. Additionally, some data points were not available for analysis, such as the duration of smoking cessation for patients in the former smoker cohort as well as the pack years for current and former smokers. An additional limitation is the fact that patients who actively use vaporizers only were not included in the study. Self-reporting also introduces recall bias or response bias because nonsmokers may actually be current or former smokers. Additionally, the study was not designed to evaluate pseudarthrosis, so although all patients were required to have more than a year of clinical follow-up, not all patients had appropriate imaging to determine fusion status after surgery. Had CT imaging been obtained for each patient, the present study would have been able to draw more significant conclusions regarding the association between smoking status and nonunion after ACDF.

Conclusion

In the current study, current and former smoking was associated with more severe symptoms at baseline for PCS-12, VAS Neck pain, and VAS Arm pain scores in patients undergoing ACDF. However, in spite of baseline differences, all groups showed similar rates of improvement, and smoking status was not found to be an independent predictor of patient outcomes. These findings suggest that smoking status alone does not influence patient-reported outcomes after ACDF.




Declaration of Conflicting Interests

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Ethical Board Review Statement

This study was approved by the institutional review board at the Thomas Jefferson University Hospital. Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

References

- Muzević D, Splavski B, Boop FA, Arnautović KI. Anterior cervical discectomy with instrumented allograft fusion: lordosis restoration and comparison of functional outcomes among patients of different age groups. *World Neurosurg.* 2018;109:e233-e243. doi:10.1016/j.wneu.2017.09.146
- Hilibrand AS, Fye MA, Emery SE, Palumbo MA, Bohlman HH. Impact of smoking on the outcome of anterior cervical arthrodesis with interbody or strut-grafting. *J Bone Joint Surg Am.* 2001;83:668-673.
- Peolsson A, Vavruch L, Öberg B. Predictive factors for arm pain, neck pain, neck specific disability and health after anterior cervical decompression and fusion. *Acta Neurochir (Wien).* 2006;148:167-173. doi:10.1007/s00701-005-0660-x
- Pearson RG, Clement RGE, Edwards KL, Scammell BE. Do smokers have greater risk of delayed and non-union after fracture, osteotomy and arthrodesis? A systematic review with meta-analysis. *BMJ Open.* 2016;6:e010303. doi:10.1136/bmjopen-2015-010303
- Jia H, Lubetkin EI. Trends in quality-adjusted life-years lost contributed by smoking and obesity. *Am J Prev Med.* 2010;38:138-144. doi:10.1016/j.amepre.2009.09.043
- Jansson KA, Németh G, Granath F, Jönsson B, Blomqvist P. Health-related quality of life in patients before and after surgery for a herniated lumbar disc. *J Bone Joint Surg Br.* 2005;87:959-964. doi:10.1302/0301-620X.87B7.16240
- Sandén B, Försth P, Michaëlsson K. Smokers show less improvement than nonsmokers two years after surgery for lumbar spinal stenosis: a study of 4555 patients from the Swedish spine register. *Spine (Phila Pa 1976).* 2011;36:1059-1064. doi:10.1097/BRS.0b013e3181e92b36
- Jackson KL II, Devine JG. The effects of smoking and smoking cessation on spine surgery: a systematic review of the literature. *Global Spine J.* 2016;6:695-701. doi:10.1055/s-0036-1571285
- Song KS, Piyaskulkaew C, Chuntarapas T, et al. Dynamic radiographic criteria for detecting pseudarthrosis following anterior cervical arthrodesis. *J Bone Joint Surg Am.* 2014;96:557-563.
- Radcliff K, Davis R, Hisey M, et al. Long-term evaluation of cervical disc arthroplasty with the Mobi-CÓ cervical disc: a randomized, prospective, multicenter clinical trial with seven-year follow-up. *Int J Spine Surg.* 2017;11:31. doi:10.14444/4031
- Champely S. pwr: Basic Functions for Power Analysis. Version 1.2-2. <https://CRAN.R-project.org/package=pwr>. Accessed November 8, 2019.
- Parker SL, Godil SS, McGirt MJ. Determination of minimum clinically important difference in pain, disability and quality of life after anterior cervical discectomy and fusion. *Spine J.* 2012;12(9, suppl):S120. doi:10.1016/j.spinee.2012.08.323
- Carreon LY, Glassman SD, Campbell MJ, Anderson PA. Neck Disability Index, short form-36 physical component summary, and pain scales for neck and arm pain: the minimum clinically important difference and substantial clinical benefit after cervical spine fusion. *Spine J.* 2010;10:469-474. doi:10.1016/j.spinee.2010.02.007
- Godil SS, Parker SL, Zuckerman SL, Mendenhall SK, McGirt MJ. Accurately measuring the quality and effectiveness of cervical spine surgery in registry efforts: determining the most valid and responsive instruments. *Spine J.* 2015;15:1203-1209. doi:10.1016/j.spinee.2013.07.444
- Singh A, Gnanalingham K, Casey A, Crockard A. Quality of life assessment using the Short Form-12 (SF-12) questionnaire in patients with cervical spondylotic myelopathy. *Spine (Phila Pa 1976).* 2006;31:639-643. doi:10.1097/01.brs.0000202744.48633.44
- Lee CE, Browell LM, Jones DL. Measuring health in patients with cervical and lumbosacral spinal disorders: is the 12-item Short-Form Health Survey a valid alternative for the 36-item Short-Form Health Survey? *Arch Phys Med Rehabil.* 2008;89:829-833. doi:10.1016/j.apmr.2007.09.056
- National Imaging Associates. *2016 NIA Clinical Guidelines for Medical Necessity Review: Blue Cross Blue Shield of South Carolina and Bluechoice Health Plan of South Carolina.* Columbia, MD: National Imaging Associates; 2016.
- Davis RJ, Kim KD, Hisey MS, et al. Cervical total disc replacement with the Mobi-C cervical artificial disc compared with anterior discectomy and fusion for treatment of 2-level symptomatic degenerative disc disease: a prospective, randomized, controlled multicenter clinical trial. *J Neurosurg Spine.* 2013;19:532-545. doi:10.3171/2013.6.SPINE12527
- Tetreault LA, Kopjar B, Vaccaro A, et al. A clinical prediction model to determine outcomes in patients with cervical spondylotic myelopathy undergoing surgical treatment. *J Bone Joint Surg Am.* 2013;95:1659-1666.
- Eubanks JD, Thorpe SW, Cheruvu VK, Braly BA, Kang JD. Does smoking influence fusion rates in posterior cervical arthrodesis with lateral mass instrumentation? *Clin Orthop Relat Res.* 2011;469:696-701. doi:10.1007/s11999-010-1575-2

21. An HS, Simpson MJ, Glover MJ, Stephany J. Comparison between allograft plus demineralized bone matrix versus autograft in anterior cervical fusion. *Spine (Phila Pa 1976)*. 1995; 20:2211-2216.
22. Bishop RC, Moore KA, Hadley MN. Anterior cervical interbody fusion using autogeneic and allogeneic bone graft substrate: a prospective comparative analysis. *J Neurosurg*. 1996;85: 206-210. doi:10.3171/jns.1996.85.2.0206
23. Lau D, Chou D, Ziewacz JE, Mummaneni PV. The effects of smoking on perioperative outcomes and pseudarthrosis following anterior cervical corpectomy: clinical article. *J Neurosurg Spine*. 2014;21:547-558. doi:10.3171/2014.6.SPINE13762
24. Luszczuk M, Smith JS, Fischgrund JS, et al. Does smoking have an impact on fusion rate in single-level anterior cervical discectomy and fusion with allograft and rigid plate fixation? *Clinical article. J Neurosurg Spine*. 2013;19:527-531. doi:10.3171/2013.7.SPINE13208
25. Glassman SD, Anagnost SC, Parker A, Burke D, Johnson JR, Dimar JR. The effect of cigarette smoking and smoking cessation on spinal fusion. *Spine (Phila Pa 1976)*. 2000;25:2608-2615. doi:10.1097/00007632-200010150-00011