Patient characteristics of smokers undergoing lumbar spine surgery: an analysis from the Quality Outcomes Database

Anthony L. Asher, MD,¹ Clinton J. Devin, MD,² Brandon McCutcheon, MD,³ Silky Chotai, MD,² Kristin R. Archer, PhD,^{4,5} Hui Nian, PhD,⁶ Frank E. Harrell Jr., PhD,⁶ Matthew McGirt, MD,¹ Praveen V. Mummaneni, MD,⁷ Christopher I. Shaffrey, MD,⁸ Kevin Foley, MD,⁹ Steven D. Glassman, MD,¹⁰ and Mohamad Bydon, MD,³ for the QOD Vanguard Sites

¹Department of Neurological Surgery, Carolina Neurosurgery and Spine Associates and Neuroscience Institute, Carolinas Healthcare System, Charlotte, North Carolina; ²Departments of Orthopaedic Surgery and Neurological Surgery, Vanderbilt Spine Center, Vanderbilt University Medical Center, Nashville, Tennessee; ³Department of Neurosurgery, Mayo Clinic, Rochester, Minnesota; ⁴Departments of ⁴Orthopaedic Surgery, Vanderbilt Spine Center, ⁵Physical Medicine and Rehabilitation, and ⁶Biostatistics, Vanderbilt University School of Medicine, Nashville, Tennessee; ⁷Department of Neurological Surgery, University of California, San Francisco, California; ⁸Department of Neurosurgery, University of Virginia Medical Center, Charlottesville, Virginia; ⁹Department of Neurosurgery, University of Tennessee Health Sciences Center, Semmes Murphey Neurologic and Spine Institute, Memphis, Tennessee; and ¹⁰Department of Orthopedic Surgery, University of Louisville, and the Norton Leatherman Spine Center, Louisville, Kentucky

OBJECTIVE In this analysis the authors compare the characteristics of smokers to nonsmokers using demographic, socioeconomic, and comorbidity variables. They also investigate which of these characteristics are most strongly associated with smoking status. Finally, the authors investigate whether the association between known patient risk factors and disability outcome is differentially modified by patient smoking status for those who have undergone surgery for lumbar degeneration.

METHODS A total of 7547 patients undergoing degenerative lumbar surgery were entered into a prospective multi-center registry (Quality Outcomes Database [QOD]). A retrospective analysis of the prospectively collected data was conducted. Patients were dichotomized as smokers (current smokers) and nonsmokers. Multivariable logistic regression analysis fitted for patient smoking status and subsequent measurement of variable importance was performed to identify the strongest patient characteristics associated with smoking status. Multivariable linear regression models fitted for 12-month Oswestry Disability Index (ODI) scores in subsets of smokers and nonsmokers was performed to investigate whether differential effects of risk factors by smoking status might be present.

RESULTS In total, 18% (n = 1365) of patients were smokers and 82% (n = 6182) were nonsmokers. In a multivariable logistic regression analysis, the factors significantly associated with patients' smoking status were sex (p < 0.0001), age (p < 0.0001), body mass index (p < 0.0001), educational status (p < 0.0001), insurance status (p < 0.001), and employment/occupation (p = 0.0024). Patients with diabetes had lower odds of being a smoker (p = 0.0008), while patients with coronary artery disease had greater odds of being a smoker (p = 0.044). Patients' propensity for smoking was also significantly associated with higher American Society of Anesthesiologists (ASA) class (p < 0.0001), anterior-alone surgical approach (p = 0.018), greater number of levels (p = 0.0246), decompression only (p = 0.0001), and higher baseline ODI score (p < 0.0001). In a multivariable proportional odds logistic regression model, the adjusted odds ratio of risk factors and direction of improvement in 12-month ODI scores remained similar between the subsets of smokers and nonsmokers.

CONCLUSIONS Using a large, national, multiinstitutional registry, the authors described the profile of patients who undergo lumbar spine surgery and its association with their smoking status. Compared with nonsmokers, smokers

ABBREVIATIONS ASA = American Society of Anesthesiologists; BMI = body mass index; BP = back pain; CAD = coronary artery disease; LP = leg pain; NRS = numeric rating scale; ODI = Oswestry Disability Index; OR = odds ratio; PRO = patient-reported outcome; QOD = Quality Outcomes Database.

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were younger, male, nondiabetic, nonobese patients presenting with leg pain more so than back pain, with higher ASA classes, higher disability, less education, more likely to be unemployed, and with Medicaid/uninsured insurance status. Smoking status did not affect the association between these risk factors and 12-month ODI outcome, suggesting that interventions for modifiable risk factors are equally efficacious between smokers and nonsmokers.

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KEY WORDS QOD; patient-reported outcomes; smoking; lumbar; surgery

IN the modern era, data scientists are able to amass ever-larger quantities of clinically relevant data at rapidly increasing rates. The Quality Outcomes Database (QOD), formerly known as the National Neurosurgery Quality and Outcomes Database (N²QOD), is a manifestation of this trend.^{2,24} While administrative data sets historically provided researchers with large sample sizes, they often lacked important clinical information. Conversely, at their individual institutions, researchers had the power to generate highly granular clinical data but at the cost of a reduced sample size and, thus, statistical power. The QOD, in contrast, offers the benefits of both paradigms and allows spine surgeons to gain new insight into critical clinical topics.

There is extensive literature documenting that patient smoking status is strongly associated with worse outcomes following spine surgery. One study found that rates of readmission, need for intensive care unit admission, length of stay, and total cost following spine surgery were increased for smokers relative to nonsmokers.⁴ A separate study demonstrated higher rates of reoperation among smokers receiving a single- or multiple-level laminectomy.⁶ Similar results have also been noted for minimally invasive spine surgery. Gulati et al. reported decreased improvement in patient Oswestry Disability Index (ODI) scores at 1 year among smokers relative to nonsmokers following microdecompression for lumbar spinal stenosis.¹² A separate study noted a 2-fold increased risk of deterioration of patient ODI scores for smokers receiving decompression for lumbar spinal stenosis.²⁸ Therefore, the impact of patient smoking status on outcomes has been previously quantified.^{4–6,12,13,15,17,18,21,23,26,27,30–34} However, the question remains: compared with nonsmokers, what characteristics of smokers contribute to the less desirable outcomes after spine surgery?

In this analysis, we compare the clinical characteristics of smokers with those of nonsmokers among patients undergoing degenerative lumbar surgery and included in the QOD data set. Our study aims were: 1) to determine the characteristics of the smokers, and 2) to investigate the effect of risk factors for 12-month patient-reported outcomes (PROs) on smokers and nonsmokers.

Methods

Data Source

Patients undergoing elective spine surgery for degenerative lumbar disease were entered into the prospective multicenter QOD registry over a 2-year period. The QOD is a prospective observational registry designed to collect measures of surgical safety and PROs at 12 months af-

ter surgery and establish risk-adjusted expected morbidity. The overall goal is to improve efficiency and quality of care for the most common lumbar surgical procedures performed by spine surgeons. The QOD registry enrolls spine surgery patients from 74 participating centers across 28 US states via representative sampling.^{2,24} Baseline and yearly postoperative pain, disability, and quality of life scores were assessed via self-administration or phone interview by an independent data coordinator not involved with clinical care. Data were collected through a secure password-protected Web-based portal (Research Electronic Data Capture, or REDCap) into a national aggregate database.¹⁶ For this study, a retrospective analysis of the prospectively collected data was conducted.

Inclusion and Exclusion Criteria

Patients undergoing lumbar surgery performed for primary stenosis, spondylolisthesis, disc herniation, symptomatic mechanical disc collapse, and revision surgery, including recurrent same-level disc herniation and adjacent-segment disease, who had at least 12 months of follow-up, were eligible for inclusion. Exclusions included spinal infection, tumor, fracture, traumatic dislocation, deformity, pseudoarthrosis, same-level recurrent multilevel stenosis, pseudoarthrosis, same-level recurrent multilevel stenosis, neurological paralysis due to preexisting spinal disease or injury, less than 18 years of age, incarceration, unavailable information regarding ODI scores at baseline and 12 months postoperatively, and unavailable data on smoking status.

Outcome Measures

The primary outcome of interest was 12-month postoperative ODI score.⁹ Secondary measures were assessed using validated questionnaires and included: 1) pain, using the numeric rating scale (NRS) for back pain (NRS-BP) and leg pain (NRS-LP);²⁰ and 2) preference-based health status, using the EQ-5D.⁷

Statistical Analysis

Mean, standard deviation, quartiles for continuous variables, and frequencies for categorical variables were calculated for patient demographics. Bivariate analyses were conducted using the Mann-Whitney U-test for continuous data and chi-square test for nominal data. Patients were dichotomized as smokers (current smokers) and nonsmokers.

A multivariable logistic regression model was fitted for smoking status (yes or no). The odds of being a smoker were calculated with respect to patient demographic and

FIG. 1. Adjusted effects of variables on smoking status, demonstrating the odds of being a smoker. VA = Veterans Affairs.

comorbidity data (Fig. 1). The independent variables included in the model are listed in Table 1 and demonstrated in Fig. 1. For continuous variables, odds ratios (ORs) were calculated comparing the 75th percentile to the 25th percentile. The association between other risk factors and patient smoking status was computed using the following formula: Wald chi-square value minus predictor degree of freedom (Fig. 2). The higher the difference, the higher is the importance of that predictor for patient smoking status. To investigate whether the effect of patient risk factors on 12-month ODI outcome is associated with patient smoking, we fitted separate multivariable proportional odds ordinal logistic regression models (Fig. 3) in subsets of smokers and nonsmokers. Two-sided *p* values less than

0.05 were considered statistically significant. The analysis was performed using the R statistical program (version 3.1.2, www.R-project.org).¹⁴

Results

A total of 7547 patients undergoing degenerative lumbar surgery with 12 months of follow-up were analyzed. In total, 18% (*n* = 1365) of patients were smokers and 82% (*n* = 6182) were nonsmokers. Table 1 demonstrates the patient baseline characteristics, diagnosis, and surgery-specific variables in smokers and nonsmokers.

Characteristics of Smokers

In a multivariable logistic regression analysis, the fac-

TABLE 1. Phenotypic characteristics of smokers compared with nonsmokers

Variable	Total	Smokers (%)	Nonsmokers (%)	p Value
No. of patients	7547	1365	6182	
Mean age $\pm$ SD (yrs)	7532	52 $\pm$ 13	60 $\pm$ 14	<0.001
Sex	7544			0.019
Male		745 (55)	3155 (51)	
Female		620 (45)	3024 (49)	
Mean BMI $\pm$ SD	7528	29.5 $\pm$ 6.2	30.5 $\pm$ 6.9	<0.001
Race	7547			<0.001
White		1202 (88)	5634 (91)	
Black		131 (10)	368 (6)	
Other		32 (2)	180 (3)	
Education	7490			<0.001
Low education		856 (63)	2709 (44)	
High education		504 (37)	3421 (56)	
Occupation	7518			<0.001
Sedentary		159 (12)	1040 (17)	
Labor job		493 (36)	1831 (30)	
Not working		708 (52)	3287 (53)	
Compensation		87 (6)	198 (3)	<0.001
Insurance	7530			
Medicaid/uninsured		198 (15)	200 (3)	
Medicare/VA gov- ernment		363 (27)	2565 (42)	
Private		798 (59)	3406 (55)	
Anxiety	7532	307 (22)	860 (14)	<0.001
Depression	7535	385 (28)	1161 (19)	<0.001
Diabetes	7546	174 (13)	1098 (18)	<0.001
CAD	7533	145 (11)	716 (12)	0.32
Prior surgery	7540	158 (12)	638 (10)	0.18
Dominant symptom	7547			<0.001
Back & leg equal		727 (53)	2653 (43)	
Back dominant		260 (19)	1263 (20)	
Leg dominant		378 (28)	2266 (37)	
Symptom duration	7487			0.93
>3 mos		1188 (88)	5391 (88)	
<3 mos		165 (12)	743 (12)	
Ambulation	6924			0.078
Independent		1039 (84)	4487 (85)	
Others		198 (16)	800 (15)	
Diagnosis	7544			0.004
Primary		1176 (86)	5493 (89)	
Revision		189 (14)	686 (11)	
Approach	7334			<0.001
Posterior		1284 (97)	5916 (98)	
Anterior		40 (3)	94 (2)	
Surgical levels	7133			0.1
1		517 (40)	2283 (39)	
2		567 (44)	2496 (43)	

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TABLE 1. Phenotypic characteristics of smokers compared with nonsmokers

Variable	Total	Smokers (%)	Nonsmokers (%)	p Value
Surgical levels (continued)	7133			0.1
3		163 (13)	839 (14)	
4		37 (3)	231 (4)	
Arthrodesis	7484	441 (32)	2218 (36)	0.41
Interbody graft	7363	348 (25)	1776 (29)	0.68
ASA class	7472			<0.001
I		37 (3)	460 (7)	
II		803 (59)	3374 (55)	
III		511 (38)	2287 (37)	

VA = Veterans Affairs.

tors associated with patient smoking status were analyzed in a risk-adjusted fashion (Fig. 1). Patient smoking status was significantly associated with age (younger age: $p < 0.0001$), sex (male: $p < 0.0001$), body mass index (BMI) ($p < 0.0001$), educational status (low education level: $p < 0.0001$), insurance status (Medicaid/uninsured: $p < 0.001$), and employment/occupation (sedentary type of occupation: $p = 0.0024$). Patients presenting with dominant LP had higher odds of being a smoker ($p = 0.0001$). Patients with diabetes had lower odds of being a smoker ($p = 0.0008$), while patients with coronary artery disease (CAD) had higher odds of being a smoker ($p = 0.044$). Patients' propensity for smoking was also significantly associated with higher classification according to the Physical Status Classification System of the American Society of Anesthesiologists (ASA) ($p < 0.0001$), an anterior-alone surgical approach ($p = 0.018$), greater number of levels ($p = 0.0246$), decompression only ($p = 0.0001$), as well as higher baseline ODI score ($p < 0.0001$). Figure 2 displays the adjusted and unadjusted importance of each variable included in the multivariable model. The variables that had the greatest association with smoking status were patient age, BMI, ASA classification, education, and insurance status.

Outcomes

All patients demonstrated a significant improvement in ODI, NRS-LP, NRS-BP, and EQ-5D scores ($p < 0.001$). The smokers had significantly worse 12-month ODI scores (31 ± 24 vs 22 ± 20 , $p < 0.001$), NRS-BP (4.1 ± 3.2 vs 2.9 ± 2.9 , $p < 0.001$), NRS-LP (3.4 ± 3.4 vs 2.3 ± 2.9 , $p < 0.001$), and EQ-5D (0.70 ± 0.25 vs 0.79 ± 0.20 , $p < 0.001$) compared with nonsmokers (Table 2).

Effect Modification of Risk Factors on 12-Month Outcomes

In a multivariable proportional odds logistic regression model, to evaluate the effect of smoking on the risk factors associated with worse 12-month ODI outcome, the adjusted OR of risk factors and direction of improvement

FIG. 2. Predictor importance for association of baseline characteristics with smoking status.

in 12-month ODI scores remained similar between the subsets of smokers and nonsmokers (Fig. 3). Similarly, the adjusted OR of risk factors and direction of improvement in 12-month NRS-BP, NRS-LP, and EQ-5D outcomes were similar between smokers and nonsmokers (Supplemental Figs. 1–3).

Discussion

This study uses prospectively collected data from the QOD registry to investigate differences in patient characteristics between smokers and nonsmokers undergoing surgery for degenerative lumbar disease. We found that smokers were significantly different from nonsmokers with regard to demographic characteristics, socioeconomic measures, comorbidities, and baseline PROs. Smokers were more likely to be younger, male, nondiabetic, non-obese, presenting with dominant LP, to have a higher ASA

class, greater disability, less education, less likelihood to be employed, and a Medicaid/uninsured insurance status. In terms of surgical variables, the smokers were less likely to undergo fusion surgery, and for those undergoing fusion, the smokers had a higher number of levels involved compared with nonsmokers. Despite these differences, the adjusted OR of factors associated with outcomes and the direction of improvement in 12-month ODI scores remained similar between the subsets of smokers and nonsmokers.

Understanding the characteristics of smokers can be useful for clinicians evaluating patients with a history of smoking to recognize that they are associated with a unique profile of demographic, socioeconomic, and comorbidity characteristics that are fundamentally different from their nonsmoking counterparts. While clinicians should consider the biological effects of smoking on post-operative healing and functional outcomes, this study may motivate clinicians to additionally consider the broader

FIG. 3. Adjusted effect of variables on 12-month (12m) ODI scores for smokers and nonsmokers. Figure is available in color online only.

TABLE 2. Baseline PROs, 12-month PROs, and change in scores from baseline to 12 months postoperatively for smokers and nonsmokers

PROs	Total	Smokers (%)	Nonsmokers (%)	p Value
Baseline PROs				
ODI	7545	54 ± 16	47 ± 17	<0.001
NRS-BP	7537	7.1 ± 2.5	6.3 ± 2.8	<0.001
NRS-LP	7539	7.4 ± 2.4	6.8 ± 2.7	<0.001
EQ-5D	7504	0.49 ± 0.22	0.56 ± 0.22	<0.001
12-mo PROs				
ODI	7545	31 ± 24	22 ± 20	<0.001
NRS-BP	7537	4.1 ± 3.2	2.9 ± 2.9	<0.001
NRS-LP	7539	3.4 ± 3.4	2.3 ± 2.9	<0.001
EQ-5D	7547	0.70 ± 0.25	0.79 ± 0.20	<0.001
Change in score PROs				
ODI	7545	23 ± 22	25 ± 20	<0.001
NRS-BP	7537	3.0 ± 3.3	3.4 ± 3.3	<0.001
NRS-LP	7539	3.0 ± 3.3	4.4 ± 3.6	<0.001
EQ-5D	7547	0.21 ± 0.27	0.24 ± 0.24	0.002

Data for the smoking and nonsmoking groups given as mean percentages ± SDs.

milieu of comorbidities and other preoperative characteristics that will influence postoperative outcomes for patients who smoke. Therefore, in addition to counseling patients regarding smoking cessation, it is vital to understand that other interventions might be needed in this population to achieve better outcomes. For instance, prior studies have demonstrated that a higher education level might allow for better understanding of the disease process compared with patients with lower education levels.^{19,29} In our analysis, the smokers had lower education levels compared with nonsmokers; therefore, providing additional counseling on the disease process would allow these patients to have realistic postoperative expectations, making them more treatment compliant, and ultimately resulting in better postoperative recovery.

Previous studies have demonstrated that socioeconomic factors including lower levels of education, unemployment, workers' compensation, and disability insurance were associated with poor outcomes following spine surgery.^{1,3,8,10,11,25} Some of these factors characterized smokers in our study. Furthermore, consistent with other studies, our previous analysis has demonstrated that being a smoker is associated with poor disability outcomes following lumbar spine surgery.^{3-5,9,11,15,17,18,21-23,25,26,32-34} Therefore, it made sense to evaluate if being a smoker would have any effect on the previously described risk factors associated with poor outcomes. On comparing the adjusted OR of the risk factors for the 12-month disability (ODI) outcome, we found that all the risk factors were similarly associated with outcomes in both smokers and nonsmokers. This suggests that higher BMI, lower education status, unemployment, higher ASA classification, higher number of levels operated on, history of diabetes, and history of CAD results in worse outcomes in both smokers and nonsmokers.

Therefore, the strategies on the interventions addressing the modifiable risk factors for disability outcomes could be equally efficacious in smokers and nonsmokers.

This study has several inherent limitations. First, it is limited by the absence of detailed clinical imaging. As a result, this study cannot perform risk adjustment based on radiographic findings, which may be useful in assessing patient disease severity. Furthermore, the inclusion of multiple degenerative pathologies might introduce some heterogeneity and associated bias. While risk adjustment was robust, there may be unobserved confounders that cannot be accounted for in this study. The long-term complications or reoperations are not captured in this registry. This is particularly relevant as smoking may affect the durability of both fusion and nonfusion procedures, which may affect observed outcomes over a longer study period. Another limitation of this study was the lack of follow-up imaging data. The smokers may have higher rates of pseudarthrosis, which could affect the observed outcomes. A number of previous studies have demonstrated the association of smoking status with nonfusion and poor functional outcomes.^{4-6,12,13,15,17,18,21,23,26,27,30-33,35} The goal of this study was to determine the characteristics of smokers and to evaluate the effect of other risk factors for 12-month PROs on smokers and nonsmokers. The QOD registry does not capture detailed data on the intensity of tobacco use; therefore, a dose-quantity relationship of smoking to outcomes cannot be established.

This study demonstrates the strengths of a "big data" approach to clinical research. The QOD national project includes a diverse network of health care institutions and patient types, which allows for a true representative sampling of patients undergoing elective lumbar spine surgery. Furthermore, this is the first study to characterize smokers undergoing surgery for lumbar degenerative pathologies and to determine if smoking status has any impact on the other risk factors associated with PROs.

Conclusions

Using a large, national, multiinstitutional registry, we described the profile of patients who undergo lumbar spine surgery in association with their smoking status. Compared with nonsmokers, smokers were younger, male, nondiabetic, nonobese patients, presenting with LP more so than BP, had higher ASA classification, greater disability, were less educated, more likely to be unemployed, and had Medicaid/uninsured insurance status. The smoking status did not affect the association between these risk factors and 12-month ODI outcome, suggesting that interventions for modifiable risk factors are equally efficacious between smokers and nonsmokers.

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Appendix

QOD Vanguard Sites

Anthony L. Asher, MD,¹ Matthew J. McGirt, MD,¹ Clinton J.

Devin, MD,² Joseph S. Cheng, MD,² Kevin T. Foley, MD,³ Jeffrey M. Sorenson, MD,³ John J. Knightly, MD,⁴ Steven D. Glassman, MD,⁵ Thomas B. Briggs, MD,⁶ Adam Kremer, MD,⁷ Wesley E. Griffith, MD,⁸ Noam Y. Stadlan, MD,⁹ Thomas W. Grahm, MD,¹⁰ Meic H. Schmidt, MD,¹¹ Praveen V. Mummaneni, MD,¹² and Mark E. Shaffrey, MD.¹³

¹Department of Neurological Surgery, Carolina Neurosurgery and Spine Associates and Neuroscience Institute, Carolinas Healthcare System, Charlotte, North Carolina; ²Departments of Orthopaedic Surgery and Neurosurgery, Vanderbilt Spine Center, Vanderbilt University Medical Center, Nashville, Tennessee; ³Department of Neurosurgery, University of Tennessee Health Sciences Center, Semmes Murphey Neurologic and Spine Institute, Memphis, Tennessee; ⁴Department of Neurosurgery, Atlantic Neurosurgical Specialists, Morristown, New Jersey; ⁵Department of Orthopedic Surgery, University of Louisville, and the Norton Leatherman Spine Center, Louisville, Kentucky; ⁶Springfield Neurologic and Spine Institute, Springfield, Missouri; ⁷Department of Neurosurgery, Brain and Spine Center, Holland, Michigan; ⁸Department of Neurosurgery, Bay Care Clinic Neurological, Green Bay, Wisconsin; ⁹Department of Neurosurgery, North Shore University Health System, Skokie, Illinois; ¹⁰Department of Surgery, East Texas Medical Center, Tyler Neurosurgical, Tyler, Texas; ¹¹Department of Neurosurgery, University of Utah, Salt Lake City, Utah; ¹²Department of Neurological Surgery, University of California, San Francisco, California; and ¹³Department of Neurosurgery, University of Virginia Medical Center, Charlottesville, Virginia.

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Disclosures

Dr. Devin reports being a consultant to Pacira and has performed defense expert witness work. Dr. Mummaneni reports being a consultant to DePuy Spine; having direct stock ownership in Spinicity/ISD; receiving honoraria from AOSpine; and receiving royalties from DePuy Spine, Thieme Publishing, and Springer

Publishing. Dr. Glassman reports being an employee of Norton Healthcare; a patent holder for Medtronic; a consultant for Medtronic; a past president of the Scoliosis Research Society; and receiving funds from NuVasive directly to his database company (no funds paid directly to an individual or an individual's institution).

Author Contributions

Conception and design: Asher, Devin, Chotai, Archer, McGirt, Bydon. Acquisition of data: Chotai, Nian, Harrell. Analysis and interpretation of data: Asher, Devin, McCutcheon, Chotai, Nian, Harrell, Bydon. Drafting the article: Devin, McCutcheon, Chotai. Critically revising the article: Asher, Devin, McCutcheon, Chotai, Archer, McGirt, Mummaneni, Shaffrey, Foley, Glassman, Bydon. Reviewed submitted version of manuscript: Asher, Devin, McCutcheon, Chotai, Archer, McGirt, Mummaneni, Shaffrey, Foley, Bydon. Approved the final version of the manuscript on behalf of all authors: Asher. Statistical analysis: Nian, Harrell. Administrative/technical/material support: Chotai, Nian. Study supervision: Asher, Devin, Harrell, Mummaneni, Bydon.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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Correspondence

Anthony L. Asher, Department of Neurological Surgery, Carolina Neurosurgery and Spine Associates, 225 Baldwin Rd., Charlotte, NC 28204. email: tony.asher@cnsa.com.