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CLINICAL RESEARCH

Smoking is Associated with Increased Blood Loss and Transfusion Use After Lumbar Spinal Surgery

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Abstract

Background Little is known about the association between smoking and intraoperative blood loss and perioperative transfusion use in patients undergoing spinal surgery. However, we found that although many of the common complications and deleterious effects of smoking on surgical patients had been well documented, the aspect of blood loss seemingly had been overlooked despite data reported in nonorthopaedic sources to suggest a possible connection.

Questions/Purposes We asked: (1) Is smoking associated with increased estimated blood loss during surgery in patients undergoing lumbar spine surgery? (2) Is smoking associated with increased perioperative transfusion usage?

Methods Between 2005 and 2009, 581 lumbar decompression procedures (with or without fusion) were performed at one academic spine center. Of those, 559 (96%) had sufficient chart documentation to categorize patients by smoking status, necessary intra- and postoperative data to allow analysis with respect to bleeding and transfusion-related endpoints, and who did not meet exclusion criteria. Exclusion criteria included: patients whose smoking status did not fit in our two categories, patients with underlying coagulopathy, patients receiving anticoagulants (including aspirin and platelet inhibitors), history of hepatic disease, history of platelet disorder or other blood dyscrasias, and patient or family history of any other known bleeding disorder. Smoking history in packs per day was obtained for all subjects. We defined someone as a smoker if the patient reported smoking up until the day of their surgical procedure; nonsmokers were patients who quit smoking at least 6 weeks before surgery or had no history of smoking. We used a binomial grouping for whether patients did or did not receive a transfusion perioperatively. Age, sex, number of levels of discectomies, number of levels decompressed, number of levels fused, and use of instrumentation were recorded. The same approaches were used for transfusions in all patients regardless of smoking history; decisions were made in consultation between the surgeon and the anesthesia team. Absolute indications for transfusion postoperatively were: a hemoglobin less than 7 g/dL, continued symptoms of dizziness, tachycardia, decreased exertional tolerance, or hypotension that failed to respond to fluid resuscitation. Multiple linear regression analyses correcting for the above variables were performed to determine associations with intraoperative blood loss, while logistic regression was used to analyze perioperative transfusion use.

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Each author certifies that his or her institution approved or waived approval of the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at University Hospitals of Cleveland, Cleveland, OH, USA.

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Results After controlling for potentially relevant confounding variables noted earlier, we found smokers had increased estimated blood loss compared with nonsmokers (mean, 328 mL more for each pack per day smoked; 95% CI, 249–407 mL; $p < 0.001$). We also found that again correcting for confounders, smokers had increased perioperative transfusion use compared with nonsmokers (odds ratio, 13.8; 95% CI, 4.59–42.52).

Conclusions Smoking is associated with increased estimated surgical blood loss and transfusion use in patients undergoing lumbar spine surgery. Patients who smoke should be counseled regarding these risks and on smoking cessation before undergoing lumbar surgery.

Level of Evidence Level III, therapeutic study.

Introduction

Substantial intraoperative blood loss can occur during spinal surgery owing to anatomic vascularity and surgical exposures used for these operations [14, 52]. As such, many patients undergoing spinal decompression procedures (with or without fusions) receive blood transfusions. Segal et al. [42] reported that spinal fusions are among the top 10 surgical procedures associated with blood transfusions. Bleeding not only leads to increased surgical time and difficulty during surgery, but also a postoperative epidural hematoma may be a neurologically devastating complication associated with increased postoperative bleeding [24, 25, 48]. The increased blood loss may lead to transfusion use during the perioperative setting that can carry associated morbidity. Transfusions of even one unit of blood in surgical patients are associated with increased risk of wound complications, postoperative infections, renal dysfunction, pulmonary complications, systemic sepsis, composite morbidity, and postoperative length of stay [6, 10, 12, 16, 21, 29, 32, 33, 43]. The risks of transfusion must be balanced with the need to maintain appropriate levels of perfusion to end-organs and the spinal cord. There are several case reports describing infarctions of the portions of the spinal cord secondary to hypotension [5, 7, 8, 49].

Smoking is known to cause alterations in vascular homeostasis and the normal clotting cascade [22, 44]. Research has shown that smoking directly leads to alterations in platelet membranes and causes impairment of their natural function [13, 35, 38]. Owing to the well-documented negative effects smoking has on many normal physiologic functions of the human body, we sought to determine whether patients with a smoking history were at an increased risk of blood loss and blood transfusions after undergoing lumbar spinal surgery compared with patients who did not smoke. Little research has evaluated the association between smoking and blood loss during spinal surgery [27]. The most-definitive available research in the area of orthopaedics has been performed in the setting of total joint arthroplasty [18]. However, subsequent studies in that subspecialty failed to incorporate smoking status in their variable analyses [23, 36, 37, 39, 41]. Zheng et al. [53] incorporated smoking in their analysis of factors affecting blood loss and transfusions in patients undergoing revision lumbar decompression, fusion, and instrumentation. They did not find that smoking was associated with either of these endpoints; however their cohort included only 112 patients, and so the study may have been insufficiently powered to draw firm conclusions on this important endpoint.

We therefore asked: (1) Is smoking associated with increased estimated blood loss (EBL) during surgery in patients undergoing lumbar spine surgery? (2) Is smoking associated with increased use of perioperative transfusions?

Methods

Study Design and Setting

Between 2005 and 2009, 581 lumbar decompression procedures (with or without fusion) were performed at one academic spine center. Of those, 559 (96%) had sufficient chart documentation to categorize the patients by smoking status and necessary intra- and postoperative data to allow analysis with respect to bleeding and transfusion-related endpoints, and who did not meet exclusion criteria (Table 1). We defined someone as a smoker if the patient reported smoking up until the day of their surgical procedure. Nonsmokers were patients who quit smoking at least 6 weeks before surgery or had no history of smoking. The cutoff was 6 weeks based on a combination of orthopaedic and nonorthopaedic sources. Lindstrom et al. [30] showed that smoking cessation 4 weeks preoperatively led to decreases in postoperative complications in patients having general surgery and orthopaedic surgery. Thomsen et al. [47], in a review of preoperative smoking cessation, recommended 4 to 8 weeks of smoking cessation before surgery, as this resulted in reductions of postoperative morbidity in patients undergoing elective surgery. The 22 patients whose smoking status did not fit in either of these two groups were excluded. Exclusion criteria included: patients whose smoking status did not fit in our two aforementioned categories, patients with underlying coagulopathy, patients receiving anticoagulants (including aspirin and platelet inhibitors), history of hepatic disease, history of platelet disorder or other blood dyscrasias, and

Table 1. Patient demographics

Demographic	Smokers	Nonsmokers	p value
Average age (years) (SD)	55.1 (13.5)	53.2 (16.8)	0.939
Total number of patients	219	317	
Males	139 (63%)	176 (56%)	0.521
Females	80 (47%)	141 (54%)	0.485
Levels decompressed (mean)	3.24	2.99	0.001
1	1	8	
2	44	86	
3	98	142	
4	59	72	
5	11	7	
6	6	2	
Levels fused (mean)	0.73	0.58	0.112
0	133	198	
1	56	77	
2	11	28	
3	1	8	
4	12	4	
5	6	2	
Levels instrumented (mean)	0.59	0.38	0.013
0	152	230	
2	45	67	
3	3	13	
4	5	3	
5	8	2	
6	6	2	
Number of discectomies (mean)	0.82	0.68	0.042
0	90	138	
1	87	141	
2	34	38	
3	8	0	

patient or family history of any other known bleeding disorder.

Participants/Study Subjects

Of the 537 patients, the group included 317 nonsmokers (59%) and 220 smokers (41%). Smoking history in packs per day was obtained on all subjects, rounding to the nearest 0.5 packs per day.

Variables, Outcome Measures, Data Sources, and Bias

Intraoperative blood loss was recorded for each patient to the nearest milliliter by the surgical and anesthesia teams after the procedure. After approval from the institutional review board, the electronic medical records were reviewed by one reviewer (EY), who was not blinded to the smoking status of the patient. All surgical procedures were performed by one surgeon (NA). No patients predonated blood before their surgery and cell savers were not used during any of the operations. In addition, transexamic acid was not used in any patients in the cohort. The two study groups had similar distributions of age and sex (Table 1). If a patient received a blood transfusion intraoperatively or postoperatively then he or she was grouped as such. The decision to perform intraoperative transfusions was made by the spinal surgeon and the anesthesia team. Transfusion use requires evaluation of blood loss, hemoglobin or hematocrit, and signs of inadequate perfusion and oxygenation of vital organs. For most patients, a reduction in blood volume less than 15% or less than 750 mL does not result in a transfusion. However, losses greater than those values often necessitate discussion between the anesthesiologist and surgical team regarding the needs of the patient.

Absolute indications for transfusion from the surgeon after surgery were a hemoglobin less than 7 g/dL, and continued symptoms of dizziness, tachycardia, decreased exertional tolerance, or hypotension that failed to respond to fluid resuscitation.

Statistical Analysis

Multiple linear regression and logistic regression analyses correcting for age, sex, number of levels of discectomies, number of levels decompressed, number of levels fused, and number of levels instrumented were performed to determine the association between (1) intraoperative blood loss and smoking and (2) postoperative transfusion use and smoking, respectively. We used a binomial grouping for whether patients received a transfusion during the perioperative period. Statgraphics® XVI software was used (Statpoint Technologies Inc, Warrenton, VA, USA).

Results

After controlling for potentially relevant confounding variables such as age, sex, number of levels of discectomies, number of levels decompressed, number of levels fused, and number of levels instrumented; we found smoking was associated with increased EBL (mean, 328 mL more for each pack per day smoked; 95% CI, 249–407 mL; $p < 0.001$)(Table 2). Stated otherwise, if we compared two identical patients with respect to all of the variables listed above, smoking one pack per day was associated with almost 330 mL more operative blood loss for the

smoker compared with the nonsmoker. This relationship is linear with respect to packs per day smoked, therefore based on our analysis we can estimate an additional 330 mL operative blood loss for each additional pack per day smoked.

Next, after controlling for confounding variables such as age, sex, number of levels of discectomies, number of levels decompressed, number of levels fused, and number of levels instrumented, we found that smoking was associated with increased use of transfusions after surgery for each pack per day smoked (odds ratio, 13.8; 95% CI, 4.59–42.52) (Table 3).

Discussion

Cigarette smoking has long been linked with many detrimental effects for patients undergoing orthopaedic surgery. These perioperative complications include decreased wound healing, increased infections, impaired fracture healing, surgical nonunion, and inferior arthroplasty outcomes [1, 9, 11, 17, 26, 27, 46, 50, 51]. Despite these numerous, well-studied, negative effects that smoking has on the surgical outcomes of patients, little has been reported regarding the association of smoking on intraoperative blood loss, if such an association exists [27]. Smoking has been attributed to alterations in vascular homeostasis and the normal clotting cascade [22, 44]. Research has shown that smoking directly leads to alterations in platelet membranes and causes impairment of their natural function [13, 35, 38], therefore it seemed plausible to us that there would be an association between smoking and blood loss after spinal surgery. Should that be the case, it would be a modifiable risk factor that potentially could help patients avoid the neurologic compli cations of bleeding after spine surgery (such as development of a compressive hematoma), and the known deleterious effects of transfusions [15, 16, 20, 32, 40, 42, 43, 45, 52]. Our results suggest that smoking is strongly associated with increased surgical blood loss and perioperative transfusions in patients undergoing lumbar spine surgery.

Our study has some limitations. We did not screen patients for nicotine in their system at the time of surgery to be sure that we had an objective measure to ensure patients were grouped in the appropriate categories. We thought that because there was no requirement that patients discontinue smoking, the patients could freely disclose their smoking status without repercussions. However, we recognize the chance that some patients may have been dishonest. Second, one of the most important clinical findings that we arrived at, the association of smoking with increasing transfusions, is frequently a judgment call made by the physician overseeing the patient's care during the postoperative period. Indications for transfusions in our patient population normally were hemoglobin less than 7 g/dL, or patients who continued to have symptoms of dizziness, tachycardia, decreased exertional tolerance, or hypotension that failed to respond to fluid resuscitation.

Because not all of our patients went through the preadmission screening process, we did not have preoperative complete blood count values for all of the included patients. We thought that our exclusion criteria would prevent many patients with grossly abnormal findings from inclusion in the study cohort. However, we acknowledge that a patient's hemoglobin and hematocrit play a part in the decision-making process when discussing whether a blood transfusion should be used, and patients with lower preoperative values may be at an increased risk of transfusion use. It also would have been advantageous to know the number of units that each patient received for those who received transfusion(s). However, these data were not available for all patients in the cohort, which is why we grouped patients in only two distinct categories. This does not affect the marked increased risk of transfusion use in patients who are smokers, but it would have allowed us to provide a more-nuanced picture of transfusion use. We also did not record American Society of Anesthesiologists classification for the patients included in the study. Although smoking does affect this classification, the

Table 2. Multiple linear regression model for estimated intraoperative blood loss

Variable	Coefficient	Standard error	95% Confidence interval	p value	R^2
					0.67
Smoking	327.9	39.7	249–407	<0.001	
Age	1.9	1.7	−2 to 5	0.287	
Sex	6.4	46.3	−86 to 98	0.891	
Levels decompressed	68.0	29.7	9–127	0.024	
Levels fused	65.3	41.9	−18 to 148	0.122	
Levels instrumented	114.2	47.3	20–208	0.018	
Number of discectomies	−18.7	35.5	−89 to 52	0.599	

Table 3. Logistic regression model for perioperative transfusion use

Variable	Coefficient	Standard error	Odds ratio	95% Confidence interval	R^2
					0.40
Smoking	2.63	0.57	13.8	4.59–42.52	
Age	0.02	0.02	1.0	0.97–1.07	
Male	0.44	0.61	1.6	0.46–5.20	
Levels decompressed	0.68	0.39	2.0	0.91–4.29	
Levels fused	0.31	0.46	1.3	0.55–3.38	
Levels instrumented	1.10	0.70	3.0	0.75–12.07	
Number of discectomies	0.30	0.49	1.35	0.52–3.55	

variability and interobserver consistency in grading patients with this system has been shown to be "fair" at best [2, 31]. Finally, in our data collection we did not specifically denote if interbody devices were used to help facilitate the fusions when they were performed. Although this is a relatively short step (in terms of surgical time) compared with other portions of the spinal fusion procedure, it does add operative time and may contribute to blood loss.

Research has shown that cigarette smoking is associated with decreases in cutaneous blood flow [28], however some others have found the opposite to be true depending on which area of the body the researchers were measuring [3]. The hypothesis that cigarette smoke may lead to vastly different outcomes in circulation responses depending on anatomic location may be important. Although in recent years there has been more of an effort to further understand the perioperative bleeding and transfusion risk factors for patients undergoing elective surgery [18, 19, 23, 36, 37, 41], the role that smoking may play was not examined in these studies. There is even less research on these issues in spinal surgery [27]; Zheng et al. [53] were among the first to look at predictors of blood loss and transfusion use in patients undergoing spinal surgery. They found that number of levels fused, body weight, and high preoperative hemoglobin predicted increased intraoperative blood loss [53]. Their factors predicting blood transfusion were number of levels fused, age, and low preoperative hemoglobin. However, they did not find any association between smoking status and blood loss or postoperative transfusion use. The small sample size of only 112 patients in their study may not have been large enough to pick up the association that smoking has on blood loss and postoperative transfusion use. We believe our larger study allowed us to discern differences that might have been missed by their smaller study. They also used a binomial grouping of people as smokers or nonsmokers. We took this a bit further by quantitatively recording packs per day. This allows us to better see the association of increasing amounts of smoking on blood loss and transfusion use.

Du Plooy et al. [13] found that smoking decreased the elastic modulus of platelets, which suggests a biophysical alteration indicative of cytoskeletal rearrangement resulting in "softer" platelets. Padmavathi et al. [35] also looked at the effect smoking had on the platelet membranes. Their results showed a decrease in Na^+/K^+ ATPase activity in cigarette smokers compared with control subjects. Na^+/K^+ ATPase is a marker of membrane function and a change in its activity has consequences downstream for appropriate functionality in the human body [34]. Pretorius [38] later showed that changes in the platelet membrane fluidity attributable to Na^+/K^+ ATPase alterations from smoking could be viewed on scanning electron microscopy, further supporting this argument. Similarly, Padmavathi et al. [35] showed, in a separate study, that smoking induced alterations in the erythrocyte membrane. The red blood cells of smokers exhibited increased fragility and hemolysis. This increased fragility could contribute to postoperative anemia in patients who smoke and therefore put them at greater risk of receiving a transfusion. Our results also showed a strong positive association between smoking and perioperative transfusions. Transfusions also are hypothesized to have immunomodulating effects that increase the risk of surgical site infections, and they carry the added risk of blood-borne infections [4, 12, 21, 29]. Research has shown that one unit of transfused blood is associated with increased risk of wound complications, postoperative infections, renal dysfunction, pulmonary complications, systemic sepsis, composite morbidity, and postoperative length of stay [16].

Smoking is associated with increased estimated surgical blood loss and transfusions in patients undergoing lumbar spine surgery. This is another negative consequence that we have seen with cigarette smoking and surgical outcomes that must be discussed with patients before they undergo spinal surgery. Our research findings have changed the way that we counsel patients before undergoing elective lumbar surgery, and we attempt to impress on them the negative effects of increased bleeding during the perioperative period, and the marked increased risk of transfusions if they are unable to quit smoking before surgery. In smokers who are going to undergo a large

lumbar decompression procedure, it may be pertinent to attempt to use blood conservation techniques such as cell-savers or tranexamic acid. In the future, we hope investigators will examine the effects of smoking on the clotting cascade at the cellular level to help obtain a clearer picture of the effects of smoking. We also acknowledge that further research to examine the optimal timing of smoking cessation to avoid some of the deleterious effects that we have presented here would be beneficial.

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