Published in final edited form as:

Anesthesiology. 2016 September ; 125(3): 457–464. doi:10.1097/ALN.0000000000001211.

Perioperative Visual Loss in Spine Fusion Surgery: Ischemic Optic Neuropathy in the United States from 1998 to 2012 in the Nationwide Inpatient Sample

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Abstract

Background—Perioperative ischemic optic neuropathy (ION) causes visual loss in spinal fusion. Previous case control studies are limited by study size and lack of a random sample. The purpose of this study was to study trends in ION incidence in spinal fusion, and risk factors in a large nationwide administrative hospital database.

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Competing Interests

Drs. Roth and Lee have served as expert witnesses in cases of perioperative eye injuries on behalf of patients, physicians, and hospitals.

Previous presentation

This work was presented in part at the Annual Meeting of the American Society of Anesthesiologists in San Diego, CA, October, 2015

Methods—In the Nationwide Inpatient Sample (NIS) for 1998–2012, procedure codes for posterior thoracic, lumbar or sacral spine fusion, and diagnostic codes for ION were identified. ION was studied over five three-year periods (1998–2000, 2001–2003, 2004–2006, 2007–2009, and 2010–2012). National estimates were obtained using trend weights in a statistical survey procedure. Univariate and Poisson logistic regression assessed trends and risk factors.

Results—The nationally estimated volume of thoracic, lumbar, and sacral spinal fusion from 1998–2012 was 2,511,073. ION was estimated to develop in 257 patients (1.02/10,000). The incidence rate ratio for ION (IRR) significantly decreased between 1998 and 2012 (IRR 0.72 per 3 y, 95% confidence intervals (CI) 0.58–0.88, $P = 0.002$). There was no significant change in the incidence of retinal artery occlusion. Factors significantly associated with ION were: age (IRR 1.24 per 10 y of age, CI 1.05–1.45, $P = 0.009$), transfusion (IRR 2.72, CI 1.38–5.37, $P = 0.004$), and obesity (IRR 2.49, CI 1.09–5.66, $P = 0.030$). Female gender was protective (IRR 0.30, CI 0.16–0.56, $P < 0.000$).

Conclusions—Perioperative ION in spinal fusion significantly decreased from 1998 to 2012 by about 2.7-fold. Aging, male gender, transfusion, and obesity significantly increased the risk.

Keywords

Blindness; Nationwide Inpatient Sample; Optic neuropathy; ischemic; Retinal artery occlusion; Spinal fusion; Vision loss

Introduction

Perioperative visual loss (POVL) in spinal fusion surgery is a rare but devastating complication, most commonly due to ischemic optic neuropathy (ION), although other known causes include retinal arterial occlusion (RAO) and cortical blindness. Patients who undergo spinal fusion or cardiac surgery are at the greatest risk for the development of ION.¹ As the utilization of spinal fusion in the United States is the highest in the world,² it is imperative to uncover the risk factors for, and determine how to prevent rare but serious complications such as ION. In a case control study of 80 subjects with ION following spinal fusion in the American Society of Anesthesiologists (ASA) Postoperative Visual Loss Registry vs unaffected control patients from 17 North American medical centers, we showed that the risk factors for ION included male gender, obesity, the use of a Wilson frame for surgical positioning, anesthesia duration, higher estimated blood loss, and % colloid of non-blood replacement during the procedure.³

The incidence of POVL in spine surgery has been approximated at 1–10/10,000.^{4,5} Estimates differ widely depending upon size of the study and the data source; e.g., administrative data, single vs multiple institutions, inclusion of all spine surgery, fusions alone, anatomical locations of the surgery, and year of the study, amongst other factors.³ Although few anesthesiologists and surgeons were familiar with POVL in the 1980's and 1990's, the increasing publication of case reports in the literature,⁶ publicity associated with the ASA POVL Registry,^{7,8} and other studies of POVL in the 2000's^{9–12} appear to have increased awareness of this complication. Nonetheless, in a survey by the Anesthesia Patient Safety Foundation (APSF), 87% of anesthesiologists opined that most surgeons do not recognize

the risk of perioperative ION, and 52% believed the same for anesthesia professionals.¹³ There have been other efforts to heighten awareness of POVL in spine surgery among anesthesiologists, and surgeons. These included two ASA Advisories on Postoperative Visual Loss, first in 2006, the other in 2012,^{14,15} and a Consensus Statement on Postoperative Visual Loss from the APSF.¹³

Based upon clinical observations, we hypothesized that the incidence of ION in spinal surgery has been decreasing. We also theorized that examination of spinal fusion ION cases in a large, randomly collected database close to the present time would provide new data on pre- and perioperative risk factors. Accordingly, there were two main goals of the present study: 1) to evaluate the incidence trends of ION associated with spinal fusion, and specifically, to determine if the incidence has decreased, 2) to use a large nationwide database to identify risk factors for development of ION in spine fusion surgery.

Materials and Methods

As there were no patient identifiers, the University of Chicago and University of Illinois Institutional Review Boards deemed the study “exempt.” We studied discharge data in the Nationwide Inpatient Sample (NIS) from 1998 to 2012. The database is maintained by the Healthcare Cost and Utilization Project (HCUP) under the Agency for Healthcare Research and Quality (AHRQ). The hospital discharge record includes patient demographics, diagnoses (principal and < 14 secondary), procedures (principal and < 14 secondary), charges (in dollars), length of stay (in days), discharge status, outcomes, and medical diagnoses.^{1,16} Diagnoses and procedures are coded using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

The NIS is roughly a 20% stratified sample of non-federal U.S. inpatient hospital discharges and is derived from routine hospital discharge data. In 2012 the sampling was redesigned to improve the accuracy of national estimates; sampling is from all participating hospitals rather than a sample of hospitals. AHRQ provided updated discharge weights on its internet site (hcupnet.ahrq.gov) for the 1998–2012 NIS to ensure accurate weighting of the sample, and enable analysis across multiple years.¹⁷ We thus used these “trend weights” in the “survey” function of Stata (Stata Corp., College Station, TX) for all patient level analysis.

Quality control and reliability of the NIS have been examined each year since 2000. National estimates of essential health care parameters in the NIS were precise and accurate compared with the American Hospital Association Annual Survey, National Hospital Discharge Survey, and Medicare Inpatient data.¹⁸

Data Classification

As previously reported,³ ICD-9-CM codes for primary procedure of posterior thoracic, lumbar or sacral spine fusion in the NIS from 1998 to 2012 were studied, excluding anterior approach to the spine (Table 1). Since most ION cases after spinal fusion involve the thoracic and lower vertebrae,⁷ cervical spine fusion was excluded. To ensure complete coverage of relevant procedure codes, ICD-9-CM codes were confirmed against Current Procedural Technology (CPT) procedure spinal fusion codes using Encoder Pro.com

(Optum, Salt Lake City, UT). Patients discharged with a principal or secondary diagnostic ICD-9-CM code of ischemic optic neuropathy (377.41) were considered to have developed ION during the hospitalization. For comparison of incidence trends we also identified patients with a diagnosis of retinal artery occlusion (RAO, 362.3; 362.30–0.34, Table 1).

Patient and Surgical Characteristics

Patient characteristics analyzed included: age (years, continuous variable), gender, length of hospital stay (days), and yearly inflation-adjusted total hospital charges (both as continuous variables), type of admission (elective, urgent, emergent), discharge status (home, nursing facility, died, etc.), and race. Medical diagnoses (ICD-9 codes are in Table 2) studied were: atherosclerosis, coronary artery disease, carotid artery stenosis, diabetes mellitus, hypertension, obesity, peripheral vascular disease, and smoking. Hospital conditions included anemia and transfusion. Stroke was included as postoperative, acute, embolic, and thrombotic.

Analysis

STATA v14.0-MP was used to analyze data. We utilized AHRQ trend weights in the survey function in STATA for all estimates and regressions. Missing data points were noted for race, type of admission, discharge status and race. “Missing” data are reported as “unknown.” Except for race, all other missing data points were excluded in the regression analysis. To calculate incidence of ION and RAO, we divided the study into three-year periods (1998–2000, 2001–2003, 2004–2006, 2007–2009, and 2010–2012). This enabled the numerator (cases per time period) to reach the threshold for reporting (>10), while the denominator was the number of spinal fusion procedures per time period. (AHRQ prohibits data reporting of any data cell where $n < 10$). To study if age was a risk factor, 10-yr age groups were studied, i.e., 18–30, 31–40 years, etc.

Patient characteristics in spinal fusion groups with or without ION for 1998–2012 were tabulated using the national estimates. Univariate, followed by multivariate Poisson regressions, assessed risk factors in the discharges from 1998 to 2012.¹⁹ A Poisson model was used because it was deemed appropriate for modeling count data. $P < 0.2$ was the minimum criteria for inclusion of variables in the subsequent multiple Poisson regression, and $P < 0.05$ in the multiple Poisson regression model indicated a significant risk factor. Results are reported as incidence risk ratios (IRR). The variance inflation factor (VIF) examined for collinearity.²⁰ Pearson’s goodness-of-fit assessed fit of the model.

Results

There were an estimated 2,511,073 discharges in the U.S. from 1998 to 2012 with procedure codes for posterior thoracic, lumbar, and sacral spinal fusion. The national estimates (Table 3) for ION were 257 (1.02/10,000), and for RAO, 224 (0.89/10,000). The volume of procedures per three years increased nearly 3-fold from 262,279 in 1998–2000 to 733,454 in 2010–2012 (Table 3), but ION in spine fusion (Fig. 1) decreased significantly ($P = 0.002$) from 1.63/10,000 in 1998–2000 to 0.60/10,000 in 2010–2012. There was no significant change in incidence of RAO during the study period (Fig. 1).

Table 4 shows the characteristics in the national estimates of those who sustained ION and those who did not. ION patients were older, and males predominated among ION patients. At least 20% of the race information was not provided. Mean total inflation-adjusted charges for the hospitalization and length of hospital stay were higher for ION than non-affected. A higher proportion of ION patients had a blood transfusion (ION 29.6%; non-ION 14.0%); the % of patients with obesity was greater in those with ION (17.1%) than in non-affected (9.8%). Mean number of vascular factors was similar for the two groups; stroke was infrequent, but with higher % in ION cases.

Poisson multivariate analysis models considered 3-y interval incidence, age (10-y intervals), gender, transfusion, obesity, and stroke (those factors with $P < 0.2$ in univariate analysis, Table 5, were entered into the model). Atherosclerosis, carotid artery stenosis, peripheral vascular disease, and race other than White, Hispanic, or Asian/Pacific Islander had insufficient sample size, and therefore risk with these parameters could not be calculated accurately. In the final model (Table 6), the IRR for ION decreased from 1998 to 2012 (IRR 0.72 per 3-y period, CI 0.58–0.88, $P = 0.002$). Factors significantly associated with ION were: increasing age (IRR 1.24 per 10 y of age, CI 1.05–1.45, $P = 0.009$), blood transfusion (IRR 2.72, CI 1.38–5.37, $P = 0.004$); and obesity (IRR 2.49, CI 1.09–5.66, $P = 0.030$). Being female was protective (IRR 0.30, CI 0.16–0.56, $p < 0.000$). The Poisson regression showed good fit, as Pearson's goodness-of-fit test was not significant at the 5% level. Furthermore, lack of collinearity in the model was suggested by VIF < 10 for all covariates.

Discussion

POVL after spine fusion surgery continues to be a devastating complication, with ION the most frequent cause of visual loss in this surgical cohort. Encouragingly, this study illustrated significantly decreasing ION in spinal fusion; incidence in 2010–2012 was about 1/3 that in 1998–2000. The lack of change in incidence of RAO suggests that the mechanisms of these disorders are different; moreover, the RAO results serve as an inherent control further confirming the validity of the results.

We cannot determine the mechanism of this trend in ION. A possible cause is changes in surgical and anesthesia practice, perhaps driven by the heightened awareness generated by the literature, advisories, and consensus statements. However, there are other possible trends that cannot be assessed by our study, such as changes in surgical patient selection, intraoperative positioning, and post-operative management.

The mechanism of perioperative ION, particularly posterior ischemic optic neuropathy, remains elusive but retrospective studies have revealed associated factors. A case control study from a single institution examined 126,666 general anesthetic records and found 17 patients with perioperative ION; a subpopulation underwent spine fusion. They could not identify differences in intraoperative hemodynamic parameters between ION patients and the matched controls, suggesting either that patient-specific characteristics may be involved, or that the number of cases identified yielded insufficient study power.¹² Subsequently, a case-control study compared perioperative data between 80 spinal fusion cases with ION from the ASA POVL Registry and 315 unaffected control patients undergoing similar

procedures from 17 North American institutions. Male gender, obesity, Wilson frame use, longer anesthetic duration, greater estimated blood loss, and a lower percentage of colloid in non-blood fluid administration were significant and independent risk factors for ION.³

In this study, using NIS data, we identified four factors, increasing age, male gender, blood transfusion, and obesity, that were associated with development of perioperative ION in a multivariate model. While the NIS database does not provide intraoperative data, we demonstrated that two of the factors overlapped with the earlier case control study: male gender and obesity. Transfusion may be a surrogate for blood loss.

The strengths of this study included a large database, the size of which exceeded that examined in our previous case control study.³ In the 2012 case control study, the 80 patients with ION had been anonymously submitted by medical practitioners, quality improvement administrative personnel, and patients. Biased sampling technique or incorrectly entered data could not be ruled out, and some data points were missing in the records.³ For the unaffected controls, the study used a much smaller sampling of hospitals compared to the NIS; hospitals from which the affected patients were derived was anonymous, hence it is not known if the sampling was representative of all patients in the US that underwent the procedure. But, the NIS has the advantage of providing a randomized sampling of discharges from hospitals.

Why men were at higher risk for ION remains unclear since there are no known anatomic variations between the male and female visual pathways. An influence of female hormones including estrogen could play a role.²¹ Acute venous congestion of the head and neck secondary to patient position is a possible mechanism for ischemic damage to the optic nerve, which corresponds well with one of the theories on ION pathogenesis.²² Anatomic differences between men and women, which may become evident when they are positioned on the Wilson frame, may play a role in causing greater interstitial fluid accumulation in men that may predispose to a higher incidence of ION. It is possible that obese men are more likely to lose greater amounts of blood and require more fluid during spine surgery.

A new finding was that age was a risk factor for ION in spinal fusion. There was a 24% increase in incidence risk ratio per 10 years of age. It may be related to older patients requiring more complex surgery, or to increased vulnerability of the optic nerve to physiologic insults associated with major spine surgery, as the optic nerve undergoes significant degeneration with age.²³ We found no influence of diabetes, hypertension, coronary artery disease, number of vascular risk factors, or smoking on the risk of developing ION. Stroke (none were postoperative stroke) was not significant in the multivariate analysis. However, sample sizes of affected patients were small and could have influenced these results. Due to missing data, it is not possible to assess the impact of any possible racial disparities on the results.

Our study demonstrated longer length of stay and higher hospital charges in patients who sustained ION. While these patients typically undergo more in-hospital diagnostic procedures, and/or treatment of ION, we cannot definitively conclude that longer stay and higher charged were caused by ION. Patients who are older and undergo more complex

surgery, e.g., greater number of spine levels fused, and hence sustain longer hospital stays, could also be the same patients that are at risk of ION. However, we were unable to study the effect of number of levels fused as these data were only sparsely present in the database.

In addition to understanding the risk factors associated with ION, there has been a coordinated and concerted effort to increase awareness and help guide patient management. In 2006 (and revised in 2012, but the latter cannot be related to the results in this study) the ASA produced practice advisory statements to help educate and guide practice for spine fusion surgery.¹⁵ We cannot determine from the present study what role, if any, these advisory statements have had on the changing incidence of ION. One notable change in spine surgery has been the increasing use of “minimally-invasive” surgical techniques.²⁴ These have been shown to result in less blood and fluid requirements compared to the traditional “open” approach.^{24,25} Although it would have been relevant to study the impact of this change on ION incidence, there was no specific procedure code for the “minimally invasive” procedure before 2013.²⁶

There are limitations to this study. The NIS database relies on the accuracy of diagnosis and coding. Verification of each individual case and the associated medical diagnoses are not possible as the discharge records are de-identified. Presently, there are not enough data in the literature to assess the accuracy of coding in NIS for uncommon complications such as ION and RAO.²⁷ Both over- and under-coding are possible. Also, it is not possible to rule out if changes in coding frequency of ION or of the spinal fusion procedure codes are involved in the incidence data results. The coding discharge information depends upon entry of the data by professional coders; however, the accuracy of the information in turn depends upon the diagnoses recorded by physicians and the procedure description provided by the surgeon. To avoid confounding issues with procedure coding, a wide range of codes for posterior spinal fusion was used, and compared to CPT codes, which are more commonly used for procedure coding in the US for billing purposes. However, given the nationwide scope of the NIS, systematic bias in this coding appears improbable. Some cases of ION may have been pre-existing which would lead to a false elevation of the incidence. The severity of injury using the NIS cannot be quantified, and the type of ION (AION vs PION) cannot be differentiated. The NIS only identifies diagnosed cases of ION but does not stratify the extent of loss of vision. NIS data lack longitudinal information (i.e. a single individual cannot be tracked across multiple hospitalizations, or for followup after surgery). NIS does not contain intraoperative data such as anesthetic technique, length of surgery, surgical positioning, blood loss, or volume of fluids infused.¹⁶

Definitive conclusions concerning changes in intraoperative technique and practice cannot be made from this study. This area remains challenging to appropriately study in the clinical setting since rates of ION are low and deliberately manipulating intraoperative variables in a randomized controlled design would be difficult if not unethical. Despite the continual and dramatic increase in spinal fusion utilization, the rates of ION after spine fusion in our study have declined significantly between 1998 and 2012. Further study of large multicenter databases that contain more pertinent intraoperative data may allow assessment of whether perioperative surgical and anesthetic practice has been modified consistent with the recommendations of the national practice advisories.

Acknowledgments

The authors are grateful to Ms. Elaine Hrinyo, Billing Manager, Department of Anesthesia and Critical Care, University of Chicago Medicine, for assistance with CPT codes, and the Encoder program.

Funding was provided by National Institutes of Health (Bethesda, Maryland) Grants RO1 EY10343 to Dr. Roth, UL1 RR024999 to the University of Chicago Institute for Translational Medicine, K23 EY024345 to Dr. Moss, Core Grant P30 EY001792 to the Department of Ophthalmology of the University of Illinois, and an Unrestricted Grant from Research to Prevent Blindness (New York, NY) to the University of Illinois Department of Ophthalmology & Visual Sciences.

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Figure 1.

The Y-axis shows the three year incidence of ION (ischemic optic neuropathy) and RAO (retinal artery occlusion) per time period (x-axis), using national estimates from the NIS. The data are shown as incidence point estimates $\pm$ 95% confidence intervals. Three year periods were used, as AHRQ does not allow reporting results < 10 . The incidence of ION, but not RAO, significantly decreased over time

Table 1

ICD-9-CM and corresponding CPT procedure codes for spinal fusion, and ICD-9-CM diagnosis code for ischemic optic neuropathy in the Nationwide Inpatient Sample

	Description	ICD-9-CM Code	CPT
Diagnosis	Ischemic Optic Neuropathy (ION)	377.41	
	Retinal Vascular Occlusion (RVO)	362.3 362.30–4	
Procedures	Dorsal and Dorsolumbar Fusion of The Posterior Column, Posterior Technique	81.05	22610, 22612, 22614, 22800, 22802, 22804, 22851
	Lumbar And Lumbosacral Fusion Of The Posterior Column, Lateral Transverse Process Technique	81.07	22612, 22614, 22630, 22632, 22633, 22634, 22800, 22842, 22851
	Lumbar And Lumbosacral Fusion Of The Anterior Column, Posterior Technique	81.08	0195T, 0196T, 0309T, 22586, 22612, 22514, 22630, 22632, 22633, 22634, 22800, 27279, 27280
	Refusion Of Dorsal And Dorsolumbar Spine, Posterior Column, Posterior Technique	81.35	22610, 22612, 22614, 22800, 22802, 22804, 22851
	Refusion Of Lumbar And Lumbosacral Spine, Posterior Column, Lateral Transverse Process Technique	81.37	22612, 22614, 22630, 22632, 22800, 22842, 22851
	Refusion Of Lumbar And Lumbosacral Spine, Anterior Column, Posterior Technique	81.38	0195T, 0196T, 0309T, 22586, 22612, 22614, 22630, 22632, 22800

To ensure complete coverage of relevant procedure codes, ICD-9-CM procedure codes for posterior approach for thoracic, lumbar, or sacral spinal fusion were confirmed against a list of all Current Procedural Technology (CPT) procedure spinal fusion codes using Encoder [Pro.com](https://www.pro.com) (Optum, Salt Lake City, UT).

Table 2

ICD-9-CM codes for patient characteristics

Patient Characteristics		ICD-9-CM
1.	Atherosclerosis	440. ×
2.	Coronary Artery Disease	414.0×
3.	Carotid Artery Stenosis	433.1×
4.	Diabetes Mellitus	250.0×
5.	Hypertension	401.×
6.	Obesity	278.0×
7.	Peripheral Vascular Disease	443.×
8.	Smoking	V15.82, 305.1
9.	Anemia	280.×,285.2×
10.	Transfusion	99.00, 99.04
11.	Stroke	997.02,434.91, 434.11,434.01

ICD-9-CM= Internal Classification of Diseases, Ninth Revision, Clinical Modification. An “×” at the end of a ICD-9-CM code signifies that multiple suffix codes were used to search for associated conditions.

Table 3

National Estimates of Ischemic Optic Neuropathy (ION), and Retinal Arterial Occlusion (RAO) in Thoracic, Lumbar and Sacral Spine Fusion from 1998 to 2012 in the Nationwide Inpatient Sample (NIS)

Year	Spinal Fusion Cases (#)	ION among Spinal fusion cases (#) [95% CI]	ION per 10,000 spinal fusions [95% CI]	RAO among Spinal fusion cases (#) [95% CI]	RAO per 10,000 spinal fusions [95% CI]
1998–2000	262,279	43 [15–72]	1.63 [0.57–2.75]	23 [2–45]	0.88 [0.076–1.72]
2001–2003	399,773	52 [19–84]	1.30 [0.48–2.10]	33 [7–60]	0.83 [0.18–1.50]
2004–2006	492,133	69 [32–105]	1.40 [0.65–2.13]	34 [8–61]	0.69 [0.16–1.24]
2007–2009	623,434	49 [11–87]	0.79 [0.18–1.40]	67 [26–104]	1.07 [0.42–1.67]
2010–2012	733,454	44 [13–74]	0.60 [0.18–1.01]	66 [29–104]	0.90 [0.40–1.42]
Total	2,511,073	257 [182–331]	1.02 [0.72–1.32]	224 [151–296]	0.89 [0.60–1.18]

ION (ischemic optic neuropathy) in posterior spinal fusion procedures decreased significantly between 1998 and 2012, however, RAO (retinal artery occlusion) remained unchanged. To calculate incidence of ION and RAO per 10,000 cases, time was divided into three-year periods (1998–2000, 2001–2003, 2004–2006, 2007–2009, and 2010–2012). This enabled numerator (ION or RAO cases per time period) to reach the threshold for reporting (>10), while the denominator was the number of spinal fusion procedures per time period. Estimates from the NIS (Nationwide Inpatient Sample) were created using the trend weights and stratum variables from the NIS and the survey function of STATA (Stata Corp, College Station, TX). CI = confidence intervals for the population estimates.

Table 4

Characteristics for all Spinal Fusion Patients, and for Those Specifically with Ischemic Optic Neuropathy in the Nationwide Inpatient Sample (NIS) 1998 to 2012, Based upon Population Estimates

		Ischemic Optic Neuropathy (ION)	Unaffected
All patients: number of discharges		257	2,510,816
Mean age (years): all patients (95% confidence intervals, CI)		60.0 [56.9–63.1]	56.1 [55.8–56.3]
Mean length of stay in days (95% CI)		7.4 [6.1–8.7]	4.9 [4.8–5.0]
Mean Total Hospital Charges (95% CI)		132,504 [103,544 – 161,465]	95,347 [92,150–98,545]
Gender	Male (%)	179 (69.6)	1,122,459 (44.7)
	Female (%)	78 (30.4)	1,387,191 (55.2)
Type of Admission	Elective (%)	153 (60)	1,870,707 (75)
	Non-elective (%)	34 (13)	254,576 (10)
	Unknown	70 (27)	385,533 (15)
Discharge Status	Routine (%)	122 (45.9)	1,650,983 (65.7)
	Various transfers (%)	95 (35.7)	493,573 (19.7)
	Home health care (%)	39 (14.7)	354,058 (14.1)
	Other (%)	0 (0)	8,304 (0.3)
	Unknown	0 (0)	459 (0.02)
Race	White (%)	181 (81.9)	1,675,794 (66.9)
	Black (%)	10 (4.5)	129,545 (5.2)
	Hispanic (%)	10 (4.5)	116,325 (4.6)
	Asian or Pacific Islander (%)	10 (4.5)	19,461 (0.8)
	Other (%)	10 (4.5)	53,763 (0.3)
	Unknown	67 (26.1)	515,927 (20.5)
Transfusion (%)		76 (29.6)	350,464 (14.0)
Obesity (%)		44 (17.1)	247,176 (9.8)
Mean number of vascular factors listed below (95% CI)		1.07 [0.77–1.35]	0.91 [0.90–0.93]
Stroke (%)		10 (3.9)	3967 (0.2)
Hypertension (%)		125 (48.6)	1,073,017 (42.7)
Diabetes (%)		43 (16.7)	332,748 (13.3)
Atherosclerosis (%)		10 (3.9)	38,635 (0.3)
Peripheral vascular disease		10 (3.9)	31,265 (1.2)
Coronary artery disease (%)		34 (13.2)	215,690 (8.6)
Smoking (%)		57 (22.2)	584,316 (23.3)
Carotid artery stenosis (%)		0 (0.0)	5,996 (0.2)

Results are nationwide estimates using NIS weighting and the STATA survey function. Numbers are presented as count estimates or means with percent in parentheses and respective 95% confidence intervals in brackets when indicated. Results with $n < 10$ could not be reported. See Methods for diagnostic codes used to identify characteristics. Spinal fusion cases were lumbar, thoracic or sacral, using a posterior surgical approach. Total charges (not including professional fees) were inflation adjusted to 2012 dollars using Bureau of Labor Statistics (<http://www.bls.gov/data/>).

Table 5

Univariate Analysis for Ischemic Optic Neuropathy for Spinal Fusion in the Nationwide Inpatient Sample 1998 to 2012

		Incidence Risk ratio	95% Confidence Intervals	P-value
Ischemic Optic Neuropathy 3-yr interval (continuous)		0.72	0.58–0.88	0.002
Retinal Artery Occlusion 3-yr interval (continuous)		1.04	0.83–1.31	0.737
10-year age (continuous)		1.23	1.03–1.46	0.022
Gender (Male=0, Female=1)		0.30	0.16–0.56	<0.000
<i>Race (Reference: White)</i>				
Hispanic		0.323	0.04–2.59	0.287
Asian or Pacific Islander		2.70	0.33–21.7	0.352
Other		–		
Transfusion		2.72	1.37–5.40	0.004
Obesity		2.41	1.06–5.48	0.036
Vascular Factors	Stroke	7.38	0.89–61.27	0.064
	Hypertension	1.11	0.58–2.16	0.748
	Diabetes	1.07	0.48–2.40	0.87
	Atherosclerosis	–		
	Peripheral vascular disease	–		
	Coronary artery disease	1.00	0.43–2.32	0.995
	Smoking	1.05	0.54–2.05	0.89
	Carotid artery stenosis	–		

Univariate regression using a Poisson regression shows a decrease in ischemic optic neuropathy (ION) for female gender and procedures performed closer to 2012. Increases in ION counts is observed with older patients, obese patients and those receiving a blood transfusion. A similar Poisson regression with retinal artery occlusion showed no change in the rate during the same time period. Data coding is indicated in the left column of the table. Dashes indicate not enough data available for regression analysis or no ION cases containing that characteristic.

Table 6

Multivariate Analysis for ION (ischemic optic neuropathy) for Spinal Fusion in the Nationwide Inpatient Sample from 1998 to 2012

	Incidence Risk Ratio	95% Confidence Intervals	Poisson Regression P-value	Variance Inflation Factor (VIF)	Pearson goodness-of-fit P-value
ION 3-Year interval (continuous)	0.72	0.58–0.88	0.002	1.03	0.9999
Gender (Male=0, Female=1)	0.30	0.16–0.56	<0.000	1.02	
Age (per 10yrs)	1.24	1.05–1.45	0.009	1.04	
Transfusion	2.72	1.38–5.37	0.004	1.02	
Obesity	2.49	1.09–5.66	0.030	1.02	
Stroke	7.27	0.87–60.48	0.067	1.00	

Surgery closer to 2012 and female gender decreased risk for ION, and increasing age, transfusion and obesity increased risk. Values from univariate analysis (Table 5) with $P < 0.2$ were entered into the multivariate regression model using the Poisson regression. VIF values < 10 indicated lack of collinearity. We cannot reject the hypothesis that the data is Poisson distributed because the Pearson goodness-of-fit test is not significant at the 5% level.