The Spine Journal 19 (2019) 597–601

Clinical Study

Postoperative stroke after anterior cervical discectomy and fusion in patients with carotid artery stenosis: a statewide database analysis

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Received 5 July 2018; revised 14 September 2018; accepted 17 September 2018

Abstract

BACKGROUND: Carotid artery injury and stroke secondary to prolonged retraction remains an extremely rare complication in anterior cervical discectomy and fusion (ACDF). However, multiple studies have demonstrated that carotid artery retraction during the surgical approach may alter the normal blood flow, leading to a significant reduction in the cross-sectional area of the vessel. Others have suggested that dislodgment of atherosclerotic plaques following manipulation of the carotid artery can be a potential risk for intracranial embolus and stroke.

PURPOSE: We aimed to evaluate: (1) the incidence of postoperative stroke following ACDF and (2) incidence of other postoperative complications in a cohort of patients who had a diagnosis of carotid artery stenosis (CAS) versus those who did not.

PATIENT SAMPLE: This study utilized the Statewide Planning and Research Cooperative System database from January 1, 2009 to December 31, 2013. All patients who underwent (ACDF) and had a preoperative diagnosis of CAS were identified using the International Classification of Disease, ninth revision codes. Those who had a previous history of stroke were excluded. Patients who had CAS were propensity score matched to patients without history of CAS for demographics and Charlson/Deyo comorbidity scores.

OUTCOME MEASURES: Incidence of postoperative stroke and other complications were compared between the cohorts. The threshold for statistical significance was set at a $p < .05$. This study received no funding. The authors report no conflict of interests relevant to this study.

RESULTS: There were 34,975 patients who underwent an ACDF in the study time period. After excluding those under the age of 18 and with history of previous stroke, there were 61 patients who had CAS that were compared with a propensity-matched cohort. The CAS cohort had a

FDA device/drug status: Not applicable.

Author disclosures: ***MC***: Consulting: Stryker (B), Sage Products (B), DJ Orthopaedics (B), Cymedica (C), Peerwell (C), Reflexion (C). outside the submitted work. ***TEM***: Royalties: Stryker (E); Consulting: Stryker (E), RTI Surgical (B); Speaking and/or Teaching Arrangements: Synthes (D); Trips/Travel: Synthes (D), Stryker (B); Board of Directors: SpineLine (nonfinancial), The Spine Journal (B), NASS, outside the submitted work. ***JS***: Consulting: Stryker (D); Board of Directors: Clinical Spine Surgery, outside the submitted work. ***MPS***: Royalties: Biomet Spine (B); Consulting: Intellirod (A), Stryker Spine (B), Globus (B); Speaking and/or Teaching Arrangements: Stryker (B); Board of Directors: AANS/CNS Section on Disorders of the Spine (Chair Exhibits Committee), Council of State Neurosurgical Societies (Vice Chair); Scientific Advisory Board: Intellirod (B). ***CBP***: DePuy, A Johnson & Johnson CompanyEthicon: Paid presenter or speaker. Other authors: nothing to disclose.

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https://doi.org/10.1016/j.spinee.2018.09.011

significantly higher incidence of postoperative stroke during their hospitalization (6.6% vs 0%, p < .042). The CAS cohort also had higher rates of acute renal failure (27.9% vs 4.9%, p = .01) and sepsis (18% vs 4.9%, p = .023). There were no stroke related deaths.

CONCLUSIONS: Patients with CAS who underwent ACDF had a statistically significant greater incidence of developing a postoperative stroke. To the best of our knowledge, no previous study has evaluated the development of postoperative stroke in patients with CAS undergoing ACDF. Larger, multicenter studies are needed to estimate the true incidence of stroke in this specific patient population. However, our results may illustrate the importance of preoperative optimization, approach-selection, and postoperative stroke surveillance in patients with a history of CAS who undergoes ACDF.

Keywords: ACDF; Anterior cervical discectomy and fusion; Carotid stenosis; Complications; Outcomes; Stroke.

Introduction

The surgical approach for an anterior cervical discectomy and fusion (ACDF) involves lateral retraction of the sternocleidomastoid muscle and the carotid sheath, as well as medial retraction of the trachea and esophagus, among other structures. Carotid sheath retraction required for the surgical approach may alter carotid arterial flow dynamics. This has been studied and demonstrated to be secondary to a significant reduction in the cross-sectional area in a study of ACDF utilizing duplex ultrasound [1,2].

Consequences of altered blood flow in the carotid artery could potentially lead to cerebrovascular ischemia. In addition, dislodgment of atherosclerotic plaques following physical manipulation of the carotid artery is a potential risk for intracranial embolus and resulting stroke [2–6]. Nevertheless, complications related to carotid artery injury and cerebrovascular ischemia are rare [7]. However, these incidents may be severe, resulting in long-term morbidity and even mortality. Theoretically, this may be particularly evident in patients with pre-existing carotid artery stenosis (CAS), where prolonged lateral retraction of the carotid artery may provoke a stroke secondary to direct carotid artery injury, atherosclerotic plaque embolization, or significantly decrease in blood flow in an already stenotic vessel. However, to the best of our knowledge, no study has evaluated the incidence of stroke in patients with carotid artery disease.

Therefore, the purpose of this study was to asses and compare the rates of postoperative stroke following ACDF in a cohort of patients with and without pre-existing CAS. The secondary purpose of this study was to compare and assess other postoperative complications between these two groups.

Materials and methods

Database

This study utilized the Statewide Planning and Research Cooperative System (SPARCS) database from January 1, 2009 to December 31, 2013. The SPARCS database is publicly available through the New York State Department of Health's Bureau of Health Informatics and contains patient-level discharge information collected through a collaboration of both industry and government bodies. In total, all patients seen in the state of New York in outpatient, inpatient, emergency department visits, hospital admissions, and ambulatory surgery are represented within the dataset. In order to improve accuracy, the New York State Department of Health collaborates with the Vital Statistics Birth Registry, the Vital Statistics Death Registry, and the Bureau of Biometrics to routinely vet the SPARCS database. Since this dataset is de-identified, this study was exempted from human-subjects review by the institutional review board.

Patient selection

All patients who underwent ACDF between 2009 and 2013 were identified using the International Classification of Diseases, ninth edition (ICD-9) Codes 81.02 (n = 34,975). Patients who were less than age 18 years and patients who had a previous history of having a stroke (ICD-9 codes: 433.00, 433.01, 433.11, 433.20, 433.21, 433.30, 433.31, 433.80, 433.81, 433.90, 433.91, 434.00, 434.01, 434.10, 435.8, 435.9, 434.11 43490, and 434.91) that predated the ACDF were excluded (n = 416). We only included patients with ICD-9 codes specific for thromboembolic strokes or occlusion of the cerebral vasculature and no hemorrhagic strokes were included. Next, patients who had a preoperative diagnosis of carotid stenosis and cervical degenerative disease among those who underwent ACDF were identified (n = 61). Then, using propensity score matching based on age, sex, and Charlson/Deyo scores, a total of 61 patients who had carotid stenosis (ICD-9 code 433.10) were matched (1:1) to patients who did not have carotid stenosis. The total number of patients who reportedly had carotid stenosis in the database was 98,000 patients. Complications of interest, including the incidence of postoperative stroke, were identified using ICD-9 codes during the admission of when the ACDF

occurred. The purpose of only analyzing the admission during the ACDF was to capture strokes that may have occurred perioperatively or in the immediate postoperative period.

Study population

Demographics obtained from SPARCS for analysis included age, sex, race, insurance provider, Charlson/Deyo scores, admission type (emergency department [ED] vs elective), and total hospital charges for each visit from 2009 to 2011. The Charlson/Deyo scores is a comorbidity index that allows for a comorbidity score to be calculated from ICD-9 CM codes. A total of 61 patients were included in both the carotid stenosis, and the no stenosis groups. Although the propensity-matched stenosis group was, on average, significantly older than the no stenosis group (68.6 vs 60 years, $p < .001$), the groups did not vary with respect to race, primary expected payer, total charges, hospital lengths of stay, or Charlson/Deyo scores (Table 1). A total of 24.5% of patients in the no CAS cohort and 31% in the CAS cohort underwent ACDF through and ED admission ($p > .05$).

Table 1
Propensity matched comparison of cohorts

	No CAS	CAS	p Value
Sample size	61	61	
Age	60	68.6	p < .001
Sex			
Female	31	25	P = .275
Male	30	36	
Deyo Index	0.98	1.18	p = .377
Race			
White	85.20%	85.20%	p = .406
Black	9.80%	3.30%	
Hispanic	1.60%	3.30%	
Other	3.30%	8.20%	
Primary expected payer			
Medicare	55.70%	59.00%	p = .489
Medicaid	11.50%	9.80%	
Private insurance	23.00%	27.90%	
Other	9.80%	3.30%	
Underlying diagnosis*			
• Degenerative cervical conditions (cervical stenosis, cervical spondylosis, cervical spondylolisthesis, cervical degenerative disc disease.	61 29	61 32	P > .05
• Cervical myelopathy			
Admission types:			
• Emergency department	15 (24.5%)	19 (31%)	P > .05
• Elective	46 (75.5%)	42 (69%)	
Length of stay during ACDF (in days)	5.8	4.8	p = .736
Total charges of ACDF (in USD)	50,025	58,568	p = .561

CAS, carotid artery stenosis; ACDF, anterior cervical discectomy and fusion; USD, United States Dollars.

* Patients may have multiple diagnoses codes.

Statistical analysis

Following the previously described propensity match, the incidence of complications was compared with chi-square analysis. The threshold for statistical significance was set at a $p < .05$. All statistical analyses were performed using SPSS Statistics Version 24.0 (IBM Corporation, Armonk, NY, USA).

Results

Incidence of postoperative stroke

The CAS cohort had a significantly higher postoperative incidence of stroke than the group of individuals without CAS (6.6% vs 0%, $p < .042$) (Table 2a).

Other postoperative complications

The CAS cohort also had higher rates of acute renal failure (27.9% vs 4.9%, p=.01) and sepsis (18% vs 4.9%, p = .023) in comparison to those without CAS. The patients in the CAS cohort also had higher rates of surgical site infection (11.5% vs 6.6%, p = .343), wound dehiscence (3.3% vs 1.6%, p = .559), myocardial infarction (3.3% vs 1.6%, p = .559), pneumonia (13.1% vs 6.6%, p = .224), and higher total charges ($58,568 vs $50,025, p = .56; however, these were not statistically significant. The CAS cohort in comparison had lower rates of pulmonary embolism (1.6% vs 3.3%, p = .559) and hematoma (4.9% vs 6.6%, p = .697); however, this was not statistically significant (Table 2b).

Discussion

Surgical exposure for ACDF involves lateral retraction of the carotid sheath, which may alter carotid arterial flow dynamics. It has been demonstrated that such retraction can lead to significant reduction in the cross-sectional area of the vessel in a study of ACDF utilizing duplex ultrasound [1,2]. This may lead to reduction of cerebral perfusion and/or dislodgment of atherosclerotic plaques [2–6], which may theoretically be more likely in an already diseased vessel. Therefore, in the present study, we assessed the rate of postoperative stroke in patients who underwent an ACDF and either did or did not have CAS. These data demonstrate a statistically significant higher rate of postoperative stroke in patients who had preoperative diagnosis of CAD who underwent ACDF in comparison to those without CAS (6.6% vs 0% respectively, p = .042). This finding was demonstrated after controlling for various baseline patients characteristics using propensity score matching in a homogenous sample of patients who underwent ACDF for cervical degenerative diseases.

In addition, patients with CAS also had a statistically significantly higher risk of having other postoperative complications such as acute renal failure (27.9% vs 4.9%, p = .01) and sepsis (18% vs 4.9%, p = .023). Although not

Table 2a
Propensity matched analysis of stroke

	No CAS	CAS	p Value
Stroke	0%	6.60%	p < .042

CAS, carotid artery stenosis.

Table 2b
Propensity matched analysis of complications

Parameters	No CAS	CAS	p Value
Hematoma	6.60%	4.90%	p=.697
Wound infection	6.60%	11.50%	p = .343
Wound dehiscence	1.60%	3.30%	p = .559
Acute renal failure	4.90%	27.90%	p = .001
Sepsis	4.90%	18.00%	p = .023
Pulmonary embolism	3.30%	1.60%	p = .559
Deep vein thrombosis	3.30%	3.30%	p = 1
Blood transfusion	1.60%	1.60%	p = 1
Acute myocardial infarction	1.60%	3.30%	p = .559
Pneumonia	6.60%	13.10%	p = .224

CAS, carotid artery stenosis.

statistically significant, patients in the CAS cohort also had higher rates of surgical site infection (11.5% vs 6.6%, p = .343), wound dehiscence (3.3% vs 1.6%, p = .559). The authors recognize that the rates of these surgical complications as well as the length of hospital stay in both cohorts are higher than what is encountered in practice. Some of the reported complications such as sepsis and renal failure are very rare in clinical practice as a postoperative complication following ACDF. One explanation could be the unique characteristics of our patient population who may have multiple associated risk factors and baseline comorbidities with CAS including, hypertension, sedentary lifestyle, hyperlipidemia, metabolic syndrome, obesity, diabetes, and smoking [12]; which are known significant risk factors for developing all of these surgical complications. The propensity score match have also rendered the non-CAS group sicker as well (than the general population). In addition, a high percentage of patients in both cohorts were ED admissions (31% in the CAS and 24.5% in the non-CAS). These patients may have been less medically optimized perioperatively. All of these factors may explain the higher than expected complications such as the wound infection rate (6.6%) and the longer length of stay particularly in the noncase group.

Our findings are supported by Pollard et al. [1] who measured the carotid artery blood flow of 15 patients intraoperatively and found that carotid artery flow was significantly altered during retraction. This alteration is due to the change in vessel surface area which they found to be an average decrease in of 14% with placement of retractor and a maximum decrease of 70%. It can be inferred that, with the decrease in surface area and altered flow, there is a possibility of carotid artery injury and cerebrovascular ischemia. Cheung et al. [2] conducted a literature review focusing on the complications of anterior and posterior cervical spine surgery and discussed the etiology of carotid injury and cerebral ischemia, stating there is a 14% to 30% decrease in the carotid artery surface area which occurs during retraction. Hartl et al. [7] performed a retrospective study which analyzed a large cohort of patients who underwent anterior cervical spine surgery with no history of previous vascular disease and found no reported cases of carotid artery injury or cerebrovascular accidents. These findings, in part, support the present study, which resulted in zero strokes in the cohort of patients which did not have a prior CAS diagnosis. In addition, they also performed a literature search yielding 5 cases of both carotid artery injury and cerebrovascular accident.

Several case reports have also described patients suffering strokes following ACDF [3,4,6,8,9]. Graffeo et al. [3] reported a case of a patient with multiple comorbidities, including previously undiagnosed atherosclerosis, who developed a stroke on the third postoperative day. Yeh et al. [4] reported a lethal stroke following ACDF and suggested that prolonged carotid artery retraction may result in stroke, even in a normal vessel.

This study has several limitations. The sample size of the study was small. However, the total number of patients who had ACDF (n = 34,975) or a diagnosis code of CAS (n = 98,000) were also relatively for a database that captured 12 million total cases. Also, it is important to note that current evidence shows that patients with higher degrees of carotid stenosis (70%–99%) are those patients who are more critical and require close follow-ups and may undergo surgical management for the established benefits [10]. Only those more clinically relevant patients may be recorded in the database. Conversely, patients with less severe stenosis receive less attention, are typically managed conservatively, and may not be coded into the current database. Therefore, the true number of patients with CAS and, in turn, those who may encounter complications with an invasive procedure like ACDF may be in fact be underestimated. Furthermore, propensity matching of patients decreases the amount of confounding variables. In addition, the significant age difference between the 2 cohorts (with the CAS cohort being older (68 vs 60 mean years) may confound the higher rate of stroke. However, CAS may be present in approximately 2% of the total population in patients ranging from 60 to 70 years old [11,12]. In addition, the ICD-9 system does not allow us to determine the degree of stenosis, which would be helpful as it would allow us a more in-depth analysis. Moreover, given that this is a retrospective, administrative database study, in-hospital data collection and coding bias may theoretically underestimate postoperative complications which may occur at a later time or may be underreported. Additionally, coding errors inherent to administrative databases may further

decrease the reliability of our findings. Nevertheless, to the best of the author's knowledge, it is the first analysis of its kind. Also, we were unable to determine stroke laterality, which would offer more convincing evidence that stroke may have been due to manipulation of the ipsilateral vessel. Despite these limitations, this is the first study to compare rates of stroke in ACDF in patient with and without CAS and serves as in impetus for future studies.

Conclusions

In the present study, we found that patients with CAS who underwent ACDF had a statistically significant greater rate of developing a postoperative stroke in comparison to patients without CAS. It is important to note that the data presented does not offer a "cause and effect" explanation but rather a finding of association. Nevertheless, these patients may benefit from an alternative surgical approach or from medical or surgical optimization of their CAS before undergoing ACDF. Therefore, screening patients for atherosclerotic risk factors and underlying vascular pathologies before surgical intervention may identify high-risk patients. This may be particularly relevant in patients with higher degrees of carotid stenosis (>70% loss of lumen diameter) in whom the current evidence have demonstrated higher risk for complications including strokes if left untreated [10]. Intraoperatively, care should be taken to avoid extensive manipulation and prolonged retraction. However, the authors are unable to conclude or advise approaching these patients from the contralateral uninvolved side. Although this may theoretically help avoid potential stroke risk, it could be argued that the uninvolved side may be providing the majority of the perfusion to the brain, and therefore, it may not also be safe to retract the artery providing the dominant supply. Therefore, this will be the focus of future research directed at this point. In addition, the authors encourage similar studies using other databases to see if results are consistent. Ideally, these studies should be prospective and aim to assess whether medical or surgical optimization of a cohort with CAS before undergoing ACDF results in decreasing the incidence of postoperative stroke and other postoperative complications in this patient population.

Acknowledgments

This study received no funding. The authors have no financial disclosures relevant to this study.

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