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Establishing objective volume-outcome measures for anterior and posterior cervical spine fusion

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ABSTRACT

Objectives: There is a growing literature on the relationship between provider volume and patient outcomes, specifically within joint arthroplasty and lumbar spine surgery. Such benchmarks have yet to be established for many other spinal procedures, including cervical fusion. We sought to determine whether outcomes-based volume measures for both surgeons and hospitals can be established for cervical spine fusion procedures.

Patients and methods: This was a retrospective review of patient data in the Florida Statewide Inpatient Dataset (SID; 2011–14). Patients identified in the Florida SID who underwent either anterior or posterior cervical fusion were identified along with the operative surgeons and the hospitals where the procedures were performed. Socio-demographic data, as well as medical and surgical characteristics were obtained, as were the development of complications and readmissions up to 90 days following hospital discharge. Surgeon and hospital volume were plotted separately against the number of complications and readmissions in an adjusted spline analysis. Multivariable logistic regression analysis was subsequently performed to assess the effect of surgeon and hospital volume on post-operative complications and readmissions.

Results: There were 8960 patients with posterior cervical fusion and 57,108 anterior cervical fusions (total = 66,068) identified for inclusion in the analysis. The patients of low-volume surgeons were found to have an increased (OR 1.83; 95% CI 1.65, 2.02) likelihood of complications following anterior and posterior (OR 1.45; 95% CI 1.24, 1.69) cervical fusion. Low-volume surgeons demonstrated increased likelihood of readmission, irrespective of anterior (OR 1.37; 95% CI 1.29, 1.47) or posterior (OR 1.31; 95% CI 1.16, 1.48) approach. No clinically meaningful differences in the likelihood of complications or readmissions were detected between high- and low-volume hospitals.

Conclusions: This study demonstrates objective volume-outcome measures for surgeons who perform anterior and posterior cervical fusions. Our results have immediate applicability to clinical practice and may be used to benchmark procedural volume. Findings with respect to hospitals speak against the need for healthcare regionalization in this specific clinical context.

1. Introduction

In the last decade, there has been increased awareness in the medical field regarding the correlation between procedural volume and outcomes, particularly in the surgical specialties [1–3]. This has led to a move among hospitals and providers to make "volume pledges," especially in the setting of more complex procedures and surgeries that are infrequently performed [4]. At the same time it is unclear whether volume-outcome relationships exist, or are influential, in the case of surgical interventions that are common and widely performed across the United States.

Within the orthopaedic field, at least, some evidence supports the presence of important volume-outcome relationships, even among very common interventions such as joint replacement [5,6], lumbar discectomy and lumbar fusions [7]. Cervical fusion procedures are frequently performed in the US and indications for these types of interventions have grown in the last 20 years [8]. At the same time, studies suggest that the number of surgeons performing these types of procedures is concomitantly on the rise [9]. While some investigations have also reported that a volume-outcome relationship may exist for cervical

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spine procedures, these studies have largely been impaired by their methodologic approach, limited surveillance regarding adverse events and lack of objective determinations regarding what constitutes a high- or low-volume provider [10,11].

Therefore, we sought to investigate whether a meaningful volume-outcome relationship existed for both anterior and posterior cervical fusion for surgeons, as well as medical centers, performing these procedures. In the event that such measures could be generated, we secondarily sought to quantify the effect that our volumetric estimates had on the development of complications and readmissions within 90-days following cervical spine surgery. There are no studies to the authors' knowledge that have investigated the relationship between cervical fusion procedural volume and post-surgical outcomes in the setting of objectively generated volumetric cut-offs).

2. Patients and methods

The data for this study was obtained from the records of patients who underwent anterior or posterior cervical spine procedures in the years 2011–2014 and had their information imparted to the Florida Statewide Inpatient Dataset (SID). Maintained by the Federal Government, the Florida SID receives information on all inpatient hospitalizations at non-Federal healthcare facilities in the state [7,12,13]. The SID also surveils all patients for up to 90-days following hospital discharge for the development of complications, readmissions or death. Use of the Florida SID is attractive, as the demographic, educational and healthcare institutional diversity within the State allow ready generalization to the US as a whole [7]. Data from the Florida SID has previously been employed in prior work regarding healthcare quality, including works dedicated to orthopaedic procedures [12,13] and lumbar spine surgery [7].

A query of the Florida SID was performed to identify adult patients who underwent either anterior or posterior cervical fusion based upon International Classification of Disease – 9th revision (ICD-9) procedure codes (available from the authors by request). Demographic and clinical information was obtained for those patients who met inclusion criteria. This comprised age at the time of surgery, race as defined in the SID, biologic sex, insurance status, income quartile by zip code, medical comorbidities characterized using the Deyo modified Charlson scale [14], and length of stay. The primary surgeon who performed the surgery and the hospital where it occurred were identified using anonymized codes provided by the State [7]. The patient records were then abstracted to identify those individuals who were readmitted, or sustained a complication, within 90 days of discharge. The presence of complications was determined using a previously published ICD-9 coding algorithm [15] that accounted for mortality, venous thromboembolic events, myocardial infarction, renal failure, other urologic complications, delirium, wound breakdown, neurologic compromise, respiratory failure, sepsis, shock, and surgical site infections.

Anterior and posterior fusion procedures were considered independently in this analysis. The annual surgical volume for surgeons as well as hospitals was used as the predictor variable. Potential confounders adjusted for our models included patient age, race, biologic sex, insurance status, income quartile by zip code, medical comorbidities, and hospital length of stay. Race was categorized based upon standardized designations utilized in the Florida SID [7]: White, Black, Hispanic, or Other (e.g. Native American, Asian/Pacific Islander, Other Race or Unknown Race). Insurance status was classified as private insurance, Medicare, Medicaid, or Other Insurance Status (e.g. Self-Pay, No Charge, and Other Insurance).

2.1. Statistical analysis

Statistical testing was performed independently for both anterior and posterior cervical fusion procedures. A two-step approach was used. In step 1, a spline analysis was performed to identify objective volume-based benchmarks associated with the development of post-surgical complications and/or readmission. These outcome measures were selected based on their established correlation with healthcare quality and the current emphasis on minimizing these events from third-party payers including Medicare [6–8,11,15]. In the second phase, the independent association of these volumetric benchmarks with complications and readmissions were assessed using multivariable regression tests that accounted for other confounders in the model.

In the spline analysis, individual surgeon and hospital procedure volume were plotted against the number of complications and readmissions in a model that adjusted for all potential confounders [6,7,16]. Hospital volume was also used as an additional covariate in the analyses used to make determinations for surgeon volume. Based upon previously published techniques [6,7,16], volumetric cut-offs were established at procedure volumes that captured a majority of both complication and readmission events. These objective volumetric cut-points were then used to create a categorical variable with one cohort of surgeons and hospitals ("high-volume") above the cut-point, and the other below that value ("low- volume"). A logistic regression analysis was subsequently performed including the categorical volume-outcome measure and all co-variates assessing for independent predictors of 90-day complications and readmissions. Regression results were expressed as odds ratios (OR) with 95% confidence intervals (CI) and *p*-values. ORs and 95% CI exclusive of 1.0 were considered statistically significant predictors of the outcome of interest. All statistical testing was performed using SAS v9.4 (SAS Institute, Cary, NC). This study was approved by institutional IRB prior to initiation.

3. Results

In the time period under study, there were 8960 posterior cervical fusions and 57,108 anterior cervical fusions (total = 66,068) identified for inclusion in the analysis. These procedures were performed by 4622 providers at 290 different institutions across Florida. The average age at time of surgery for the anterior fusion cohort was 55.7 years (SD 12.44) and 61.6 years (SD 13.79) for the posterior group. The majority of patients in both cohorts were classified as white (Table 1). A slight majority (52%) of patients who underwent posterior fusion procedures were insured through Medicare, while the plurality (47%) of those receiving anterior fusions maintained private insurance. The average number of anterior procedures performed by a surgeon was 11.5 (SD

Table 1
Demographic and clinical characteristics of patients included in this analysis by procedure.

Characteristic	Anterior Cervical Fusion	Posterior Cervical Fusion
Age (SD)	55.7 (12.4)	61.6 (13.8)
Male Sex (%)	27,034 (47)	5179 (58)
White (%)	46,224 (81)	6992 (78)
Number of Co-morbidities (%)		
Zero	26,524 (46)	2379 (27)
One	6975 (12)	845 (9)
Two	8799 (15)	1415 (16)
Three or more	14,810 (26)	4321 (48)
Insurance (%)		
Medicaid	2575 (5)	553 (6)
Medicare	19,609 (34)	4670 (52)
No charge	447 (1)	49 (1)
Other Insurance	6189 (11)	665 (7)
Private Insurance	27,129 (48)	2822 (32)
Self Pay	1159 (2)	201 (2)
ZIP Code Income Quartile		
1st Quartile	16,300 (29)	2809 (32)
2nd Quartile	18,993 (34)	2887 (33)
3rd Quartile	15,026 (27)	2232 (26)
4th Quartile	5690 (10)	818 (9)