Original Article

Perioperative outcomes of cervical disc arthroplasty: no difference between orthopaedic and neurologic surgeons

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Background: Given differences in residency training background, there has been increasing interest in characterizing differential outcomes between orthopaedic surgeons (OS) and neurosurgeons (NS) with regards to outcomes after cervical disc arthroplasty (CDA). This study aimed to assess if there were differences in perioperative outcomes of CDA between OS and NS.

Methods: Patients who underwent a single-level CDA between 2012 and 2019 were identified from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database using current procedural terminology codes. The patients were subsequently stratified into those who underwent CDA with OS versus NS, and propensity score-matched to adjust for differences in patient characteristics. Differences were assessed in medical and surgical complications, as well as operative time and healthcare utilization parameters [reoperations, readmissions, and lengths-of-stay (LOS)].

Results: A total of 2,148 patients were identified (NS: n=1,395; OS: n=753). After 1:1 propensity score matching (n=741 each), there were no differences in characteristics between patients who underwent CDA by OS versus NS (P>0.05). There were no significant differences in any of the medical or surgical complications between the two groups (P>0.05 for each). There was a significant difference in the operative time between NS and OS (103.7±36.18 *vs.* 98.75±36.69 minutes; P=0.009). There were no significant differences in readmissions, reoperations, or LOS between the two groups (P>0.05 for each).

Conclusions: There were no differences in medical or surgical complications, as well as in reoperations, readmissions, and LOS in patients who underwent a single-level CDA between OS and NS. There was a statistically significant shorter operative time of four minutes for OS as compared to NS, which is unlikely to have clinical relevance.

Keywords: Cervical disc arthroplasty (CDA); surgeon training; outcomes; complications; healthcare utilization

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Introduction

Given variable training pathways and subtle technical variations, the differences in surgical outcomes of spine surgery between orthopaedic (OS) and neurologic surgeons (NS) have been previously studied (1-4). The studies primarily analyzed lumbar laminectomies, lumbar fusions, and anterior cervical discectomies and fusion (ACDF). The results of the studies have been heterogeneous, with some studies showing no differences in outcomes and other studies associating each group with higher rates of complications.

Spine surgeons of OS and NS backgrounds undergo dissimilar residency training before a final common pathway of fellowship. Such difference has sparked a debate regarding readiness for a spine surgery practice and a potential training-related variation in postsurgical outcomes. However, it is critical to note that inter-program variation within a single specialty, the difference among surgeons in the rate of pursuing post-residency or enfolded spine fellowships, the focus of the fellowship, as well as the scope of practice are all factors that impact training and are likely to dilute—or even eliminate—potential differences influenced by pre-fellowship training. Cervical disc arthroplasty (CDA) is a relatively novel procedure that can be an alternative to ACDF or posterior foraminotomy to treat cervical spine disease (5-7). To the best of our knowledge, there have been no studies assessing the differences in perioperative outcomes of CDA between OS and NS. Given the relative novelty of CDA, such comparison is critical to addressing potential areas of training deficit that may translate into differences in outcomes among spine surgeons of different training backgrounds (8-10).

Given the similar rigor of fellowship training required of both OS and NS as well as the novelty of current iterations of CDAs, we hypothesized there would be no significant difference in perioperative outcomes of CDA between OS and NS. The goal of this study was to evaluate whether any difference in perioperative outcomes existed between OS and NS patients who underwent a single-level CDA. Specifically, we assessed differences in (I) medical complications; (II) surgical complications; (III) operative time; (IV) overall and inpatient-specific lengths-of-stay (LOS); (V) reoperation; and (VI) readmission rates in the perioperative and early (30-day) postoperative period.

Highlight box

Key findings

- There were no differences in medical or surgical complications, reoperations, readmissions, and lengths-of-stay in patients who underwent a single-level cervical disc arthroplasty between orthopaedic and neurosurgeons.

What is known and what is new?

- Spine surgeons of orthopaedic and neurologic backgrounds undergo dissimilar residency training before a final common pathway of fellowship.
- Such difference has sparked a debate regarding readiness for a spine surgery practice and a potential training-related variation in postsurgical outcomes.

What is the implication, and what should change now?

- This continues to support the similarity in rigor of spine surgical training and practice in orthopaedic and neurologic pathways, particularly as it relates to more novel procedures, such as the current iteration of the cervical disc replacement.

Methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database (11) was queried for patients who underwent a primary single-level CDA between 2012 and 2019 utilizing the principle treatment CPT code 22856. Patients who underwent >1 level CDA were excluded through the elimination of cases with an additional CPT code 22858, 0092T, or repeats of the CPT code 22856 (12). Furthermore, revision CDA cases were identified and excluded using the CPT codes 22861, 22864, 0098T, 0095T, and 0375T. The patients were subsequently stratified into those who underwent CDA with OS versus NS utilizing a "surgeon specialty" variable contained within the dataset.

Univariate analysis of patient characteristics was utilized to determine significant differences between the NS and the OS cohorts. The patients were subsequently propensity score-matched according to baseline-captured determinants, including: age, sex, body mass index (BMI), and underlying comorbidities on a 1:1 basis to adjust for differences in patient characteristics (13). Perioperative outcomes were categorized as medical or surgical. Medical complications included acute renal failure, urinary tract infection, pneumonia, requiring mechanical ventilation postoperatively, deep vein thrombosis requiring treatment, and sepsis. Surgical complications included superficial surgical site infection, deep surgical site infection, wound dehiscence, and blood transfusion. Differences in rates of reoperation, readmission, overall and inpatient-specific LOS, and operative time were assessed between the two groups.

Rates and frequencies were assessed as categorical variables, which were compared via Fisher's exact test (14). Means and standard deviations (SDs) of continuous variables were compared using the two-sample *t*-test. All tests were two sided and the threshold of statistical significance was set at $P<0.05$. All calculations were performed using base programming language R (R Foundation for Computation Science, Vienna, Austria) along with the MatchIt package for propensity score matching (15).

The study was conducted in accordance with the

Declaration of Helsinki (as revised in 2013). The study was based on a publicly available de-identified database; therefore, institutional review board approval or individual consent was not required.

Results

A total of 2,148 patients receiving single-level CDA were identified, with a mean ± SD age of 44.99±10.12 years, a BMI of 29.49±6.18 kg/m^2, and a slight male predominance (51.2%). All procedures were conducted by NS (n=1,395, 64.94%) or OS (n=753, 35.06%). Univariate analysis of patient characteristics demonstrated lower age (P=0.044), hypertension prevalence (P=0.001), and steroid use (P=0.021) within the OS cohort. In addition, a greater prevalence of American Society of Anesthesiologists (ASA) scores III and IV were detected within the NS group (22.37% *vs.* 17.40%; P=0.039) (*Table 1*).

Propensity score matching was performed to adjust for significant differences in the univariate analysis (*Table 2*). Analysis of the matched cohorts demonstrated similar 30-day postoperative rates of medical complications in NS and OS: acute renal failure, urinary tract infection, pneumonia, postoperative mechanical ventilation, deep vein thrombosis requiring treatment, and sepsis (P>0.99 for all) (*Table 3*). Furthermore, there were no significant differences in the 30-day postoperative rates of surgical complications: superficial surgical site infection (0.40% *vs.* 0.13%; P=0.624), deep surgical site infection (P>0.99), wound dehiscence (P>0.99) and blood transfusion (P>0.99) between the two groups. However, operative time was shorter in the OS cohort compared to NS (103.7±36.18 *vs.* 98.75± 36.69 minutes; P=0.009).

The NS and OS cohorts had similar LOS (0.96±0.93 *vs.* 1.03±1.4 days; P=0.285). There were no significant differences in rates of reoperation (1.21% *vs.* 0.67%; P=0.422), and readmission (1.21% *vs.* 0.94%; P=0.803) (*Table 3*).

Discussion

This was a retrospective administrative database study that aimed to analyze differences in outcomes of patients undergoing single-level CDA between OS and NS. We initially hypothesized there would be no significant difference in perioperative outcomes of single-level CDA when performed by these two groups. The findings of this study support our hypothesis, and there were no differences in medical or surgical complications, as well as for reoperations, readmissions, and LOS between OS and NS in patients who underwent a single-level CDA. The only statistically significant finding was a shorter operative time 4 minutes for OS as compared to NS, however, we believe this is of little clinical significance.

Overall, the complication rates reported in the present NSQIP dataset-based investigation do not deviate from those reported in institutional studies as well as insurance-based datasets after anterior cervical spine procedures. Tasiou *et al.* (16) reported a superficial wound infection of 0.9% in their institutional cohort of 114 patients. More recently, Joo *et al.* (17) utilized the Pearl Driver database to evaluate 90-day outcomes after ACDF and reported a rate of 0.3% for wound dehiscence, 1.7% for pneumonia and 0.4% for the need for transfusion. Such rates are slightly higher than those reported in the present investigation, which may be attributable to the longer follow up period (90 days) in the study by Joo *et al.*, compared to the 30-day outcome measures evaluated in the present study.

The majority of the current literature is heterogeneous with regards to differences in clinical or functional outcomes between OS or by NS (1,2). In a retrospective ACS-NSQIP analysis of elective spine decompressions with or without fusions performed on 50,361 patients from 2006 to 2012, there were no significant differences between OS and NS 30-day perioperative outcomes, apart from a 2-fold increased probability of undergoing perioperative transfusion as well as a slightly increased odds for prolonged LOS when performed by an OS versus NS (2). Another multi-institutional study using NSQIP analyzed 197,682 patients undergoing 1 of 3 common spine surgeries (lumbar fusion, lumbar laminectomy, or ACDF) and found no significant difference in rates of surgical complications, all-cause readmission, and revision surgery between OS and NS (3).

Some studies have noted differences in outcomes. In an analysis of 10,509 patients from the 2007–2015 Humana commercial database who underwent 1- to 2-level posterior lumbar fusions, there were no statistically significant differences in 90-day complication rates or costs. This study did note a significantly higher rate of dural tears, as well as lower rates of wound complications and lower reimbursement for OS (4). A similar study evaluated 14,701 lumbar decompressions from 2006–2011 and noted longer operative times for NS patients; however, OS patients experienced increased intraoperative blood transfusions, peripheral nerve injury, and longer hospitalizations. Importantly, this study did note significant differences in pre-operative patient comorbidities and did not propensity

Table 1 Differences in demographics and comorbidities of patients who underwent a CDA between OS and NS

Variable	NS (n=1,395)	OS (n=753)	P value
Age (years)	45.31±10.17	44.39±10	0.044*
Body mass index (kg/m^2)	29.59±6.13	29.32±6.25	0.332
Sex			0.39
Female	671 (48.10)	377 (50.07)	
Male	724 (51.90)	376 (49.93)	
Body mass index classification			0.717
Normal weight	267 (19.14)	155 (20.58)	
Obese class I	371 (26.60)	202 (26.83)	
Obese class II	164 (11.75)	72 (9.56)	
Obese class III	87 (6.24)	46 (6.11)	
Overweight	501 (35.91)	276 (36.65)	
Underweight	5 (0.36)	2 (0.27)	
Diabetes			0.292
Insulin-dependent	31 (2.22)	11 (1.46)	
Non-insulin dependent	1,364 (97.78)	742 (98.54)	
Smoker	286 (20.5)	175 (23.24)	0.152
Dyspnea on moderate exertion	22 (1.58)	14 (1.86)	0.760
COPD	20 (1.43)	4 (0.53)	0.083
Hypertension	338 (24.23)	137 (18.19)	0.001*
Steroids	43 (3.08)	11 (1.46)	0.021*
Functional health status			>0.99
Independent	1,391 (99.71)	751 (99.73)	
Partially dependent	4 (0.29)	2 (0.27)	
ASA classification			0.039*
1—no disturb	147 (10.54)	93 (12.35)	
2—mild disturb	930 (66.67)	526 (69.85)	
3—severe disturb	312 (22.37)	131 (17.40)	
4—life threat	6 (0.43)	3 (0.40)	
Race			0.097
American Indian or Alaska Native	10 (0.72)	2 (0.27)	
Asian	40 (2.87)	13 (1.73)	
Black or African American	88 (6.31)	60 (7.97)	
Native Hawaiian or Pacific Islander	7 (0.5)	1 (0.13)	
White	1,250 (89.61)	677 (89.91)	
Bleeding disorders	5 (0.36)	5 (0.66)	0.334
Open wound/wound infection	1 (0.07)	1 (0.13)	>0.99
Outpatient (LOS <1 day)	684 (49.03)	361 (47.94)	0.6297

Data are shown as mean ± SD or n (%). *, P<0.05. CDA, cervical disc arthroplasty; OS, orthopaedic surgeons; NS, neurosurgeons; COPD, chronic obstructive pulmonary disease; LOS, lengths-of-stay; SD, standard deviation; ASA, American Society of Anaesthesiology.

Table 2 Differences in demographics and comorbidities of patients who underwent a CDA between OS and NS after propensity matching

Variable	NS (n=741)	OS (n=741)	P value
Age (years)	44.66±9.98	44.39±9.95	0.599
Body mass index (kg/m^2)	29.37±6.16	29.3±6.29	0.831
Sex			0.436
Female	387 (52.23)	371 (50.07)	
Male	354 (47.77)	370 (49.93)	
Body mass index classification			0.997
Normal weight	154 (20.78)	155 (20.92)	
Obese class I	195 (26.32)	196 (26.45)	
Obese class II	69 (9.31)	70 (9.45)	
Obese class III	50 (6.75)	46 (6.21)	
Overweight	272 (36.71)	272 (36.71)	
Underweight	1 (0.13)	2 (0.27)	
Diabetes			0.850
Insulin-dependent	11 (1.48)	11 (1.48)	
Non-insulin dependent	31 (4.18)	27 (3.64)	
Smoker	172 (23.21)	170 (22.94)	0.951
Dyspnea on moderate exertion	13 (1.75)	11 (1.48)	0.837
COPD	6 (0.81)	3 (0.4)	0.506
Hypertension	138 (18.62)	134 (18.08)	0.840
Steroids	9 (1.21)	11 (1.48)	0.823
Functional health status			>0.99
Independent	740 (99.87)	739 (99.73)	
Partially dependent	1 (0.13)	2 (0.27)	
ASA classification			0.933
1—no disturb	99 (13.36)	93 (12.55)	
2—mild disturb	507 (68.42)	515 (69.5)	
3—severe disturb	131 (17.68)	130 (17.54)	
4—life threat	4 (0.54)	3 (0.4)	
Race			0.529
American Indian or Alaska Native	2 (0.27)	2 (0.27)	
Asian	19 (2.56)	13 (1.75)	
Black or African American	54 (7.29)	60 (8.1)	
Native Hawaiian or Pacific Islander	4 (0.54)	1 (0.13)	
White	662 (89.34)	665 (89.74)	
Bleeding disorders	0 (0.00)	2 (0.27)	0.500
Open wound/wound infection	0 (0.00)	1 (0.13)	>0.99
Outpatient (LOS <1 day)	357 (48.18)	354 (47.78)	0.8776

Data are shown as mean ± SD or n (%). CDA, cervical disc arthroplasty; OS, orthopaedic surgeons; NS, neurosurgeons; COPD, chronic obstructive pulmonary disease; LOS, lengths-of-stay; SD, standard deviation; ASA, American Society of Anaesthesiology.

Table 3 Peri- and post-operative outcomes after cervical disc arthroplasty

Outcome	Before propensity score matching			After propensity score matching		
	Neurosurgery (n=1,395)	Orthopedics (n=753)	P value	Neurosurgery (n=741)	Orthopedics (n=741)	P value
Medical						
Acute renal failure	1 (0.07)	0 (0.00)	>0.99	0 (0.00)	0 (0.00)	>0.99
Urinary tract infection	1 (0.07)	1 (0.13)	>0.99	1 (0.13)	1 (0.13)	>0.99
Pneumonia	2 (0.14)	0 (0.00)	0.544	1 (0.13)	0 (0.00)	>0.99
Mechanical ventilation	2 (0.14)	1 (0.13)	>0.99	1 (0.13)	1 (0.13)	>0.99
DVT requiring therapy	1 (0.07)	0 (0.00)	>0.99	1 (0.13)	0 (0.00)	>0.99
Occurrences sepsis	0 (0.00)	1 (0.13)	0.351	0 (0.00)	1 (0.13)	>0.99
Surgical						
Total operation (minutes)	103.83±36.32	98.64±36.6	0.002	103.7±36.18	98.75±36.69	0.009
Superficial incisional SSI	4 (0.29)	1 (0.13)	0.663	3 (0.40)	1 (0.13)	0.624
Deep SSI	1 (0.07)	0 (0.00)	>0.99	0 (0.00)	0 (0.00)	>0.99
Wound dehiscence	0 (0.00)	1 (0.13)	0.351	0 (0.00)	1 (0.13)	>0.99
Transfusions	1 (0.07)	0 (00.00)	>0.99	1 (0.13)	0 (0.00)	>0.99
Healthcare utilization						
Any reoperation	11 (0.79)	5 (0.66)	>0.99	9 (1.21)	5 (0.67)	0.422
Any readmission	15 (1.08)	7 (0.93)	0.826	9 (1.21)	7 (0.94)	0.803
Lengths-of-stay (days)	0.99±1.21	1.03±1.39	0.498	0.96±0.93	1.03±1.4	0.285

Data are shown as mean ± SD or n (%). DVT, deep venous thrombosis; SSI, surgical site infection; SD, standard deviation.

match their cohorts, which may have confounded results.

There are several limitations to this study. This study is ultimately a retrospective cohort study that did not prospectively randomize patients. As such, it is inherently limited by the information available in the NSQIP database (18,19). Nevertheless, with the available dataset, we were able to provide propensity matching which mitigates potential cohort biases or differences. Our study was unable to capture or control for important variables such as extent of surgeon training in spine surgery or years of experience as these are unavailable in the NSQIP database (20). It is critical to note that sample size limitations may have obscured potentially statistically significant differences in the outcomes of interest between NS and OS. However, it is notable that absolute adverse outcomes incidence after CDA performed by NS and OS was remarkably low, which renders any potential statistical significance devoid of clinical relevance. Further investigations with larger sample sizes are suggested to further explore potential associations between surgeon training and post-CDA outcomes. Our study was limited to 30-day perioperative outcomes and complications (21). In the present study, we analyzed only patients who underwent a single-level CDA, excluding patients who received a second- or third-level CDA during the same surgery. Although the literature suggests similar outcomes and functional recovery of patients undergoing single versus multi-level CDA (22), future studies may need to evaluate the perioperative outcomes of multi-level CDA between OS and NS. To the best of our knowledge, this is the first study to compare OS *vs.* NS sub-specialty outcomes for CDA.

Conclusions

With different training pathways and sometimes subtle technical differences, the perioperative outcomes of spine surgeries conducted by OS *vs.* NS continue to be investigated. The current landscape of literature has failed

to find a consistent difference in lumbar decompressions with and without fusions and ACDFs. Similarly in our study, there were no differences in medical or surgical complications, as well as reoperations, readmissions, and LOS in patients who underwent a single-level CDA between OS and NS. There was a statistically significant shorter operative time of 4 minutes for OS as compared to NS, which is unlikely to have any clinical significance. We feel this continues to support the similarity in rigor of spine surgical training and practice in orthopaedic and neurologic pathways, particularly as it relates to more novel procedures, such as the current iteration of the CDA. Future studies should continue to assess perioperative outcomes at the institutional-level in a prospective manner, which could offer more in-depth data granularity and longer-term results.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was based on a publicly available de-identified database; therefore, institutional review board approval or individual consent was not required.

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