Journal of Spine
ISSN: 2165-7939

Goz V, et al., J Spine 2014, 3:5
DOI: 10.4172/2165-7939.1000178

Research Article Open Access

Cervical Disc Arthroplasty versus Anterior Cervical Discectomy and Fusion; Utilization and Perioperative Outcomes

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Rec date: Jun 19, 2014, **Acc date:** Sep 16, 2014, **Pub date:** Sep 18, 2014

Abstract

Summary of Background Data: Anterior cervical discectomy and fusion (ACDF) is the gold standard surgical intervention for cervical degenerative disc disease (DDD). Cervical disc arthroplasty (CDA) has been introduced as an alternative. CDA offers the potential advantage of preserving intersegmental motion and preventing adjacent segment degeneration. Although a number of trials demonstrated non-inferiority of CDA compared to ACDF in terms of symptom/function related outcomes, little data is available comparing perioperative outcomes.

Methods: The Natiowide Inpatient Sample (NIS) database was queried for ACDFs or CDAs between 2005 and 2010. Univariate analyses was used comparing the two procedures in terms of patient demographics, comorbidities, perioperative complications, length of stay (LOS), total hospital charges, and mortality. Complications rates that were significant on univariate analysis were analyzed via logistic regression models that account for age, gender, and overall comorbidity burden. National estimates of annual total number of procedures were calculated.

Results: An estimated 9,910 CDAs and 699,289 ACDFs were performed in the United States between 2005 and 2010. The CDA cohort was younger and with less comorbidities than the ACDF cohort. The CDA cohort experienced less post-operative dysphagia, hematoma, acute anemia secondary to intraoperative blood loss, or ARDS. ACDF was associated with less cardiac complications, peripheral vascular, and device related complications. All complications remained statistically significant in logistic regression models. CDA had a lower average LOS (1.56 versus 2.23 days, p<.0001) and was associated with less total charges ($39,563 versus $43,477, p<.0001). Mortality was lower after CDA (0.10% versus 0.22%, p=.01).

Conclusions: This data suggests that CDA may be safer, associated with lower mortality, lower hospital charges and shorter LOS compared to ACDF. However, baseline differences between the two cohorts, including age and comorbidity burden, may play a confounding role in these findings. This information could be important in developing an evidence-based paradigm for surgical management of cervical DDD.

Keywords: Cervical fusion; Cervical disc arthoplasty; Disc replacement; Anterior cervical discectomy and fusion; Degenerative disc disease; Perioperative complications; Cervical radiculopathy; Hospital charges; Clinical outcomes

Introduction

Degenerative disc disease (DDD) of the cervical spine is an increasingly common condition. DDD can present as axial pain, radiucolopathy, myelopathy, headache, or sensory/motor deficits due to neural compression. Surgery is an accepted treatment option for intractable radiculopathy or myelopathy. Use of invasive surgical intervention for the treatment of axial pain or headache is controversial, and lacks strong evidence of efficacy. The annual incidence of cervical radiculopathy is reported to be 83 per 100,000 people in the United States, with a peak incidence of 202 per 100,000 in the 50 to 54 age group [1,2] Although up to 83% of patients with DDD are satisfied with conservative management at two years, a subset of patients fail to improve [3,4]. Patients with concordant imaging and physical examinations who continue to have intractable radiculopathy, with or without neurologic deficits, after exhaustive conservative management may require surgical intervention. Anterior cervical discectomy and fusion (ACDF) is the current gold standard for surgical management of intractable radiculopathy secondary to cervical DDD. Originally described by Robinson and Smith in 1955 the procedure has maintained a high rate of success [5-9].

Although over 90% of patients are satisfied with their short-term clinical improvement, the loss of motion and altered natural biomechanics in the cervical spine after fusion can have adverse long-term consequences [10-12].This can lead to increased stress at adjacent levels and development of adjacent level pathology [12-15]. Cervical disc arthroplasty (CDA) has been recently introduced as an alternative to ACDF. CDA offers the potential advantage of preserving intersegmental motion and preventing adjacent segment degeneration. Four randomized clinical trials (RCTs) and a recent meta-analysis

have compared CDA and ACDF in terms of symptom related clinical outcomes [16-20].

The RCTs demonstrated non-inferiority of CDA compared to ACDF in terms of improvement in the Neck Disability Index (NDI), serious adverse events associated with the implant or procedure, neurologic status, avoidance of subsequent surgery at the index level, and overall success defined as improvement in all 4 categories. As these studies were inadequately powered to demonstrate superiority of one procedure of the other, a meta-analysis of the four trials was performed. This demonstrated superiority of CDA in terms of neurologic improvement, survivorship (avoidance of a subsequent procedures at index level), and overall success.

In order to further define the role of CDA in the surgical management of cervical DDD, more information is needed comparing perioperative outcomes and procedural costs of CDA versus ACDF. This study aimed to accomplish both of those goals with the use of data from a national administrative database.

Methods

The study used data from the Nationwide Inpatient Sample (NIS) database. NIS is part of the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality (AHRQ). The database contains an approximate 20 percent stratified sample of U.S hospital admissions, for a total of between 7 and 8 million admissions per year [21]. The database contains information on patient demographics, hospital characteristics, length of stay, payment source, total hospital charges, and outcomes as well as procedure and diagnosis codes using the International Classification of Diseases, 9th Revision (ICD-9) system.

This study used NIS data between 2005 and 2010. Patients undergoing ACDF were identified via ICD-9 procedure codes for cervical fusion with anterior approach (81.02) and discectomy (80.51). Use of interbody cages was identified with ICD-9 code 84.51. Patients undergoing CDA were identified with ICD-9 code 84.62. Because CDA is approved for single level DDD only, we excluded patients with ICD-9 code 81.63 (fusion or refusion of 3-7 levels).

Patient demographics, including age, gender, specific comorbidities (Appendix A), and overall comorbidity burden as estimated by a modified Charlson comorbidity index, were compared between the ACDF and CDA patient populations [22]. National trends in utilization of the two procedures were estimated using weights provided as part of the NIS database. Sample weights allow for extrapolation of unweighted data to generate national estimates. Outcomes including length of stay, 14 specific complications (Appendix B), total hospital charges, and mortality were compared between the two groups. Post-operative complications were identified via ICD-9 diagnosis codes (996.X – 999.X).

Univariate analysis included chi square test and t tests for categorical and continuous data, respectively. P-value less than .05 was considered significant. Complications that showed a statistically significant association with ACDF or CDA were analyzed via a multivariate logistic regression model that adjusted for age, gender, and overall comorbidity burden. All analysis was done via R statistical programming language [23]. Data in the NIS database is de-identified, and since this research does not include direct interaction with patients, it is exempt from review by the institutional review board.

Results

A total of 699,288 ACDFs and 9,910 CDAs were performed in the United States between 2005 and 2010. The number of CDAs increased from 344 in 2005 to 2483 in 2010. ACDFs increased from 105,986 in 2005 to 125,365 in 2010. Interbody cages were used in 44% of ACDFs. Patients undergoing CDA were on average younger than those undergoing ACDF (45 years old versus 51 years old, p<0.0001). Patient gender for the two procedures was not statistically different (p=.2751). CDA patients were less frequently covered by Medicare (5.7% versus 21.2%, p<0.0001), and had a lesser overall comorbidity burden (modified Charlson score 0.14 versus 0.29, p<0.0001). CDA patients had a lower prevalence of the comorbidities investigated (Table 1).

Comorbidities	CDA(%)	ACDF(%)	p value
HIV	0.05	0.07	0.3291
Anemia (Deficiency)	1.6	2.31	<.0001
Rheumatoid Arthritis/Collagen Vascular Disease	0.95	1.92	<.0001
Anemia (chronic blood loss)	0.15	0.11	0.2286
Congstive Heart Failure	0.25	1.06	<.0001
Chronic Lung Disease	11.13	13.49	<.0001
Coagulapathy	0.3	0.6	<.0001
Diabetes	5.84	12	<.0001
Hypertension	24.56	37	<.0001
Liver Disease	0.8	0.81	0.8302
Electrolyte Imbalance	0.8	2.37	<.0001
Metastatic Cancer	0.15	0.24	0.0776
Neurologic	1.5	2.83	<.0001
Obesity	6.24	7.35	<.0001
Paralysis	0.45	1.6	<.0001
Peripheral Vascular	0.2	1.01	<.0001
Pulmonary	0.05	0.19	0.0016
Renal	0.25	0.97	<.0001
Cancer (non metastatic)	0.1	0.27	0.0013
Cardiac Valvular Disorders	1.6	2.14	0.0002
Pathologic Weight loss	0.1	0.46	<.0001

Table 1: Comorbidities in the ACDF and CDA cohorts

CDA was associated with higher rates of postoperative device related complications (2.49% versus 0.95%, p<0.0001), cardiac complications (0.61% versus 0.34%, p=0.00015), and peripheral vascular complications (0.07% versus 0.02%, p=0.0074) (Table 2). ACDF was associated with higher incidence of postoperative dysphagia (1.34% versus 0.27%, p<0.0001), hematoma/seroma (0.49% versus 0.27%, p=0.0052), acute anemia secondary to perioperative hemorrhage (0.79% versus 0.27%, p<0.0001), ARDS (1.04% versus

0.14%, p<0.0001), and venous thromboembolic events (0.57% versus 0.33%, p=.0091).

Complications	ACDF (%)	CDA (%)	p value
Dysphagia	1.34	0.27	<.0001
Device Related	0.95	2.49	<.0001
CNS	0.23	0.14	0.1811
Cardiac	0.34	0.61	0.0002
Peripheral Vascular	0.02	0.07	0.0074
Respiratory	0.37	0.34	0.6724
Gastrointestinal	0.27	0.27	0.6566
Genitourinary	0.39	0.27	0.2501
Postoperative Shock	0.01	0	0.3945
Hematoma/Seroma	0.49	0.27	0.0052
Wound Dehiscence	0.02	0	0.2503
Infection	0.08	0.01	0.6907
Acute Anemia (Hemorrhage)	0.79	0.27	<.0001
ARDS	1.04	0.14	<.0001
VTE	0.57	0.33	0.0091

Table 2: Perioperative complications in the ACDF and CDA cohorts

Logistic regression models showed that all complications except for VTE that were associated with ACDF or CDA on univariate analysis remained significant when adjusting for patient age, gender, and overall comorbidity burden (Table 3). VTE did not show a statistically significant difference in the logistic regression models (p=0.1529) Overall perioperative mortality was higher in the ACDF group (0.22% versus 0.10%, p=0.0119). Logistic regression adjusting for the same covariates as above showed no statistically significant difference in mortality between ACDF and CDA (p=.3659).

Complication	Odds Ratio (CDA)	p value
Acute Anemia (Hemorrhage)	0.53	0.0031
ARDS	0.09	<.0001
Cardiac	2.64	<.0001
Device related	2.23	<.0001
Dysphagia	0.23	<.0001
Hematoma/Seroma	0.37	0.0035
Peripheral Vascular	4.76	0.0005
VTE	0.64	0.1529

Table 3: Results of logistic regression models adjusting for age, race, gender, and overall comorbidity burden. Odd ratios in the table are for CDA, odds ratio for ACDF is set to 1. Odds ratios above 1 represent increased risk, below 1 is decreased risk as compared to ACDF.

Average length of stay was longer for ACDF with 2.23 days comparing to 1.56 days for CDA (p<0.0001). The average total charges were $43,477 for the ACDF cohort and $39,563 for the CDA cohort (p<0.0001).

Discussion

This study of data from the NIS between 2005 and 2010 compared the charges and outcomes of 699,288 ACDFs and 9,910 CDAs. The number of both procedures has been increasing since 2005. CDA increased by a factor of 7.2 (from 344 to 2,483) while ACDFs increased by a factor of 1.18 (from 105,986 to 125,365). This increase in utilization was reported by Nestrenko et al. through 2008, and has continued according to our data through 2010 [24]. Increasing utilization trends have been reported for a number of procedures in multiple surgical fields [25-27].

Although a number of factors potentially contribute to these trends, it is difficult to say with any certainty which is the key drivers for the increase in utilization. The U.S. population is growing older and staying active well into old age, this may result in a greater demand for functional joints and a pain free back. Another set of potential contributors is improvements in anesthesia and perioperative care leading to a change in surgical patient selection; patients that were once not considered surgical candidates due to comorbidities can now safely be operated on.

The technology involved in spine surgery has been rapidly evolving. As surgical techniques become less invasive and perioperative management of patients improves, recovery time for surgeries is quickly shrinking. These factors make surgical options more appealing to patients. The increasing number of fellowship trained spine surgeons may also be contributing to the number of surgeries by making surgical spinal interventions more accessible in parts of the country where they once were not. Until further research evaluating the possible drivers of increased surgical intervention is conducted, the above reasons remain only conjectures about potential contributing factors.

In order to optimize performance, surgical treatment of cervical spondylosis will require attention to maintain functional joints. The theoretical benefits of CDA include preservation of segmental motion and prevention of adjacent level degeneration. These theoretical benefits are more relevant for younger, more active patients. This likely explains the trend observed in this study for CDA procedures performed in a healthier patient population. In this study, CDA patients were younger by an average of 6 years, with less comorbidity than those undergoing ACDF, a finding that is consistent with previous reports [24].

Safe and effective surgery is the standard, but as surgical techniques expand, patient selection for the appropriate procedure must account for the patient's activity level and expectations. It is important to note that preservation of motion has not been demonstrated to impact pain or function as assessed by the NDI and SF-36. There is conflicting evidence regarding rates of adjacent level degeneration in ACDF and CDA. Although some studies comparing the two procedures found no difference in radiographic evidence of adjacent level degeneration, one RCT found a statistically significant lower rate after CDA [28-33]. Still, no studies to date have replicated this clinically. Since CDA is a recently developed technique, more time is needed for longitudinal trials to detect the impact of CDA on adjacent level pathology.

Mortality was an infrequent event (0.22% and 0.10% for ACDF and CDA respectively) with no statistically significant difference once adjusting for age, race, gender and overall comorbidity burden. CDA and ACDF have different profiles in terms of perioperative complications. The CDA cohort experienced a statistically significant higher incidence of device related complications, cardiac and peripheral vascular complications. The rate of dysphagia, ARDS, hematoma/seroma, and acute anemia from hemorrhage was lower in the CDA cohort. The latter complications are known risks associated with anterior approach to the cervical spine, which is involved in both procedures. The potential for CDA to spare soft tissues involved in the dissection remains to be evaluated. Differences in the rate of complications between CDA versus ACDF remained statistically significant when adjusted for patient age, gender, and overall comorbidity burden via logistic regression models.

The lower rate of acute anemia secondary to hemorrhage suggests less intra operative blood loss in the CDA group. This contrasts with data from the ProDisc-C trial showing that CDA was associated with a slightly greater intraoperative blood loss compared to ACDF [17]. The greater blood loss associated with ProDisc-C installation is possibly linked having to cut a keel for the ProDisc implant. The database used in this study does not contain information on perioperative blood loss and further studies are necessary to clarify this issue. To our knowledge this is the first report comparing perioperative complications of the two procedures.

The patient cohort that received CDA required less healthcare resource utilization than the cohort that received ACDF. Patients receiving CDA had a shorter LOS (1.56 days compared to 2.23 days) and lower total hospital charges ($39,562 versus $43,477). It is important to note that the charges data in the NIS database is the amount billed by the hospital for each hospitalization. Although this represents the majority of the total charges accounting for charges of instrumentation, facility fees, admission charges, medications, and ancillary staff, it should be noted that any professional fees for the procedure (surgeon and anesthesiologist) are excluded to the extent such services were provided by non-hospital employees. For improved estimation of total charges, further studies on the total charges of ACDF and CDA should include professional fees.

Based on the contributing variables to the overall charges, the authors hypothesize that this trend in decreased charges for CDA will hold after the addition of professional fees. Professional fees are billed using Current Professional Terminology (CPT) codes. ACDF procedures can be associated with as many as 4 different CPT codes while CDA has a single code. The use of interbody cages, used in 44% of ACDFs in our study, further increases the charges of the procedure. It is also important to recognize that charges are a weak proxy for actual costs incurred; however, the general trends in charges over time and comparison of charges across procedures remains informative as to the likely trends and differences in underlying costs and hospital resource utilization.

Thus this analysis suggests patients receiving CDA are charged less, have fewer perioperative complications, and utilize fewer healthcare resources. Cost-minimization strategies abide by the paradigm that if two treatment options have largely equivalent outcomes, the less expensive treatment is preferred. Though the charges may not be determined with adequate certainty in many instances, the depth of data involved in a national database increases the reliability of the estimation reported here. The current state of evidence comparing CDA and ACDF suggests non-inferiority of CDA in symptomatic relief of cervical degenerative disc disease. The elegant simplicity of cost-minimization and the added theoretical benefit of preserved motion with CDA argue favorably for this increasing utilization of this procedure in managing single-level DDD of the cervical spine.

A number of limitations affect this study. The CDA group was, on average, 6 years younger and had a lower comorbidity burden as measured by the modified Charlson index and therefore patient selection may play a confounding role in measured outcomes. Although the multivariate regression analysis used would decrease that bias it is unlikely that the regression model fully accounts for the aforementioned confounders. Additionally, the indications for these procedures may differ. Different indications, such as cervical radiculopathy or myelopathy, may have an effect on perioperative outcomes. Due to the nature of the NIS database only events that occur during the operative admission are captured and thus events that lead to readmissions or occur in the outpatient setting cannot be identified. The granularity of the database in terms of distinguishing various patient and procedure characteristics, as well as capturing specific perioperative complications is limited by the ICD-9 coding system. Another limitation of this study is the presence of only hospital billing information and absence of professional fees. Further studies comparing cost of the two procedures need to assess costs, rather than charges, and should include both institution and physician costs in order to accurately capture the total cost of each procedure.

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