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Research Article

Correlation between Severity of Preoperative Cervical Disc Degeneration and Postoperative Improvement in Health-Related Quality-of-Life Outcomes

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Abstract

Objective: Cervical disc degeneration is a common radiographic finding among patients with cervical spine pathology, however there is little literature exploring severity of cervical disc degeneration and postoperative health-related quality of life (HRQOL) outcomes following anterior cervical discectomy and fusion (ACDF). The purpose of this study was to explore the relationship between severity of cervical disc degeneration and postoperative HRQOL outcomes in patients status post 1- and 2-level ACDF.

Methods: Patient demographics, case characteristics, and minimum one-year HRQOL outcomes were obtained via SQL query and manual chart reviews. Cervical disc degeneration was graded using a previously established scoring system incorporating: middle intervertebral disc height loss, anterior osteophyte length, and endplate sclerosis. Statistical analysis was performed with regression to examine the relationship between severity of disc degeneration and patient/ clinical outcomes.

Results: Of the 211 patients in the final cohort, 27 had mild degeneration, 100 moderate degeneration, and 84 severe degeneration. While all groups demonstrated statically significant improvement in NDI, VAS neck, VAS arm and SF-12 PCS, patients with severe disc degeneration reported significantly more improvement in SF-12 PCS (β:3.6;p=0.01) and VAS Neck (β:-1.1;p=0.01) scores compared with the mild and moderate disc degeneration groups.

Conclusions: Our data suggests that ACDF patients suffering from severe disc degeneration preoperatively report the greatest improvement in symptoms and functional status compared to patients with mild and moderate disease.

Keywords: cervical, disc degeneration, HRQOL outcomes

Introduction

Chronic neck pain is one of the leading causes of disability worldwide with recent estimates recording more than 350 million people as of 2015, a 21.1% increase since 2005.[1] While chronic neck pain can be caused by a variety of pathologies, one of the most common involves chronic degenerative changes of the cervical spine.[2,3] The surrounding muscles, ligaments, and joints can all be sources of pain in cervical degeneration; however, many studies have focused on the role of the sinuvertebral nerves at the intervertebral disc level.[4–7] In effect, degeneration of cervical intervertebral discs has been described as a potential etiology for chronic pain.[8,9]

A biomechanical study by Cloward in 1958 showed that mechanical and electrical stimulation of cervical intervertebral discs lead to the production of evoked pain potentials in sinuvertebral nerves.[10] As such, disruption of the intervertebral disc, and not just its adjacent structures, was shown as a possible source of pain radiating to the neck and arms. In addition, intervertebral disc tears have been found to be associated with neck pain, as researchers have tracked the anatomic origin of cervicogenic pain to specific sinuvertebral nerves innervating the discs directly.[11–14] While the exact pathophysiology of cervical disc degeneration is yet to be fully elucidated, there is evidence of increased matrix metalloproteinases, proinflammatory cytokines, and decreased total cell number within degenerated intervertebral disc tissues.[15–17] Additionally, clinical studies have shown cervical disc degeneration to be associated with Modic Changes (particularly Type II) and cervical spine alignment (i.e. decreased T1-slope, increased neck tilt and C2-7 sagittal vertical axis).[18,19] Considering the severity of cervical disc degeneration on radiography, in conjunction with a patient's history and physical examination, can help guide patient treatment to maximize short and long-term outcomes.

Furthermore, as the U.S. continues to place increased emphasis on value-based care, studies assessing patient perspectives and patient-reported outcomes are increasingly important for managing the clinical decision-making processes.[20] Current literature, however, is scant regarding patient-reported outcomes after anterior cervical discectomy and fusion (ACDF) in patients with varying degrees of cervical disc degeneration severity. The aim of this study was to determine if the severity of preoperative cervical disc degeneration affects health-related quality-of-life outcomes (HRQOL) following an ACDF procedure.

Materials and Methods

After Institutional Review Board approval, a retrospective cohort study was conducted in patients who underwent a one - or two-level anterior cervical discectomy and fusion (ACDF) between January 2013 and December 2017 at a single academic hospital system. All procedures were performed by one of seven fellowship-trained spine surgeons. Standardized Query Language (SQL) searches identified cohort patients by using Common Procedural Terminology (CPT) codes: 22551, 22552, 22853, 22859, and 22845. Study inclusion criteria were: 1) patients ≥18 years old, 2) underwent a primary one- or two-level ACDF procedure, and 3) available preoperative and postoperative radiographic imaging for analysis. Patients were excluded if: 1) were under the age of 18, 2) surgical intervention was performed for infection, malignancy or trauma, 3) the procedure was associated to a revision surgery, and 4) underwent combined anterior/posterior cervical fusion procedures.

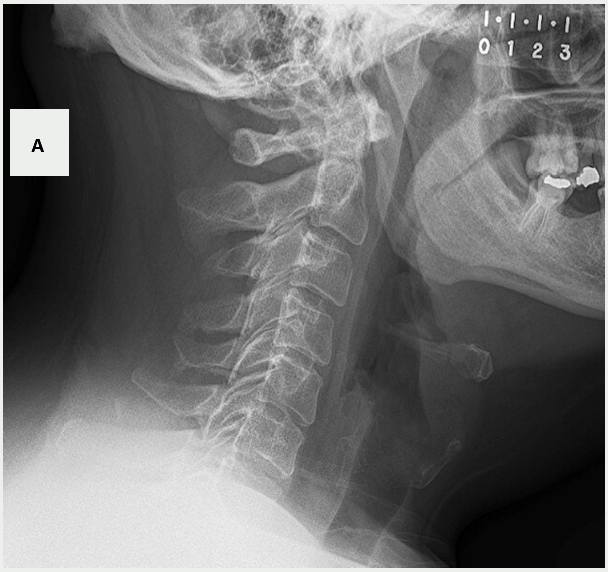
Patient Demographics, Surgical Characteristics, and Health-Related Quality-of-Life Outcomes

Patient demographic data and surgical case characteristics were obtained via SQL search and manual chart review. Demographic data of interest included: age, gender, body mass index (BMI), smoking status, and Charlson Comorbidity Index (CCI). Surgical case characteristics of interest included: preoperative diagnosis, number of levels fused, and length of follow-up. Health-related quality-of-life (HRQOL) outcomes were obtained from the OBERD software system (Columbia, MO USA) in the form of Short Form-12 Physical (PCS-12) and Mental (MCS-12) Composite Scores, Neck Disability Index (NDI), and Visual Analogue Scale (VAS) Arm and Back scores.

Radiographic Measurements and Disc Severity Score

Severity of cervical disc degeneration was scored on the 9-point system devised by Walraevens et al. based on lateral radiographs and consisting of three different parameters: 1) intervertebral disc height loss, 2) anterior osteophytes, and 3) endplate sclerosis.[21] Intervertebral disc height loss was defined as the percentage of height loss obtained by measuring the middle disc height at the index level divided by the normal middle disc height at an adjacent level (0 points = 0%, 1 point = ≤ 25%, 2 points = > 25% to ≤ 50%, 3 points = > 50% to ≤ 75%, and 4 points = > 75%). Anterior osteophytes were recorded based on the measurement of their length in relation to the length of the corresponding vertebral body (0 points = No osteophytes, 1 point = ≤ 1/8 anteroposterior vertebral body length [AP VB length], 2 points = > 1/8 to ≤ 1/4 AP VB length, and 3 points = > 1/4 AP VB length). Endplate sclerosis was defined by its visual detectability (0 points = no sclerosis, 1 point = noticeable sclerosis, 2 points = apparent sclerosis). The sum of the three parameters was then used to calculate the Disc Severity Score (degree of degeneration) as follows:

1. No cervical disc degeneration = 0
2. Mild cervical disc degeneration = 1 – 3 points (**Figure 1A)**
3. Moderate cervical disc degeneration = 4 – 6 points (**Figure 1B**)
4. Severe cervical disc degeneration = 7 – 9 points (**Figure 1C**)



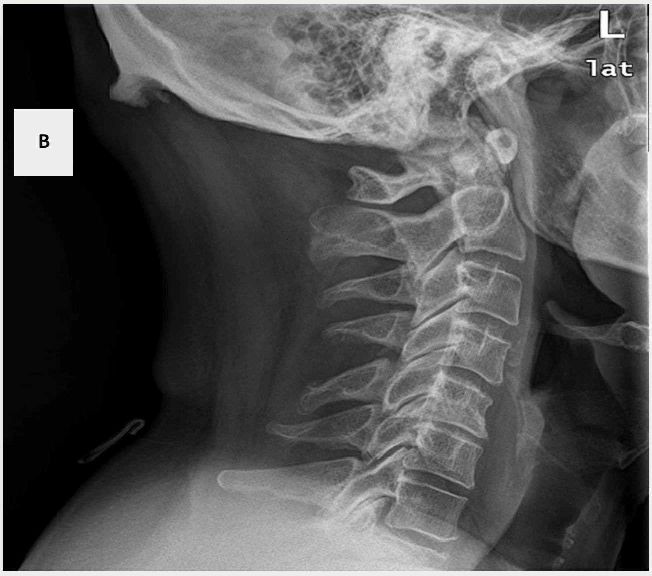
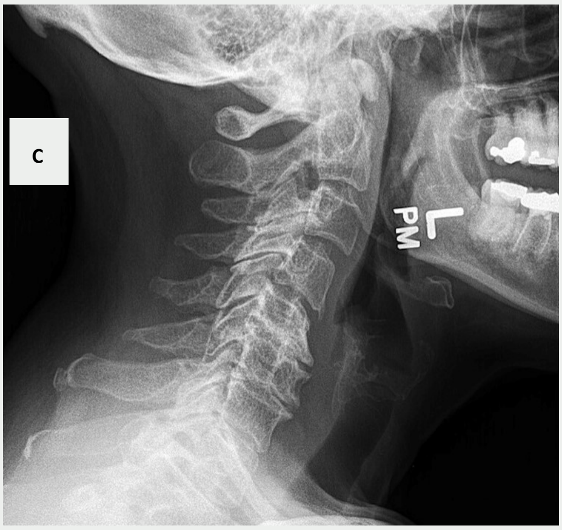


Figure 1: A) *52 year-old male with preoperative mild disc degeneration at C4-5.*

B) *61 year-old male with preoperative moderate disc degeneration at C5-6.*



C) *67 year-old female with severe disc degeneration at C5-6.*

In the case of two-level disc disease, our group used the worse of the two disc degeneration severity scores from each level in the analysis. Inter-rater reliability among measurements done by two authors (PDP, MM) for intervertebral disc height loss, anterior osteophytes, endplate sclerosis, and overall severity grade were 0.88, 0.91, 0.87, and 0.88.

Statistical Analysis

Standard descriptive statistics including proportions, means/medians, and 95% confidence intervals/interquartile ranges were reported for patient demographic data, follow-up, and HRQOL outcomes. Normally distributed data were compared using parametric tests and reported as means with 95% confidence intervals, while non-normally distributed (skewed) data were compared using non-parametric tests and reported as medians with interquartile ranges. Sample means between the three groups were compared using a parametric ANOVA test or a nonparametric Kruskal-Wallis test. Categorical data were compared using Pearson's chi-squared test (χ^2). Multivariate linear regression analysis was performed to determine the effect of severity of cervical disc degeneration, controlling for age, BMI, CCI, number of levels, and preoperative diagnosis. For all analyses, p-values less than 0.05 were considered statistically significant. All statistical analyses were performed using SPSS Statistics version 26 (IBM Corporation, Armonk, NY).

Results

Patient Demographic/Surgical Case Characteristics

Final analysis included a total of 211 patients. Twenty-seven had mild cervical disc degeneration, 100 had moderate cervical disc degeneration, and 84 had severe cervical disc degeneration (**Table 1**). Univariate analysis revealed a significant relationship between age and severity of cervical disc degeneration (p= 0.03), with patients in the mild cohort having a median age of 52.5 [49.0, 56.0] years, moderate cohort with median age of 55.5 [53.0, 58.0] years, and severe cohort with median age of 58.0 [56.0, 61.0] years. Furthermore, a significantly greater proportion of patients (p< 0.001) with severe disc degeneration had one-level fusions (75.0%), whereas the majority of mild and moderate cervical disc degeneration was seen in patients who underwent two-level fusions. No significance was appreciated between severity of cervical disc degeneration and gender, BMI, CCI, smoking status, preoperative diagnosis, and length of follow-up.

Table 1: Patient Demographics

	Mild (n = 27)	Moderate (n = 100)	Severe (n = 84)	p-value[1,2]
Age	52.5 [49.0, 56.0]	55.5 [53.0, 58.0]	58.0 [56.0, 61.0]	0.03*
Sex				0.75
Female	11 (40.7%)	48 (48.0%)	37 (44.0%)	
Male	16 (59.3%)	52 (52.0%)	47 (56.0%)	
BMI	29.7 [27.8, 31.5]	30.8 [29.6, 32.1]	28.8 [27.5, 30.1]	0.06
CCI	1.0 [0.0, 2.0]	1.5 [1.0, 3.0]	2.0 [1.0, 3.0]	0.26
Smoking Status				0.83
Never	15 (55.6%)	63 (63.0%)	55 (65.5%)	
Former	8 (29.6%)	25 (25.0%)	17 (20.2%)	
Current	4 (14.8%)	12 (12.0%)	12 (14.3%)	
Preoperative Diagnosis				0.17
Myelopathy	6 (22.2%)	39 (39.0%)	33 (39.3%)	
Radiculopathy	20 (74.1%)	53 (53.0%)	49 (58.3%)	
Myeloradiculopathy	1 (3.7%)	8 (8.0%)	2 (2.4%)	
Number of Levels Fused				< 0.001*
1	7 (25.9%)	31 (31.0%)	63 (75.0%)	
2	20 (74.1%)	69 (69.0%)	21 (25.0%)	
Follow-Up (Months)	15.8 [12.9, 18.7]	16.4 [14.5, 18.3]	15.9 [13.9, 17.9]	0.80

[1] *Independent-samples t-test or Mann-Whitney U test for Age, BMI, CCI, Follow-Up*
[2] *Pearson chi-squared test for Gender, Smoking Status, Preoperative Diagnosis, Number of Levels Fused*
** Significance established at p < 0.05*

BMI: Body Mass Index, CCI: Charleson Comorbidity Index

HRQOL Outcomes and Severity of Cervical Disc Degeneration

PCS-12 delta (change in PCS-12 score from the preoperative to postoperative time periods) showed a significant increase with increasing severity of cervical disc degeneration (p= 0.02), with mild patients reporting an improvement of 3.6 points, moderate patients reporting a 4.9-point improvement, and severe patients reporting a 9.4-point improvement at final follow-up (**Table 2**). Multiple linear regression analysis showed a similar significant difference among the three groups (β: 3.6; p= 0.01).

Furthermore, a significant relationship was observed among mild, moderate, and severe disc degeneration groups with respect to postoperative VAS Neck (2.4 vs. 1.5 vs. 0.8, respectively; p= 0.002) and VAS Neck delta (-2.6 vs. -3.8 vs. -4.6, respectively; p= 0.04) scores at final follow-up. These findings were further corroborated by regression analysis showing a significant relationship among the three groups (β: -1.1; p= 0.004). Patients within each cohort reported significant perioperative improvement in all HRQOL parameters, with the exception of MCS-12 scores in the mild and moderate cohorts.

Table 2: Patient-Reported Outcomes Stratified by Severity of Disc Degeneration

	Mild (n = 27)	**Moderate (n = 100)**	**Severe (n = 84)**	**p-value**	**Regression Analysis[1]**
PCS-12					
Pre-Op	35.1 [32.0, 38.3]	34.8 [32.9, 36.7]	33.5 [31.0, 35.9]	0.78	β: 3.6 [1.1, 6.1] p-value: 0.01*
Post-Op	38.6 [34.8, 42.4]	39.1 [36.8, 41.3]	42.4 [39.8, 45.0]	0.11	
Delta	3.6 [-0.1, 7.3]	4.9 [2.5, 7.4]	9.4 [6.6, 12.1]	0.02*	
p-value[2]	0.046*	< 0.001*	< 0.001*		
MCS-12					
Pre-Op	51.3 [46.7, 55.9]	50.3 [47.9, 52.5]	49.9 [46.9, 52.9]	0.88	β: 2.6 [-0.5, 5.8] p-value: 0.10
Post-Op	50.1 [44.9, 55.4]	50.2 [47.7, 52.8]	53.9 [51.5, 56.3]	0.12	
Delta	-2.4 [-8.1, 3.2]	0.9 [-2.0, 3.9]	3.8 [0.2, 7.3]	0.27	
p-value[2]	0.78	0.31	0.03*		
NDI					
Pre-Op	42.3 [34.7, 49.9]	40.3 [35.8, 44.7]	38.6 [33.7, 43.4]	0.70	β: -1.4 [-6.1, 3.3] p-value: 0.54
Post-Op	28.7 [16.7, 40.7]	33.7 [23.4, 43.9]	20.2 [10.9, 29.6]	0.17	
Delta	-18.0 [-23.8, -12.1]	-17.2 [-21.6, -12.7]	-19.9 [-26.4, -13.4]	0.73	
p-value[2]	0.01*	< 0.001*	0.002*		
VAS Neck					
Pre-Op	5.4 [4.4, 6.4]	5.3 [4.7, 6.0]	5.3 [4.6, 5.9]	0.97	β: -1.1 [-1.9, -0.4] p-value: 0.004*
Post-Op	2.4 [1.4, 3.5]	1.5 [0.9, 2.0]	0.8 [0.4, 1.1]	0.002*	
Delta	-2.6 [-3.9, -1.3]	-3.8 [-4.7, -2.9]	-4.6 [-5.3, -3.8]	0.04*	
p-value[2]	0.002*	< 0.001*	< 0.001*		
VAS Arm					
Pre-Op	6.2 [5.4, 7.0]	5.0 [4.4, 5.7]	4.9 [4.2, 5.6]	0.21	β: -0.3 [-1.1, 0.4] p-value: 0.39
Post-Op	3.5 [2.2, 4.8]	2.7 [2.1, 3.4]	2.1 [1.4, 2.7]	0.07	
Delta	-2.9 [-4.1, -1.7]	-3.0 [-3.9, -2.1]	-3.2 [-3.9, -2.4]	0.97	
p-value[2]	0.001*	< 0.001*	< 0.001*		

[1] Independent-samples t-test or Mann-Whitney U test

[2] Paired-sample t-test or Wilcoxon Rank sum test

[3] Multiple linear regression controlling for age, BMI, CCI, number of levels, preoperative diagnosis

** Significance established at p < 0.05*

PCS-12: Physical Component of SF-12, MCS-12: Mental Component of SF-12, ODI: Oswestry Disability Index, VAS: Visual Analog Scale

Discussion

Neck pain has been cited as one of the leading causes of disability around the world, with an increasing prevalence rate over the past few years.[1] While numerous etiologies can be attributed to neck pain, a combination of history, physical examination, and radiographic findings can help guide non-operative or operative management. As the United States healthcare system moves towards a value-based care reimbursement model, physicians and administrators are placing increased emphasis on patient perspectives and outcomes.[22,23] The current study focused on health-related quality-of-life outcomes in patients of varying degrees of cervical disc degeneration after ACDF interventions.

Our results suggest that as cervical disc degeneration increases in severity, patients report significantly higher levels of perioperative improvement in VAS Neck and PCS-12 scores following ACDF. These parameters appear to correlate with patient perspectives of their neck pain and overall health, respectively.[24,25] These observations are concordant with previously published reports.[26–28] In a retrospective study by Wang et al. segmental instability at the superior adjacent vertebrae, as well as static spinal cord compression from bony elements and dynamic compression from increased mobility at the superior adjacent vertebrae, were reported as factors associated with severe cervical disc degeneration.[29] The authors note that the anterior nature of the pathology allows ACDF to be particularly effective in these cases, as it provides an approach to help remove osteophytes and disc segments contributing to cord compression. Furthermore, removing herniated disc fragments and fusing the corresponding segments help address dynamic causes of spinal cord compression, as well as provide stability to the region.[30,31] Based on our findings, mild and moderate forms of cervical disc degeneration appear to have fewer of these degenerative factors, while patients with severe disc degeneration often experience all of them, and to a relatively greater degree. As such, these patients are likely to exhibit greater relative improvement compared to milder cases, largely due to the greater degree of relief provided by an ACDF procedure. Guidelines for surgical management of patients presenting with radiculopathy, which can be attributed to cervical disc degeneration, have often been advocated in patients with moderate to severe symptoms that are progressive in nature or unresponsive to 6 weeks of conservative therapy.[32–34] While our study shows patients with severely symptomatic degenerative disc disease clearly benefit from the bony decompression and increased distraction of the intervertebral space after ACDF, the improvement noted in patients with mild and moderate disc disease shows the procedure can also be of value in symptomatic patients with even mild findings.

It is important to note that while a variety of degenerative disc classification systems exist, a goal standard is yet to be identified. Current cervical disc degeneration grading systems utilize different imaging modalities such as radiographs, MRIs, and discography.[35] A study by Miyazaki et al. reported MRI to be the most sensitive method of detecting cervical disc pathology, developing a grading system based on: 1) signal intensity of the nucleus pulposus, 2) structure of the nucleus pulposus, 3) distinction between nucleus pulposus and annulus fibrosus, and 4) intervertebral disc height.[36] More recently, Suzuki et al. improved upon this system and developed an MRI grading scheme based on the previous four factors, with the addition of disc bulge/herniation as a factor.[37] Subsequently, their study reported a relatively higher intra- and inter-rater reliability compared to the Miyazaki system. While these systems can truly be useful for clinical and research purposes, currently, no universally accepted system exists to assess severity of cervical disc degeneration. Our study uses the Walraevens system due to its relatively high inter-rater and intra-rater reliability (ICC: 0.78 and 0.86, respectively). Furthermore, due to the widespread use of plain radiography in clinics, it can be correlated clinically more readily when compared to more selective, expensive imaging modalities (i.e. CT and MRI). Nevertheless, the development of a more standardized grading system is still necessary to facilitate communication between providers and investigators in a precise and reliable fashion.

While the present study provides information about clinical outcomes in the context of varying degrees of degenerative disc disease severity, it does come with limitations. First, as a retrospective cohort study, there are inherent selection and information biases with the inclusion of certain patient populations, as well as patients lost to follow-up and misclassifications due to possible errors in categorization. Furthermore, confounding variables and/or recall bias may lead to limitations as well. For instance, a significant difference was noted between severity of disc degeneration and levels fused, with patients suffering from more severe disc degeneration undergoing a higher proportion of one-level fusions compared to those with mild degeneration, in whom 2-level fusions were noted more frequently. This observation could be explained by the cohort's limited sample size of only one- and two-level fusion patients, as well as surgeon practice preference for reducing the risk of development of ASD by deferring multilevel fusions in patients with increased likelihood of ASD. To address this, our study utilized regression analysis, controlling for pertinent demographic/surgical characteristics to lessen the effects of confounding. Second, small sample sizes, particularly in the mild cervical disc degeneration group, can be suboptimal

Finally, the Walraevens classification system relied on lateral cervical radiographs, however correlation with MRI findings would provide additional information regarding the severity of disease. Clinical practice and the retrospective nature of this study prevented an adequate evaluation of radiographic and MRI findings together, although future studies utilizing both imaging modalities can provide further insight into the relationship between cervical disc degeneration and clinical/functional outcomes.

Conclusions

Overall, our study suggests patients with severe cervical disc degeneration report significantly greater improvement in HRQOL outcomes compared to patients with mild or moderate disease. These results highlight the efficacy of surgical intervention in patients with varying levels of cervical disc degeneration, and provide surgeons another consideration when determining management options for patients with cervical disc-related pain.

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