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Impact of age within younger populations on outcomes following cervical surgery in the ambulatory setting

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ABSTRACT

Objective: To determine the effect of age within the younger population seen at ambulatory surgical centers on patient-reported outcome measures (PROMs) after cervical spine surgery.
Methods: Patients of age <65 years undergoing single-level anterior cervical discectomy and fusion (ACDF) or cervical disc replacement (CDR) were included. Patients were divided by mean age of initial population (46 years). PROMs included Patient-reported Outcome Measurement Information System Physical Function (PROMIS-PF), 12-Item Short-Form Physical Component Survey (SF-12 PCS), Visual Analog Scale (VAS) neck, VAS arm, Neck Disability Index (NDI) collected preoperatively and at postoperative time points up to 2 years.
Results: 138 patients were included, with 66 patients <46 years. Both cohorts demonstrated improvement from preoperative baseline with regard to all studied PROMs at multiple time points postoperatively ($p \leq 0.042$, all). Between groups, the older cohort demonstrated greater mean PROMIS-PF scores preoperatively and at 6 weeks ($p \leq 0.011$, both), while VAS arm scores were lower in the older group at 1 year ($p = 0.002$), and NDI scores were lower in the older group at 6 weeks and 1 year ($p < 0.027$, both). Minimal Clinically Important Difference (MCID) achievement rates were greater in the younger group in PROMIS PF at 2 years ($p = 0.002$), and in the older group in VAS arm score at 1 year ($p = 0.007$).
Conclusion: Both cohorts showed significant improvement at multiple postoperative time points for all PROMs. Between groups, the older group reported more favorable physical function, VAS arm, and NDI scores at several time points. However, MCID achievement rates only significantly differed in two PROMs at singular time points. Difference in age in patients <65 years likely does not significantly affect long-term outcomes after cervical spine surgery.
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1. Introduction

The rate of spine procedures performed on an annual basis has seen steady increase over the past several decades.[1–4] Regarding cervical spine surgery alone, multiple studies have cited drastic increase in procedure rates, with one study reporting an almost 7-fold increase in spinal fusions as indicated for degenerative cervical spine disease from the 1993 to 2002 period.[2,3] While cervical spine procedures have increased, utilization of ambulatory surgical centers (ASCs) for these procedures has escalated even more dramatically.[2,4] In a retrospective study of the management of patients with degenerative cervical spine disease across four states, there was a 60.5% increase in cervical procedures performed at an ASC per capita from 2005 to 2009, while the same procedures only increased by 8.7% per capita in the inpatient setting during the same period.[4] While the increase in ASC utilization may be attributed to a variety of factors, including cost-benefit and productivity, such a dramatic increase in popularity demands further study of the patient population encountered in the ASC setting.[4,5]

Age is a commonly studied demographic in surgical populations, in which its use as a prognostic factor has been extensively studied in a variety of surgical fields, including spine surgery. However, there is inherent selection bias regarding age in populations

Abbreviations: ACDF, anterior cervical discectomy and fusion; CDR, cervical disc replacement; PROM, patient-reported outcome measure; MCID, minimum clinically important difference.

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selected for ambulatory surgical care, also known as outpatient care, in which we see a significantly younger population on average compared to traditional inpatient care.[5] In 2006, 79.3% of patients receiving outpatient surgical care for musculoskeletal conditions presented between the ages of 15–64, while only 17.0% of patients presented older than the age of 65.[6] With this younger population comprising a greater than 4-fold portion of the ASC setting compared to those above 65 years of age, it is imperative to investigate how outcomes differ with further stratification of age in this younger population.[6] The goal of this study is to evaluate the potential relationship that age may play in this younger demographic in regard to commonly evaluated outcome measures to allow surgeons to more effectively manage expectations in the preoperative stage.

2. Methods

2.1. Patient population

Informed consent was obtained for all patients following Institutional Review Board approval (ORA #14051301) for this study. Data was obtained through search of a prospectively-maintained, retrospective database of spine surgery patients from a single-surgeon in association with a single academic institution. Patients were included if they were under the age of 65 years at time of surgery and had undergone either a single-level ACDF or CDR indicated due to herniated nucleus pulposus. Patients with other indications for surgery, specifically acute trauma, infection, or malignancy, were excluded. The resulting population was then divided into two cohorts by the mean age of the total population, 46 years. The younger cohort was defined as those less than 46 years of age at time of surgery, while the older cohort was defined as those greater than or equal to 46 years of age at time of surgery.

2.2. Data collection

Demographics collected for both cohorts included age, female or male gender, ethnicity (Caucasian, African-American, Hispanic, Asian, or other), comorbidities (diabetic status, body mass index [BMI], smoking status, hypertension status, American Society for Anesthesiologists [ASA] classification, Charlson Comorbidity Index [CCI] score) and insurance provider (Medicare/Medicaid, Workers' Comp versus Private). Both cohorts' perioperative characteristics were collected and analyzed, including prevalence of central and foraminal stenosis, operative time in minutes (min), estimated blood loss in milliliters (mL), length of stay in hours, postoperative visual analog scale (VAS) reported pain, and postoperative narcotic consumption in oral morphine equivalents (OME). Patient-reported outcome measures (PROMs) were collected during the preoperative period and at several postoperative time points, including 6 weeks, 12 weeks, 6 months, and 1 year, and 2 years after surgery. Outcome measures studied included Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS PF) and 12-item Short Form Physical Component Score (SF-12 PCS) to evaluate physical function, Neck Disability Index (NDI) scores to evaluate disability, and VAS neck and VAS arm pain scores to evaluate pain.

2.3. Statistical analysis

All analysis of observed findings was conducted utilizing Stata 16.0 (StataCorp LP, College Station, TX) software. Demographic and perioperative characteristics were compared between cohorts utilizing chi-square tests and independent sample t-tests for categorical and continuous variables respectively. Paired t-tests were used for comparison of preoperative and postoperative mean PROM scores within each cohort. Independent t-tests were used to compare mean PROM scores between cohorts at each time point. Achievement rate of minimum clinically important difference (MCID) was determined by comparison of the degree of change between preoperative and postoperative mean PROM scores within each cohort to predetermined threshold values established within the literature, noted as: 4.5 for PROMIS PF, 8.1 for SF-12 PCS, 8.5 for NDI, 2.6 for VAS neck pain, and 4.1 for VAS arm pain.[7,8] Comparison of rate of MCID achievement between cohorts was conducted with chi-square analyses. For all analyses performed, a p-value cutoff of less than 0.05 was utilized as the threshold to denote significance.

3. Results

3.1. Descriptive analysis

A total of 138 patients were identified that met the parameters of this study. After division of the cohorts, 66 patients were found to be less than 46 years of age at the time of operation with 72 patients greater than or equal to 46 years of age at time of surgery. The majority of patients were male (64.5%), Caucasian (73.1%), and had private insurance (62.2%) (Table 1). Of the demographic data collected, the cohorts only significantly differed in ASA classification, with a majority of the older cohort reporting a score greater than or equal to two (80.7%, compared to 44.0% in the younger cohort; $p < 0.001$), and CCI score, with the older cohort reporting an elevated mean score (1.1) when compared to the younger cohort (0.5) ($p = 0.005$) (Table 1). Per study design, all patients presented with an indication of herniated nucleus pulposus. The older cohort was observed to experience a higher prevalence of central stenosis (47.1% compared to 23.1% in the younger cohort; $p = 0.004$) (Table 2). Sixty-five and 73 patients underwent ACDF and CDR, respectively. No significant differences were noted between cohorts for the type of procedure (Table 2). No other perioperative characteristics observed differed significantly between the two cohorts.

3.2. Primary outcome measures

PROMs chosen for this study were collected and analyzed in Table 3. Both cohorts showed significant improvement in postoperative PROMIS PF scores when compared to their mean preoperative scores at all time points at and after 12 weeks up to 2 years ($p \leq 0.029$, all) (Table 3). The older cohort did have significantly higher PROMIS PF scores at the preoperative and 6-week time points compared to the younger cohort ($p \leq 0.011$, both) (Table 3). Regarding mean SF-12 PCS scores, both cohorts showed significant improvement at two postoperative time points when compared to their preoperative scores, 12-week and 6-month marks for the younger cohort, and 6-week and 1-year marks for the older cohort ($p \leq 0.042$, all) (Table 3). Regarding VAS neck scores, the younger cohort showed significant improvement in mean scores for all postoperative time points prior to the 2-year mark when compared to the preoperative mean score ($p \leq 0.025$, all) (Table 3). The older cohort showed significant improvement in mean scores for VAS neck pain for all postoperative time points measured when compared to their preoperative baseline score ($p \leq 0.015$, all) (Table 3). No significant difference between mean VAS neck pain scores was found between groups at any time point studied. For the younger population, mean VAS arm pain scores were significantly improved from the preoperative period up to and including the 6-month time point, after which time significance was no longer seen ($p < 0.001$, all) (Table 3). The older cohort saw significant improvement in mean VAS arm pain scores extending to the 1-year mark but did not see significance at the 2-year time point

Table 1
Patient demographics.

Characteristic	Total(n = 138)	Age <46(n = 66)	Age ≥46(n = 72)	*p-value
Age (mean ± SD, years)	45.2 ± 9.3	37.0 ± 5.3	52.7 ± 4.8	<0.001
Gender				0.139
Female	35.5% (49)	29.2% (19)	41.4% (29)	
Male	64.5% (89)	70.8% (46)	58.6% (41)	
Ethnicity				0.942
Caucasian	73.1% (98)	72.3% (47)	73.9% (51)	
African-American	9.0% (12)	7.3% (5)	10.8% (7)	
Hispanic	12.7% (17)	12.3% (8)	13.0% (9)	
Asian	2.2% (3)	1.5% (1)	2.9% (2)	
Other	3.0% (4)	3.1% (2)	2.9% (2)	
Diabetic Status				0.940
Non-Diabetic	97.0% (131)	96.9% (63)	97.1% (68)	
Diabetic	3.0% (4)	3.1% (2)	2.9% (2)	
BMI (mean ± SD, kg/m^2)	28.6 ± 4.78	28.2 ± 5.1	28.9 ± 4.5	0.374
Smoking Status				0.377
Non-Smoker	85.8% (115)	83.1% (54)	88.4% (61)	
Smoker	14.2% (19)	16.9% (11)	11.6% (8)	
Hypertension Status				0.272
Non-hypertensive	85.8% (115)	89.2% (58)	82.6% (57)	
Hypertensive	14.2% (19)	10.8% (7)	17.4% (12)	
ASA Classification				**<0.001**
<2	36.5% (39)	56.0% (28)	19.3% (11)	
≥2	63.5% (68)	44.0% (22)	80.7% (46)	
CCI Score (Mean ± SD)	0.73 ± 0.6	0.5 ± 0.6	1.1 ± 1.13	**0.005**
Insurance Type				0.075
Medicare/Medicaid	1.5% (2)	0.0% (0)	2.9% (2)	
Workers' Comp	36.3% (49)	44.6% (29)	28.6% (20)	
Private	62.2% (84)	55.4% (36)	68.6% (48)	

BMI = body mass index; CCI = Charlson Comorbidity Index; ASA = American Society of Anesthesiologists; SD = standard deviation; Workers' Comp = workers' compensation.
Boldface indicates significance.
*p-values calculated using Student's t-test for continuous variables and chi-square analysis for categorical variables.

Table 2
Perioperative characteristics.

Characteristic	Total(n = 138)	Age <46(n = 66)	Age ≥46(n = 72)	*p-value
Spinal Pathology				
Herniated Nucleus Pulposus	100% (135)	100% (60)	100% (70)	–
Central Stenosis	35.6% (48)	23.1% (15)	47.1% (33)	**0.004**
Foraminal Stenosis	20.7% (28)	20.0% (13)	21.4% (15)	0.608
Myeloradiculopathy	87.5% (119)	89.1% (57)	86.1% (62)	0.603
Surgical Procedure				0.320
ACDF	47.1% (65)	51.5% (34)	43.1% (31)	
CDR	52.9% (73)	48.5% (32)	56.9% (41)	
Operative Time(Mean ± SD; min)	48.7 ± 10.2	47.9 ± 7.4	49.6 ± 12.4	0.344
Estimated Blood Loss(Mean ± SD; mL)	27.0 ± 7.0	27.2 ± 7.6	26.7 ± 6.3	0.678
Length of Stay (Mean ± SD; hours)	6.0 ± 2.8	5.7 ± 1.7	6.4 ± 3.6	0.220
Postoperative Vas pain POD 0	4.5 ± 2.3	4.5 ± 2.1	4.6 ± 2.4	0.922
Postoperative Narcotic Consumption POD 0	20.4 ± 16.6	18.6 ± 14.9	22.1 ± 18.0	0.227

ACDF = anterior cervical discectomy and fusion; CDR = cervical disc replacement; POD = postoperative day; mL = milliliters; SD = standard deviation.
Boldface indicates significance.
*p-values calculated using Student's t-test for continuous variables and chi-square analysis for categorical variables.

($p \leq 0.007$, all) (Table 3). When compared to the younger cohort, the older cohort had significantly lower VAS arm pain scores at the 1-year period ($p = 0.002$) (Table 3). Both cohorts saw significant improvement in mean NDI scores at all postoperative time points measured when compared to their baseline measures in the preoperative period ($p \leq 0.013$, all) (Table 3). The older cohort noted significantly lower mean NDI scores at the 6-week and 1-year time points when compared to the younger population ($p \leq 0.027$, both) (Table 3). Overall MCID achievement rates for each PROM studied were greater than or equal to 44.4% (Table 4). The younger cohort saw significantly greater MCID achievement for PROMIS PF score at the 2-year time point; however, the older cohort had significantly greater MCID achievement for VAS arm pain scores at the 1-year time point ($p \leq 0.007$, both) (Table 4). No other significance was found between groups for MCID achievement at any other time point.

4. Discussion

4.1. Literature cross-analysis

Utilization of ASCs for elective surgery has greatly affected the landscape of elective surgery over the past two decades. Spine surgery alone saw a greater than 5-fold increased rate of ASC use from 1994 to 2006, with prevalence of cervical spine surgery in ASC increasing 7-fold compared to the rate of inpatient cases.[4,5] While cost-benefit analyses are routinely cited, one of the factors contributing to this shift is likely the multitude of data demonstrating the safety of common cervical spine procedures, most notably the anterior cervical discectomy and fusion (ACDF).[9–11]

Table 3
Mean patient reported outcomes.

PROM	Age <46 Mean ± SD	*p-value	Age ≥46 Mean ± SD	*p-value	†p-value
PROMIS PF					
Preoperative	38.3 ± 6.3	–	41.9 ± 7.0	–	**0.011**
6-week	38.6 ± 7.0	0.924	45.3 ± 8.2	0.212	**0.001**
12-week	46.4 ± 8.3	**<0.001**	47.4 ± 12.3	**0.009**	0.687
6-month	46.2 ± 10.7	**<0.001**	50.2 ± 11.7	**<0.001**	0.237
1-year	47.2 ± 9.4	**0.029**	52.8 ± 6.4	**0.004**	0.083
2-year	49.1 ± 12.6	**0.001**	41.4 ± 4.3	**0.024**	0.956
SF-12 PCS					
Preoperative	34.2 ± 8.4	–	35.0 ± 9.1	–	0.664
6-week	34.3 ± 7.7	0.822	37.5 ± 8.5	**0.037**	0.091
12-week	40.9 ± 10.9	**0.010**	40.1 ± 12.0	0.204	0.755
6-month	43.5 ± 10.1	**<0.001**	40.8 ± 9.7	0.074	0.366
1-year	43.2 ± 12.5	0.083	44.9 ± 10.3	**0.042**	0.674
2-year	42.8 ± 12.2	0.118	38.0 ± 13.7	0.222	0.406
VAS neck					
Preoperative	6.5 ± 2.1	–	6.1 ± 2.3	–	0.238
6-week	3.9 ± 2.3	**<0.001**	3.2 ± 2.8	**<0.001**	0.197
12-week	2.6 ± 2.2	**<0.001**	2.4 ± 2.6	**<0.001**	0.765
6-month	2.8 ± 2.3	**<0.001**	2.4 ± 2.7	**<0.001**	0.458
1-year	3.9 ± 2.6	**0.025**	3.2 ± 3.4	**0.014**	0.481
2-year	3.8 ± 3.5	0.211	4.0 ± 2.7	**0.015**	0.901
VAS arm					
Preoperative	5.9 ± 2.5	–	6.0 ± 2.6	–	0.850
6-week	2.8 ± 2.6	**<0.001**	2.3 ± 2.6	**<0.001**	0.389
12-week	2.5 ± 3.0	**<0.001**	3.1 ± 3.3	**<0.001**	0.372
6-month	3.0 ± 2.8	**<0.001**	3.1 ± 3.1	**<0.001**	0.891
1-year	4.6 ± 2.6	0.443	1.8 ± 1.9	**0.007**	**0.002**
2-year	2.5 ± 3.4	0.338	3.8 ± 3.9	0.208	0.518
NDI					
Preoperative	45.0 ± 19.2	–	40.2 ± 16.5	–	0.147
6-week	36.9 ± 18.6	**0.013**	27.5 ± 21.2	**<0.001**	**0.027**
12-week	25.6 ± 19.1	**<0.001**	22.7 ± 23.0	**<0.001**	0.527
6-month	23.8 ± 17.8	**<0.001**	21.9 ± 22.2	**<0.001**	0.679
1-year	27.4 ± 19.6	**0.002**	11.2 ± 14.2	**<0.001**	**0.016**
2-year	24.2 ± 28.6	**0.012**	22.2 ± 20.3	**0.008**	0.881

Boldface indicates significance.
*p-values calculated using paired sample *t*-test to determine preoperative to postoperative improvement.
†p-values calculated using Student's t-test to compare mean PROMs between both cohorts.

Many prior studies have established the safety and efficacy of ACDF performed at an ASC, even in cases of three- or four-level fusions, finding no increased complication or readmission rates in these cohorts.[9–17] Cervical disc replacement (CDR) has garnered attraction recently as an alternative to ACDF due to the preservation of motion with comparable outcomes.[18] Several studies have found CDR to be equivalent to, if not superior to, ACDF for single-level disease due to motion preservation, improved disability scores, and decreased risk of adjacent segment disease in long-term follow-up.[18–21] While additional studies may be beneficial to continue demonstrating the efficacy of CDR in comparison to ACDF, especially in the ambulatory setting, the rising prominence of CDR necessitated its inclusion within this study.

With increased ASC utilization for many orthopaedic surgical procedures, there has been a shift in demographics compared to traditional inpatient care. One of the most notable demographic changes seen in the outpatient setting is a decreased mean age, with Crawford et al. (2015) reporting the largest demographic of individuals undergoing orthopaedic surgery at an ASC to be between 45 and 64 years of age.[22] Cullen at al. (2009) reported patients undergoing any orthopaedic surgery at an ASC to be four times as likely to be younger than 65 years of age instead of older.[6] Similarly, in several studies of ACDF safety in ASC discussed prior, the authors routinely reported that the inpatient cohorts were significantly older compared to their ASC counterparts, with Baird et al. (2014) reporting patients greater than 70 years of age to account for only 2.5% of all cases in the outpatient setting.[4,9,11] While the general effect of age on surgical outcomes has been studied extensively, the selection bias for younger patients for outpatient surgery warrants further evaluation of the effect that age plays within this new demographic to guide surgeons in patient selection as well as management of patient expectations.

Prior studies have evaluated age in cervical surgery in both inpatient and outpatient settings, with the majority finding age greater than 65 years to be an independent risk factor for worse postoperative outcomes along with greater complication rates.[2,16,17,23,24] Two studies contrasted this data, with Chotai et al. (2017) reporting equivalent outcomes for both cohorts divided by age at 65 years and Scerrati (2021) finding age to not be an independent risk factor for functional outcomes specifically after ACDF.[25,26] One study conducted by Hirvonen et al. (2020) studied a younger population, adults age 18–40 years, and reported high rates of long-term, greater than 90% patient follow-up at 12 years, satisfaction after ACDF with persistently improved NDI scores.[27] However, this study did not have an older cohort to which the younger patients were compared. During review of the literature in recent years, only three studies regarding cervical spine surgery were identified that stratified patients by age beyond a single cut-off of 65 years. Lee et al. (2020) studied differences in elderly patients with cohorts separated into those 65–74 years of age and those age 75 or older, finding no difference between groups after ACDF regarding VAS pain scores, NDI score, or Odom's criteria.[28] Croci et al. (2022) separated their patients into three groups: young (<65 years), early elderly (65–74 years), and late elderly (≥75 years) and found the young patients to have worse significantly worse VAS pain and NDI scores preoperatively and at three

Table 4
Minimum clinically important difference.

PROM	Age <46%, (n)	Age ≥46%, (n)	*p-value
NDI			
6-week	37.8% (14)	54.2% (26)	0.135
12-week	100.0% (55)	100.0% (58)	–
6-month	71.8% (28)	72.7% (24)	0.930
1-year	55.6% (10)	69.2% (9)	0.440
2-year	85.7% (6)	100.0% (6)	0.335
Overall	48.7% (55)	51.8% (59)	0.332
PROMIS PF			
6-week	35.7% (10)	33.3% (8)	0.857
12-week	60.7% (17)	50.0% (12)	0.438
6-month	63.6% (14)	72.2% (13)	0.564
1-year	60.0% (9)	60.0% (6)	1.000
2-year	75.0% (9)	0.0% (0)	**0.002**
Overall	55.6% (30)	44.4% (24)	0.257
SF-12 PCS			
6-week	18.8% (6)	30.3% (10)	0.280
12-week	31.3% (10)	28.0% (7)	0.790
6-month	50.0% (13)	41.2% (7)	0.571
1-year	35.3% (6)	36.4% (4)	0.954
2-year	40.0% (4)	50.0% (4)	0.671
Overall	57.5% (23)	42.5 (17)	0.483
VAS neck			
6-week	41.5% (17)	49.0% (24)	0.476
12-week	70.2% (33)	62.8% (27)	0.456
6-month	65.1% (28)	66.7% (22)	0.888
1-year	31.6% (6)	53.9% (7)	0.208
2-year	62.5% (5)	50.0% (3)	0.640
Overall	54.4% (43)	45.6%	0.129
VAS arm			
6-week	35.0% (14)	44.7% (21)	0.359
12-week	43.2% (19)	40.0% (16)	0.768
6-month	30.8% (12)	40.0% (12)	0.425
1-year	10.5% (2)	53.9% (7)	**0.007**
2-year	42.7% (3)	20.0% (1)	0.408
Overall	52.7% (29)	47.3% (26)	0.782

Boldface indicates significance.
*p-values calculated using chi-square analysis.

and twelve months postoperative compared to the two older cohorts.[29] Further, NDI and VAS arm pain scores improved significantly more in the two older groups at the three-month period; however, overall MCID achievement was greater in VAS arm and NDI for younger patients.[29] These mixed findings appear to indicate that while younger patients may present in a poorer preoperative state regarding outcome measures, the younger cohort saw greater effect overall from surgical intervention compared to their older cohorts, while the older cohorts still saw significant improvement as well in the short-term. However, this study is still limited in application to ambulatory surgical center demographics as no stratification of patient age occurred beneath 65 years of age.

Only one study regarding cervical surgery, conducted by Omidi-Kashani et al. (2014), was found to stratify this younger population, separating patients into two groups by those younger than 45 years of age and those 45 years of age or older.[30] While not statistically significant, the younger group was reported to have lower VAS pain and NDI scores preoperatively compared to the older cohort.[30] Both groups reported significant improvement in VAS pain and NDI scores at time of last postoperative follow-up, time not specified; however, the older cohort demonstrated significantly greater improvement in NDI scores compared to the younger cohort and additionally, while not significant, did show greater improvement in VAS pain score.[30] While this study did not directly report changes in physical function, improvement in NDI score has been strongly correlated with improvement in PROMIS PF score.[31]

In our study, we found both cohorts to have significant improvement in all outcome measures evaluated when compared to their preoperative baseline scores at least two or more postoperative time points. Regarding physical function, the younger cohort (age <46 years) showed significant improvement in mean PROMIS PF scores from preoperative baseline at all time points after and including 12 weeks. The older cohort (age ≥46 years) was observed to have similar findings, with significant improvement in mean PROMIS PF scores from the 12-week time point onward, continuing to the 2-year mark. Utilizing the correlation between NDI score and PROMIS PF, these results are similar to those seen in the study conducted by Omidi-Kashani et al. (2014).[30] In contrast to their study, our younger cohort was observed to have significantly lower PROMIS PF scores at the preoperative and 6-week postoperative periods compared to the older cohort. While both cohorts showed improvement in SF-12 PCS score in all postoperative time points, significance was only found at two-time points for each cohort: 12-week and 6-month periods for the younger cohort, 6-week and 1-year time points for the older cohort. In light of the diffuse significance seen in PROMIS PF score improvement, the lack of significance seen in SF-12 PCS score may be due to lack of power from loss to follow-up. MCID achievement in PROMIS PF significantly differed between cohorts at the 2-year time point in favor of the younger cohort; however, no significant differences were noted at any other time points in PROMIS PF or any time points regarding SF-12 PCS.

Regarding pain, both groups showed significant improvement in VAS neck and arm scores at many postoperative time points compared to their preoperative baseline scores. The younger cohort saw significant improvement at all postoperative time points, excluding the 2-year mark. Significance was not noted at the 2-year mark; however, the score reported was still lower than those seen in the preoperative, 6-week, and 1-year periods, leading us to conclude that lack of significance was primarily due to loss to follow-up. Similarly, the older cohort showed significant improvement in VAS neck score at all postoperative time points including the 2-year mark. Correlating results were found for VAS arm scores for both cohorts, showing significant improvement up to 6 months in the younger cohort and up to 1 year in the older cohort. In contrast to the study by Omidi-Kashani et al. (2014), the older cohort showed significantly lower mean VAS arm score at the 1-year time point compared to the younger cohort.[30] MCID achievement differed significantly in VAS arm scores in favor of the older group at the 1-year time point, but no significant difference in achievement rate was noted at any other time point for either VAS pain score.

Regarding disability, similar to the Omidi-Kashani et al. (2014) study, both cohorts showed significant improvement in NDI score at all postoperative time points continuing to final follow-up at 2 years.[30] Additionally, the older cohort showed significantly lower mean NDI scores than the younger cohort at the 6-week and 1-year time points, concurring with the Omidi-Kashani et al. (2014) description of significantly greater improvement in NDI score seen in the older population in their study.[30] MCID did not significantly differ at any time point regarding NDI between groups.

4.2. Limitations

While this study holds several strengths, including consistent technique due to data originating from a single-surgeon database, moderate follow-up time extending to 2 years, isolated spinal pathology of herniated nucleus pulposus, and use of thoroughly studied outcome measures in the form of PROMs and MCID achievement, there are several severe limitations. First, while single-level surgeries were utilized to compare more uniform data, generalization of these findings to multi-level surgeries is then limited. Further, while this study prioritized evaluation of PROMs, specifically analyzing physical function, pain, and disability, this study did not evaluate rates of postoperative complication between groups, which is likely the greatest limiting factor for surgeon recommendation regarding these two cohorts. Although we reported the number of patients with cervical myeloradiculopathy, the PROMs utilized within this study may not adequately address other myelopathic symptoms such as fine motor work or bowel and bladder issues. The PROMs used in this study merely assess the basics of physical function, pain, and neck disability. Usage of the modified Japanese Orthopaedic Association scoring system or Nurick grading system in future studies may mitigate this limitation and allow for further comparison of patients' improvement in these more detailed myelopathic concerns. Patients with isolated myelopathic symptoms may have varying results as mentioned by the limitations of these PROMs; however, only two patients reported isolated myelopathic symptoms in this study, both within the older population, limiting our ability to analyze this subset of the population. Use of multiple surgeons or institutions may additionally allow for greater power to further study mid-to long-term outcomes in these patient groups, where in our case we found several outcomes to lack significance at our study endpoint likely due to lack of power. Notably, ASA classification and CCI scores were both significantly poorer in the older population, similar to prior studies.[24] Larger sample sizes may allow for propensity matching while maintaining power to account for these differences that inherently bias the study. Finally, while both ACDF and CDR procedures were included due to their overlap in indication with the goal of increasing generalizability of the study, surgeons who routinely perform one of these techniques may be limited in application of these findings due to the heterogeneous nature of the study.

5. Conclusion

There is a gross sparsity of data regarding the influence of age on cervical spine surgery outcomes as stratified in younger populations more commonly encountered in the ambulatory setting. While the younger group presented with poorer physical function status preoperatively, both younger (<46 years) and older (46–64 years) groups experienced significant improvement in many outcomes regarding function, pain, and disability postoperatively in short-to mid-term postoperative periods. Older patients may report significantly better scores than younger patients regarding function, pain, and disability in the postoperative period; however, younger patients may notice more tangible improvement in function at later postoperative time points, while older patients may report more tangible improvement in pain. The broad spectrum of improvement seen for both cohorts along with the mixed results noted indicate that cervical spine surgery is effective for both young and middle-aged populations and requires further study to elucidate differences that potentially exist between this younger demographic seen in the ambulatory setting.

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CRediT authorship contribution statement

Timothy J. Hartman: Conceptualization, Methodology, Visualization, Formal analysis, Software, Investigation, Writing – original draft, Writing – review & editing. **James W. Nie:** Conceptualization, Methodology, Visualization, Formal analysis, Software, Investigation, Writing – original draft, Writing – review & editing. **Hanna Pawlowski:** Project administration, Data curation, Investigation, Writing – review & editing. **Michael C. Prabhu:** Project administration, Data curation, Investigation, Writing – review & editing. **Nisheka N. Vanjani:** Project administration, Data curation, Investigation, Writing – review & editing. **Kern Singh:** Conceptualization, Methodology, Supervision, Resources, Investigation, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Kern Singh reports a relationship with Zimmer Biomet that includes: consulting or advisory. Kern Singh reports a relationship with Stryker that includes:. Kern Singh reports a relationship with RTI Surgical that includes:. Kern Singh reports a relationship with Lippincott Williams and Wilkins that includes:. Kern Singh reports a relationship with Thieme that includes:. Kern Singh reports a relationship with Jaycee Publishing that includes:. Kern Singh reports a relationship with Slack Publishing that includes:. Kern Singh reports a relationship with Avaz Surgical LLC that includes: equity or stocks. Kern Singh reports a relationship with Vital 5 LLC that includes: board membership and equity or stocks. Kern Singh reports a relationship with K2M that includes: consulting or advisory. Kern Singh reports a relationship with TDi LLC that includes: board membership. Kern Singh reports a relationship with Minimally Invasive Spine Study Group that includes: board membership. Kern Singh reports a relationship with Contemporary Spine Surgery that includes: board membership. Kern Singh reports a relationship with Orthopedics Today that includes: board membership. Kern Singh reports a relationship with Vertebral Columns that includes: board membership. Kern Singh reports a relationship with Cervical Spine Research Society that includes: board membership. Kern Singh reports a relationship with International Society for the Advancement of Spine Surgery that includes: board membership. Kern Singh reports a relationship with American Academy of Orthopaedic Surgeons that includes: board membership. Kern Singh reports a relationship with Cervical Spine Research Society that includes: funding grants.

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