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Impact of Gender on Postsurgical Outcomes in Patients Undergoing Anterior Cervical Discectomy and Fusion

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ABSTRACT

Background: Prior studies associate male gender with higher complication rates following anterior cervical discectomy and fusion (ACDF), but none has investigated gender influence on patient-reported outcome measures (PROMs) and minimal clinically important difference (MCID) following single-level ACDF.

Methods: Patients undergoing primary, single-level ACDF were divided into female and male groups. Visual analog scale (VAS) neck/arm, Neck Disability Index (NDI), 12-item short form (SF-12) physical composite score (PCS), PROM information system physical function (PROMIS-PF), and veterans RAND 12-item (VR-12) health survey PCS were collected preoperatively and postoperatively. Simple linear regression analysis evaluated the predictive capability of gender on PROMs. Multiple regression analysis was performed to determine the effects of gender on mean PROMs while accounting for insurance type. Established MCID values determined achievement rates across PROMs. χ^2 analysis compared MCID achievement by gender.

Results: A total of 179 women and 134 men were included. Cohorts differed in insurance type, length of stay, and discharge day ($P \leq 0.017$, all). Women improved in PROMs at all timepoints ($P \leq 0.049$, all) except SF-12 PCS 6 weeks and PROMIS-PF 6 weeks. Men improved in PROMs at all timepoints ($P \leq 0.042$) except VAS arm 2 years, SF-12 PCS 6 weeks and 2 years, PROMIS-PF 6 weeks, and VR-12 PCS 6 weeks. Women demonstrated higher SF-12 PCS ($P = 0.043$) and VR-12 PCS ($P = 0.035$) 2 years. Multiple regression determined that VAS neck and arm from 6 weeks to 6 months, NDI from preoperative to 6 months, SF-12 PCS and VR-12 PCS from preoperative to 12 weeks, and PROMIS-PF preoperative, 6 weeks, and 6 months were significantly affected by gender and insurance status ($P \leq 0.031$, all). MCID achievement rate did not differ for any PROM between genders.

Conclusion: Women reported significantly higher long-term physical function health (SF-12 PCS and VR-12 PCS) compared with men, while disability and pain did not differ. Nevertheless, no significant differences in MCID achievement were observed for any PROM studied. Gender does not appear to play a significant role in clinically meaningful recovery following single-level ACDF.

Clinical Relevance: Gender has little value in prognostication for determining clinically meaningful recovery after single-level ACDF.

Level of Evidence: 3.

Cervical Spine

Keywords: gender, ACDF, PROM, MCID

INTRODUCTION

Anterior cervical decompression and fusion (ACDF) is commonly performed to treat symptomatic cervical degenerative diseases such as disc herniation and spondylotic myelopathy.[1–5] Cervical disc arthroplasty is another procedural management option for cervical degenerative pathology; however, 132,000 ACDFs are performed yearly compared with 1600 cervical disc arthroplasties.[6] Substantial evidence shows that both single- and multilevel ACDF procedures result in high fusion rates and significant improvements in postoperative patient outcomes.[7,8]

Throughout the years, the metrics used to measure success following spinal surgery have evolved.[9] Spinal surgeons are increasingly utilizing patient-reported outcome measures (PROMs) to understand patients' perceptions of their health status at preoperative and postoperative timepoints.[9,10] A number of PROMs have been validated for evaluating the efficacy of ACDF, including Neck Disability Index (NDI), visual analog scale (VAS) neck and arm, 12-item short form (SF-12) survey physical composite score (PCS), PROM information system physical function (PROMIS-PF), and veterans RAND 12-item (VR-12) PCS.[9,11–14]

As stated in a report by the Institute of Medicine in 2001, to effectively analyze patients' outcomes, differences due to sex should be addressed.[15] Unfortunately, limited literature provides outcome comparisons between women and men because if there are insignificant findings, analyses are often excluded.[15]

While scarce, a growing number of studies have begun addressing gender's influence on the epidemiology and management of spinal disease. One study demonstrated

equal representation of each gender in degenerative disc disease in the cervical region.[16] A study on preoperative management found that a significantly greater proportion of women utilized pain-relieving treatments such as opioids, nonsteroidal anti-inflammatory drugs, muscle relaxants, epidural steroid injections, and physical/occupational therapy during the 5-year period prior to ACDF.[17] Following ACDF, Basquesa et al reported men were at significantly greater risk for adverse events, including death.[18] While the impact of gender on PROMs and minimal clinically important difference (MCID) achievement for lumbar fusions has been addressed,[19–24] no study to our knowledge has evaluated this relationship for cervical fusion surgery. For this reason, we aim to investigate the implications of gender on PROMs and MCID achievement across PROMs in patients undergoing single-level ACDF.

METHODS

Patient Population

Institutional Review Board approval (Office of Research Affairs No. 14051301) and patient-informed consent were obtained prior to the start of the study. A prospectively maintained single-surgeon database was retrospectively reviewed to identify patients who had undergone ACDF. Patients who underwent primary, single-level ACDF were included. Patients who underwent fusion for traumatic, infectious, or malignant indications were excluded.

Data Collection

Patient demographics were collected, including gender, age, body mass index, obesity status, ethnicity, diabetic status, smoking status, blood pressure, American Society of Anesthesiologists score, ageless Charlson Comorbidity Index, and insurance type (Medicare/Medicaid, workers' compensation [WC], or private). Perioperative characteristics were recorded, including spinal pathology, operative duration (minutes), estimated blood loss (mL), length of stay, and day of discharge. Spinal pathologies of patients included degenerative spondylolisthesis, recurrent herniated nucleus pulposus, and stenosis. PROMs were recorded preoperatively and at 6-week, 12-week, 6-month, 1-year, and 2-year postoperative timepoints. PROMs examined for this study were VAS neck and arm, NDI, SF-12 PCS, PROMIS-PF, and VR-12 PCS.

Statistical Analysis

All data analyses were performed with Stata 16.0 (StataCorp LP, College Station, TX). Patients were divided into male and female groups based on gender. Patient demographics and perioperative characteristics were compared between groups using X^2 analysis or paired sample *t* test for categorical and continuous variables, respectively. Mean PROMs were calculated, with significance in change from preoperative to postoperative values determined using paired sample *t* test. Differences in mean scores between cohorts were evaluated using simple linear regression analysis. Of note, the results of an independent *t* test will be equivalent to regression analysis if the categorical predictor has only 2 levels, as in our case (men, women).[25] Multiple regression analysis was performed to further evaluate the effect of gender on PROMs while accounting for insurance status. The proportion of patients in each cohort who reached an established MCID for each PROM was determined. MCID achievement was assessed by comparing postoperative improvements in PROM scores from preoperative baseline to the following previously established threshold values: 2.6 for VAS neck,[26] 4.1 for VAS arm,[26] 8.5 for NDI,[26] 8.1 for SF-12 PCS,[26] and 4.5 for PROMIS-PF.[27] Intergroup differences in achievement of MCID were compared using χ^2 analysis. A P value ≤ 0.05 was used as a marker for statistical significance in all analyses performed.

RESULTS

Descriptive Analysis

A total of 313 patients who underwent a single-level ACDF and met the inclusion and exclusion criteria were included (Table 1). Within this cohort, 179 women and 134 men were identified. The mean age for women was 47.7 years and for men was 46.7 years, and the mean body mass index for women was 28.9 kg/m^2 and for men was 29.6 kg/m^2 (Table 1). The only significant difference in demographics by gender was insurance type ($P = 0.005$). Patient demogrpahics are reported in Table 1. A significantly larger percentage of men had a spinal pathology of central stenosis compared with women ($P = 0.035$) . Women were seen to have a significantly greater length of stay and ($P < 0.001$) and day of discharge ($P = 0.017$) . There were no other statistically significant differences between cohorts for other perioperative variables (Table 2).

Primary Outcome Measures

Table 3 includes a summary of all PROM outcome measures assessed. Women demonstrated significant improvements from preoperative scores at all postoperative timepoints for VAS neck, VAS arm, NDI, and VR-12 PCS. For both SF-12 PCS and PROMIS-PF, women demonstrated significant improvement at the

Table 1. Patient demographics.

Characteristic	Women (n = 134)	Men (n = 179)	P Value[a]
Age, y, mean ± SD	47.7 ± 10.3	46.7 ± 10.1	0.373
Body mass index, kg/m^2, mean ± SD	28.9 ± 6.6	29.6 ± 5.0	0.287
Obesity status, % (n)			0.269
Nonobese	60.5% (81)	54.2% (97)	
Obese	39.6% (53)	45.8% (82)	
Ethnicity, % (n)			0.505
African-American	14.9% (20)	14.5% (26)	
Asian	3.0% (4)	0.6% (1)	
Hispanic	5.2% (7)	6.7% (12)	
White	73.9% (99)	76.0% (136)	
Other	3.0% (4)	2.2% (4)	
Diabetic status, % (n)			0.169
Nondiabetic	91.0% (122)	95.0% (170)	
Diabetic	9.0% (12)	5.0% (9)	
Smoking status, % (n)			0.667
Nonsmoker	79.4% (104)	81.4% (144)	
Smoker	20.6% (27)	18.6% (33)	
Blood pressure, % (n)			0.874
Normotensive	74.8% (98)	74.0% (131)	
Hypertensive	25.2% (33)	26.0% (46)	
American Society of Anesthesiologists score, % (n)			0.719
≤2	89.6% (112)	88.2% (135)	
>2	10.4% (13)	11.8% (18)	
Charlson Comorbidity Index score, mean ± SD	2.0 ± 1.6	1.7 ± 1.6	0.101
Insurance type, % (n)			**0.005**
Medicare/Medicaid	9.0% (12)	5.0% (9)	
Workers' compensation	25.4% (34)	42.5% (76)	
Private	65.7% (88)	52.5% (94)	

Note: **Boldface** indicates significance.
[a]P value calculated using χ^2 analysis or paired sample t test.

12-week, 6-month, 1-year, and 2-year timepoints (P > 0.050, all), but they did not demonstrate significant improvement from preoperative scores to the 6-week timepoint. Men demonstrated significant improvement from preoperative scores at all postoperative timepoints for VAS neck and NDI (P > 0.050, all; Table 3). For VAS arm, PROMIS-PF, SF-12 PCS, and VR-12 PCS, men significantly recovered from preoperative scores at each timepoint (P < 0.050, all) except for VAS arm at 2 years, SF-12 PCS at 6 weeks and 2 years, PROMIS-PF at 6 weeks, and VR-12 PCS at 6 weeks and 2 years (Table 3). There were statistically significant differences between male and female PROM scores at the 2-year timepoint for SF-12 PCS (P = 0.043) and VR-12 PCS (P = 0.035). However, there were no other statistically significant differences in other PROM scores between men and women for any pre- or postoperative timepoint (Table 4). Upon multiple regression analysis, insurance and gender were significant

Table 2. Perioperative characteristics.

Characteristic	Women (n = 134)	Men (n = 179)	P Value[a]
Spinal pathology, % (n)			
Degenerative spondylolisthesis	0.8% (1)	1.1% (2)	0.739
Recurrent herniated nucleus pulposus	95.5% (128)	91.1% (163)	0.127
Central stenosis	18.7% (25)	29.1% (52)	**0.035**
Foraminal stenosis	6.7% (9)	5.0% (9)	0.525
Operative time, min, mean ± SD	55.1 ± 14.1	57.7 ± 14.5	0.120
Estimated blood loss, mL, mean ± SD	41.6 ± 19.8	41.1 ± 21.1	0.811
Length of stay, h, mean ± SD	24.9 ± 13.5	19.4 ± 12.6	**<0.001**
Postoperative narcotic consumption, mean ± SD			
POD 0	47.0 ± 36.4	47.2 ± 45.2	0.975
POD 1	18.9 ± 18.8	20.5 ± 30.6	0.603
Day of discharge, % (n)			**0.017**
POD 0	26.3% (35)	42.9% (75)	
POD 1	63.9% (85)	52.0% (91)	
POD 2	9.0% (12)	4.6% (8)	
POD 3	0.8% (1)	0.0% (0)	
POD 4	0.0% (0)	0.6% (0)	

Abbreviation: POD, postoperative day of discharge.
Note: **Boldface** indicates statistical significance.
[a]P value calculated using χ^2 analysis or paired sample t test.

Table 3. Impact of gender on PROMs.

PROM	Women (Mean ± SD)	P Value[a]	Men (Mean ± SD)	P Value[b]
VAS neck				
Preoperative	6.4 ± 2.4	-	6.0 ± 2.2	-
6 wk	4.0 ± 2.5	**<0.001**	3.3 ± 2.6	**<0.001**
12 wk	2.9 ± 2.8	**<0.001**	2.9 ± 2.4	**<0.001**
6 mo	3.0 ± 2.8	**<0.001**	2.7 ± 2.5	**<0.001**
1 y	3.2 ± 3.1	**0.006**	3.5 ± 2.7	**<0.001**
2 y	4.2 ± 2.6	**0.002**	4.3 ± 2.9	**0.042**
VAS arm				
Preoperative	6.5 ± 2.7	-	5.7 ± 2.5	-
6 wk	2.2 ± 2.7	**<0.001**	2.7 ± 2.5	**<0.001**
12 wk	3.1 ± 3.5	**<0.001**	2.5 ± 2.4	**<0.001**
6 mo	2.9 ± 3.3	**<0.001**	2.4 ± 2.5	**<0.001**
1 y	3.0 ± 2.7	**0.011**	4.0 ± 3.4	**0.028**
2 y	3.3 ± 2.8	**0.005**	3.9 ± 3.3	0.235
NDI				
Preoperative	42.9 ± 19.6	-	40.9 ± 17.8	-
6 wk	30.5 ± 20.2	**<0.001**	32.5 ± 19.8	**<0.001**
12 wk	25.0 ± 19.7	**<0.001**	28.1 ± 20.4	**<0.001**
6 mo	25.4 ± 21.1	**<0.001**	22.0 ± 20.5	**<0.001**
1 y	23.9 ± 20.0	**0.010**	26.1 ± 23.6	**<0.001**
2 y	22.6 ± 16.0	**0.004**	33.7 ± 23.9	**0.023**
SF-12 PCS				
Preoperative	37.6 ± 7.4	-	37.9 ± 10.5	-
6 wk	39.1 ± 9.4	0.019	38.0 ± 10.0	0.393
12 wk	44.5 ± 9.1	**<0.001**	43.8 ± 11.5	**<0.001**
6 mo	40.5 ± 10.0	**0.003**	43.4 ± 9.6	**<0.001**
1 y	44.3 ± 8.4	**0.002**	43.1 ± 12.2	**0.007**
2 y	46.1 ± 8.4	**0.013**	37.6 ± 13.1	0.218
PROMIS-PF				
Preoperative	39.1 ± 6.6	-	40.8 ± 7.8	-
6 wk	42.4 ± 6.9	0.141	39.3 ± 7.3	0.550
12 wk	46.2 ± 11.2	**0.003**	45.4 ± 10.4	**0.004**
6 mo	45.9 ± 9.2	**<0.001**	47.4 ± 10.9	**<0.001**
1 y	47.1 ± 7.9	**0.049**	48.0 ± 9.4	**0.002**
2 y	48.3 ± 11.0	**0.019**	46.0 ± 9.6	**0.004**
VR-12 PCS				
Preoperative	36.5 ± 7.5	-	36.4 ± 10.0	-
6 wk	40.2 ± 8.5	**0.024**	36.3 ± 10.1	0.928
12 wk	42.9 ± 10.1	**0.012**	40.7 ± 11.6	**0.031**
6 mo	42.9 ± 9.8	**0.001**	45.9 ± 9.3	**<0.001**
1 y	45.7 ± 8.5	**0.006**	44.7 ± 11.6	**0.001**
2 y	47.5 ± 7.9	**0.011**	38.7 ± 13.5	0.343

Abbreviations: NDI, Neck Disability Index; PCS, physical composite score; PROM, patient-reported outcome measure; PROMIS-PF, PROM information system physical function; SF-12 PCS, 12-item short form survey PCS; VAS, visual analog scale; VR-12 PCS, veterans RAND 12-item health survey PCS.
Note: **Boldface** indicates statistical significance.
[a]P values calculated using paired sample t test for improvement from preoperative to postoperative PROMs among women.
[b]P values calculated using paired sample t test for improvement from preoperative to postoperative PROMs among men.

Table 4. Impact of gender on PROMs.

PROM	Women (Mean ± SD)	Men (Mean ± SD)	*P* Value[a]	*P* Value[b]
VAS neck				
Preoperative	6.4 ± 2.4	6.0 ± 2.2	0.278	0.364
6 wk	4.0 ± 2.5	3.3 ± 2.6	0.138	**<0.001**
12 wk	2.9 ± 2.8	2.9 ± 2.4	0.877	**<0.001**
6 mo	3.0 ± 2.8	2.7 ± 2.5	0.600	**0.003**
1 y	3.2 ± 3.1	3.5 ± 2.7	0.647	0.357
2 y	4.2 ± 2.6	4.3 ± 2.9	0.892	0.735
VAS arm				
Preoperative	6.5 ± 2.7	5.7 ± 2.5	0.076	0.121
6 wk	2.2 ± 2.7	2.7 ± 2.5	0.317	**0.005**
12 wk	3.1 ± 3.5	2.5 ± 2.4	0.245	**0.009**
6 mo	2.9 ± 3.3	2.4 ± 2.5	0.407	**0.013**
1 y	3.0 ± 2.7	4.0 ± 3.4	0.274	0.325
2 y	3.3 ± 2.8	3.9 ± 3.3	0.672	0.685
NDI				
Preoperative	42.9 ± 19.6	40.9 ± 17.8	0.574	**<0.001**
6 wk	30.5 ± 20.2	32.5 ± 19.8	0.608	**<0.001**
12 wk	25.0 ± 19.7	28.1 ± 20.4	0.434	**<0.001**
6 mo	25.4 ± 21.1	22.0 ± 20.5	0.418	**<0.001**
1 y	23.9 ± 20.0	26.1 ± 23.6	0.712	0.684
2 y	22.6 ± 16.0	33.7 ± 23.9	0.217	0.457
SF-12 PCS				
Preoperative	37.6 ± 7.4	37.9 ± 10.5	0.799	**0.004**
6 wk	39.1 ± 9.4	38.0 ± 10.0	0.490	**0.002**
12 wk	44.5 ± 9.1	43.8 ± 11.5	0.722	**0.011**
6 mo	40.5 ± 10.0	43.4 ± 9.6	0.214	0.166
1 y	44.3 ± 8.4	43.1 ± 12.2	0.692	0.314
2 y	46.1 ± 8.4	37.6 ± 13.1	**0.043**	0.120
PROMIS-PF				
Preoperative	39.1 ± 6.6	40.8 ± 7.8	0.345	**<0.001**
6 wk	42.4 ± 6.9	39.3 ± 7.3	0.105	**0.026**
12 wk	46.2 ± 11.2	45.4 ± 10.4	0.793	0.153
6 mo	45.9 ± 9.2	47.4 ± 10.9	0.634	**0.031**
1 y	47.1 ± 7.9	48.0 ± 9.4	0.800	0.995
2 y	48.3 ± 11.0	46.0 ± 9.6	0.528	0.844
VR-12 PCS				
Preoperative	36.5 ± 7.5	36.4 ± 10.0	0.923	**0.003**
6 wk	40.2 ± 8.5	36.3 ± 10.1	0.070	**<0.001**
12 wk	42.9 ± 10.1	40.7 ± 11.6	0.436	**0.003**
6 mo	42.9 ± 9.8	45.9 ± 9.3	0.207	0.090
1 y	45.7 ± 8.5	44.7 ± 11.6	0.735	0.803
2 y	47.5 ± 7.9	38.7 ± 13.5	**0.035**	0.093

Abbreviations: NDI, Neck Disability Index; PCS, physical composite score; PROM, patient-reported outcome measure; PROMIS-PF, PROM information system physical function; SF-12 PCS, 12-item short form survey PCS; VAS, visual analog scale; VR-12 PCS, veterans RAND 12-item health survey PCS.
Note: **Boldface** indicates statistical significance.
[a]*P* values calculated using simple linear regression of PROMs by gender.
[b]*P* values calculated using multiple regression of PROMs by gender and insurance type.

effectors for the following mean PROMs: VAS neck and arm from 6 weeks to 6 months ($P \leq 0.003$, all), NDI from preoperative to 6 months ($P < 0.001$, all), SF-12 PCS and VR-12 PCS from preoperative to 12 weeks ($P \leq 0.011$, all), and PROMIS-PF at preoperative, 6 weeks, and 6 months following fusion ($P \leq 0.031$, all; Table 4). There were no significant differences or trends noticed in MCID achievement rates between men and women at any individual timepoint or for overall across all PROMs studied ($P > 0.050$, all; Table 5).

DISCUSSION

ACDF is the gold standard surgery for the management of symptomatic cervical degeneration, with over 100,000 procedures performed per year in the United States.[6,28–30] Despite this, not much is known about the influence of gender on cervical pathology development or management. In epidemiological writings of Stockholm Public Health, a higher proportion of women (25%) experienced neck pain vs men (16%), and women suffered from greater delays in recovery.[24,31] Additional studies have supported this notion with Fillingim et al observing that women report increased neck pain from various causes including migraine, fibromyalgia, irritable bowel syndrome, temporomandibular, and musculoskeletal disorders.[32] Meanwhile, Fakhoury et al. demonstrated that cervical degenerative pathology occurs in the older population with similar incidence among sexes.[16] On the contrary, Kim et al demonstrated a higher incidence of symptomatic disc herniation in women, with a separate study reporting that women have a 1.38-fold higher risk of developing cervical disc disease.[33,34] Interestingly, range of motion (as measured by head-neck flexion-extension), which may indicate functional status, was increased in women with degenerative spine disease vs male counterparts.[35] Moreover, 30 days following ACDF, the male gender was significantly associated with a greater incidence of complications such as any adverse event, pneumonia, sepsis, cardiac arrest requiring pulmonary resuscitation, and mortality.[18] While aforementioned studies address differences in epidemiologic characteristics, movement ability, and postsurgical complications by gender, and separate studies for lumbar fusion have addressed patient-perceived outcomes by gender, no prior study to our knowledge has compared PROMs or MCID achievement among men and women undergoing ACDF.[19] The current study addresses this shortcoming by investigating the impact of gender on physical functioning, disability, and pain-related PROMs and MCID attainment across these PROMs following ACDF.

Insurance Status

One important baseline demographic difference among cohorts was insurance status, for which men had more WC patients vs women. Meanwhile, a greater proportion of women had private insurance or Medicare/Medicaid compared with male counterparts. In a meta-analysis of lumbar spine studies, WC claimants were shown to experience inferior postoperative pain and disability scores with delayed return to work in comparison with non-WC

Table 5. Impact of gender on minimal clinically important difference achievement.

Minimal Clinically Important Difference	6 wk	12 wk	6 mo	1 y	2 y	Overall
VAS arm	*n* = 49	*n* = 42	*n* = 39	*n* = 15	*n* = 5	*n* = 71
Women	51.3% (20)	44.7% (17)	34.3% (12)	29.4% (5)	25.0% (2)	64.4% (29)
Men	38.7% (29)	37.9% (25)	44.3% (27)	25.0% (10)	18.8% (3)	51.9% (42)
P value[a]	0.197	0.492	0.338	0.729	0.722	0.172
VAS neck	*n* = 58	*n* = 69	*n* = 61	*n* = 23	*n* = 9	*n* = 97
Women	43.2% (19)	68.2% (30)	64.1% (25)	31.6% (6)	33.3% (3)	72.6% (37)
Men	49.4% (39)	55.7% (39)	55.4% (36)	43.6% (17)	35.3% (6)	70.6% (60)
P value[a]	0.510	0.185	0.382	0.380	0.920	0.807
NDI	*n* = 54	*n* = 63	*n* = 62	*n* = 28	*n* = 14	*n* = 91
Women	56.4% (22)	71.1% (27)	67.7% (23)	58.8% (10)	77.8% (7)	75.0% (33)
Men	43.8% (32)	56.3% (36)	67.2% (39)	48.7% (18)	46.7% (7)	71.8% (56)
P value[a]	0.205	0.137	0.968	0.487	0.134	0.702
SF-12 PCS	*n* = 26	*n* = 42	*n* = 29	*n* = 16	*n* = 12	*n* = 76
Women	30.6% (11)	39.1% (18)	37.0% (10)	35.3% (6)	50.0% (7)	50.8% (32)
Men	25.0% (15)	34.3% (24)	48.7% (19)	35.7% (10)	35.7% (5)	47.8% (44)
P value[a]	0.553	0.595	0.347	0.977	0.445	0.717
PROMIS-PF	*n* = 19	*n* = 22	*n* = 24	*n* = 15	*n* = 19	*n* = 42
Women	42.9% (9)	60.0% (9)	66.7% (10)	50.0% (5)	57.1% (8)	72.0% (18)
Men	37.0% (10)	48.2% (13)	63.6% (14)	58.8% (10)	61.1% (11)	66.7% (24)
P value[a]	0.683	0.461	0.850	0.656	0.821	0.658

Abbreviations: NDI, Neck Disability Index; PROMIS-PF, patient-reported outcome measure information system physical function; SF-12 PCS, 12-item short form survey physical composite score; VAS, visual analog scale.

Note: Data presented as % (*n*). **Boldface** indicates statistical significance.

[a]*P* values calculated using χ^2 analysis.

counterparts.[36] Yoo et al. further demonstrated that WC patients demonstrate poorer physical function preoperatively and postoperatively following ACDF; thus, our findings of inferior physical function among men at 2 years may be partially confounded due to increased WC patients within this cohort.[37] Furthermore, Rasouli et al. and Taylor et al. highlighted that Medicare/Medicaid patients undergoing ACDF are more likely to experience longer postoperative stay, higher readmission rates, and require emergency department visits at 30 and 90 days following fusion, while Segal et al illustrated that Medicaid patients experience greater disparity in access to spine care.[38–40] With established trends in literature on outcomes associated with different insurance types, it was deemed imperative to take this potential confounder into account for our analysis. Therefore, multiple regression analysis was performed to determine the impact of gender on mean PROMs while accounting for insurance status. While gender and insurance were revealed to be significant effectors for all PROMs, significance in association was primarily confined to the early to intermediate postoperative period (up to 6 months). However, as mean PROMs prior to multiple regression did not differ among our cohorts during this period from preoperative to 6 months, varying insurance status among groups may have masked potential differences, an important limitation of our study. Nevertheless, since insurance status did not demonstrate predictive capability for any PROM at 1 or 2 years following ACDF, our finding of inferior physical function among men at 2 years demonstrated prior to multiple regression analysis is less likely to have been influenced by this potential source of confounder bias.

Patient-Reported Outcome Measures

Physical Function

While neither gender cohort significantly improved in early postoperative (6 weeks) physical functioning for PROMIS-PF and SF-12 PCS metrics, physical function (PROMIS-PF, SF-12 PCS, and VR-12 PCS) scores did not significantly differ between women and men during this period. Both genders significantly improved for PROMIS-PF from preoperative to 12 weeks through 2 years, SF-12 PCS 12 weeks through 1 year, and VR-12 PCS 6 weeks through 1 year, with no significant differences in PROMs by gender during respective time periods. However, for SF-12 PCS and VR-12 PCS, men did not exhibit significant physical recovery at 2 years following ACDF. In addition, men exhibited significantly lower physical health scores vs women in these PROMs (SF-12 PCS and VR-12 PCS) by the 2-year mark. Of note, MCID achievement rates did not significantly differ by gender for any physical function PROM at any timepoint.

Due to significant variability in metrics of the 3 physical PROMs assessed in our study, it is worthwhile to discuss

the utility of these questionnaires in evaluation of ACDF success. While traditional "legacy" PROMs such as SF-12 PCS, pain scores (VAS, Numerical Rating Scale), disability indices (Oswestry Disability Index [ODI], NDI), and disease-specific questionnaires (cervical spine outcomes questionnaire, Japanese Orthopaedic Association myelopathy questionnaire) have been well supported for evaluation of postsurgical outcomes following ACDF, these surveys are prone to limitations.[41] The delivery of a wide variety of questionnaires introduces respondent burden and constraints the precision of metrics, complicating the interpretation of results.[41,42] In response, the National Institute of Health (in 2004) developed the PROMIS questionnaire, a standardized tool that can evaluate numerous health-related outcomes for a broad range of illnesses in diverse patient populations.[41,43] PROMIS is calculated by computerized adaptive tests based on item response theory methods to provide more precise and applicable results compared with traditional PROMs.[42] PROMIS also improves efficiency by reducing questionnaire burden, ceiling and floor effects, and sample size requirements.[41,42] In support of its concurrent validity, the PROMIS survey has demonstrated a correlational relationship with "legacy" PROMs in evaluating spine surgery outcomes.[11,41] For instance, PROMIS-PF was strongly correlated with SF-12 PCS and NDI scores at preoperative and postoperative timepoints after ACDF surgery, demonstrating convergent and discriminant validity in evaluating physical performance.[11,19] PROMIS-PF was also significantly associated with pain, disability, and physical functioning PROMs at the longer-term 2-year follow-up after ACDF.[44] Parrish et al. concluded that PROMIS-PF is a suitable tool for the assessment of physical abilities (eg, strength, movement, and coordination) prior to ACDF surgery and is useful in predicting postoperative clinical outcomes.[41] With previously mentioned evidence supporting the benefits and concurrent validity of PROMIS vs traditional PROMs (including SF-12), and only the recent validation of VR-12 PCS (in 2020) with limited supporting studies, we believe PROMIS-PF results may be most helpful for accurate assessment of physical recovery following ACDF.[14,19]

Although early postoperative physical functioning may not significantly improve, both genders should be encouraged that physical ability will most likely improve at subsequent timepoints till at least 1 year following ACDF. While PROMIS-PF findings of our study indicate long-term physical functioning is unrelated to gender and will likely improve for both cohorts at the 2-year postoperative mark, our results show 2 separate physical function PROMs (SF-12 PCS and VR-12 PCS) that were significantly reduced for men at 2 years. It is thus imperative to inform men that even if they achieve comparable clinical achievement with women and PROMIS-PF indicates long-term postoperative improvement, they may be at greater risk for decline in physical ability at 2 years following ACDF. Through shared decision-making among surgeon and patient, a tailored rehabilitation strategy can then be selected based on the patient's individualized goals of care.

Pain

ACDF remains the procedure of choice for the reduction of pain stemming from cervical pathologies, with patients reporting over 80% reduction in neck pain and 90% reduction in arm pain following the procedure.[45] A 10-year prospective study by Buttermann et al. found decreased use of narcotics and resolution of most neurological deficits following ACDF, with 85% to 95% patients reporting their surgery was successful.[8] Existing literature has consistently concluded that female patients experience more pain and discomfort following various medical procedures.[32,46–48] Multiple publications discovered that female patients reported significantly greater pain sensitivity and sensation during invasive procedures.[32,49] Rollman et al. similarly observed a higher frequency of musculoskeletal pain with increased development of chronic pain among the female population.[32,50] Spine researchers have indicated that female patients experience worse absolute pain, back pain, leg pain, and pain sensitivity with reduced pain tolerance following lumbar procedures.[22–24,32,33,51,52] Norrbrink et al. further elucidated that increased pain in women led to greater opiate and nonsteroidal anti-inflammatory drug use vs male counterparts after spinal cord injuries.[52] Despite such findings, evaluation by gender differences of patient-reported pain outcomes following cervical operations has been sparse.

The present study found that women demonstrated significant improvement from preoperative to all postoperative ratings for VAS neck and arm. While men showed significant progress from preoperative to all postoperative timepoints in VAS neck, they did not demonstrate significant pain relief at the 2-year follow-up for VAS arm. Nevertheless, gender was not a significant predictor of arm or neck pain, and MCID achievement across pain PROMs did not differ between groups throughout the 2-year follow-up.

As mentioned, gender-based outcome studies on spinal procedures have indicated that female patients

suffer from heightened pain postoperatively, a potential source of discouragement in this population. Our findings should invoke a vote of confidence as female patients will likely have a reduction in pain at shorter- and longer-term follow-up points following ACDF. Furthermore, male patients can be provided guidance on rehabilitation techniques aimed at stabilizing cervical and scapular musculature in order to optimize long-term outcomes of arm pain following ACDF.[53,54]

Disability

Multiple studies have demonstrated that women experience significantly greater disability (as measured by ODI) than men at baseline and following degenerative lumbar surgery through 2 years postoperatively.[20,21] Ungureanu et al. found that women reported significantly greater disability across all domains of ODI, including pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, sex life, and traveling. However, inferior disability did not translate to poorer quality of life as measured by health-related quality of life.[55] Pochon et al. further concluded that women demonstrated higher disability and increased health care-seeking behavior (vs male counterparts) following degenerative spine surgery when controlling for pain.[56]

On the contrary, the present study found no significant difference in mean values or predictive capability of gender on NDI at baseline or any follow-up timepoint. Jevotovsky et al. also found no significant difference in baseline NDI by gender in patients with neck pain.[21] For lumbar intervention, Siccoli et al. observed comparable improvements in disability in both genders, with no significant difference in clinical success.[23] These findings are consistent with our NDI and MCID achievement results, demonstrating no significant differences by gender for any timepoint. As NDI is the most widely used and powerfully validated instrument assessing disability in individuals with neck pain, our finding that women and men report similar levels of postoperative disability has meaningful implications.[57,58] Although existing spine literature may discourage surgical intervention in the female population, surgeons should assure patients that ACDF offers substantial benefit in recovery from disability-related symptoms to both women and men equally in patient-perceived and clinical relevance realms.[59]

MCID Achievement

Interestingly, a higher percentage of women experienced overall MCID improvements across all PROMs studied. However, this was by a small margin, and our findings overwhelmingly demonstrated no statistically significant difference for MCID attainment rates among gender cohorts for any PROM. MCID calculation for PROMs is context-dependent in prior literature, with factors such as socioeconomic status, disease severity, and patient expectations influencing the calculation of threshold values.[60,61] In an assessment of MCID by Copay et al, inconsistencies in PROM scores can affect the thresholds used to calculate MCID, thus affecting the utility of MCID in determining clinical significance.[62] Regardless of probable improvements in patient-perceived metrics, men should be advised to attend follow-up appointments and participate in recommended rehabilitation to maximize postoperative clinical improvement. However, due to the lack of statistical significance in differences observed, men should not be discouraged by their slightly lower rates of clinically meaningful recovery.

Limitations

The present study has noteworthy limitations in its design and execution. Due to the retrospective nature of this study, subject selection bias from loss to follow-up may have skewed our findings. All surgeries were performed by 1 surgeon at 1 academic institution, which may reduce the external validity of our results. In addition, this study was based on patients' perceptions, which may have contributed to subjective interpretation and recall bias. We also found significant differences among genders in insurance type, hospital stay length, and diagnosis of central stenosis, introducing confounding variables that may provide bias to our findings.

CONCLUSION

Our findings demonstrated that women and men do not significantly differ in most PROMs or MCID achievement rates throughout the postoperative follow-up period after ACDF. While women demonstrated significantly improved long-term physical function compared with men in SF-12 PCS and VR-12 PCS metrics, the applicability of such findings may be limited as longer-term PROMIS-PF scores did not differ by gender. While clinically meaningful recovery was slightly higher among women, this was a

modest difference and did not reach statistical significance for any PROM. Findings from our study indicate that while gender differences may exist in a few longer-term PROMs, vast similarities between outcomes among cohorts indicate gender does not play a significant role in patient-perceived or clinical postoperative success after single-level ACDF.

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