Impact of Educational Background on Preoperative Disease Severity and Postoperative Outcomes Among Patients With Cervical Spondylotic Myelopathy

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Study Design: Retrospective review of a prospectively maintained database.

Objective: Assess differences in preoperative status and postoperative outcomes among patients of different educational backgrounds undergoing surgical management of cervical spondylotic myelopathy (CSM).

Summary of Background Data: Patient education level (EL) has been suggested to correlate with health literacy, disease perception, socioeconomic status (SES), and access to health care.

Methods: The CSM data set of the Quality Outcomes Database (QOD) was queried for patients undergoing surgical management of CSM. EL was grouped as high school or below, graduate-level, and postgraduate level. The association of EL with baseline disease severity (per patient-reported outcome measures), symptoms >3 or ≤ 3 months, and 24-month patient-reported outcome measures were evaluated.

Results: Among 1141 patients with CSM, 509 (44.6%) had an EL of high school or below, 471 (41.3%) had a graduate degree, and 161 (14.1%) had obtained postgraduate education. Lower EL was statistically significantly associated with symptom duration of >3 months (odds ratio = 1.68), higher arm pain numeric rating scale (NRS) (coefficient = 0.5), and higher neck pain NRS (coefficient = 0.79). Patients with postgraduate education had statistically significantly lower Neck Disability Index (NDI) scores (coefficient = -7.17), lower arm pain scores (coefficient = −1), and higher quality-adjusted life-years (QALY) scores (coefficient = 0.06). Twenty-four months after surgery, patients of lower EL had higher NDI scores, higher pain NRS scores, and lower QALY scores ($P < 0.05$ in all analyses).

Conclusions: Among patients undergoing surgical management for CSM, those reporting a lower educational level tended to present with longer symptom duration, more disease-inflicted disability and pain, and lower QALY scores. As such, patients of a lower EL are a potentially vulnerable subpopulation, and their health literacy and access to care should be prioritized.

Key Words: cervical spondylotic myelopathy, education, patient-reported outcome measures

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Social determinants of health have been increasingly studied to evaluate their impact on a patient's response to medical interventions.[1–4] These social determinants of health are composed of a multitude of factors, including sex, race, socioeconomic status (SES), employment status, and housing status.[4] Among these factors, education level and health literacy play a pivotal role.[2,5–8] Lower education levels of the patient and/or the primary caregiver have been associated with prolonged disease duration, poor follow-up and retention rates, and increased disease-related morbidity.[1] Surgical interventions for spinal pathologies are particularly susceptible to being impacted by poor patient educational levels and poor health literacy due to the inherent complexity of these pathologies.[1,9] Particularly in the realm of spine surgery, few studies have investigated the impact of various social situations and phenotypes on patient outcomes in the short term and long term.

To this end, in the pursuit of identifying the optimal patient to undergo cervical spondylotic myelopathy (CSM), numerous studies have attempted to evaluate the impact of biological, radiographic, clinical, and socioeconomic factors on postoperative outcomes.[4,10–13] This study aims to fully characterize the educational backgrounds of patients undergoing surgery for CSM and to understand the impact of educational level on preoperative presentation and postoperative outcomes following surgery for CSM in a large, multicenter, prospectively collected data set.

METHODS

Patient Cohort

Patients from the CSM data set of the Quality Outcomes Database (QOD) were included in this analysis. The CSM database is a subset of the original cervical module of the QOD, and it constitutes a collaborative effort from 14 high-enrolling sites aiming at higher accuracy and granularity of data, as well as higher rates of follow-up. Inclusion criteria for this cohort were myelopathy as an indication for surgery and a modified Japanese Orthopedic Association (mJOA) score of 17 or lower. The 24-month follow-up rate in this cohort is 89.2% for clinical outcomes and 87.4% for patient-reported outcome measures (PROMs).

Participating sites obtained Institutional Review Board approvals at the inception of the QOD registry. Since the current study uses deidentified patient information from an already existing registry, no additional Institutional Review Board approval or consent was required.

Educational Level and Baseline Characteristics

Patients who pursued education past college were allocated to the postgraduate group; patients with a 2-year or 4-year college degree were included in the graduate group; and the remaining patients—without any tertiary education degree—were included in the high school or below group. Other baseline characteristics of interest were age, sex, self-reported race and ethnicity, SES index,[14] insurance coverage, smoking status, medical comorbidities, American Society of Anesthesiologists grade, employment status, baseline symptoms and symptom duration, underlying pathology, and PROM scores, such as mJOA, Neck Disability Index (NDI), neck and arm pain numeric rating scale (NRS), and 5-dimension Euro-QoL scores (measured in quality-adjusted life-years—QALY). Age was analyzed as a binary variable using the median value of the sample as a cutoff. Duration of symptoms $-\leq 3$ versus >3 months since the initial perception of symptoms—was employed as an indicator of a delay in presentation and, hence, access to health care. The severity of myelopathy was classified per the mJOA score as mild (15–17), moderate (12–14), and severe (<12).[15]

Postoperative Outcomes

Clinical outcomes of interest included estimated blood loss, length of stay, nonroutine discharge disposition (defined as discharge destination other than home), readmissions, and reoperations. PROMs of interest were patient satisfaction and change in mJOA, NDI, neck and arm pain, NRS, and QALY. Satisfaction was defined as a score of 1 or 2 on the North American Spine Society scale. NDI percentage scores were assessed, with higher scores indicating greater disability. NRS pain scales ranged from 0 to 10, with higher scores signifying more intense pain. Improvement in PROMs was analyzed as the achievement of minimal clinically important differences (MCID). The MCID for mJOA was calculated based on the CSM severity at baseline, as previously described;[16] the MCID for NDI, neck NRS, and arm NRS was defined as a 30% decrease from baseline;[17] and the MCID for QALY was defined as an increase of more than or equal to 0.24.[18]

Imputation of Nonavailable Data

Multiple-model imputation was performed to generate replacement values for missing baseline data, and the final imputed data were used for the analysis.[19] The method of model development was chosen based on the class of each variable; predictive mean matching was used for continuous data, logistic regression for binary data, ordinal logistic regression for ordinal data, and polytomous logistic regression for unordered categorical data. The multivariable imputation by chained equations was performed using the mice package.[20] The number of imputations was set to 20, and the number of iterations was set to 30.[21]

Statistical Analysis

Continuous variables were presented as means with SD and categorical variables were presented as frequencies with proportions. Univariate analyses of continuous outcomes were performed via analysis of variance, while χ^2 tests were performed for categorical outcomes. To assess the impact of the educational level on the duration of symptoms and the preoperative PROMs, multivariable logistic and linear regressions were performed for binary and continuous outcomes, respectively. Age, sex, and socioeconomic indicators, such as insurance coverage, patient-reported race, SES index, employment status, workers' compensation, and liability claim, were adjusted for in these models. Patients with nonavailable outcomes were excluded from all analyses. The R software (Version 4.1.3, R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analyses.[22]

RESULTS

Patient Characteristics

A total of 1141 patients undergoing surgery for CSM as an indication at 14 sites were included in this analysis. Of these, 509 (44.6%) had an educational level of high school or below, 471 (41.3%) had a graduate degree, and 161 (14.1%) had obtained some form of postgraduate degree. Patients of lower educational level were more likely covered by Medicaid (11.4% vs. 4.2% and 0.6%, respectively, $P < 0.001$), be unemployed (59.1% vs. 52.7% and 41.6%, $P < 0.001$), smoke (24.2% vs. 14.6% and 6.2%, $P < 0.001$), be of a lower SES index, and have comorbidities compared with patients of graduate and postgraduate level, respectively. In terms of clinical presentation, patients with a lower educational background were more commonly presenting with radicular motor deficits (36.3% vs. 27.8% and 24.2%, $P = 0.002$) and with a duration of symptoms of more than 3 months (89.7% vs. 83.5% and 84%, $P = 0.012$) than patients of graduate and postgraduate levels. Univariate analysis showed that patients of lower educational background reported lower mJOA and QALY scores and higher pain NRS and NDI scores. A univariate comparison of all baseline patient characteristics of interest between different levels of education can be found in Table 1.

Baseline Disease Severity

The association of educational background with the duration of symptoms and the disease severity at presentation adjusted for demographic and socioeconomic factors is presented in Table 2. Compared with patients with graduate-level education, patients with a background of high school or below had 1.68 times higher odds of presenting more than 3 months after the perception of symptoms, as well as 0.5 and 0.79 points higher arm and neck pain scores, respectively, in the NRS scale. Similarly, patients that had obtained a postgraduate degree had lower NDI scores by 7.17 points, lower arm pain scores by 1 point, and higher QALY scores by 0.06 points. All analyses were adjusted for age, sex, insurance coverage, race, SES index, employment status, workers' compensation, and liability claim.

PROMs

Postoperative satisfaction at 3 months from surgery was more common among patients with graduate-level education; nevertheless, no statistically significant difference was documented at the 24-month follow-up, with the 3 groups achieving highly similar satisfaction rates.

A relatively consistent pattern emerged across analyses of different PROMs among the 3 groups, as represented in Figures 1 and 2. More specifically, baseline discrepancies at all 5 PROMs of interest were maintained across follow-up time points, with the 3 groups scoring statistically differently at all investigated parameters, long-term mJOA aside. At 24 months after surgery, patients of lower educational status presented higher NDI scores than patients of graduate and postgraduate levels (23.1 vs. 20.9 and 15.3, $P < 0.001$); higher arm pain NRS scores (2.6 vs. 2.1 and 1.4, $P < 0.001$); higher neck pain NRS scores (2.7 vs. 2.7 and 2, $P < 0.05$); lower QALY scores (0.701 vs. 0.742 and 0.795, $P < 0.001$).

However, in comparing the rates of MCID achievement in NDI, mJOA, arm and neck pain NRS, and QALY, discrepancies between the three education groups were scarce. At the 24-month time point, the 3 groups

TABLE 1. Baseline Patient Characteristics, Demographics, and Operative Details of the Included Cohort by Education Level

Variables	High school or below (N = 509), n (%)	Graduate level (N = 471), n (%)	Postgraduate level (N = 161), n (%)	*P*
Age	60.4 (11.8)	60.0 (11.5)	62.6 (12.4)	0.053*,†
Age > 61 y old	240 (47.2)	230 (48.8)	100 (62.1)	**0.003***,†
Female sex	242 (47.5)	235 (49.9)	64 (39.8)	0.084*,†
BMI	30.6 (6.3)	29.8 (6.5)	29.7 (6.7)	0.091
Insurance	—	—	—	**< 0.001**‡,†
Medicaid	58 (11.4)	20 (4.2)	1 (0.6)	—
Medicare	199 (39.1)	173 (36.7)	68 (42.2)	—
Private	235 (46.2)	259 (55.0)	85 (52.8)	—
Uninsured	8 (1.6)	5 (1.1)	2 (1.2)	—
VA/government	9 (1.8)	14 (3.0)	5 (3.1)	—
Employment	—	—	—	**< 0.001**‡,*,†
Employed or on short-term leave	208 (40.9)	223 (47.3)	94 (58.4)	—
Unemployed	301 (59.1)	248 (52.7)	67 (41.6)	—
Workers' compensation	13 (2.6)	7 (1.5)	3 (1.9)	0.488‡
Liability claim	36 (7.1)	19 (4.0)	3 (1.9)	**0.013**‡,†
Self-reported race	—	—	—	**< 0.001**‡,†
Black	113 (22.2)	54 (11.5)	17 (10.6)	—
White	372 (73.1)	395 (83.9)	141 (87.6)	—
Other	24 (4.7)	22 (4.7)	3 (1.9)	—
SES index	51.6 (4.3)	53.4 (5.0)	56.3 (5.4)	**< 0.001**‡,*,†
Smoking	123 (24.2)	69 (14.6)	10 (6.2)	**< 0.001**‡,*,†
Diabetes mellitus	128 (25.1)	95 (20.2)	22 (13.7)	**0.006***,†
Depression	111 (21.8)	105 (22.3)	35 (21.7)	0.980
Anxiety	83 (16.3)	99 (21.0)	30 (18.6)	0.166
Osteoarthritis	162 (31.8)	132 (28.0)	32 (19.9)	**0.013***,†
COPD	47 (9.2)	28 (5.9)	6 (3.7)	**0.027**†
ASA grade	—	—	—	0.059‡
1	6 (1.2)	13 (2.8)	5 (3.1)	—
2	232 (45.6)	229 (48.6)	81 (50.3)	—
3	259 (50.9)	226 (48.0)	70 (43.5)	—
4	12 (2.4)	3 (0.6)	5 (3.1)	—
Radicular motor deficit	185 (36.3)	131 (27.8)	39 (24.2)	**0.002**†
Numbness	297 (58.3)	289 (61.4)	90 (55.9)	0.409
Motor deficit	323 (63.5)	286 (60.7)	86 (53.4)	0.075†
Duration of symptoms (mo)	—	—	—	**0.012**
≤ 3	52 (10.3)	78 (16.5)	26 (16.0)	—
> 3	454 (89.7)	395 (83.5)	136 (84.0)	—
Dependent ambulation	102 (20.0)	84 (17.8)	23 (14.3)	0.243
Intervertebral disc herniation	143 (28.1)	117 (24.8)	55 (34.2)	0.070
Foraminal stenosis	208 (40.9)	216 (45.9)	64 (39.8)	0.203
Central stenosis	380 (74.7)	365 (77.5)	116 (72.0)	0.326
Listhesis/dynamic instability at level of surgery	126 (24.8)	112 (23.8)	29 (18.0)	0.205
Surgical approach	—	—	—	0.772
Anterior	357 (70.1)	321 (68.2)	113 (70.2)	—
Posterior	152 (29.9)	150 (31.8)	48 (29.8)	—
Procedure breakdown	—	—	—	**0.012**‡
ACDF	306 (60.1)	259 (55.0)	90 (55.9)	—
ACCF	43 (8.4)	46 (9.8)	10 (6.2)	—
CDA	9 (1.8)	17 (3.6)	11 (6.8)	—
Laminectomy with fusion	101 (19.8)	106 (22.5)	31 (19.3)	—
Laminectomy without fusion	36 (7.1)	19 (4.0)	13 (8.1)	—
Laminoplasty	14 (2.8)	24 (5.1)	6 (3.7)	—
Revision surgery	6 (1.2)	5 (1.1)	0	0.395
Levels treated	2.6 (1.5)	2.7 (1.6)	2.6 (1.5)	0.375
Levels grouped	—	—	—	0.932‡
1	139 (27.3)	119 (25.3)	42 (26.1)	—
2	156 (30.6)	144 (30.6)	52 (32.3)	—
3	98 (19.3)	86 (18.3)	31 (19.3)	—
≥ 4	116 (22.8)	122 (25.9)	36 (22.4)	—
Estimated blood loss, mean (SD)	90.8 (146.0)	92.4 (126.9)	80.4 (117.4)	0.629
Length of stay, mean (SD)	2.0 (2.5)	2.2 (2.1)	2.1 (2.0)	0.551

(*Continued*)

TABLE 1. Baseline Patient Characteristics, Demographics, and Operative Details of the Included Cohort by Education Level (*continued*)

Variables	High school or below (N = 509), n (%)	Graduate level (N = 471), n (%)	Postgraduate level (N = 161), n (%)	*P*
Baseline mJOA score	11.9 (2.8)	12.0 (2.9)	12.6 (2.6)	**0.013***,†
Class of myelopathy severity	—	—	—	0.193†
Mild	103 (20.2)	104 (22.1)	44 (27.3)	—
Moderate	198 (38.9)	185 (39.3)	67 (41.6)	—
Severe	208 (40.9)	182 (38.6)	50 (31.1)	—
Baseline arm pain (NRS)	5.5 (3.4)	4.8 (3.5)	3.3 (3.1)	**< 0.001**‡,*,†
Baseline neck pain (NRS)	5.9 (3.0)	5.0 (3.4)	3.8 (3.1)	**< 0.001**‡,*,†
Baseline NDI score	42.3 (19.6)	38.5 (21.2)	26.5 (18.9)	**< 0.001**‡,*,†
Baseline QALY score	0.544 (0.219)	0.553 (0.228)	0.638 (0.211)	**< 0.001***,†

*Statistically significant difference between the "graduate level" and the "postgraduate level" groups.
†Statistically significant difference between the "high school or below" and the "postgraduate level" groups.
‡Statistically significant difference between the "High school or below" and the "Graduate level" groups.
ACCF indicates anterior cervical corpectomy and fusion; ACDF, anterior cervical discectomy and fusion; ASA, American Society of Anesthesiologists; BMI, body mass index; CAD, coronary artery disease; CDA, cervical disc arthroplasty; COPD, chronic obstructive pulmonary disease; mJOA, modified Japanese Orthopedic Association; NDI, Neck Disability Index; NRS, Numeric Rating Scale; PVD, peripheral vascular disease; QALY, Quality-adjusted Life-years; SES, socioeconomic status index; VA, veteran affairs.

achieved similar MCID rates in all PROMs of interest, apart from neck pain, where patients of a lower educational background presented higher MCID rates than the other 2 groups (Table 3).

Clinical Outcomes

In a univariate analysis of clinical outcomes of interest between the 3 groups, no statistically significant differences were identified between different educational levels. More specifically, nonroutine discharge rates were 11.3%, 11.2%, and 14.8% ($P = 0.431$); 3-month readmission rates were 3.4%, 6.1%, and 7.4% ($P = 0.051$); and 24-month reoperation rates were 14.5%, 15.7%, and 11.7% ($P = 0.504$). Multivariable analyses also identified a lack of statistical significance across the different educational levels (Table 4).

DISCUSSION

A delayed initial presentation in patients with CSM has been tightly linked with increased baseline disease severity and with worsened postoperative general and neurological outcomes.[10,11,23] Rates of cervical spine surgery have increased significantly in recent years with economic costs of approximately $2 billion per year.[4,13] However, unlike many other surgical interventions, the primary purpose of surgery for CSM is to halt, rather than reverse, symptom progression. This study explored how one significant social factor influenced the outcomes following surgery for CSM.

A number of social factors have been identified that lead to worse postoperative outcomes following surgical management of CSM, including lower educational attainment.[4] As such, several social factors influence surgical outcomes and are interconnected.[24–26] In this study, multivariable regression analyses controlled for several baseline factors and still yielded significant differences when stratified by education. This suggests that education is the most significant social factor impacting baseline disease burden for patients with CSM.

One recent study identified patients who were of non-White and mixed ethnicity, low educational attainment, unemployed, lower SES designation, and had poor insurance as "high-risk" for poor outcomes following surgery for CSM.[4] More so, patients with lower educational levels presented with a longer duration of symptoms, higher baseline disease burden, and more disease-inflicted disability. Regardless of educational level, all patients benefitted from surgery. This is the first

TABLE 2. Multivariable Regression Analyses Assessing the Impact of the Patients' Educational Level on Disease Characteristics Before Surgery

	High school or below			Postgraduate level			
	Odds ratio*/coefficient†	95% CI	*P*	Graduate level	Odds ratio*/coefficient†	95% CI	*P*
Symptom duration (> 3 mo) *	**1.68**	**1.14–2.49**	**0.01**	Reference	1.17	0.71–1.94	0.543
Baseline NDI score†	2.06	−0.31–4.44	0.089	Reference	**−7.17**	**−10.53 to −3.8**	**< 0.001**
Baseline mJOA score†	0.27	**−**0.08–0.62	0.128	Reference	0.4	−0.1 to 0.9	0.115
Baseline arm pain (NRS)†	**0.5**	**0.07–0.92**	**0.021**	Reference	**−1**	**−1.6 to −0.4**	**0.001**
Baseline neck pain (NRS)†	**0.79**	**0.4–1.18**	**< 0.001**	Reference	−0.55	−1.1–0.01	0.053
Baseline QALY score†	0.02	−0.01–0.04	0.205	Reference	**0.06**	**0.02–0.1**	**0.004**

The multivariable analyses have been adjusted for age, sex, insurance coverage, race, SES index, employment status, workers' compensation, and liability claim.
*Multivariable logistic regression was performed, and the results are presented as odds ratio (OR) and 95% CI.
†Multivariable linear regression was performed, and the results are presented as coefficient and 95% CI.
mJOA indicates modified Japanese Orthopedic Association; NDI, Neck Disability Index; NRS, Numeric Rating Scale; QALY, Quality-adjusted Life-years.

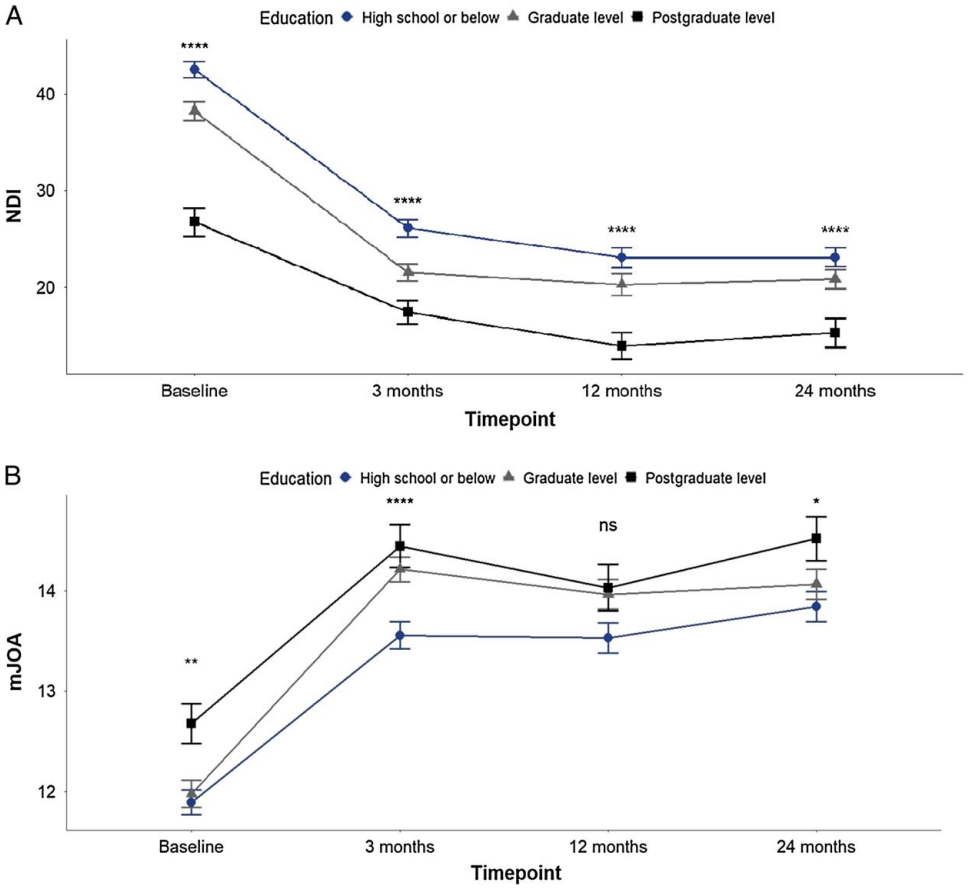

FIGURE 1. Line chart of NDI (A) and mJOA (B) at baseline and at follow-up time points among different educational levels. Levels of statistical significance annotated as follows: *$P < 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$, ****$P \leq 0.0001$. mJOA indicates modified Japanese Orthopedic Association; NDI, Neck Disability Index. full color online

investigation to explore the impact of educational level among a prospectively studied cohort of patients undergoing surgical management for CSM with long-term follow-up.

Health illiteracy is directly linked to an individual's highest educational attainment level and is closely associated with more hospitalizations, increased emergency room care visits, and suboptimal use of health care services.[23,27–31] The US Department of Education estimates that 36% of Americans have a "basic or below basic" level of health literacy.[32] In contrast to prior studies showing that 36% of the American public demonstrate basic or below basic levels of health literacy, ~45% of patients in the present study had a maximum educational level of high school or less. This emphasizes that there may be an increased frequency of patients with lower maximal educational levels presenting with CSM. In 2022, while addressing patients with CSM, Rethorn and colleagues identified 2 distinct social phenotypes of patients with CSM: a "low-risk" and "high-risk" group. The social determinants of health characterizing the high-risk group were older age, female sex, non-White race, lower educational attainment levels, and lower socioeconomic status.[4] The current study expanded on the maximum obtained educational level component to elucidate its true impact on CSM management and postoperative outcomes.

A commonly cited consequence of low health literacy and lower maximal educational attainment is an individual's delayed initial presentation and more severe baseline disease severity.[4,10,33] This baseline disease severity was assessed via a variety of PROMs. Patients with lower maximal education attainment levels (high school or below) were consistently seen to demonstrate poorer scores, indicating worsened baseline disease severity. Furthermore, patients with a maximum educational level of high school or below were 68% more likely to be seen at least 3 months after symptom onset. In the context of preoperative disease severity, patients with a maximum high school level education had more severe baseline arm and neck pain scores.

Although this delayed initial presentation is associated with poorer postoperative outcomes, it is critical to note that these patients are still candidates for surgical management of CSM.[10,33] Recent studies have assessed the impact of both preoperative symptom severity along with delayed presentation on postoperative outcomes following surgical interventions for CSM.[10,33] The findings in this study are consistent with prior literature exhibiting a benefit from surgery in all patients, irrespective of presentation

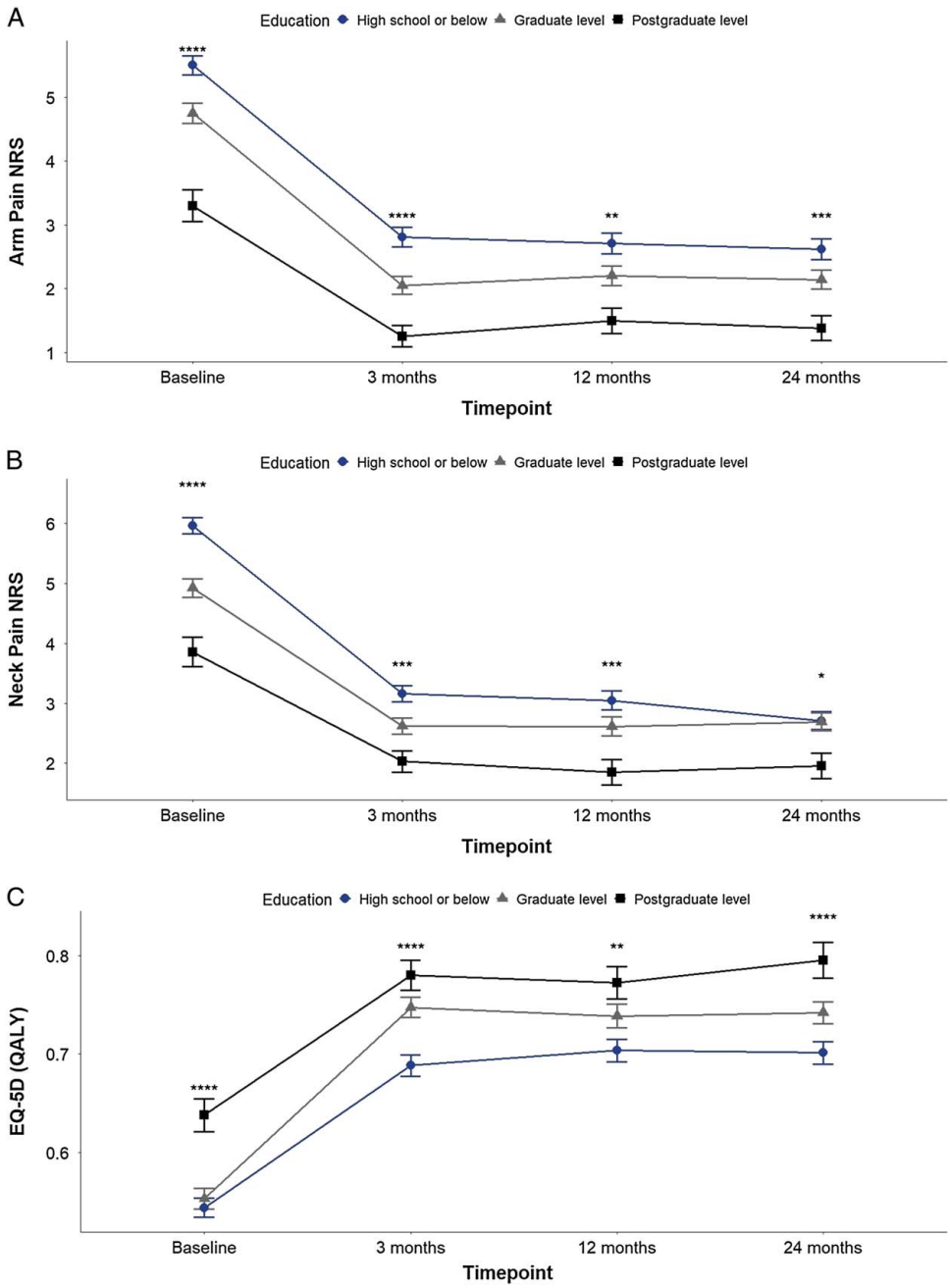

FIGURE 2. Line chart of arm pain NRS (A), neck pain NRS (B), and EQ-5D score (in QALY – C) at baseline and at follow-up time points among different educational levels. Levels of statistical significance annotated as follows: *$P < 0.05$, **$P \leq 0.01$, ***: $P \leq 0.001$, ****$P \leq 0.0001$. NRS indicates Numeric Rating Scale; QALY, Quality-adjusted Life-years. full color online

timeframe, symptom duration, or educational level. Importantly, while all patients did benefit from surgery, the recovery degree for patients of a lower educational status did not account for the initial discrepancy in disease severity. Patients of all educational groups reported similar long-term (>12 mo) satisfaction rates following surgery, further supporting surgical intervention in all groups despite an increased potential for poorer postoperative outcomes.

Ultimately, this study underlines the importance of timely referral and comprehensive consultation of patients of lower educational backgrounds to reduce the impact of social determinants of health on patient outcomes. Primary care and community-based practitioners must retain a higher index of suspicion to identify this debilitating disease to prevent unnecessary delays in care and irreversible neurological injury.[11] The role of appropriate patient and caretaker education is critical and must be provided

TABLE 3. Postoperative Patient-reported Satisfaction From Surgery, mJOA, and NDI Among Different Education Levels Compared in a Univariate Analysis

	High school or below (N = 506)	Graduate level (N = 473)	Postgraduate level (N = 162)	*P*
Satisfaction (NASS 1-2) at 3 mo, n (%)	354 (83.5)	358 (89.9)	110 (85.3)	**0.024**
Satisfaction (NASS 1-2) at 12 mo, n (%)	297 (80.9)	281 (86.2)	104 (85.2)	0.152
Satisfaction (NASS 1-2) at 24 mo, n (%)	334 (82.7)	340 (85.4)	118 (83.7)	0.565
MCID in NDI at 24 mo, n (%)	260 (63.7)	251 (63.2)	87 (61.7)	0.912
MCID in mJOA at 24 mo, n (%)	196 (59.6)	192 (58.5)	69 (56.1)	0.800
MCID in arm pain NRS at 24 mo, n (%)	228 (58.2)	213 (55.6)	71 (53.0)	0.542
MCID in neck pain NRS at 24 mo, n (%)	259 (65.2)	210 (54.5)	72 (53.7)	**0.004**
MCID in QALY at 24 mo, n (%)	135 (34.7)	138 (36.3)	42 (31.8)	0.640

Denominators vary according to the availability of follow-up per data point.

MCID indicates minimal clinically important difference; mJOA, modified Japanese Orthopedic Association; NASS, North American Spine Society; NDI, Neck Disability Index; NRS, Numeric Rating Scale; QALY, Quality-adjusted Life-years.

at an educational level that is appropriate for the audience.[1,7,23,29] Various strategies, such as utilizing multimedia-based educational interventions, have been proposed to improve the efficacy of educational material regardless of a patient's baseline educational status.[23] Finally, given the strong, known association between educational level and postoperative outcomes, educational level should be incorporated into routine preoperative screening and prehabilitation strategies.

To restate, apart from the MCID in neck pain at NRS at 24 months, which was more likely to be achieved by patients of a lower educational background, patients from the 3 cohorts were able to attain the MCID without significant differences. Despite there being no significant differences in the 24-month follow-up outcomes, patients of a lower educational background must not be ignored. Mahoney et al. had a similar result in their study evaluating educational background on the outcomes after bariatric surgery.[34] Although patients of higher and lower educational level achieved similar weight loss, their group still advocated for an increased vigilance in patients with lower education, as this group tended to have poor durability in their weight loss.[34]

In this study, there were significant differences in patient factors influencing outcomes of surgery for CSM. For example, patients with a lower educational level were more likely to smoke and have diabetes. The aforementioned factors have been individually associated with worse outcomes and satisfaction following elective spine surgery.[35–38] To eliminate baseline differences, targeted prehabilitation before elective spine surgery must be emphasized. Continued vigilance of this group is necessary to ensure the durability of outcomes.

Limitations

As with any study involving a review of registry data, this investigation is limited by features inherent to a retrospective study. However, this study benefited from a rigorously collected, multicenter, prospective cohort that has been highly standardized and evaluated in a number of prior studies for validity.[13,35–39] Missing data present within the registry was dealt with via listwise deletion, an accepted method of handling missing data.[40] In addition, the QOD registry comprises patients from 14 high-volume academic and private-practice sites, which biases the patient population towards a high-volume neurosurgical practice with more complex patients. Therefore, in this study, there may be a bias toward patients with more complex disease states. Thus, the external validity of this study must be carefully evaluated in a cohort of more

TABLE 4. Multivariable Regression Analyses Assessing the Impact of the Patients' Educational Level on 24-month Patient-reported Outcomes

	High school or below			Graduate level	Postgraduate level		
	Odds ratio*/coefficient†	95% CI	*P*		Odds ratio*/coefficient†	95% CI	*P*
Satisfaction from surgery (NASS 1-2)*	0.94	0.63 to 1.41	0.77	Reference	0.85	0.48 to 1.49	0.56
Decrease in NDI score †	−0.14	−2.58 to 2.74	0.91	Reference	−0.71	–4.16 to 2.74	0.69
Increase in mJOA score†	0.00	–0.40 to 0.66	0.99	Reference	0.11	–0.43 to 0.51	0.68
Decrease in arm pain (NRS)†	−0.09	−0.50 to 0.32	0.65	Reference	0.28	−0.29 to 0.86	0.33
Decrease in neck pain (NRS)†	−0.01	−0.55 to 0.54	0.98	Reference	−0.23	−0.99 to 0.53	0.56
Increase in QALY score†	−0.02	−0.05 to 0.01	0.19	Reference	0.01	−0.04 to 0.05	0.78

The multivariable analyses have been adjusted for baseline values of each PROM, age, sex, insurance coverage, race, SES index, employment status, workers' compensation, liability claim, and surgical approach employed.

*Multivariable logistic regression was performed, and the results are presented as odds ratio (OR) and 95% CI.

†Multivariable linear regression was performed, and the results are presented as coefficient and 95% CI.

mJOA indicates modified Japanese Orthopedic Association; NASS, North American Spine Society; NDI, Neck Disability Index; NRS, Numeric Rating Scale; QALY, Quality-adjusted Life-years.

common and less severe CSM preoperative disease burden. Further, the results should be interpreted under the national context, wherein quality of education and health care varies geographically. Lastly, radiographic details and complications have not been collected for this study. Having such information would allow for a holistic characterization of outcomes among patients with CSM hailing from different educational backgrounds.

CONCLUSIONS

In a cohort of patients undergoing surgery for the management of CSM, patients with a lower education level more frequently presented with a longer duration of symptoms, more disease-inflicted disability, higher pain scores, and poorer quality of life measures. Importantly, despite an increased baseline disease burden and delayed presentation, patients with a lower educational level still benefit from surgical management of CSM. However, they do not compensate for the initial discrepancy in baseline disease severity when compared with patients with higher educational levels. This study identifies a potentially vulnerable population of patients who are at increased risk for poor neurological outcomes after surgical intervention. Improving health literacy for patients, caretakers, and health care providers is critical to prevent unnecessary delay in care for these vulnerable patients.

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