12-10-2021

The association of patient education level with outcomes after elective lumbar surgery: a Michigan Spine Surgery Improvement Collaborative study

Travis Hamilton
Henry Ford Health, THAMILT8@hfhs.org

Mohamed Macki
Henry Ford Health, mmacki2@hfhs.org

Seok Yoon Oh

Michael Bazydlo
Henry Ford Health, mbazydl1@hfhs.org

Lonni Schultz
Henry Ford Health, lschult1@hfhs.org

See next page for additional authors

Recommended Citation

Hamilton T, Macki M, Oh SY, Bazydlo M, Schultz L, Zakaria HM, Khalil JG, Perez-Cruet M, Aleem I, Park P, Easton R, Nerenz DR, Schwalb J, Abdulhak M, and Chang V. The association of patient education level with outcomes after elective lumbar surgery: a Michigan Spine Surgery Improvement Collaborative study. J Neurosurg Spine 2021; 1-9.

Authors

Travis Hamilton, Mohamed Macki, Seok Yoon Oh, Michael Bazydlo, Lonni Schultz, Hesham Mostafa Zakaria, Jad G. Khalil, Miguelangelo Perez-Cruet, Ilyas Aleem, Paul Park, Richard Easton, David R. Nerenz, Jason M. Schwalb, Muwaffak M. Abdulhak, and Victor Chang

The association of patient education level with outcomes after elective lumbar surgery: a Michigan Spine Surgery Improvement Collaborative study

Travis Hamilton, MD,[1] Mohamed Macki, MD,[1] Seok Yoon Oh, MD,[2] Michael Bazydlo, MS,[3] Lonni Schultz, PhD,[1,3] Hesham Mostafa Zakaria, MD,[1] Jad G. Khalil, MD,[4] Miguelangelo Perez-Cruet, MD, MSc,[5] Ilyas Aleem, MD,[6] Paul Park, MD,[7] Richard Easton, MD,[8] David R. Nerenz, PhD,[9] Jason Schwalb, MD,[1] Muwaffak Abdulhak, MD,[1] and Victor Chang, MD[1]

Departments of [1]Neurosurgery and [3]Public Health Sciences, and [9]Center for Health Services Research, Henry Ford Hospital, Detroit; Departments of [4]Orthopedic Surgery and [5]Neurosurgery, William Beaumont Hospital, Royal Oak; Departments of [6]Orthopaedic Surgery and [7]Neurosurgery, University of Michigan Hospital, Ann Arbor; [8]Department of Orthopedic Surgery, William Beaumont Hospital–Troy, Michigan; and [2]Chicago Medical School, Rosalind Franklin University of Medicine and Science, Chicago, Illinois

OBJECTIVE Socioeconomic factors have been shown to impact a host of healthcare-related outcomes. Level of education is a marker of socioeconomic status. This study aimed to investigate the relationship between patient education level and outcomes after elective lumbar surgery and to characterize any education-related disparities.

METHODS The Michigan Spine Surgery Improvement Collaborative registry was queried for all lumbar spine operations. Primary outcomes included patient satisfaction determined by the North American Spine Society patient satisfaction index, and reaching the minimum clinically important difference of Patient-Reported Outcomes Measurement Information System Physical Function score and return to work up to 2 years after surgery. Multivariate Poisson generalized estimating equation models reported adjusted risk ratios.

RESULTS A total of 26,229 lumbar spine patients had data available for inclusion in this study. On multivariate generalized estimating equation analysis all comparisons were done versus the high school (HS)/general equivalency development (GED)–level cohort. For North American Spine Society satisfaction scores after surgery the authors observed the following: at 90 days the likelihood of satisfaction significantly decreased by 11% ($p < 0.001$) among < HS, but increased by 1% ($p = 0.52$) among college-educated and 3% ($p = 0.011$) among postcollege-educated cohorts compared to the HS/GED cohort; at 1 year there was a decrease of 9% ($p = 0.02$) among < HS and increases of 3% ($p = 0.02$) among college-educated and 9% ($p < 0.001$) among postcollege-educated patients; and at 2 years, there was an increase of 5% ($p = 0.001$) among postcollege-educated patients compared to the < HS group. The likelihood of reaching a minimum clinically important difference of Patient-Reported Outcomes Measurement Information System Physical Function score at 90 days increased by 5% ($p = 0.005$) among college-educated and 9% ($p < 0.001$) among postcollege-educated cohorts; at 1 year, all comparison cohorts demonstrated significance, with a decrease of 12% ($p = 0.007$) among < HS, but an increase by 6% ($p < 0.001$) among college-educated patients and 14% ($p < 0.001$) among postcollege-educated compared to the HS/GED cohort; at 2 years, there was a significant decrease by 19% ($p = 0.003$) among the < HS cohort, an increase by 8% ($p = 0.001$) among the college-educated group, and an increase by 16% ($p < 0.001$) among the postcollege-educated group. For return to work, a significant increase was demonstrated at 90 days and 1 year when comparing the HS or less group with college or postcollege cohorts.

CONCLUSIONS This study demonstrated negative associations on all primary outcomes with lower levels of education. This finding suggests a potential disparity linked to education in elective spine surgery.

https://thejns.org/doi/abs/10.3171/2021.9.SPINE21421

KEYWORDS lumbar spine; patient-reported outcomes; education level

ABBREVIATIONS BMI = body mass index; DVT = deep venous thrombosis; GED = general equivalency development; GEE = generalized estimating equation; HS = high school; MCID = minimum clinically important difference; MSSIC = Michigan Spine Surgery Improvement Collaborative; NASS = North American Spine Society; ODI = Oswestry Disability Index; PHQ-2 = Patient Health Questionnaire–2; PRO = patient-reported outcome; PROMIS PF = Patient-Reported Outcomes Measurement Information System Physical Function; RTW = return to work; SES = socioeconomic status.

SUBMITTED March 22, 2021. **ACCEPTED** September 10, 2021.
INCLUDE WHEN CITING Published online December 10, 2021; DOI: 10.3171/2021.9.SPINE21421.

Patient-reported outcomes (PROs) after surgical interventions are known to be influenced by a complex interaction of many patient characteristics. Health comorbidities, demographics, socioeconomic status (SES), and psychological factors have been proposed as variables that influence PROs.[1] SES, which consists of income, occupation, and education, has been studied extensively in the literature.[2] Generally, level of education is thought to be a marker for SES in that patients with higher levels of education have better access to healthcare and tend to have a lower comorbidity burden as a result. Nevertheless, education level remains a poorly understood variable. Regarding spine surgery, the correlation between educational achievement attained by patients and PRO remains unclear.

A handful of studies investigating the relationship between education level and PRO after elective lumbar spine surgery have shown conflicting results. Chapin et al. and Olson et al. demonstrated that education level is not a significant factor that impacts PRO after lumbar spine surgery or lumbar disc herniation, respectively.[2,3] Other studies have established education as one of many variables that can positively influence patient satisfaction and Oswestry Disability Index (ODI) scores.[4–6] A recent study of adult patients with symptomatic lumbar scoliosis indicated that factors that may have previously been shown to affect PRO, including education, did not lead to any significant change in postoperative outcomes after spine surgery.[1] The current available literature does not illustrate a clear relationship between education level and outcomes after lumbar surgery.

In this study, we aimed to investigate the association between education level and outcome after elective lumbar surgery by using data from the Michigan Spine Surgery Improvement Collaborative (MSSIC) registry. We hypothesized that lower levels of education are associated with worse outcome and could represent a potential disparity in healthcare.

Methods

Setting and Participants

Institutional review board approval was obtained for completion of this study. Patient consent was not obtained due to the retrospective nature of this study. All patient information was deidentified in compliance with IRB regulations. The details of the makeup of the MSSIC registry have been previously described.[7]

The MSSIC is a collaborative quality initiative funded by Blue Cross Blue Shield of Michigan and at the time of this study included 26 hospitals and more than 150 orthopedic spine and neurosurgeons. Practice environments ranged from rural community practice to tertiary and quaternary hospitals in an urban setting. The participants included patients receiving elective lumbar surgery for degenerative pathology, where infectious, traumatic, deformity, and neoplastic pathologies were excluded.

Study Design, Variables, and Measurements

This study was a retrospective review of prospectively collected registry data. The main variable of interest in this study was education level at the time of surgery, divided into the following, mutually exclusive cohorts: less than high school (< HS), HS/general equivalency development (GED), college, and postcollege cohorts. Primary outcomes included the following: North American Spine Society (NASS) patient satisfaction index, reaching the minimum clinically important difference (MCID) of the Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS PF) score, and return to work (RTW) for those patients who indicated at the time of surgery that they intended to return to work. These outcomes were collected at 90 days, 1 year, and 2 years after surgery. The PROMIS PF MCID was defined as an improvement of 4.5 or greater on the PROMIS PF t-score. Using the NASS patient satisfaction index, "satisfied patients" were defined as those with a score of 1 (the treatment met my expectations) or 2 (I did not improve as much as I had hoped, but I would undergo the same treatment for the same outcome), and "unsatisfied patients" were defined as those with a score of 3 (I did not improve as much as I had hoped, and I would not undergo the same treatment for the same outcome) or 4 (I am the same or worse than before treatment).

Baseline patient variables included the following: demographics, body mass index (BMI), smoking status, diabetes, history of deep venous thrombosis (DVT), PROMIS PF score at baseline, ambulatory status, depression screening using the Patient Health Questionnaire–2 (PHQ-2), duration of symptoms prior to surgery, previous history of spine surgery, type of insurance, preoperative duration of daily opioid usage, employment at baseline, and physical workload of employment. Operative and perioperative variables included the following: surgical details (fusion, number of levels treated), hospital length of stay, discharge disposition, hospital readmission within 90 days of surgery, return to operating room within 90 days, urinary retention, and surgical site infection. Baseline and operative variables were factored into our multivariate analysis.

Statistical Methods

Multivariate Poisson generalized estimating equation (GEE) models were used to calculate adjusted risk ratios. The Poisson distribution was used instead of the binomial because the outcome was not rare, which means that the odds ratio does not approximate the relative risk. By using the Poisson distribution, relative risk can be modeled directly. The GEE models were done to take into account the possible correlations among patients being treated at the same hospital. The multivariate GEE models were adjusted for age, sex, race, BMI, diabetes, history of DVT, coronary artery disease, osteoporosis, smoking status, PHQ-2 depression screen status, symptom duration, preoperative opioid use, previous spine surgery, preoperative ambulation status, insurance type, baseline PROMIS PF, fusion versus decompression alone, the number of levels treated surgically, and employment at baseline. Physical workload of employment was collected only for patients who were currently employed and was not included in the multivariate models for RTW because only 34% of the patients had data available for this variable. For the

RTW analysis, patients who planned to return to work after surgery, regardless of their current employment status, were included. The variables selected were based on prior published studies that have shown significant associations with the primary outcomes considered in this study.[8–11]

Results

Participants and Descriptive Data

Patient demographics and clinical variables are summarized in Table 1. The majority of patients had attained an education level of HS/GED (n = 12,750), and the smallest number of patients had < HS education (n = 1624). The median age was the highest in the postcollege cohort (63.3 ± 13.0 years) and lowest in the college cohort (59.3 ± 13.8 years). Regarding RTW after surgery, the majority of patients had attained an education level of high school or less, and the postcollege cohort had the lowest number of patients compared to those who intended to return to work after surgery. Within this group, 63% of patients with an educational level of HS or less were employed at baseline. The median age was lowest in the HS or less cohort (50.8 ± 13.3), whereas in the postcollege cohort the age was the highest (55.9 ± 12.9) (Table 2).

Main Results

Patient Satisfaction

The patient satisfaction rate was analyzed using the NASS patient satisfaction index at 90-day, 1-year, and 2-year increments. Patients with higher levels of education had higher rates of satisfaction after elective lumbar spine surgery (Table 3). On multivariate GEE analysis, at 90 days, the likelihood of postoperative satisfaction was significantly decreased by 11% ($p < 0.001$) among the < HS cohort, whereas it increased by 1% ($p = 0.52$) in college-educated patients and by 3% ($p = 0.01$) among college- and postcollege-educated groups compared to the HS/GED group. At 1 year, satisfaction was significantly decreased by 9% ($p = 0.02$) among < HS, but increased by 3% ($p = 0.024$) and 9% ($p < 0.001$) in college- and postcollege-educated patients, respectively, compared to the HS/GED group. At 2 years, a significant increase in patient satisfaction of 5% ($p = 0.001$) was shown among postcollege-educated patients compared to HS/GED patients (Table 3).

PROMIS PF MCID Achievement

Our analysis here showed a greater likelihood of reaching PROMIS PF MCID with higher levels of education (Table 4). The likelihood of postoperative 90-day MCID in PROMIS PF significantly increased by 5% ($p = 0.005$) among the college-educated and by 9% ($p < 0.001$) among the postcollege-educated compared to the HS/GED group, whereas the < HS cohort did not show any significance ($p = 0.099$). At 1 year, all comparison cohorts demonstrated significance in reaching PROMIS PF MCID, with a significant decrease of 12% ($p = 0.007$) among < HS, but an increase of 6% ($p < 0.001$) among college-educated and 14% ($p < 0.001$) among postcollege-educated compared to < HS/GED patients (Table 4). At 2 years, the PROMIS PF MCID significantly decreased by 19% ($p = 0.003$) among the < HS cohort, and significantly increased by 8% ($p = 0.001$) among the college-educated group and by 16% ($p < 0.001$) among the postcollege-educated group compared to the HS/GED group.

Return to Work

For RTW data, the education level was divided into 3 cohorts as follows: 1) HS or less; 2) college-educated; and 3) postcollege-educated because there was a lower volume of cases to consider for the < HS group. Our analysis also showed a greater likelihood of RTW among college- and postcollege-educated patients (Table 5). When comparing the HS/GED or less group with either college or postcollege cohorts at 90 days, 10% ($p < 0.001$) and 15% ($p < 0.001$) increases in likelihood of RTW were observed, respectively. This trend held true at the 90-day period and at 1 year but disappeared after 1 year.

Discussion

Key Results

In this study, we demonstrated a statistically significant correlation between lumbar surgery outcomes and the level of education. Patient satisfaction rates were significantly correlated with increasing education level at 90 days and 1 year after surgery. By 2 years only postcollege education versus < HS education remained significant. Postcollege-educated patients retained the highest patient satisfaction at all measured time points. Although the overall number of satisfied patients within each category was statistically different, this may not necessarily dictate clinical relevance. However, when each group is compared by the increase in educational status, there is a clear trend toward higher satisfaction. Patients with < HS education were dissatisfied at 90 days, with an increasing trend toward satisfaction by 2 years. A similar pattern was observed with PROMIS as well as RTW among college- and postcollege-educated patients. However, we observed a decline in PROMIS MCID achievement among the < HS population, reaching significance beginning 1 year after surgery. For RTW, our analysis demonstrated significant differences at 90 days and 1 year in patients who underwent lumbar spine surgery when comparing the HS or less group with college- or postcollege-educated cohorts. These differences were no longer significant after 1 year.

Interpretation

Education is considered a powerful surrogate for SES because it remains stable and not influenced by chronic disease occurring later in adult life, unlike occupation or income.[2,12] Lower SES levels are correlated with higher rates of comorbidities such as cardiovascular disease, cancer, obesity, and overall mortality.[2] Lower education levels have also been associated with more health-compromising behaviors such as smoking, poor dietary habits, and physical inactivity in addition to lower compliance with treatments.[13] Last, more comorbidities were found in unemployed patients compared to employed patients.[14] With these implications, education has become a factor to consider when executing procedures or surgical interventions. Nevertheless, education level and its impact

TABLE 1. Demographic and clinical factors by education level in patients who underwent elective lumbar surgery

Variable	Education Level				p Value
	<HS, n = 1624	HS/GED, n = 12,750	College, n = 8856	Postcollege, n = 2999	
Age	61.2 ± 14.9	59.6 ± 14.4	59.3 ± 13.8	63.3 ± 13.0	<0.001
Male	854/1613 (53%)	6,509/12,740 (51%)	4389/8839 (50%)	1682/2995 (56%)	<0.001
BMI	31.2 ± 6.9	31.3 ± 6.7	31.1 ± 6.8	29.9 ± 6.0	<0.001
Race					<0.001
White	1256/1575 (80%)	10,976/12,461 (88%)	7599/8638 (88%)	2612/2911 (90%)	
African American	153/1575 (10%)	953/12,461 (8%)	663/8638 (8%)	154/2911 (5%)	
Other	166/1575 (11%)	532/12,461 (4%)	376/8638 (4%)	145/2911 (5%)	
Current smoker	480/1565 (31%)	2,600/12,392 (21%)	1132/8623 (13%)	145/2914 (5%)	<0.001
Diabetes	470/1612 (29%)	2,953/12,701 (23%)	1834/8817 (21%)	537/2978 (18%)	<0.001
Hx of DVT	92/1608 (6%)	756/12,678 (6%)	503/8811 (6%)	161/2979 (5%)	0.654
CAD	285/1611 (18%)	1,728/12,664 (14%)	1152/8805 (13%)	391/2979 (13%)	<0.001
Osteoporosis	171/1604 (11%)	1,351/12,639 (11%)	928/8789 (11%)	373/2979 (13%)	0.021
PROMIS baseline	32.8 ± 5.1	34.4 ± 5.4	35.0 ± 5.6	36.2 ± 5.7	<0.001
Independently ambulatory	1187/1622 (73%)	10,268/12,728 (81%)	7285/8837 (82%)	2496/2994 (83%)	<0.001
PHQ-2, depression	714/1515 (47%)	4,527/12,108 (37%)	2602/8491 (31%)	642/2862 (22%)	<0.001
Symptom duration >1 yr	1052/1541 (68%)	8,039/12,226 (66%)	5321/8496 (63%)	1717/2875 (60%)	<0.001
Previous spine surgery	717/1456 (49%)	5,368/11501 (47%)	3638/8040 (45%)	1171/2764 (42%)	<0.001
Insurance type					<0.001
Private	452/1624 (28%)	5,606/12,750 (44%)	4583/8856 (52%)	1428/2999 (48%)	
Medicare/other public	841/1624 (52%)	5,827/12,750 (46%)	3795/8856 (43%)	1512/2999 (50%)	
Medicaid	331/1624 (20%)	1,317/12,750 (10%)	478/8856 (5%)	59/2999 (2%)	
Preop daily opioid use duration					<0.001
Naïve	580/1439 (40%)	5,476/11,740 (47%)	4275/8122 (53%)	1782/2797 (64%)	
<6 wks	150/1439 (10%)	1,176/11,740 (10%)	879/8122 (11%)	333/2797 (12%)	
6 wks–3 mos	74/1439 (5%)	676/11,740 (6%)	387/8122 (5%)	107/2797 (4%)	
>3 mos	635/1439 (44%)	4,412/11,740 (38%)	2581/8122 (32%)	575/2797 (21%)	
Fusion	889/1613 (55%)	6,638/12,740 (52%)	4445/8841 (50%)	1398/2995 (47%)	<0.001
No. of levels operated on					0.006
1	776/1571 (49%)	6,028/12,386 (49%)	4446/8612 (52%)	1425/2916 (49%)	
2	452/1571 (29%)	3,732/12,386 (30%)	2469/8612 (29%)	855/2916 (29%)	
3	203/1571 (13%)	1,596/12,386 (13%)	1044/8612 (12%)	397/2916 (14%)	
≥4	140/1571 (9%)	1,030/12,386 (8%)	653/8612 (8%)	239/2916 (8%)	
Length of stay	2 (1, 3)	2 (1, 3)	2 (1, 3)	2 (1, 3)	<0.001
Discharge home	1381/1611 (86%)	11,292/12,729 (89%)	7935/8832 (90%)	2657/2995 (89%)	<0.001
Readmitted w/in 90 days	150/1612 (9%)	890/12,738 (7%)	633/8839 (7%)	188/2993 (6%)	0.002
Returned to OR w/in 90 days	82/1612 (5%)	560/12,738 (4%)	382/8839 (4%)	104/2993 (3%)	0.054
Urinary retention	107/1612 (7%)	782/12,738 (6%)	616/8839 (7%)	234/2993 (8%)	0.004
SSI	50/1612 (3%)	263/12,738 (2%)	163/8839 (2%)	36/2993 (1%)	<0.001
At least 1 complication	371/1612 (23%)	2,750/12,738 (22%)	1939/8839 (22%)	647/2993 (22%)	0.597
Satisfaction at 90 days	633/849 (75%)	6,200/7,400 (84%)	4563/5336 (86%)	1751/1960 (89%)	<0.001
Satisfaction at 1 yr	380/574 (66%)	4,259/5,594 (76%)	3251/4026 (81%)	1288/1493 (86%)	<0.001
Satisfaction at 2 yrs	281/403 (70%)	2,823/3,755 (75%)	2148/2698 (80%)	920/1108 (83%)	<0.001
PROMIS MCID at 90 days	449/834 (54%)	4,268/7,323 (58%)	3219/5207 (62%)	1227/1906 (64%)	<0.001
PROMIS MCID at 1 yr	301/570 (53%)	3,256/5,398 (60%)	2520/3806 (66%)	999/1409 (71%)	<0.001
PROMIS MCID at 2 yrs	198/393 (50%)	2,147/3,595 (60%)	1654/2553 (65%)	706/1018 (69%)	<0.001

CAD = coronary artery disease; Hx = history; OR = operating room; SSI = surgical site infection.
Values for age, BMI, and PROMIS baseline are expressed as the median ± SD, and values for the length of stay are expressed as the median number of days (IQR). All other values are expressed as the number of patients (%).

TABLE 2. Demographic and clinical factors by education level among patients preoperatively planning to return to work

Variable	Education Level			p Value
	HS or Less, n = 4524	College, n = 3810	Postcollege, n = 1354	
Age	50.8 ± 13.3	51.7 ± 12.7	55.9 ± 12.9	<0.001
Male	2771/4519 (61%)	2040/3802 (54%)	769/1354 (57%)	<0.001
BMI	31.4 ± 6.9	31.2 ± 6.8	30.2 ± 6.2	<0.001
Race				0.138
White	3953/4434 (89%)	3316/3715 (89%)	1173/1323 (89%)	
African American	261/4434 (6%)	238/3715 (6%)	72/1323 (5%)	
Other	220/4434 (5%)	161/3715 (4%)	78/1323 (6%)	
Current smoker	1143/4419 (26%)	522/3729 (14%)	63/1328 (5%)	<0.001
Diabetes	694/4506 (15%)	530/3794 (14%)	187/1345 (14%)	0.132
Hx DVT	160/4500 (4%)	138/3791 (4%)	57/1346 (4%)	0.501
CAD	325/4499 (7%)	238/3795 (6%)	86/1348 (6%)	0.194
PROMIS baseline	35.2 ± 5.4	35.8 ± 5.6	36.6 ± 5.6	<0.001
Independently ambulatory	4086/4517 (90%)	3418/3802 (90%)	1209/1350 (90%)	0.530
PHQ-2, depression	1552/4360 (36%)	1001/3684 (27%)	283/1307 (22%)	<0.001
Symptom duration >1 yr	2634/4396 (60%)	2100/3677 (57%)	716/1305 (55%)	0.002
Previous spine surgery	1432/3808 (38%)	1265/3299 (38%)	454/1214 (37%)	0.761
Insurance type				<0.001
Private	3285/4524 (73%)	3003/3810 (79%)	1011/1354 (75%)	
Medicare/other public	687/4524 (15%)	585/3810 (15%)	309/1354 (23%)	
Medicaid	552/4524 (12%)	222/3810 (6%)	34/1354 (3%)	
Employed at baseline	2848/4486 (63%)	2822/3778 (75%)	1112/1347 (83%)	<0.001
Medium/heavy physical workload	870/1450 (60%)	585/1381 (42%)	169/557 (30%)	<0.001
Preop daily opioid use duration				<0.001
Naïve	2001/4197 (48%)	1958/3517 (56%)	838/1281 (65%)	
<6 wks	517/4197 (12%)	469/3517 (13%)	183/1281 (14%)	
6 wks–3 mos	289/4197 (7%)	192/3517 (5%)	52/1281 (4%)	
>3 mos	1390/4197 (33%)	898/3517 (26%)	208/1281 (16%)	
Fusion	1935/4519 (43%)	1579/3803 (42%)	528/1354 (39%)	0.040
No. of levels operated on				0.029
1	2479/4350 (57%)	2204/3667 (60%)	731/1302 (56%)	
2	1260/4350 (29%)	977/3667 (27%)	367/1302 (28%)	
3	407/4350 (9%)	306/3667 (8%)	129/1302 (10%)	
≥4	204/4350 (5%)	180/3667 (5%)	75/1302 (6%)	
RTW at 90 days	1339/2407 (56%)	1472/2145 (69%)	611/803 (76%)	<0.001
RTW at 1 yr	1224/1745 (70%)	1304/1619 (81%)	536/649 (83%)	<0.001
RTW at 2 yrs	838/1187 (71%)	851/1086 (78%)	389/489 (80%)	<0.001

Values are expressed as the median ± SD or number of patients (%).

on outcomes after spine surgery remain an underappreciated factor.

It is interesting to note that patient satisfaction remained significantly increased beyond 90 days after surgery in the college- and postcollege-educated groups, whereas the patients with < HS were least satisfied at 90 days. In addition, the PROMIS MCID achievement score for < HS patients became progressively worse by 2 years postoperatively. This can be partly explained by at least 1 study that examined whether the likelihood of achieving MCID in ODI in the second year increased significantly if the patient had achieved MCID in the first year following lumbar fusion surgery.[7,15] This MCID achievement in ODI after 2 years is a key finding given that a previous study with 4 years of ODI assessment failed to exhibit a significance in ODI score at 1 year postsurgery. There are conflicting reports in the literature regarding PRO and education. According to Olson et al., a higher education level was not associated with better surgical outcomes for SF-36 Bodily Pain, SF-36 Physical Function, and ODI scores at any point in time up to 4 years.[2] Two other studies evaluating change in ODI score also noted similar findings in which education

TABLE 3. Results of multivariate GEE models for association between education and satisfaction in patients who underwent elective lumbar surgery

Variable	90 Days, n = 11,410		1 Yr, n = 8509		2 Yrs, n = 5804	
	RR (95% CI)	p Value	RR (95% CI)	p Value	RR (95% CI)	p Value
Education level—vs HS/GED						
<HS	0.89 (0.86, 0.93)	<0.001	0.91 (0.84, 0.99)	0.020	0.96 (0.88, 1.04)	0.292
College	1.01 (0.99, 1.03)	0.520	1.03 (1.00, 1.06)	0.024	1.03 (1.00, 1.07)	0.058
Postcollege	1.03 (1.01, 1.05)	0.011	1.09 (1.06, 1.12)	<0.001	1.05 (1.02, 1.09)	0.001
Age, 5-yr increments	1.01 (1.00, 1.01)	0.007	1.00 (0.99, 1.00)	0.126	1.00 (0.99, 1.00)	0.362
Male	1.00 (0.99, 1.02)	0.853	0.98 (0.96, 1.01)	0.139	0.99 (0.96, 1.01)	0.281
Race/ethnicity—vs White						
African American	0.95 (0.91, 0.99)	0.010	0.85 (0.80, 0.91)	<0.001	0.85 (0.78, 0.94)	0.001
Other	0.94 (0.90, 0.99)	0.012	0.94 (0.88, 1.00)	0.061	0.92 (0.85, 0.99)	0.031
BMI, 5-U increments	1.00 (0.99, 1.00)	0.553	0.99 (0.98, 1.00)	0.016	0.99 (0.98, 1.00)	0.048
Diabetes	0.99 (0.97, 1.01)	0.214	1.00 (0.97, 1.03)	0.868	1.01 (0.97, 1.04)	0.775
Hx of DVT	1.00 (0.97, 1.04)	0.833	0.99 (0.95, 1.04)	0.689	1.04 (0.98, 1.10)	0.242
CAD	0.98 (0.96, 1.01)	0.160	0.96 (0.92, 0.99)	0.022	0.96 (0.91, 1.00)	0.072
Osteoporosis	0.98 (0.96, 1.01)	0.160	1.01 (0.96, 1.05)	0.812	1.00 (0.96, 1.04)	0.842
Current smoker	0.95 (0.92, 0.98)	<0.001	0.93 (0.89, 0.96)	<0.001	0.95 (0.91, 0.99)	0.011
PHQ-2, depression	0.94 (0.92, 0.96)	<0.001	0.94 (0.91, 0.97)	<0.001	0.92 (0.89, 0.96)	<0.001
Symptom duration >1 yr	0.95 (0.93, 0.97)	<0.001	0.94 (0.92, 0.96)	<0.001	0.93 (0.90, 0.95)	<0.001
Preop opioid use duration—vs naïve						
<6 wks	1.04 (1.01, 1.06)	0.002	1.04 (1.01, 1.07)	0.021	1.05 (1.01, 1.09)	0.018
6 wks–3 mos	1.03 (0.99, 1.06)	0.141	1.05 (1.01, 1.10)	0.023	1.03 (0.97, 1.09)	0.377
>3 mos	0.98 (0.96, 0.99)	0.007	0.95 (0.92, 0.97)	<0.001	0.96 (0.92, 0.99)	0.023
Previous spine surgery	0.94 (0.93, 0.96)	<0.001	0.92 (0.90, 0.94)	<0.001	0.92 (0.89, 0.96)	<0.001
Independently ambulatory preop	1.01 (0.98, 1.03)	0.629	0.99 (0.96, 1.03)	0.694	1.04 (1.00, 1.09)	0.074
Private insurance	1.03 (1.02, 1.05)	<0.001	1.02 (1.00, 1.05)	0.092	1.03 (1.00, 1.07)	0.084
PROMIS baseline, 5-U increments	1.01 (1.00, 1.02)	0.024	1.02 (1.01, 1.03)	0.006	1.02 (1.00, 1.03)	0.019
Fusion	1.04 (1.02, 1.06)	<0.001	1.02 (0.99, 1.05)	0.132	1.00 (0.97, 1.03)	0.752
No. of levels operated on—vs 1						
2	1.00 (0.98, 1.01)	0.809	0.98 (0.96, 1.01)	0.244	0.98 (0.95, 1.00)	0.096
3	0.99 (0.97, 1.02)	0.632	0.96 (0.92, 1.00)	0.035	0.99 (0.94, 1.04)	0.650
≥4	0.96 (0.94, 0.99)	0.014	0.93 (0.88, 0.98)	0.008	0.88 (0.83, 0.94)	<0.001

level was one of many comorbidities that influenced ODI outcomes.[4,6] Although our study showed a progressive trend toward higher patient satisfaction among the education groups at each interval, the overall number of satisfied patients is relatively similar. Although this may not have a strong clinical impact, this information can be useful to help surgeons to guide discussions regarding their patients' expectations. Another factor to consider is that patients with higher education levels are less likely to have physically demanding occupations, and that the long-term differences are related to the nature of employment relative to education level. Our study illustrates the potential interaction between higher education and reaching MCID on PROMIS PF, which has not previously been reported.

Regarding RTW, previous studies have identified several risk factors for failure to return to work, such as African American race, liability insurance for disability, less than a college education, workers' compensation, manual labor as occupation, current smoking status, and depression.[16–19] One study further categorized these risk factors into variables independent of surgical outcomes and safety profile of surgery, and discovered that physically demanding jobs and workers' compensation limited patients from RTW. Patients with a physically rigorous job meant that RTW involved careful discussions with the employer to potentially change their job description to lessen future injuries.[16] Our study demonstrated that patients with lower education level were less likely to return to work, and this may be explained by occupational risk factors as mentioned above. Patients with lower education are more likely to work in demanding, manual labor jobs, which preclude them from RTW. In light of this, we observed a less significant difference with RTW and PROMIS score, which may hint that patients are returning to work despite having impaired physical function.

Limitations and Generalizability

Our study is not without limitations. Given that this

TABLE 4. Results of multivariate GEE models for association between education and PROMIS MCID achievement in patients who underwent elective lumbar surgery

	90 Days, n = 11,393		1 Yr, n = 8257		2 Yrs, n = 5533	
Variable	RR (95% CI)	p Value	RR (95% CI)	p Value	RR (95% CI)	p Value
Education level—vs HS/GED						
<HS	0.94 (0.87, 1.01)	0.099	0.88 (0.80, 0.97)	0.007	0.81 (0.71, 0.93)	0.003
College	1.05 (1.01, 1.08)	0.005	1.06 (1.03, 1.10)	<0.001	1.08 (1.03, 1.13)	0.001
Postcollege	1.09 (1.05, 1.13)	<0.001	1.14 (1.09, 1.19)	<0.001	1.16 (1.10, 1.22)	<0.001
Age, 5-yr increments	1.01 (1.01, 1.02)	0.001	0.99 (0.99, 1.00)	0.123	0.98 (0.97, 0.99)	0.001
Male	1.00 (0.97, 1.03)	0.863	1.00 (0.97, 1.04)	0.966	1.07 (1.03, 1.11)	<0.001
Race/ethnicity—vs White						
African American	0.82 (0.76, 0.89)	<0.001	0.88 (0.81, 0.96)	0.002	0.90 (0.82, 0.98)	0.019
Other	0.97 (0.90, 1.04)	0.349	0.98 (0.90, 1.06)	0.572	0.98 (0.89, 1.07)	0.589
BMI, 5-U increments	0.97 (0.96, 0.98)	<0.001	0.96 (0.94, 0.97)	<0.001	0.94 (0.92, 0.96)	<0.001
Diabetes	0.99 (0.96, 1.02)	0.618	0.96 (0.91, 1.01)	0.103	0.98 (0.93, 1.04)	0.538
Hx of DVT	0.96 (0.91, 1.02)	0.192	0.90 (0.84, 0.97)	0.005	1.05 (0.97, 1.14)	0.203
CAD	0.95 (0.91, 1.00)	0.037	0.94 (0.90, 0.98)	0.003	0.90 (0.85, 0.96)	0.001
Osteoporosis	0.93 (0.89, 0.98)	0.005	0.96 (0.91, 1.01)	0.139	1.01 (0.94, 1.09)	0.694
Current smoker	0.90 (0.85, 0.94)	<0.001	0.88 (0.83, 0.93)	<0.001	0.89 (0.84, 0.94)	<0.001
PHQ-2, depression	0.93 (0.89, 0.96)	<0.001	0.94 (0.90, 0.98)	0.001	0.91 (0.87, 0.95)	<0.001
Symptom duration >1 yr	0.92 (0.90, 0.95)	<0.001	0.91 (0.88, 0.94)	<0.001	0.87 (0.84, 0.91)	<0.001
Preop opioid use duration—vs naïve						
<6 wks	1.06 (1.02, 1.11)	0.005	1.03 (0.98, 1.08)	0.229	1.04 (0.99, 1.10)	0.129
6 wks–3 mos	1.08 (1.01, 1.15)	0.016	1.05 (0.99, 1.12)	0.112	1.06 (0.98, 1.15)	0.139
>3 mos	0.87 (0.84, 0.91)	<0.001	0.83 (0.79, 0.86)	<0.001	0.86 (0.82, 0.91)	<0.001
Previous spine surgery	0.88 (0.86, 0.91)	<0.001	0.86 (0.83, 0.89)	<0.001	0.86 (0.83, 0.90)	<0.001
Independently ambulatory preop	1.14 (1.09, 1.18)	<0.001	1.11 (1.05, 1.17)	<0.001	1.18 (1.12, 1.25)	<0.001
Private insurance	1.06 (1.02, 1.10)	0.002	1.09 (1.05, 1.13)	<0.001	1.11 (1.07, 1.16)	<0.001
PROMIS baseline, 5-U increments	0.80 (0.79, 0.82)	<0.001	0.83 (0.81, 0.85)	<0.001	0.81 (0.79, 0.83)	<0.001
Fusion	0.91 (0.88, 0.94)	<0.001	1.01 (0.98, 1.05)	0.556	1.02 (0.98, 1.07)	0.293
No. of levels operated on—vs 1						
2	0.97 (0.94, 1.00)	0.058	1.01 (0.97, 1.04)	0.774	0.95 (0.91, 0.98)	0.006
3	0.93 (0.88, 0.98)	0.007	0.94 (0.89, 1.00)	0.042	0.88 (0.82, 0.95)	0.001
≥4	0.86 (0.80, 0.92)	<0.001	0.90 (0.83, 0.97)	0.008	0.83 (0.76, 0.90)	<0.001

study is a retrospective review of prospectively collected data, there is the potential for hidden bias that cannot be fully accounted for in our analytical models. In particular, many of the key variables in this study are patient reported, and there is a potential for bias if patients chose not to respond or were lost to follow-up by choice (i.e., not at random). Another limitation is the inability to include physical workload information in the multivariate RTW models because of the large amount of missing information for this variable. In addition, as with all large multicenter registry data, there is always the potential for some small anomalies in data quality.

Despite these limitations we believe our data to be widely generalizable. The data derived from this study include 26 hospitals across the state ranging from academic tertiary care centers in large metropolitan areas to community hospitals with private practice surgeons in less densely populated areas. There may be some demographic features unique to the population of Michigan that may not be applicable to other study populations. Despite this, we believe our findings to be widely generalizable.

Conclusions

Achieving PROMIS PF MCID and patient satisfaction rates with surgery appears to correlate with a higher level of education. Postcollege-educated patients were assessed with the best outcomes, whereas those with < HS education fared the worst. Overall, these findings suggest a potential disparity linked to education in elective lumbar spine surgery. As with many disparities in healthcare, awareness is oftentimes underappreciated. We hope that by publishing this study we are able to increase the awareness of neurosurgeons and orthopedic spine surgeons to the potential barriers that exist within a subset of their patients in order to facilitate communication and provide extra support if needed.

TABLE 5. Results of multivariate GEE models for association between education and RTW in patients who underwent elective lumbar surgery

Variable	90 Days, n = 3831		1 Yr, n = 2840		2 Yrs, n = 1967	
	RR (95% CI)	p Value	RR (95% CI)	p Value	RR (95% CI)	p Value
Education level—vs HS/GED or less						
College	1.10 (1.05, 1.15)	<0.001	1.05 (1.01, 1.09)	0.020	1.03 (0.98, 1.08)	0.206
Postcollege	1.15 (1.09, 1.21)	<0.001	1.05 (1.00, 1.10)	0.036	1.03 (0.97, 1.10)	0.325
Age, 5-yr increments	1.00 (0.99, 1.01)	0.849	0.98 (0.97, 0.99)	<0.001	0.97 (0.96, 0.98)	<0.001
Male	1.01 (0.97, 1.06)	0.558	1.07 (1.03, 1.11)	<0.001	1.05 (1.00, 1.11)	0.042
Race/ethnicity—vs White						
African American	0.68 (0.57, 0.81)	<0.001	0.81 (0.70, 0.94)	0.004	0.81 (0.66, 0.99)	0.043
Other	0.83 (0.74, 0.94)	0.003	0.92 (0.84, 1.01)	0.076	0.96 (0.87, 1.06)	0.425
BMI, 5-U increments	0.99 (0.97, 1.00)	0.169	1.00 (0.99, 1.01)	0.909	0.99 (0.97, 1.01)	0.175
Diabetes	1.02 (0.95, 1.08)	0.633	1.02 (0.97, 1.08)	0.403	1.04 (0.97, 1.12)	0.246
Hx of DVT	0.96 (0.86, 1.07)	0.430	0.93 (0.82, 1.04)	0.198	0.97 (0.85, 1.12)	0.713
CAD	0.93 (0.85, 1.02)	0.133	0.90 (0.83, 0.98)	0.019	0.95 (0.83, 1.08)	0.393
Current smoker	0.89 (0.83, 0.95)	<0.001	0.94 (0.89, 0.99)	0.024	0.97 (0.90, 1.04)	0.337
Employed at baseline	2.38 (2.17, 2.61)	<0.001	1.87 (1.72, 2.05)	<0.001	1.73 (1.58, 1.89)	<0.001
PHQ-2, depression	0.92 (0.87, 0.97)	0.004	0.99 (0.95, 1.03)	0.644	0.97 (0.91, 1.04)	0.452
Preop opioid use duration—vs naïve						
<6 wks	1.08 (1.02, 1.16)	0.016	1.10 (1.05, 1.15)	<0.001	1.07 (1.02, 1.13)	0.012
6 wks–3 mos	1.01 (0.91, 1.12)	0.809	1.07 (1.00, 1.14)	0.055	1.10 (0.99, 1.21)	0.076
>3 mos	0.96 (0.90, 1.02)	0.176	0.96 (0.91, 1.02)	0.190	0.98 (0.91, 1.05)	0.538
Independently ambulatory preop	1.05 (0.98, 1.14)	0.171	1.11 (1.02, 1.19)	0.011	1.13 (1.01, 1.25)	0.030
Private insurance	1.16 (1.08, 1.23)	<0.001	1.24 (1.18, 1.31)	<0.001	1.28 (1.18, 1.39)	<0.001
Symptom duration >1 yr	0.98 (0.95, 1.03)	0.461	0.97 (0.94, 1.01)	0.120	0.96 (0.92, 1.00)	0.060
Previous spine surgery	1.00 (0.96, 1.04)	0.912	0.99 (0.95, 1.03)	0.500	0.94 (0.90, 0.99)	0.014
PROMIS baseline, 5-U increments	1.01 (1.00, 1.03)	0.150	1.01 (0.99, 1.02)	0.531	1.01 (0.99, 1.03)	0.325
Fusion	0.75 (0.71, 0.80)	<0.001	0.93 (0.89, 0.97)	0.001	0.97 (0.92, 1.02)	0.296
No. of levels operated on—vs 1						
2	0.96 (0.92, 1.01)	0.087	0.95 (0.92, 0.99)	0.021	0.96 (0.91, 1.02)	0.201
3	0.90 (0.85, 0.96)	0.002	0.96 (0.90, 1.04)	0.327	0.97 (0.90, 1.05)	0.423
≥4	0.81 (0.72, 0.91)	<0.001	0.89 (0.79, 1.01)	0.075	0.90 (0.79, 1.03)	0.138

Acknowledgments

Although Blue Cross Blue Shield of Michigan (BCBSM) and the MSSIC work collaboratively, the opinions, beliefs, and viewpoints expressed by the authors do not necessarily reflect the opinions, beliefs, and viewpoints of BCBSM or any of its employees. Support for MSSIC is provided by BCBSM and Blue Care Network as part of the BCBSM Value Partnerships program.

References

1. Yanik EL, Kelly MP, Lurie JD, Baldus CR, Shaffrey CI, Schwab FJ, et al. Effect modifiers for patient-reported outcomes in operatively and nonoperatively treated patients with adult symptomatic lumbar scoliosis: a combined analysis of randomized and observational cohorts. *J Neurosurg Spine*. 2020;33(1):17-26.
2. Olson PR, Lurie JD, Frymoyer J, Walsh T, Zhao W, Morgan TS, et al. Lumbar disc herniation in the Spine Patient Outcomes Research Trial: does educational attainment impact outcome? *Spine (Phila Pa 1976)*. 2011;36(26):2324-2332.
3. Chapin L, Ward K, Ryken T. Preoperative depression, smoking, and employment status are significant factors in patient satisfaction after lumbar spine surgery. *Clin Spine Surg*. 2017;30(6):E725-E732.
4. Slover J, Abdu WA, Hanscom B, Weinstein JN. The impact of comorbidities on the change in Short-form 36 and Oswestry scores following lumbar spine surgery. *Spine (Phila Pa 1976)*. 2006;31(17):1974-1980.
5. Adogwa O, Parker SL, Shau DN, Mendenhall SK, Bydon A, Cheng JS, et al. Preoperative Zung depression scale predicts patient satisfaction independent of the extent of improvement after revision lumbar surgery. *Spine J*. 2013;13(5):501-506.
6. McGirt MJ, Bydon M, Archer KR, Devin CJ, Chotai S, Parker SL, et al. An analysis from the Quality Outcomes Database, Part 1. Disability, quality of life, and pain outcomes following lumbar spine surgery: predicting likely individual patient outcomes for shared decision-making. *J Neurosurg Spine*. 2017;27(4):357-369.
7. Chang V, Schwalb JM, Nerenz DR, Pietrantoni L, Jones S, Jankowski M, et al. The Michigan Spine Surgery Improvement Collaborative: a statewide Collaborative Quality Initiative. *Neurosurg Focus*. 2015;39(6):E7.

8. Macki M, Hamilton T, Lim S, Telemi E, Bazydlo M, Nerenz DR, et al. Disparities in outcomes after spine surgery: a Michigan Spine Surgery Improvement Collaborative study. *J Neurosurg Spine*. 2021;35(1):91-99.
9. Zakaria HM, Mansour T, Telemi E, Xiao S, Bazydlo M, Schultz L, et al. Patient demographic and surgical factors that affect completion of patient-reported outcomes 90 days and 1 year after spine surgery: analysis from the Michigan Spine Surgery Improvement Collaborative (MSSIC). *World Neurosurg*. 2019;130:e259-e271.
10. Macki M, Alvi MA, Kerezoudis P, Xiao S, Schultz L, Bazydlo M, et al. Predictors of patient dissatisfaction at 1 and 2 years after lumbar surgery. *J Neurosurg Spine*. 2020;32(3):373-382.
11. Zakaria HM, Mansour TR, Telemi E, Asmaro K, Macki M, Bazydlo M, et al. Use of Patient Health Questionnaire-2 scoring to predict patient satisfaction and return to work up to 1 year after lumbar fusion: a 2-year analysis from the Michigan Spine Surgery Improvement Collaborative. *J Neurosurg Spine*. 2019;31(6):794-801.
12. Dionne CE, Von Korff M, Koepsell TD, Deyo RA, Barlow WE, Checkoway H. Formal education and back pain: a review. *J Epidemiol Community Health*. 2001;55(7):455-468.
13. Laaksonen M, Talala K, Martelin T, Rahkonen O, Roos E, Helakorpi S, et al. Health behaviours as explanations for educational level differences in cardiovascular and all-cause mortality: a follow-up of 60 000 men and women over 23 years. *Eur J Public Health*. 2008;18(1):38-43.
14. Walid MS, Robinson ECM, Robinson JS Jr. Higher comorbidity rates in unemployed patients may significantly impact the cost of spine surgery. *J Clin Neurosci*. 2011;18(5):640-644.
15. Adogwa O, Elsamadicy AA, Han JL, Cheng J, Karikari I, Bagley CA. Do measures of surgical effectiveness at 1 year after lumbar spine surgery accurately predict 2-year outcomes? *J Neurosurg Spine*. 2016;25(6):689-696.
16. Khan I, Bydon M, Archer KR, Sivaganesan A, Asher AM, Alvi MA, et al. Impact of occupational characteristics on return to work for employed patients after elective lumbar spine surgery. *Spine J*. 2019;19(12):1969-1976.
17. Asher AL, Devin CJ, Archer KR, Chotai S, Parker SL, Bydon M, et al. An analysis from the Quality Outcomes Database, Part 2. Predictive model for return to work after elective surgery for lumbar degenerative disease. *J Neurosurg Spine*. 2017;27(4):370-381.
18. DiGiorgio AM, Mummaneni PV, Park P, Chan AK, Bisson EF, Bydon M, et al. Correlation of return to work with patient satisfaction after surgery for lumbar spondylolisthesis: an analysis of the Quality Outcomes Database. *Neurosurg Focus*. 2020;48(5):E5.
19. Chotai S, Sivaganesan A, Parker SL, McGirt MJ, Devin CJ. Patient-specific factors associated with dissatisfaction after elective surgery for degenerative spine diseases. *Neurosurgery*. 2015;77(2):157-163.

Disclosures

Dr. Abdulhak is a consultant for SeaSpine and Ulrich Medical, and also receives royalties from SeaSpine. Dr. Chang is a consultant for Globus Medical. He receives some salary support (unrelated to this study) from BCBSM. Dr. Khalil is a consultant for Stryker, Medtronic, NuVasive, Relievant, Camber Spine, SI Bone, Thompson, and Centinel Spine. He has direct stock ownership in Medtronic, Johnson & Johnson, and NuVasive, and he receives royalties from Camber Spine. He also receives clinical or research support for the study described (includes equipment or material) from Medtronic, Stryker, NuVasive, Johnson & Johnson, Centinel Spine, Relievant, Limiflex, Fziomed, Synergy, Providence Medical, and SI Bone. Dr. Park is a consultant for Globus and NuVasive; receives royalties from Globus; and receives support of a non–study-related clinical or research effort that he oversees from Cerapedics, SI Bone, DePuy, and ISSG. Dr. Perez-Cruet has direct stock ownership in Thompson MIS, is in the Orthofix speaker's bureau, and receives royalties from Thieme Publishing. Dr. Schwalb receives support of a non–study-related clinical or research effort that he oversees from Medtronic. He receives clinical or research support for the study described (includes equipment or material) from BCBSM.

Author Contributions

Conception and design: Chang, Schwalb, Abdulhak. Acquisition of data: Hamilton, Macki, Oh, Bazydlo, Zakaria, Khalil, Perez-Cruet, Aleem, Park, Easton, Schwalb. Analysis and interpretation of data: Chang, Hamilton, Macki, Bazydlo, Schultz, Zakaria, Khalil, Perez-Cruet, Aleem, Park, Easton, Nerenz, Schwalb, Abdulhak. Drafting the article: Hamilton, Macki, Khalil, Perez-Cruet, Park. Critically revising the article: Chang, Abdulhak. Reviewed submitted version of manuscript: Hamilton, Zakaria, Nerenz. Approved the final version of the manuscript on behalf of all authors: Chang. Statistical analysis: Oh, Schultz, Nerenz. Study supervision: Chang, Abdulhak.

Supplemental Information

Previous Presentations

Some of this material was presented at the AANS/CNS Annual Meeting of the Spine and Peripheral Nerves, March 5–8, 2020, Las Vegas, NV.

Correspondence

Victor Chang: Henry Ford Hospital, Detroit, MI. vchang1@hfhs.org.