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Anterior Cervical Discectomy and Fusion Results in Clinically Significant Improvements in Patients With Preoperative Sleep Difficulties

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ABSTRACT

Background: Individual items within the Patient Health Questionnaire-9 (PHQ-9) have not been assessed as predictors of postoperative outcomes. Our objective is to study the relationship between responses to individual PHQ-9 items and achievement of a minimum clinically important difference (MCID) following anterior cervical discectomy and fusion (ACDF).

Methods: A prospective surgical database was reviewed for primary, single-level ACDF procedures performed for degenerative spinal pathology. Patient demographics, preoperative spinal pathology, and perioperative characteristics were recorded. Patient-reported outcome measures (PROMs) including PHQ-9, visual analog scale (VAS) neck and arm, Neck Disability Index, 12-item Short Form physical component score (SF-12 PCS), and Patient-Reported Outcomes Measurement Information System Physical Function were administered at preoperative and 6-week, 12-week, 6-month, 1-year, and 2-year postoperative timepoints. MCID achievement was determined by comparing postoperative PROM improvement from baseline to previously established values. Logistic regression assessed responses to each individual question of the preoperative PHQ-9 as predictors of MCID achievement in each other PROMs.

Results: Sixty-six ACDF patients were included with a mean age of 47.2 years. Herniated nucleus pulposus was the most common preoperative spinal diagnosis (95.6%). The mean operative duration was 50.3 minutes, the mean estimated blood loss was 27.5 mL, and most patients were discharged on postoperative day 0 (81.8%). A majority of patients achieved MCID for all measures except SF-12 PCS. PHQ-9 question 3 significantly predicted MCID achievement for VAS neck ($P = 0.045$), VAS arm ($P = 0.049$), and SF-12 PCS ($P = 0.037$). No other PHQ-9 items or overall PHQ-9 scores significantly predicted MCID achievement.

Conclusion: Question 3 of the PHQ-9 regarding "trouble falling asleep, staying asleep, or sleeping too much" significantly predicted clinically meaningful improvement in neck pain, arm pain, and physical function following ACDF, although overall PHQ-9 scores did not. Providers should inform patients experiencing significant sleep-related difficulties that they may be especially likely to benefit from ACDF surgery.

Clinical Relevance: Evaluation of sleep from the PHQ-9 predicts clinically relevant improvement in neck pain, arm pain, and physical function in patients undergoing ACDF.

Level of Evidence: 3.

Cervical Spine

Keywords: anterior cervical discectomy and fusion (ACDF), patient health questionnaire-9 (PHQ-9), patient-reported outcome measures (PROMs)

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is one of the most common surgical treatments for the degeneration of the cervical spine when conservative management is insufficient.[1] Many who suffer from cervical pathology experience adversities in daily functioning, decreased productivity, and limitation of roles in their personal lives.[2] Because patients choose to undergo ACDF largely in the hope of improving overall health, clinicians track pre- and postoperative physical and mental symptom progression with great interest. The role that preoperative mental health, in particular, plays on postoperative outcomes has been previously explored in spinal fusion patients, and the results have been contrasting in nature. Several investigations report that those with greater preoperative depression, as measured by the Patient Health Questionnaire-9 (PHQ-9), experienced poorer functional outcomes and smaller improvements in postoperative quality of life.[3,4] However, Jenkins et al have demonstrated that preoperative PHQ-9 scores had minimal impact on postoperative outcomes among ACDF patients.[5]

The PHQ-9 is a patient-reported outcome measure (PROM) designed to assess a patient's depressive symptom severity using 9 questions based on the DSM-IV criteria for depressive disorders. These inquiries evaluate specific symptom criteria such as energy level, appetite, concentration, hopelessness, and sleep.[6] Each question is scored based on the frequency of symptom occurrence from 0 (never) to 3 (nearly every day), and outcome analyses are typically based on the total combined score ranging from 0 to 27. However, independent analysis of the individual questions of the PHQ-9 may also provide valuable information pertaining to various aspects of daily life. With a sense of the specific individual categories that are most predictive of postoperative outcomes, physicians may promote more targeted screenings of prospective surgical candidates and better account for those preoperative indicators.

For our present study, in order to determine whether aspects of the PHQ-9 truly have an impact on outcomes, we assessed postoperative conditions in terms of the minimum clinically important difference (MCID). MCID has gained traction in spine surgery because of its ability to quantify outcomes in terms of the level of improvement at which patients truly notice meaningful changes in their symptoms.[7] To our knowledge, studies have yet to consider the separate questions of the PHQ-9 in relation to postoperative MCID achievement in cervical spine populations. With greater insight on this topic, clinicians may identify ways to optimize postsurgical outcomes as well as administer more efficient and applicable survey questionnaires. Therefore, we aim to study the relationship between responses to individual PHQ-9 items and the achievement of MCID following ACDF.

METHODS

Patient Population

Prospectively collected data were retrospectively reviewed for patients who underwent primary, single-level ACDF procedures from April 2016 to November 2018. Exclusion criteria were patients lacking preoperative PHQ-9 data or whose procedures were performed for trauma, malignancy, or infection. All procedures were performed at a single academic institution by the same attending spine surgeon. All aspects of the current study were approved by the Institutional Review Board, and all included patients provided written informed consent.

Data Collection

Collected data included patient age, gender, body mass index, smoking status, diabetes mellitus status, American Society of Anesthesiologists physical classification, Charlson Comorbidity Index, ethnicity, insurance/payment received, preoperative spinal pathology, operative duration (from skin incision to skin closure, in minutes), estimated blood loss (in minutes), postoperative length of stay (in hours), and postoperative day (POD) of discharge. PROMs were administered at preoperative and 6-week, 12-week, 6-month, 1-year, and 2-year postoperative timepoints. PROMs consisted of PHQ-9, visual analog scale (VAS) neck, VAS arm, Neck Disability Index (NDI), 12-item Short-Form physical component score (SF-12 PCS), and Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS-PF). While the overall survey metrics were collected for the aforementioned PROMs, responses to each separate question of preoperative PHQ-9 were also collected (the details of each individual question are listed in Table 1). We then used MCID achievement rates as a way of assessing the overall success of the procedure, as it resembles the

Table 1. The Patient Health Questionnaire-9.

Over the past 2 weeks, how often have you been bothered by any of the following roblems?	Not At All	Several Days	More Than Half the Days	Nearly Every Day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling asleep, staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself—or that you're a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or, the opposite—being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3
10. If you checked off any problems, how difficult have those problems made it for you to do your work, take care of things at home, or get along with other people?	Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult

proportion of patients achieving clinically meaningful improvement across PROMs based on established literature values for delta PROMs (change from pre- to postoperative scores). Next, each individual question of the 10 PHQ-9 items was assessed as a predictor of MCID attainment for other PROMs (VAS neck, VAS arm, NDI, SF-12 PCS, and PROMIS-PF) using logistic regression analysis with OR and 95% CI. Other published manuscripts have highlighted the importance of studying the predictive ability of PROMs on MCID achievement: Leyton-Mange et al sought to demonstrate preoperative PROM threshold scores that were predictive of MCID achievement for adult spinal deformity patients,[8] while Lynch et al utilized linear regression to determine the influence of PHQ-9 on change in PROMs (ie, delta PROMs), which directly influenced MCID achievement rates.[9] In the present manuscript, we are specifically honing in on individual questions of the PHQ-9 to evaluate whether these may hold a significant predictive value of MCID achievement.

Statistical Analysis

Achievement of MCID was determined by comparing postoperative change from preoperative baseline in each PROM to the following previously established MCID values: VAS neck (2.6),[10] VAS arm (4.1),[10] NDI (8.5),[10] SF-12 PCS (8.1),[10] and PROMIS-PF (4.5).[11] Descriptive statistics were performed to report means and SD for continuous variables and percentages for categorical variables. Individual responses to each question of the PHQ-9 were assessed as predictors of MCID achievement for each of the other PROMs using logistic regression with ORs and 95% CIs.

RESULTS

A total of 66 primary, single-level ACDF patients with complete preoperative PHQ-9 data were identified. The cohort's mean age was 47.2 years, 42.4% were female, and 47.0% were obese (body mass index ≥30 kg/m^2) (Table 2)(). A majority of the patients were of white ethnicity (71.2%) and made payments through private insurance (71.2%). Herniated nucleus pulposus was present in nearly all patients (95.5%). The mean operative duration was 50.3 minutes, the mean estimated blood loss was 27.5 mL, and the mean postoperative length of stay was 10.1 hours (Table 3)(). Most patients were discharged on the day of surgery (81.8%).

Mean preoperative PROM scores were as follows: 6.1 ± 2.4 (VAS neck), 6.0 ± 2.8 (VAS arm), 37.2 ± 16.0 (NDI), 36.1 ± 8.1 (SF-12 PCS), and 39.6 ± 7.2 (PROMIS-PF). Mean postoperative scores ranged from 2.5 to 5.0 (VAS neck), 2.4 to 4.0 (VAS arm), 20.2 to 30.1 (NDI), 35.3 to 43.5 (SF-12 PCS), 40.7 to 47.9 (PROMIS-PF) (Table 4) (). A majority of patients achieved MCID in all PROM scores except SF-12 PCS (47.4%).

Question 3 of the PHQ-9 (trouble falling asleep, staying asleep, or sleeping too much) was a significant predictor of MCID achievement for VAS neck (OR: 2.0, 95% CI [1.0, 3.9], $P = 0.045$), VAS arm (OR: 1.7, 95% CI [1.0, 2.9], $P = 0.049$), and SF-12 PCS (OR: 1.7, 95% CI [1.0, 2.9], $P = 0.037$) (Tables 5 and 6). No other PHQ-9 question or overall PHQ-9 score significantly predicted MCID achievement.

Table 2. Patient demographics.

Demographics	Total (*n* = 66)
Age, y, mean ± SD	47.2 ± 10.1
Gender	
Female	42.4% (28)
Male	57.6% (38)
Body mass index	
<30 kg/m^2	53.0% (35)
≥30 kg/m^2	47.0% (31)
Smoking status	
Nonsmoker	84.9% (56)
Smoker	15.2% (10)
Diabetes	
Nondiabetic	86.4% (57)
Diabetic	13.6% (9)
American Society of Anesthesiologists classification	1.9 ± 0.6
Charlson Comorbidity Index score	1.4 ± 2.0
Ethnicity	
White	71.2% (47)
African American	12.1% (8)
Hispanic	10.6% (7)
Asian	3.0% (2)
Insurance	
Medicare/Medicaid	1.5% (1)
Workers' compensation	27.3% (18)
Private	71.2% (47)

Note: Data presented as (%) *n* unless otherwise indicated.

Table 3. Perioperative characteristics.

Characteristics	Total (*n* = 66)
Spinal pathology	
Central stenosis	42.4% (28)
Herniated nucleus pulposus	95.5% (63)
Myeloradiculopathy	87.9% (58)
Operative time,[a] min, mean ± SD	50.3 ± 10.6
Estimated blood loss, mL, mean ± SD	27.5 ± 10.1
Length of stay, h, mean ± SD	10.1 ± 7.6
Day of discharge	
POD0	81.8% (54)
POD1	18.2% (12)

Abbreviation: POD, postoperative day.
Note: Data presented as (%) *n* unless otherwise indicated.
[a]From skin incision to closure.

Table 4. Postoperative outcomes.

Outcomes	Mean ± SD
VAS neck	
Preoperative	6.1 ± 2.4
6 wk	3.3 ± 2.7
12 wk	2.8 ± 2.4
6 mo	2.5 ± 2.3
1 y	3.1 ± 2.7
2 y	5.0 ± 2.7
MCID achievement, % (*n*)	75.8% (47)
VAS arm	
Preoperative	6.0 ± 2.8
6 wk	2.4 ± 2.6
12 wk	3.0 ± 3.2
6 mo	2.8 ± 3.0
1 y	4.0 ± 3.4
2 y	3.9 ± 2.9
MCID achievement, % (*n*)	58.1% (36)
Neck Disability Index	
Preoperative	37.2 ± 16.0
6 wk	30.1 ± 19.1
12 wk	26.4 ± 19.3
6 mo	21.0 ± 18.9
1 y	20.2 ± 19.0
2 y	24.1 ± 18.2
MCID achievement, % (*n*)	70.5% (43)
12-Item Short Form physical component score	
Preoperative	36.1 ± 8.1
6 wk	35.3 ± 8.1
12 wk	38.5 ± 10.4
6 mo	42.1 ± 8.7
1 y	43.3 ± 11.3
2 y	43.5 ± 10.9
MCID achievement, % (*n*)	47.4% (27)
Patient-Reported Outcomes Measurement Information System Physical Function	
Preoperative	39.6 ± 7.2
6 wk	40.7 ± 6.7
12 wk	44.8 ± 9.4
6 mo	45.5 ± 7.8
1 y	47.9 ± 7.7
2 y	45.5 ± 8.8
MCID achievement, % (*n*)	66.0% (31)

Abbreviations: MCID, minimum clinically important difference; VAS, visual analog scale.
Note: Data presented as mean ± SD unless otherwise indicated.

Table 5. PHQ-9 items as predictors of pain and disability MCID achievement.

PHQ-9 Items	OR	95% CI	*P* Value[a,b]
VAS neck MCID			
Question 1	1.2	(0.7, 2.2)	0.550
Question 2	1.2	(0.6, 2.3)	0.667
Question 3	**2.0**	**(1.0, 3.9)**	**0.045**
Question 4	1.2	(0.6, 2.3)	0.594
Question 5	0.8	(0.4, 1.6)	0.489
Question 6	0.9	(0.4, 1.8)	0.741
Question 7	0.9	(0.5, 1.7)	0.758
Question 8	0.6	(0.3, 1.4)	0.271
Question 9[b]	-	-	-
Question 10	1.1	(0.5, 2.2)	0.843
Overall PHQ-9 score	1.0	(0.9, 1.1)	0.971
VAS arm MCID			
Question 1	1.2	(0.7, 2.1)	0.434
Question 2	1.0	(0.6, 1.7)	0.949
Question 3	**1.7**	**(1.0, 2.9)**	**0.049**
Question 4	1.0	(0.6, 1.7)	0.975
Question 5	0.6	(0.3, 1.2)	0.180
Question 6	0.7	(0.3, 1.3)	0.240
Question 7	0.9	(0.5, 1.6)	0.699
Question 8	0.8	(0.4, 1.7)	0.560
Question 9[b]	-	-	-
Question 10	0.8	(0.4, 1.4)	0.396
Overall PHQ-9 score	1.0	(0.9, 1.1)	0.683
Neck Disability Index MCID			
Question 1	1.9	(0.9, 3.7)	0.060
Question 2	1.3	(0.7, 2.5)	0.415
Question 3	**1.6**	**(0.9, 2.8)**	**0.110**
Question 4	1.6	(0.8, 3.0)	0.153
Question 5	1.2	(0.6, 2.3)	0.694
Question 6	1.5	(0.6, 3.4)	0.348
Question 7	1.4	(0.7, 2.9)	0.322
Question 8	1.1	(0.5, 2.5)	0.825
Question 9[b]	-	-	-
Question 10	2.0	(0.8, 4.6)	0.117
Overall PHQ-9 score	1.1	(0.9, 1.2)	0.291

Abbreviations: MCID, minimum clinically important difference; PHQ, Patient Health Questionnaire; VAS, visual analog scale.
Note: Boldface indicates statistical significance.
[a]*P* values calculated using logistic regression to assess each question as a predictor of MCID achievement.
[b]Unable to assess question 9 due to the limited number of patients with affirmative responses.

DISCUSSION

The relationship of preoperative mental health with the postoperative outcomes of spine surgery has been a topic of great interest in recent years. The PHQ-9 has been widely used in a variety of clinical and research settings and has been validated for quantification of depressive symptoms in patients undergoing cervical spine surgery, demonstrating strong correlations with SF-12 mental component score (MCS) and Veterans RAND-12 (VR-12) MCS among ACDF and cervical disc replacement patients.[12] As depression rates rise and preoperative management of modifiable factors shows promise, comprehensive prediction tools specifically evaluating depressive symptoms, such as PHQ-9, have become a critical component of preoperative screening.[12] Furthermore, the value-based care movement is gaining traction within the medical community as it is centralized on the needs of patients.[13] This model allows for shared-decision making grounded on each individual goal of care, and in turn, optimized resource utilization and asset allocation with potentially decreased costs, as more suitable interventions may then be chosen that more directly align with the patient's goals of treatment.[13,14] Mental health impairments are highly prevalent in the spine surgical population undergoing cervical and lumbar procedures, with an estimated depression prevalence of >50% among surgical candidates.[3] Still, few authors have addressed the utility of measuring the predictive value of preoperative mental health scores (ie, PHQ-9) on ACDF outcomes, while many have evaluated this relationship with lumbar fusion outcomes (demonstrating a pattern

Table 6. PHQ-9 items as predictors of physical function MCID achievement.

PHQ-9 Items	OR	95% CI	P Value[ab]
12-Item Short Form physical component score MCID			
Question 1	1.6	(0.9, 2.7)	0.092
Question 2	1.2	(0.7, 2.0)	0.624
Question 3	**1.7**	**(1.0, 2.9)**	**0.037**
Question 4	1.5	(0.8, 2.6)	0.167
Question 5	1.4	(0.7, 2.5)	0.355
Question 6	1.2	(0.6, 2.3)	0.632
Question 7	1.2	(0.7, 2.2)	0.460
Question 8	1.6	(0.7, 3.5)	0.253
Question 9[b]	-	-	-
Question 10	1.4	(0.7, 2.7)	0.309
Overall PHQ-9 score	1.1	(0.9, 1.2)	0.205
Patient-Reported Outcomes Measurement Information System Physical Function MCID			
Question 1	1.6	(0.9, 2.9)	0.137
Question 2	1.1	(0.6, 2.1)	0.724
Question 3	1.1	(0.6, 1.9)	0.828
Question 4	1.3	(0.7, 2.4)	0.456
Question 5	0.8	(0.4, 1.5)	0.503
Question 6	0.9	(0.5, 1.9)	0.870
Question 7	1.3	(0.7, 2.6)	0.388
Question 8	1.3	(0.5, 3.0)	0.576
Question 9[b]	-	-	-
Question 10	1.3	(0.6, 2.7)	0.473
Overall PHQ-9 score	1.1	(0.9, 1.2)	0.263

Abbreviations: MCID, minimum clinically important difference; PHQ, Patient Health Questionnaire.
Note: Boldface indicates statistical significance.
[a]*P* values calculated using logistic regression to assess each question as a predictor of MCID achievement.
[b]Unable to assess question 9 due to the limited number of patients with affirmative responses.

of poorer outcomes among those with lower baseline mental functioning).[3] This highlights the importance of continued projects such as the present study aimed at illustrating the influence of mental health on ACDF outcomes. While greater than 30% of spine surgeons do not use PROMs routinely, this is primarily due to lack of time, funding, and/or available staffing for the collection of data.[15] Such limitations are noteworthy, and continued studies may highlight the importance to stakeholders and hospitals to allocate more resources and funding to the implementation of PROMs, including PHQ-9. Ultimately, with an emphasis on preoperative mental health management and discussion of evidence-based patient expectations, routine use of PHQ-9 serves as an important avenue for optimization of postoperative PROMs and patient satisfaction.

A number of studies have assessed PHQ-9 scores as a predictor of outcomes in patients undergoing ACDF specifically, although published findings are conflicting. Alvin et al demonstrated that preoperative PHQ-9 scores, along with antidepressant use, PDQ scores, and EQ-5D scores, were significantly associated with MCID achievement in the EQ-5D quality of life score by 1 year following ACDF.[3] However, it should be noted that when significant factors were assessed together in a multiple regression model, only baseline EQ-5D scores remained a significant predictor of EQ-5D MCID achievement. These results essentially suggest that MCID achievement may be most closely dependent upon the available "room for improvement," such that patients with worse preoperative health are more likely to see greater postoperative improvements.

Jenkins et al also studied the relationship between preoperative PHQ-9 scores and postoperative MCID achievement in a variety of physical health PROMs.[5] Their results indicated that while preoperative pain, disability, and physical function were significantly associated with preoperative PHQ-9 scores, when postoperative physical health outcomes were assessed based on preoperative PHQ-9, scores were largely similar for pain and only differed at short-term or intermediate timepoints for disability and physical function. Jenkins et al's methodology differed in their choice to categorize patients based on high (≥5) or low (<5) preoperative PHQ-9 scores, rather than retaining the measure's native continuous status. Their analysis demonstrated that a significantly greater proportion of patients with high preoperative PHQ-9 scores were able to achieve an MCID in NDI compared to those with lower preoperative depression scores. However, for VAS neck, VAS arm, and SF-12 PCS, Jenkins et al observed no significant differences in MCID achievement on the basis of preoperative PHQ-9 score. Interestingly, the 3 PROMs for which we observed a significant relationship with question 3 of the PHQ-9 are also the same 3 for which Jenkins et al reported no difference based on the overall PHQ-9 score.

Largely in line with the results of Jenkins et al, our analysis revealed no significant associations between preoperative PHQ-9 score and achievement of MCID in pain or physical function, although our results did not replicate their finding regarding the achievement of MCID in NDI. Based on these results and our review of the literature, we can suggest that although PHQ-9 scores may be strongly correlated with mean scores in other health-related quality of life measures, the overall score of the PHQ-9 may not be the best predictor of the postoperative change in these outcomes that are quantified by the MCID.

Although overall PHQ-9 scores did not significantly predict MCID achievement in our cohort, we determined that one specific response item within the PHQ-9 did consistently predict MCID achievement for VAS neck, VAS arm, and SF-12 PCS. Specifically, the response item asking patients to quantify how often they had been bothered by "trouble falling asleep, staying asleep, or sleeping too much" within the last 2 weeks was a statistically significant predictor of meaningful postoperative improvement in these measures of pain and physical function.

Problems with sleep may be relatively common among patients suffering from spinal pathology.[16–18] While many cervical surgery candidates report a chief complaint of neck pain (due to various etiologies such as disc herniation, spinal stenosis, or fibromyalgia), recent studies have suggested that such pain is often coupled with sleep disorders, at a rate of 50% to 80%.[19] As the pain has important psychological and functional implications and is intricately associated with difficulties in achieving and maintaining sleep,[19] our results indicate that ACDF candidates with poor baseline sleep may clinically benefit in postoperative pain and physical functioning following surgical correction. Spinal surgeons should inform patients that pain and sleep problems can coexist and encourage individuals with poorer sleep quality who undergoing ACDF will likely reap clinically significant improvements in their arm and neck pain and physical health. Furthermore, disordered sleep may be strongly associated with other health-related symptoms in patients undergoing spine surgery. In an analysis of a national sample of cervical spine surgery patients, Pennings et al demonstrated strong correlations between NDI and PROMIS sleep disturbance, both preoperatively and at postoperative follow-up.[20] Other studies have demonstrated similar associations between sleep disturbance and disability and other health-related outcomes.[17,21]

Interestingly, a number of animal studies have demonstrated that sleep deprivation is not only associated with but may actually induce increased pain sensitivity in rats.[22,23] Wang et al studied the impact of short-term sleep disturbance on the postsurgical recovery of rats in a controlled laboratory setting and demonstrated that repeated sleep interruption resulted in increased postoperative pain response.[24] Furthermore, the authors were able to demonstrate that persistent disruption of the rats' REM sleep phase resulted in significantly decreased expression of mu and kappa opioid receptors in the ipsilateral dorsal root ganglion following surgical intervention. One important point to note is that animal studies have indicated that the effects of sleep deprivation on pain sensitivity are likely reversible. Onen et al demonstrated that decreased pain thresholds among rats were completely reversed following recovery of normal sleep.[23]

Human studies have also demonstrated direct links between sleep deprivation and increased pain sensitivity.[25–27] Azevedo et al demonstrated that following 2 nights of total sleep deprivation, VAS pain responses to a laser stimulus were significantly increased and continued to increase with successive nights of sleep deprivation.[26] Of note, this study also demonstrated that VAS ratings decreased after just 1 night of restored sleep. In fact, a recent systematic review by Stroemel-Scheder et al indicated that restoration of normal sleep may effectively reduce the pain sensitivity associated with sleep deprivation.[28]

Literature regarding problems in patients undergoing cervical spine surgery is relatively limited. However, the results of available studies indicate that sleep-related issues are likely to improve significantly following spinal surgery. Ogden et al reported significant improvements in all subscales of the Pittsburgh Sleep Quality Index, including sleep time, sleep disturbances, daytime functionality loss, and sleep quality following ACDF.[19] Löfgren et al demonstrated temporary improvements in sleep, measured via the Sickness Impact Profile; however, these authors reported that while many other postoperative benefits were lasting, these improvements in sleep/rest were only temporary in their cohort.[29] Among a cohort of lumbar stenosis patients, significant improvements in sleep disturbance were likewise reported following spinal fusion and/or decompression.[30]

Given the documented associations of sleep disturbance with increased perceptions of pain, it may initially seem counterintuitive that patients endorsing problems with sleep via the PHQ-9 would actually be more likely to achieve MCID following ACDF. However, these results make sense in the context that sleep disturbance may be a *modifiable* factor. In fact, results of previous studies in spine surgery indicate that patients with greater severity of preoperative symptoms may essentially have more "room for improvement" and therefore, may actually be more likely to achieve a meaningful degree of change following surgery. For example, Parrish et al demonstrated that patients with poorer preoperative PROMIS-PF scores demonstrated higher rates of MCID achievement in pain, disability, and physical function following ACDF, compared to those with more favorable preoperative scores.[31] Therefore, patients who report significant issues with sleep prior to surgery may be well positioned to benefit from operative intervention, given that they have a substantial unmet need that may be amenable to operative intervention.

Limitations

While this is likely the first study of its kind to assess the predictive qualities of individual PHQ-9 response items in the context of cervical spine surgery, our methodology is not without limitations. First, the self-reported nature of our study measures may introduce an element of bias. However, we feel that this is a necessary consequence of quantifying outcomes with a patient-centered focus. Additionally, the single-surgeon, single-institution aspect of our study design may limit generalizability to broader populations. Furthermore, as seen in Tables 5 and 6, question 9 was unable to be analyzed as a predictor of MCID achievement across PROMs due to a limited sample size, reducing power for this portion of our study. Finally, while the PHQ-9 itself is well-validated for use in cervical spine surgery,[12] the use of question 3 specifically to quantify sleep-related issues has not been directly assessed. Future studies should include a direct comparison of responses to question 3 with one or more measures specifically designed to assess disordered sleep.

CONCLUSION

Overall, PHQ-9 scores did not significantly predict the achievement of MCID in pain, disability, or physical function. However, a statistically significant relationship was identified between responses to question 3 of the PHQ-9, which assesses the frequency of sleep-related problems, and clinically meaningful improvements in arm pain, neck pain, and physical function. Patients with cervical disease and concomitant preoperative sleep difficulties should be encouraged that ACDF may result in clinically significant pain relief and physical health improvements postoperatively. Additional high-quality studies examining the relationship of preoperative sleep with postoperative outcomes of cervical spine surgery are warranted.

REFERENCES

1. Song K-J, Choi B-Y. Current concepts of anterior cervical discectomy and fusion: a review of literature. *Asian Spine J*. 2014;8(4):531–539. doi:10.4184/asj.2014.8.4.531
2. Fakhoury J, Dowling TJ. Cervical degenerative disc disease. In: *StatPearls*. StatPearls Publishing; 2020.
3. Alvin MD, Miller JA, Lubelski D, et al. The impact of preoperative depression and health state on quality-of-life outcomes after anterior cervical diskectomy and fusion. *Global Spine J*. 2016;6(4):306–313. doi:10.1055/s-0035-1562932
4. Patel DV, Yoo JS, Khechen B, et al. PHQ-9 score predicts postoperative outcomes following minimally invasive transforaminal lumbar interbody fusion. *Clin Spine Surg*. 2019;32(10):444–448. doi:10.1097/BSD.0000000000000818
5. Jenkins NW, Parrish JM, Yoo JS, et al. Are preoperative PHQ-9 scores predictive of postoperative outcomes following anterior cervical discectomy and fusion? *Clin Spine Surg*. 2020;33(10):E486–E492. doi:10.1097/BSD.0000000000000985
6. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med*. 2001;16(9):606–613. doi:10.1046/j.1525-1497.2001.016009606.x
7. Zuckerman SL, Devin CJ. Outcomes and value in elective cervical spine surgery: an introductory and practical narrative review. *J Spine Surg*. 2020;6(1):89–105. doi:10.21037/jss.2020.01.11
8. Leyton-Mange A, Truumees E, Bozic KJ, et al. Preoperative patient-reported outcome score thresholds predict the likelihood of reaching MCID with surgical correction of adult spinal deformity. *Spine Deform*. 2021;9(1):207–219. doi:10.1007/s43390-020-00171-9
9. Lynch CP, Cha EDK, Jadczak CN, Mohan S, Geoghegan CE, Singh K. Impact of depression on patient reported outcomes following primary versus revision ACDF. *Spine (Phila Pa 1976)*. 2021;46(20):1378–1386. doi:10.1097/BRS.0000000000004029
10. Parker SL, Godil SS, Shau DN, Mendenhall SK, McGirt MJ. Assessment of the minimum clinically important difference in pain, disability, and quality of life after anterior cervical discectomy and fusion: clinical article. *J Neurosurg Spine*. 2013;18(2):154–160. doi:10.3171/2012.10.SPINE12312
11. Steinhaus ME, Iyer S, Lovecchio F, et al. Minimal clinically important difference and substantial clinical benefit using PROMIS CAT in cervical spine surgery. *Clin Spine Surg*. 2019;32(9):392–397. doi:10.1097/BSD.0000000000000895
12. Parrish JM, Jenkins NW, Nolte MT, et al. A validation of patient health questionnaire-9 for cervical spine surgery. *Spine*. 2020;45(23):1668–1675. doi:10.1097/BRS.0000000000003644
13. Damman OC, Jani A, de Jong BA, et al. The use of proms and shared decision-making in medical encounters with patients: an opportunity to deliver value-based health care to patients. *J Eval Clin Pract*. 2020;26(2):524–540. doi:10.1111/jep.13321
14. Lee TJ, Thomas AA, Grandhi NR, et al. Cost-effectiveness applications of patient-reported outcome measures (proms) in spine surgery. *Clin Spine Surg*. 2020;33(4):140–145. doi:10.1097/BSD.0000000000000982
15. Falavigna A, Dozza DC, Teles AR, et al. Current status of worldwide use of patient-reported outcome measures (proms) in spine care. *World Neurosurg*. 2017;108:328–335. doi:10.1016/j.wneu.2017.09.002
16. Klyne DM, Barbe MF, van den Hoorn W, Hodges PW. ISSLS PRIZE IN CLINICAL SCIENCE 2018: longitudinal analysis of inflammatory, psychological, and sleep-related factors following an acute low back pain episode-the good, the bad, and the ugly. *Eur Spine J*. 2018;27(4):763–777. doi:10.1007/s00586-018-5490-7
17. Lee N-K, Jeon SW, Heo YW, et al. Sleep disturbance in patients with lumbar spinal stenosis: association with disability and quality of life. *Clin Spine Surg*. 2020;33(4):E185–E190. doi:10.1097/BSD.0000000000000944
18. Kim J, Park J, Kim SW, et al. Prevalence of sleep disturbance in patients with lumbar spinal stenosis and analysis of the risk factors. *Spine J*. 2020;20(8):1239–1247. doi:10.1016/j.spinee.2020.02.008
19. Ogden M, Akgul MH, Yuksel U, Bakar B, Kamasak K, Özveren MF. An evaluation of the quality of sleep before and after surgical treatment of patients with cervical disc herniation. *J Korean Neurosurg Soc*. 2018;61(5):600–607. doi:10.3340/jkns.2017.0248

20. Pennings JS, Khan I, Davidson CA, et al. Using PROMIS-29 to predict neck disability index (NDI) scores using a national sample of cervical spine surgery patients. *Spine J*. 2020;20(8):1305–1315. doi:10.1016/j.spinee.2020.04.028

21. Zarrabian M-M, Johnson M, Kriellaars D. Relationship between sleep, pain, and disability in patients with spinal pathology. *Arch Phys Med Rehabil*. 2014;95(8):1504–1509. doi:10.1016/j.apmr.2014.03.014

22. Hakki Onen S, Alloui A, Jourdan D, Eschalier A, Dubray C. Effects of rapid eye movement (REM) sleep deprivation on pain sensitivity in the rat. *Brain Res*. 2001;900(2):261–267. doi:10.1016/s0006-8993(01)02320-4

23. Onen SH, Alloui A, Eschalier A, Dubray C. Vocalization thresholds related to noxious paw pressure are decreased by paradoxical sleep deprivation and increased after sleep recovery in rat. *Neurosci Lett*. 2000;291(1):25–28. doi:10.1016/s0304-3940(00)01383-5

24. Wang P-K, Cao J, Wang H, et al. Short-term sleep disturbance-induced stress does not affect basal pain perception, but does delay postsurgical pain recovery. *J Pain*. 2015;16(11):1186–1199. doi:10.1016/j.jpain.2015.07.006

25. Ødegård SS, Omland PM, Nilsen KB, Stjern M, Gravdahl GB, Sand T. The effect of sleep restriction on laser evoked potentials, thermal sensory and pain thresholds and suprathreshold pain in healthy subjects. *Clin Neurophysiol*. 2015;126(10):1979–1987. doi:10.1016/j.clinph.2014.12.011

26. Azevedo E, Manzano GM, Silva A, Martins R, Andersen ML, Tufik S. The effects of total and REM sleep deprivation on laser-evoked potential threshold and pain perception. *Pain*. 2011;152(9):2052–2058. doi:10.1016/j.pain.2011.04.032

27. Schuh-Hofer S, Wodarski R, Pfau DB, et al. One night of total sleep deprivation promotes a state of generalized hyperalgesia: a surrogate pain model to study the relationship of insomnia and pain. *Pain*. 2013;154(9):1613–1621. doi:10.1016/j.pain.2013.04.046

28. Stroemel-Scheder C, Kundermann B, Lautenbacher S. The effects of recovery sleep on pain perception: a systematic review. *Neurosci Biobehav Rev*. 2020;113:408–425. doi:10.1016/j.neubiorev.2020.03.028

29. Löfgren H, Johansen F, Skogar O, Levander B. Reduced pain after surgery for cervical disc protrusion/stenosis: a 2 year clinical follow-up. *Disabil Rehabil*. 2003;25(18):1033–1043. doi:10.1080/0963828031000159647

30. Kim J, Lee SH, Kim T-H. Improvement of sleep quality after treatment in patients with lumbar spinal stenosis: a prospective comparative study between conservative versus surgical treatment. *Sci Rep*. 2020;10(1):14135. doi:10.1038/s41598-020-71145-0

31. Parrish JM, Jenkins NW, Brundage TS, Hrynewycz NM, Yoo JS, Singh K. PROMIS physical function predicts postoperative pain and disability following anterior cervical discectomy and fusion. *Clin Spine Surg*. 2020;33(9):382–387. doi:10.1097/BSD.0000000000000973

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