

## Development of new postoperative neck pain at 12 and 24 months after surgery for cervical spondylotic myelopathy: a Quality Outcomes Database study

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**OBJECTIVE** Patients who undergo surgery for cervical spondylotic myelopathy (CSM) will occasionally develop postoperative neck pain that was not present preoperatively, yet the incidence of this phenomenon is unclear. The authors aimed to elucidate patient and surgical factors associated with new-onset sustained pain after CSM surgery.

**METHODS** The authors reviewed data from the Quality Outcomes Database (QOD) CSM module. The presence of neck pain was defined using the neck pain numeric rating scale (NRS). Patients with no neck pain at baseline (neck NRS score  $\leq 1$ ) were then stratified based on the presence of new postoperative pain development (neck NRS score  $\geq 2$ ) at 12 and 24 months postoperatively.

**RESULTS** Of 1141 patients in the CSM QOD, 224 (19.6%) reported no neck pain at baseline. Among 170 patients with no baseline neck pain and available 12-month follow-up, 46 (27.1%) reported new postoperative pain. Among 184 patients with no baseline neck pain and available 24-month follow-up, 53 (28.8%) reported new postoperative pain. The mean differences in neck NRS scores were 4.3 for those with new postoperative pain compared with those without at 12 months ( $4.4 \pm 2.2$  vs  $0.1 \pm 0.3$ ,  $p < 0.001$ ) and 3.9 at 24 months ( $4.1 \pm 2.4$  vs  $0.2 \pm 0.4$ ,  $p < 0.001$ ). The majority of patients reporting new-onset neck pain reported being satisfied with surgery, but their satisfaction was significantly lower compared with patients without pain at the 12-month (66.7% vs 94.3%,  $p < 0.001$ ) and 24-month (65.4% vs 90.8%,  $p < 0.001$ ) follow-ups. The baseline Neck Disability Index (NDI) was an independent predictor of new postoperative neck pain at both the 12-month and 24-month time points (adjusted OR [aOR] 1.04, 95% CI 1.01–1.06;  $p = 0.002$ ; and aOR 1.03, 95% CI 1.01–1.05;  $p = 0.026$ , respectively). The total number of levels treated was associated with new-onset neck pain at 12 months (aOR 1.34, 95% CI 1.09–1.64;  $p = 0.005$ ), and duration of symptoms more than 3 months was a predictor of 24-month neck pain (aOR 3.22, 95% CI 1.01–10.22;  $p = 0.048$ ).

**CONCLUSIONS** Increased NDI at baseline, number of levels treated surgically, and duration of symptoms longer than

**ABBREVIATIONS** ACDF = anterior cervical discectomy and fusion; aOR = adjusted odds ratio; CSM = cervical spondylotic myelopathy; MCID = minimal clinically important difference; mJOA = modified Japanese Orthopaedic Association; NASS = North American Spine Society; NDI = Neck Disability Index; NRS = numeric rating scale; PRO = patient-reported outcome; QOD = Quality Outcomes Database; VAS = visual analog scale.

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3 months preoperatively correlate positively with the risk of new-onset neck pain following CSM surgery. The majority of patients with new-onset neck pain still report satisfaction from surgery, suggesting that the risk of new-onset neck pain should not hinder indicated operations from being performed.

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**KEYWORDS** degenerative; spine; neck pain; Quality Outcomes Database; cervical spondylotic myelopathy

**C**ERVICAL spondylotic myelopathy (CSM) is the most common pathology affecting the adult cervical spine.<sup>1</sup> Moderate to severe neck pain in the setting of CSM affects between 21% and 38% of patients with CSM preoperatively.<sup>2-5</sup> In one of the largest analyses of one- and two-level anterior cervical discectomy and fusion (ACDF) procedures, Devin et al.<sup>2</sup> found that 28.8% of 2267 patients with myelopathy reported neck pain as a predominant symptom preoperatively. However, the majority of patients undergoing CSM surgery do not have significant axial neck pain as a predominant symptom before surgery.<sup>2</sup>

Patients who undergo surgical intervention for CSM treatment will occasionally develop new postoperative neck pain that was not present preoperatively, yet the incidence of this phenomenon is unclear. Furthermore, the differences in the incidence of new postoperative pain development among CSM surgical procedures (e.g., ACDF, posterior cervical decompression and fusion, and laminoplasty) are unknown. Whether the development of new postoperative pain is related more to baseline patient characteristics or to operative factors has yet to be determined. In the current era of value-based healthcare, identification of patients who will benefit from CSM surgery rather than experience new postoperative pain deterioration is crucial for spine surgeons. The aim of this study was to better understand patient and surgical factors associated with new sustained pain onset at 12 and 24 months after surgical intervention for CSM in patients who had no pain at the preoperative baseline.

## Methods

### Data Source

The Vanguard National Neurosurgery Quality Outcomes Database (QOD) is a de-identified, multi-institutional, prospectively collected clinical registry. Because of the de-identified nature of the data set, no institutional review board approval is required for data evaluation. The CSM module of the QOD is specific to patients with CSM and is neurosurgery specific. All surgical cases included in the QOD are elective. Prior studies have described the QOD methodology for data collection and patient inclusion in detail.<sup>6-10</sup> Data from the 14 highest-volume QOD sites from across the United States were included for analysis. The QOD captures baseline, 3-month, 12-month, and 24-month patient-reported outcomes (PROs).

### Cohort Inclusion and Exclusion Criteria

All adult patients in the CSM module of the QOD were reviewed. Patients undergoing cervical spine surgery for the diagnosis of disc herniation, stenosis (foraminal or central), instability, or adjacent-segment disease are eligible for inclusion. Patients were excluded if they had a spinal infection, tumor, fracture, traumatic dislocation, deformity,

or neurological paralysis due to preexisting spine pathology. The primary diagnosis and indication for surgery must be cervical myelopathy, although other indications (e.g., radiculopathy and instability) are permitted for inclusion. CSM is coded as a surgical indication variable for QOD. Patients are consecutively enrolled at some participating sites, while other sites use random sampling. Patients with radiculopathy were included if they had myelopathy as well. Patients were included if they had baseline neck pain numeric rating scale (NRS) scores recorded. They were then stratified into new postoperative pain at the 12-month follow-up and 24-month follow-up as described below according to neck pain NRS values. Patients with missing follow-up data were reported in the descriptive tables but were not included in multivariable analyses.

### Outcome of Interest

Pain determination was assessed using the neck pain NRS. The neck pain NRS is an instrument used to evaluate subjective patient assessment of neck pain. Subjects are asked to rate their neck pain on a scale from 0 to 10, with 10 representing the most severe pain.<sup>11</sup> NRS pain scores have been shown to have a high correlation with visual analog scale (VAS) pain scores.<sup>12</sup> Test-retest reliability has been demonstrated for the neck pain NRS in patients with mechanical neck pain with an intraclass correlation coefficient of 0.76.<sup>13</sup> Prior systematic reviews have shown that patients are more compliant reporting NRS pain scores relative to VAS pain scores.<sup>14</sup>

The presence of neck pain was defined using the neck pain NRS with a threshold score  $\geq 2$  indicating neck pain. Patients with no neck pain at baseline preoperatively (neck pain NRS score  $\leq 1$ ) were then stratified based on the presence of new postoperative pain development (neck pain NRS score  $\geq 2$ ) at 12 and 24 months postoperatively. Crossover between groups (i.e., patients who had no new pain at 12 months who then had new pain at 24 months) was captured. To determine the threshold for defining onset of new neck pain, we selected a value of a change of  $\geq 1$  NRS point on the basis of prior literature that showed a minimal clinically important difference (MCID) for neck NRS of +1.5.<sup>15</sup> We chose a change from baseline  $> 1$  as sensitive for capturing patients with a change that could be clinically relevant.

### Variables of Interest

Demographic variables including age, sex, disability status, and education status and comorbidity variables including BMI, current smoking status, diabetes, anxiety, and depression were captured. Surgical variables including number of segments treated in the operation, surgical approach (anterior vs posterior), surgical indication (myeloradiculopathy vs myelopathy alone), and surgical

**TABLE 1. Comparison of patients who had developed new postoperative neck pain at 12 months versus patients who did not develop new pain**

Variable	No New Postop Pain (n = 124)	New Pain at 12 Mos (n = 46)	p Value
Mean age, yrs	64.8 ± 11.1	64.6 ± 11.7	0.925
Sex			
Male	78 (62.9)	28 (60.9)	0.808
Female	46 (37.1)	18 (39.1)	
Mean BMI	29.6 ± 6.5	28.9 ± 5.7	0.520
Surgical approach			
Anterior	73 (58.9)	20 (43.5)	0.073
Posterior	51 (41.1)	26 (56.5)	
Arthrodesis performed	105 (84.7)	35 (76.1)	0.192
Mean no. of segments treated	2.7 ± 1.7	3.5 ± 1.9	<b>0.009</b>
Radiculopathy indication for op	36 (29.0)	8 (17.4)	0.124
Anxiety at baseline	20 (16.1)	13 (28.3)	0.076
Depression at baseline	20 (16.1)	9 (19.6)	0.597
Current smoker	14 (11.3)	7 (15.2)	0.489
Diabetes	22 (17.7)	7 (15.2)	0.697
Education: high school or less	40 (32.3)	10 (21.7)	0.181
Receiving government disability benefits	4 (3.2)	3 (6.5)	0.390
Symptom duration >3 mos	104 (83.9)	37 (80.4)	0.597
Dynamic instability/lithesis at baseline	31 (25.0)	14 (30.4)	0.475
Mean baseline mJOA score	12.9 ± 2.4	12.3 ± 2.2	0.191
Mean baseline EQ-5D score	0.69 ± 0.21	0.64 ± 0.23	0.454
Mean baseline neck pain NRS score	0.26 ± 0.44	0.30 ± 0.47	0.549
Mean baseline total NDI score	13.7 ± 13.7	20.6 ± 16.2	<b>0.006</b>
Mean baseline NDI neck pain intensity subscore	0.41 ± 0.81	0.37 ± 0.53	0.745
Mean neck pain NRS score at 12 mos	0.1 ± 0.3	4.4 ± 2.2	<b>&lt;0.001</b>

Values represent the number of patients (%) or mean ± SD unless stated otherwise. Boldface type indicates statistical significance. Seventy-six percent (n = 170/224) of all QOD patients had neck pain NRS follow-up data at 12 months.

procedure were reviewed. For the purpose of multivariable analyses, procedures were grouped as those including arthrodesis (ACDF, anterior cervical corpectomy and fusion, and posterior cervical decompression and fusion) and the motion-preserving ones (cervical disc arthroplasty, posterior cervical decompression without fusion, and laminoplasty). Patient-reported satisfaction from surgery was assessed using the North American Spine Society (NASS) scale, as previously described.<sup>16</sup> The MCID of the modified Japanese Orthopaedic Association (mJOA) score was defined as an increase by 1 point for patients with mild myelopathy (mJOA scores ≥ 15), 2 points for patients with moderate myelopathy (mJOA scores 12–14), and 3 points for patients with severe myelopathy (mJOA scores ≤ 11).<sup>17</sup> The MCID of the mJOA was adjusted for in a logistic regression with satisfaction as a dependent variable to demonstrate the association of new-onset neck pain with satisfaction independently from improvement in myelopathy symptoms.

### Statistical Analysis

Multiple imputation by chained equation was performed to impute missing data among baseline variables. Predic-

tive mean matching was employed for continuous data, logistic regression for binary data, ordinal logistic regression for ordinal data, and polytomous logistic regression for unordered categorical data. The mice package was used.<sup>18</sup> Descriptive statistics were generated for patient demographics, operative variables, preoperative neck pain NRS scores, 12-month postoperative neck pain NRS scores, and 24-month postoperative neck pain NRS scores. The Student t-test was used to compare continuous variable outcomes. The chi-square test with Pearson’s correlation was used to compare categorical variable outcomes. Fisher’s exact test was used when the group size was ≤ 5. Two multivariable logistic regression analyses were performed to identify variables independently associated with new pain development at 12 months and 24 months. All baseline variables presented in Tables 1 and 2 were introduced in these models, and covariates to be finally included were selected via the LASSO optimization algorithm for parsimony and the avoidance of overfitting.<sup>19</sup> The results of the multivariable analyses are presented in the form of adjusted odds ratios (aORs) and 95% CIs. A two-tailed p value < 0.05 (α = 0.05) was considered significant. The association of postoperative satisfaction with improvement in myelop-

**TABLE 2. Comparison of patients who had development of new postoperative neck pain at 24 months versus patients who did not develop new pain**

Variable	No New Postop Pain (n = 131)	New Pain at 24 Mos (n = 53)	p Value
Mean age, yrs	65.3 ± 10.8	62.4 ± 10.4	0.096
Sex			
Male	85 (64.9)	29 (54.7)	0.198
Female	46 (35.1)	24 (45.3)	
Mean BMI	29.0 ± 6.2	29.6 ± 6.8	0.591
Surgical approach			
Anterior	80 (61.1)	31 (58.5)	0.746
Posterior	51 (38.9)	22 (41.5)	
Arthrodesis performed	112 (85.5)	45 (84.9)	0.918
Mean no. of segments treated	2.7 ± 1.6	2.9 ± 1.7	0.387
Radiculopathy indication for op	35 (26.7)	11 (20.8)	0.398
Anxiety at baseline	17 (13.0)	9 (17.0)	0.480
Depression at baseline	14 (10.7)	10 (18.9)	0.136
Current smoker	11 (8.4)	11 (20.8)	0.069
Diabetes	21 (16.0)	6 (11.3)	0.414
Education: high school or less	35 (26.7)	19 (35.8)	0.218
Receiving government disability benefits	6 (4.6)	2 (3.8)	0.808
Symptom duration >3 mos	106 (80.9)	49 (92.5)	0.052
Dynamic instability/lithesis at baseline	26 (19.8)	18 (34.0)	<b>0.042</b>
Mean baseline mJOA score	13.0 ± 2.4	12.7 ± 2.1	0.500
Mean baseline EQ-5D score	0.693 ± 0.199	0.649 ± 0.218	0.214
Mean baseline neck pain NRS score	0.25 ± 0.44	0.32 ± 0.47	0.344
Mean baseline total NDI score	13.5 ± 13.6	19.2 ± 17.3	<b>0.019</b>
Mean baseline NDI neck pain intensity subscore	0.40 ± 0.82	0.57 ± 0.89	0.240
Mean neck pain NRS score at 24 mos	0.2 ± 0.4	4.1 ± 2.4	<b>&lt;0.001</b>

Values represent the number of patients (%) or mean ± SD unless stated otherwise. Boldface type indicates statistical significance. Eighty-two percent (n = 178/218) of all QOD patients had neck pain NRS follow-up data at 24 months.

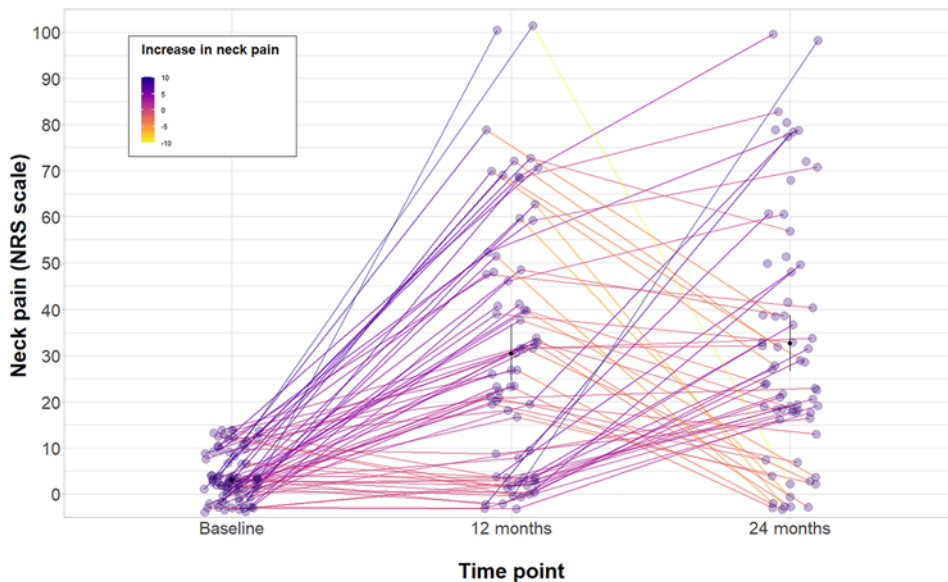
athy severity according to the mJOA was assessed using a two-sample t-test and the C-statistic of a univariate logistic regression to demonstrate the proportion of variability in satisfaction scores explained by the change in mJOA scores. All statistical analyses were performed using IBM SPSS Statistics for Windows version 28 (IBM Corp.) and R software package (version 4.2.1, The R Foundation for Statistical Computing).<sup>20</sup>

## Results

Of the 1141 patients in the CSM QOD registry, 224 (19.6%) reported no neck pain at baseline (neck pain NRS score ≤ 1). Among these 224 patients, 170 (75.9%) had available data at the 12-month follow-up and 46 (27.1%) reported new postoperative pain at 12 months. A total of 184 patients (82.1%) had available data at the 24-month follow-up, and 53 (28.8%) of them reported new postoperative neck pain at 24 months. Figure 1 displays the change in neck pain NRS score from baseline to 12 months and 24 months. There was a mean difference in neck pain NRS scores of 4.3 for patients with new postoperative pain and those without at 12 months (4.4 ± 2.2 vs 0.1 ± 0.3, p < 0.001) and a mean difference of 3.9 at 24 months (4.1 ± 2.4

vs 0.2 ± 0.4, p < 0.001). Twenty patients (43.5%) who had new pain at 12 months had sustained pain at 24 months, and 21 patients (16.9%) who had no new pain at 12 months reported pain at 24 months. Fifty-four patients (24.1%) were missing neck pain NRS follow-up data at 12 months, and 40 (17.9%) were missing neck pain NRS follow-up at 24 months.

A comparative analysis of 46 patients who developed new postoperative pain at 12 months versus 124 patients who had sustained lack of pain is shown in Table 1. Patients who reported new pain onset at 12 months had a significantly greater number of segments treated than those who did not (mean 3.5 vs 2.7, p = 0.009). The baseline Neck Disability Index (NDI) was also significantly higher for patients with new postoperative pain at 12 months (mean 20.6 vs 13.7, p = 0.006). No differences were observed for age, sex, BMI, type of surgery, radiculopathy symptoms, depression, smoking status, diabetes, education level, disability status, baseline mJOA score, baseline EQ-5D score, baseline neck NRS score, or baseline neck pain NDI subscore. There were slightly higher rates of anxiety (28.3% vs 16.1%) and posterior approaches (58.7% vs 42.7%), but these differences were not statistically significant.



**FIG. 1.** Line plot showing individual patient trajectories from baseline to 12- and 24-month neck pain NRS scores with color map indicating absolute neck NRS change between time points. Figure is available in color online only.

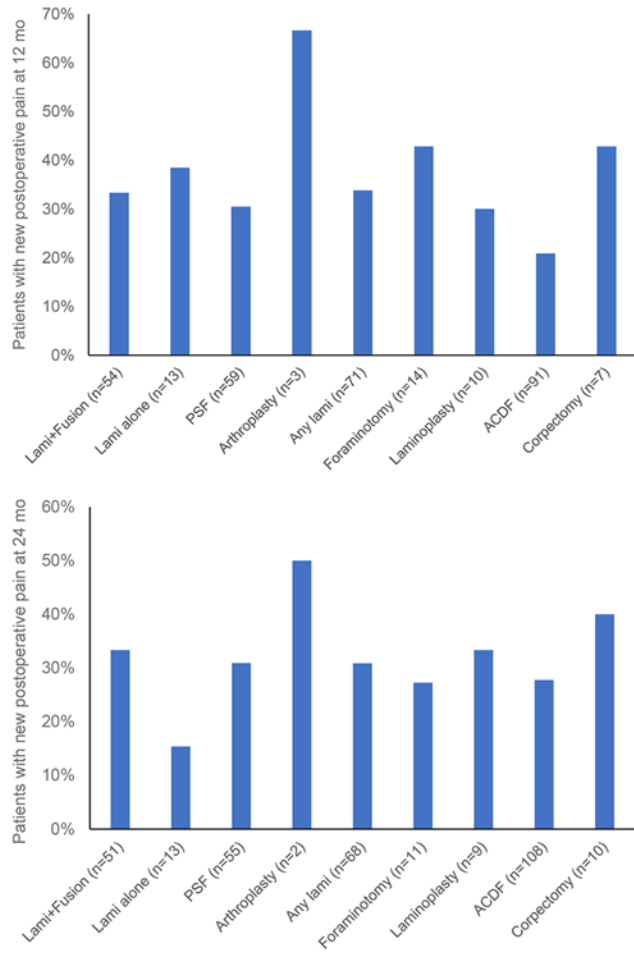
Table 2 displays the comparative analysis of 53 patients who developed new postoperative pain at 24 months versus 131 patients who continued to have no pain. Patients reporting neck pain at 24 months had greater disability at baseline, expressed as a higher NDI score (19.2 vs 13.5,  $p = 0.019$ ), and were more likely to have presented with dynamic instability or listhesis prior to surgery (34% vs 19.8%,  $p = 0.042$ ). No differences were observed in terms of sex, BMI, surgical approach, type of surgery, number of segments treated, radiculopathy symptoms, anxiety, depression, diabetes, education level, baseline mJOA score, baseline EQ-5D score, baseline neck pain NRS score, or baseline neck pain NDI subscore. Patients reporting pain at 24 months were more likely to be older (65.3 vs 62.4,  $p = 0.096$ ), smokers (20.8% vs 8.4%,  $p = 0.069$ ), and present more than 3 months after the patient-perceived initiation of symptoms (92.5% vs 80.9%,  $p = 0.052$ ), but none of these associations were statistically significant in the univariate analysis.

Figure 2 shows the rates of new pain development for various surgical procedures at 12 and 24 months. At 12 months, ACDF was associated with the lowest rate of new postoperative pain (20.9% of 91 procedures). Arthroplasty (66.7% of 3 procedures) and corpectomy (42.9% of 7 procedures) had the highest rates, although they also had the fewest procedures in the cohort. There were no statistically significant differences in the rate of new postoperative pain at 12 months when comparing each procedure type with all other procedures. At 24 months, laminectomy alone (i.e., without fusion or laminoplasty) had the lowest rate of new pain development (15.4% of 13 procedures). Arthroplasty (50% of 2 procedures), corpectomy (40% of 10 procedures), laminectomy plus posterior fusion (33.3% of 51 procedures), and laminoplasty (33.3% of 9 procedures) had the highest rates of new postoperative pain development at 24 months. There were no statisti-

cally significant differences in the rate of new postoperative pain at 24 months when comparing each procedure type with all other procedures. Figure 3 displays results of raw neck pain NRS scores at baseline and 12 months and 24 months by procedure type. Figure 4 displays box plots of neck NRS values at 12 and 24 months by new postoperative pain.

Among patients with no new-onset neck pain at 12 months, the satisfaction rate at 12 months based on the NASS scale was 94.3%, while among patients reporting pain, the satisfaction rate was 66.7% ( $p < 0.001$ ). Similarly, patients with neck pain at 24 months after surgery were less likely to report satisfaction at 24 months compared with patients with no pain (65.4% vs 90.8%,  $p < 0.001$ ). To investigate myelopathy-related outcomes as a potential confounder, we analyzed mJOA outcomes. The rates of achieving the MCID of the mJOA were 47.9% and 55.0% for patients who did and did not experience new-onset neck pain at 12 months, respectively ( $p = 0.414$ ), while the respective rates for the 24-month time point were 39.1% and 56.9% ( $p = 0.039$ ). The negative association of new-onset neck pain and satisfaction remained significant after adjusting for the achievement of MCID of the mJOA for the respective time point (aOR 0.13,  $p < 0.001$  at 12 months and aOR 0.20,  $p < 0.001$  at 24 months).

Results of the multivariable logistic regression analyses for development of new pain at both 12 and 24 months are shown in Table 3. A higher baseline NDI score was a significant predictor of neck pain at both time points. The aORs of these associations were 1.04 and 1.03, signifying that an increase in NDI at baseline by 1 point (in the percent scale) was associated with an increase in the odds of developing new-onset neck pain postoperatively (by 4% and 3%, respectively). In the analysis of 12-month outcomes, the number of segments treated was another significant predictor of new-onset neck pain (aOR 1.34,



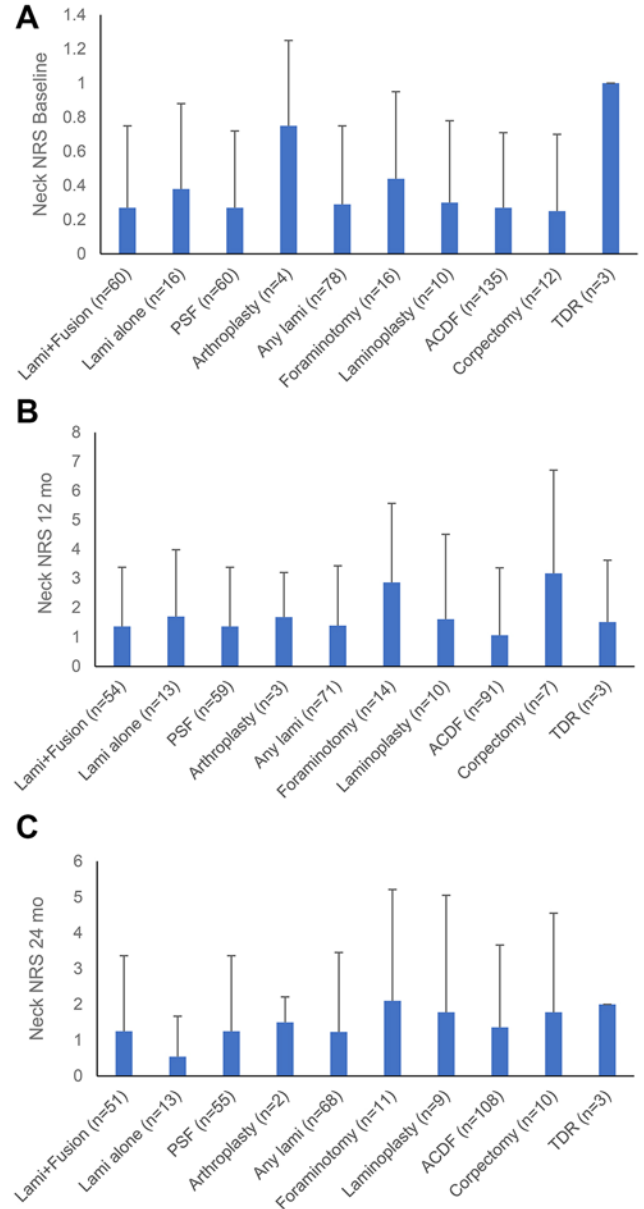
**FIG. 2.** Rates of new postoperative pain development by procedure at 12 months (upper) and 24 months (lower). Lami = laminectomy; PSF = posterior spinal fusion. Figure is available in color online only.

95% CI 1.09–1.64;  $p = 0.005$ ), whereas in the 24-month analysis, duration of symptoms > 3 months was found to be statistically significantly associated with neck pain (aOR 3.22, 95% CI 1.01–10.22;  $p = 0.048$ ).

## Discussion

Neck pain poses a significant burden on the healthcare system and on patients. As spinal interventions are performed more and more commonly to respond to the increasing incidence of CSM,<sup>21</sup> the population at risk for developing new postoperative neck pain also grows. However, before this study, there had not been a descriptive study with long-term follow-up demonstrating the incidence of, and factors predictive of, delayed-onset new neck pain after surgery for CSM.

Our results indicate that the incidence of new neck pain after CSM surgery is approximately 27.1% at 12 months and 28.8% at 24 months. The mean difference in neck pain NRS score between patients with and those without new pain was significant (4.3 at 12 months and 3.9 at 24 months). These changes are well above the MCID of the neck pain NRS score (reported from 1.5 to 4.0 depending



**FIG. 3.** Mean neck pain NRS scores by procedure at baseline (A), 12 months (B), and 24 months (C). Error bars indicate SD. TDR = total disc replacement. Figure is available in color online only.

on the method for calculating the MCID).<sup>15</sup> In our study, the emergence of new-onset neck pain translated to lower satisfaction rates at both time points, signifying the importance of new-onset neck pain for patients undergoing surgery for CSM. Nevertheless, the majority of patients with new-onset neck pain still reported satisfaction from surgery, which underlines that the risk of postoperative neck pain should not discourage patients and their physicians from proceeding with properly indicated surgeries.

## Risk Factors for New-Onset Postoperative Pain

Understanding which patients are more likely to experience prolonged new-onset pain after surgery is crucial to

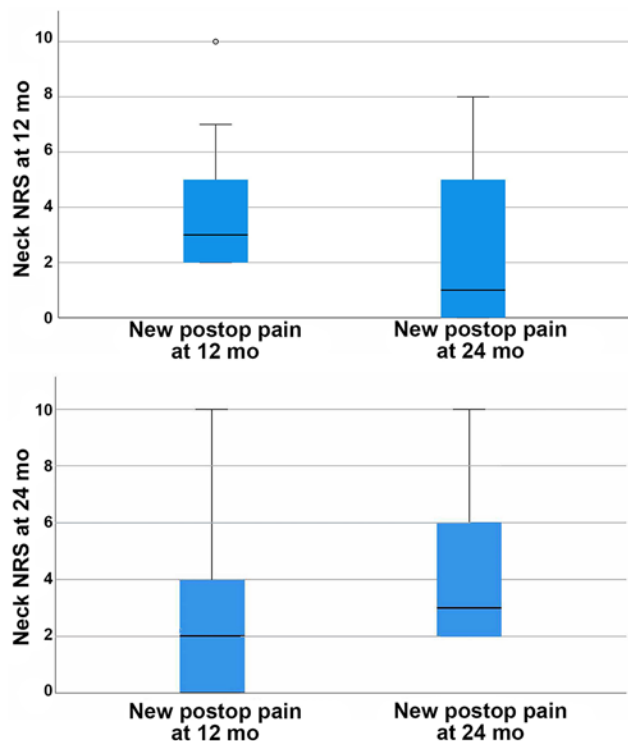


FIG. 4. Box plot showing neck pain NRS scores at 12 months (upper) and 24 months (lower) for patients who had new pain at those time points. Figure is available in color online only.

presurgical discussions and setting postoperative expectations for patients.

We investigated several risk factors for the development of new-onset postoperative pain, including demographics, comorbidities, baseline symptomatology, and baseline patient-reported measures. Baseline NDI, number of levels fused posteriorly, and duration of symptoms were found to be independent predictors of new-onset pain in our analysis. These findings are similar to those in prior research on factors associated with worse NRS pain scores at 12 months as reported by Archer et al.<sup>22</sup> Patients undergoing long-segment posterior fusions, those with higher baseline NDI scores, and those with a duration of symptoms of more than 3 months who do not have neck pain at baseline should potentially be counseled preoperatively on the risk of new-onset postoperative pain after surgery for CSM.

Interestingly, we did not identify statistically significant variation in the rate of new postoperative neck pain among specific procedures or procedure groups in either the univariate or the multivariable analysis. It should be noted that, especially for the per-procedure type analysis, the study's power was limited by a small sample size in many groups. Nevertheless, there were certain procedures with higher rates of new postoperative pain development overall (i.e., arthroplasty and corpectomy).

**Prior Literature**

Many studies have investigated neck pain as it relates to

TABLE 3. Multivariable logistic regression analyses of factors associated with development of new neck pain at 12 and 24 months postoperatively

Variable	aOR	95% CI	p Value
12-mo model (C-statistic = 0.74)			
No. of segments treated	1.34	1.09–1.64	<b>0.005</b>
Total NDI score at baseline	1.04	1.01–1.06	<b>0.002</b>
Op indication for radiculopathy	0.54	0.21–1.36	0.19
Anxiety (ref: no anxiety)	2.13	0.88–5.14	0.094
Educational level: high school or lower (ref: graduate or higher)	0.49	0.21–1.17	0.111
24-mo model (C-statistic = 0.731)			
Total NDI at baseline	1.03	1–1.05	<b>0.026</b>
Symptom duration >3 mos (ref: ≤3 mos)	3.22	1.01–10.22	<b>0.048</b>
Listhesis/dynamic instability at baseline	1.92	0.88–4.17	0.099
Age, yrs	0.98	0.95–1.01	0.25
Depression (ref: no depression)	1.94	0.74–5.1	0.176
Current smoker (ref: nonsmoker)	2.26	0.84–6.09	0.106

Boldface type indicates statistical significance.

CSM and to cervical spine surgery in general. Stull et al.<sup>23</sup> analyzed neck pain VAS scores at 1 year after 1- to 3-level ACDF, finding that the mean postoperative neck pain VAS score in myelopathic patients was 30 mm. The mean neck pain NRS score at 12 months in our ACDF group was 1.1; however, this difference could be explained by the fact that all patients in our ACDF group had no neck pain at baseline, whereas Stull et al.<sup>23</sup> reported a baseline neck pain VAS score of 55 mm in their myelopathy group. Archer et al.<sup>22</sup> analyzed the entire cervical QOD module and found that in 2641 patients with myelopathy, posterior decompression with fusion, longer symptom duration, workers' compensation, baseline total NDI score, and smoking were associated with worse neck pain NRS scores at 12 months. Rostami et al.<sup>24</sup> investigated radiographic measurements and neck pain intensity as measured by the VAS and found a significant correlation between the increase in the C2–7 angle, C1–2 angle, and operation-level angle and improvement in neck pain at the 1- and 6-month follow-ups after single-level ACDF.

Multiple studies have investigated postoperative neck pain in patients undergoing laminoplasty given that postoperative new/worsening axial neck pain is commonly reported as a disadvantage of laminoplasty.<sup>3,4</sup> However, Stephens et al.<sup>25</sup> found that in properly selected patients with myelopathy, laminoplasty was not associated with development of new postoperative axial neck pain (when compared with laminectomy and fusion). In our cohort, laminoplasty had a relatively high 24-month new pain development rate (33%), although it was not statistically different compared with other procedures. However, our findings are limited by the small number of patients in each of these surgical groups (10 laminoplasties and 3 arthroplasties). Therefore, generalized conclusions about pain devel-

opment should not be inferred from our laminoplasty and arthroplasty groups.

There are other assessment tools used to measure pain in the cervical spine population. We assessed NDI and NDI neck pain intensity subscores in our cohort. Interestingly, the neck pain NDI subscore was not significantly different between patients with and without new postoperative pain, yet the total NDI score was significantly different. This seems to indicate that patients with greater overall disability related to cervical pathology are more likely to experience new postoperative pain. The neck VAS score is another frequently used pain intensity assessment tool. However, the neck VAS and NRS scores differ in that the NRS is a reported number, whereas the VAS requires subjects to draw physically on a line.<sup>26</sup>

### Limitations

There are many limitations of the neck pain NRS score as a pain assessment tool, primarily that it is subjective and has an element of measurement noise, meaning multiple repeated measurements may not be precise despite being used by the same subject with the same pathology. Furthermore, although it has been correlated with other PROs such as neck pain VAS score, there are few robust validity studies for neck pain NRS scores. We used cutoffs of 2 for the development of new postoperative pain, which may be too sensitive (e.g., too low of a cutoff), which may have resulted in inclusion of patients for analysis who did not have clinically significant pain. The overall sample size is relatively small for the new postoperative pain development groups, and the sample size within each procedure type makes statistical comparisons difficult to properly perform (e.g., the number of arthroplasty patients in each group). The most concerning way selection bias could cloud our analysis is that patients who are lost to follow-up may be more likely to have less pain (hence not returning for follow-up due to clinical improvement), thereby artificially skewing toward a higher rate of postoperative pain development. We analyzed the patients in our cohort who had neck pain NRS scores at baseline and did not have neck pain NRS scores at the 12-month follow-up (n = 54). The mean age was 61.6 years, 67% of patients were male, and 83% had anterior-approach surgery for CSM (the majority of which were ACDF procedures). The higher rate of anterior-approach surgery compared with the results shown in Table 1 highlights the concern for patients lost to follow-up being in potentially less pain and skewing our results.

This study relies on a retrospective review of prospectively collected data, and data are collected across multiple sites by study coordinators who may not have the clinical training required to understand certain nuances relevant to this patient population and the surgical interventions performed. These data are predominantly from academic tertiary care centers and may not reflect the more general population of patients with CSM. The lack of radiographic data including fusion status and sagittal alignment is a major limitation because these have been associated with postoperative pain development.<sup>24</sup> The duration of symptoms was independently predictive of new-onset pain, yet these symptoms could be unrelated to myelopathy (e.g., long-standing arm pain).

The aORs for our multivariate analysis independent predictor variables were relatively low, indicating a low strength of associative relationship. We can attribute this observation in various parts to the heterogeneous nature of pain, the limitations of the NRS as a pain measurement tool, and the relatively small number of patients included. Finally, we did not correlate new pain development as an outcome with other PROs (e.g., quality of life and satisfaction index) but rather focused on factors predicting new pain development.

### Conclusions

Reported new-onset sustained postoperative pain at 12 months and 24 months after surgery for CSM was relatively common in this cohort, exceeding 25%. Factors associated with increased rates of new pain development included baseline NDI scores, number of segments treated (at 12 months postoperatively), and duration of symptoms. Satisfaction rates were impacted by the emergence of postoperative neck pain, but the majority of patients with new-onset neck pain still declared satisfaction with surgery, suggesting that the risk of new-onset neck pain should not hinder indicated operations from being performed. Future research focusing on pain prevention and research correlating new pain development after surgery with other patient and radiographic outcomes is warranted.

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## Author Contributions

Conception and design: Bisson, Sherrod. Acquisition of data: Bisson, Sherrod, Mulvaney, Agarwal, Chan, Asher, Coric, Virk, Fu, Foley, Park, Upadhyaya, Knightly, ME Shaffrey, Potts, CI Shaffrey, Gottfried, Than, Wang, Tumialán, Chou, Mummaneni, Bydon. Analysis and interpretation of data: all authors. Drafting the article: Sherrod, Michalopoulos. Critically revising the article: all authors. Reviewed submitted version of manuscript: Bisson, Sherrod. Approved the final version of the manuscript on behalf of all authors: Bisson.

## Supplemental Information

### Previous Presentations

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