Original Article

# The impact of postoperative neurologic complications on recovery kinetics in cervical deformity surgery


## ABSTRACT

**Objective:** The objective of the study is to investigate which neurologic complications affect clinical outcomes the most following cervical deformity (CD) surgery.

**Methods:** CD patients (C2-C7 Cobb >10°, CL >10°, cSVA >4 cm or chin-brow vertical angle >25°) >18 years with follow-up surgical and health-related quality of life (HRQL) data were included. Descriptive analyses assessed demographics. Neurologic complications assessed were C5 motor deficit, central neurodeficit, nerve root motor deficits, nerve sensory deficits, radiculopathy, and spinal cord deficits. Neurologic complications were classified as major or minor, then: intraoperative, before discharge, before 30 days, before 90 days, and after 90 days. HRQL outcomes were assessed at 3 months, 6 months, and 1 year. Integrated health state (IHS) for the neck disability index (NDI), EQ5D, and modified Japanese Orthopaedic Association (mJOA) were assessed using all follow-up time points. A subanalysis assessed IHS outcomes for patients with 2Y follow-up.

**Results:** 153 operative CD patients were included. Baseline characteristics: 61 years old, 63% female, body mass index 29.7, operative time 531.6 ± 275.5, estimated blood loss 924.2 ± 729.5, 49% posterior approach, 18% anterior approach, 33% combined. 18% of patients experienced a total of 28 neurologic complications in the postoperative period (15 major). There were 7 radiculopathy, 6 motor deficits, 6 sensory deficits, 5 C5 motor deficits, 2 central neurodeficits, and 2 spinal cord deficits. 11.2% of patients experienced neurologic complications before 30 days (7 major) and 15% before 90 days (12 major). 12% of neurocomplication patients went on to have revision surgery within 6 months and 18% within 2 years. Neurologic complication patients had worse mJOA IHS scores at 1Y but no significant differences between NDI and EQ5D (0.003 vs. 0.873, 0.458). When assessing individual complications, central neurologic deficits and spinal cord deficit patients had the worst outcomes at 1Y (2.6 and 1.8 times worse NDI scores, $P = 0.04$, no improvement in EQ5D, 8% decrease in EQ5D). Patients with sensory deficits had the best NDI and EQ5D outcomes at 1Y (31% decrease in NDI, 8% increase in EQ5D). In a subanalysis, neurologic patients trended toward worse NDI and mJOA IHS outcomes ($P = 0.263$, 0.163).



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**Conclusions:** 18% of patients undergoing CD surgery experienced a neurologic complication, with 15% within 3 months. Patients who experienced any neurologic complication had worse mJOA recovery kinetics by 1 year and trended toward worse recovery at 2 years. Of the neurologic complications, central neurologic deficits and spinal cord deficits were the most detrimental.

**Keywords:** Cervical deformity surgery, health-related quality of life, neurologic complications, outcomes, recovery kinetics

## INTRODUCTION

Adult cervical deformity (CD), a potentially severely debilitating condition, has a broad range of potential etiologies, including spondylosis, inflammatory arthropathy, trauma, infection, iatrogenic, neoplastic, congenital, and neuromuscular pathologies.[1,2] The most common cause of cervical spine deformity is kyphosis, the progression of which may lead to a myriad of incapacitating symptoms, including myelopathy, loss of horizontal gaze, adjacent segment disease, and dysphagia.[3-5]

The chief objectives of CD surgery include the maintenance or restoration of horizontal gaze, decompression of neural elements, and an overall effort to reestablish the normative alignment of the cervical spine.[5] Surgical treatment is often complex, requiring multiple approaches and an extended operative time with a potentially high rate of complications.[6-8] However, improvements in surgical technique, instrumentation, and perioperative care have facilitated a renewed interest of surgeons to study and surgically treat these higher risk deformities.[9,10]

Despite these advances, there remains a high risk of complications following adult CD surgery. In particular, neurologic complications have been found to be the most common new complication following CD surgery.[2,11] While there has been research into the effect neurologic complications have on health-related quality of life outcomes (HRQLs), these traditional outcome assessments may fail to fully appreciate the postoperative differences in patients who experience complications compared to those that do not.[6,12,13] Thus, the goal of this investigation was to assess the recovery kinetics of patients who experienced neurologic complications at 1 and 2-year postoperation using area under the curve (AUC) methodology to yield an integrated health state (IHS) score, a more encompassing reflection of a patient's postoperative clinical outcomes.

## METHODS

### Data source

This study was a retrospective review of a prospective, multicenter database of consecutive CD patients enrolled from 2013 to 2017. All 13 participating spine surgery centers obtained Institutional Review Board approval before patient enrollment, and all patients provided consent before enrollment. Inclusion criteria for the database were age ≥18 years and radiographic evidence of CD, as defined by the presence of at least one of the following criteria on baseline radiographic imaging: cervical kyphosis (C2-7 Cobb angle >10°), cervical scoliosis (C2-7 coronal Cobb angle <10°), C2-7 sagittal vertical axis (cSVA) >40 mm, or chin-brow vertical angle >25°.

### Data collection and radiographic assessment

Demographic variables, including sex, patient age, body mass index (BMI), comorbidity status, and Charlson Comorbidity Index (CCI), were collected at the preoperative interval. Surgical and complication data were collected following surgery and included operative time, estimated blood loss (EBL), surgical approach, instrumentation used, osteotomy utilization, number of levels fused, complications, reoperations, duration of stay in intensive care, and length of hospital stay. HRQL outcomes, including the EuroQol-5D-3L, neck disability index (NDI), and modified Japanese Orthopaedic Association (mJOA) questionnaires, were collected at baseline, 3 months, 6 months, and 1-year postoperative study intervals. Maximum follow-up was 2-year postoperative; complication data were collected until maximum or last follow-up.

### Classification and categorization of neurologic complications

Neurologic complications resulting from the index procedure were grouped by type: C5 motor deficit, central neurodeficit, nerve root motor deficits, nerve sensory deficits, radiculopathy, and spinal cord deficits. Neurologic complications were classified as major (M) or minor. Major complications required major surgical or medical management, while minor complications required modest deviations from the normal postoperative course. Complications were further assessed by timing and classified as intraoperative, before discharge, before 30 days, before 90 days, and after 90 days.

### Statistical analysis

Statistical analysis was performed using SPSS software (version 21.0, IBM, Armonk, 134 New York, USA). Descriptive analyses summarized demographic, clinical, surgical, and complication related data. Normality of data was determined using the Shapiro–Wilk test. Demographic, surgical, radiographic, and HRQL metrics were compared among deformity groups utilizing Chi-square tests with *post hoc* analysis for categorical variables and analysis of variance (ANOVA) or the Kruskal–Wallis test for continuous variables. ANOVA with repeated measures was used to assess significant temporal changes for continuous variables (i.e., HRQLs) among multiple follow-up visits within each complication group. Linear and logistic regression analysis assessed baseline and surgical factors predictive of experiencing a neurologic complication.

Normalized HRQLs were developed and analyzed, permitting the calculation of an IHS using the validated area-under-the-curve methodology.[14,15] First, all reported preoperative and postoperative (3 months, 6 months, 1 year, and 2 years) values for each outcome measure were divided by the corresponding preoperative score for each patient. Preoperative normalized HRQL score for all patients was therefore 1, with any follow-up normalized HRQL scores being >1, equal to 1, or <1, depending on patient improvement or deterioration relative to their baseline.[15] Normalized scores were plotted against postop time points for each patient, and the creation of a line through all points generated trapezoidal shapes. The area of each trapezoid was calculated and summed together to obtain the total follow-up length area, as Figure 1 demonstrates. Dividing the total area (AUC) by the cumulative follow-up time yielded the IHS, singular value of a patient's entire recovery timeline. Low NDI IHS scores indicate a better outcome (better recovery process), and high EQ5D and mJOA IHS scores represent a better outcome (better recovery process). IHS means were compared across procedure groups utilizing parametric and nonparametric tests as appropriate.

## RESULTS

### Baseline patient characteristics

153 CD patients undergoing operative correction were included for analysis. The overall cohort had a mean age of 61.1 ± 10.4, a mean BMI of 29.7 ± 8.0 kg/m$^2$, a mean CCI score of 0.92 ± 1.29, and was comprised of 63% females. 43% had a prior history of spine surgery, 30% had a history of depression or anxiety, 9% had a history of diabetes, 33% had a history of smoking, and 16% had a history of osteoporosis. When assessing baseline myelopathy symptoms, 42% of patients had gait abnormalities, 54% hand numbness, 39% hand clumsiness, 25% hyperreflexia, and 7.4% lower limb spasticity. Mean baseline alignment was CL-7.0 ± 21.5°, mean cSVA 46.2 ± 24.8, mean SVA of 4.5 ± 68.5, mean PT 20 ± 11.3, and a mean PI-LL of 1.8 ± 17.7 [Table 1].

### Surgical and radiographic summary

18% of patients underwent an anterior approach, 49% a posterior approach, and 33% had a combined approach. Mean fusion length was 8.1 ± 4.6 levels; modes for upper-most and lower-most instrumented vertebrae were C3 and T3, respectively. The mean operative time was 531 ± 275.5 min, mean EBL was 924.2 ± 729.5 ccs, and mean postoperative length of stay was 7.5 ± 10.0 days. Following surgery, both neurologic complication patients and nonneurologic complication patients achieved similar postoperative deformity correction [Table 2].

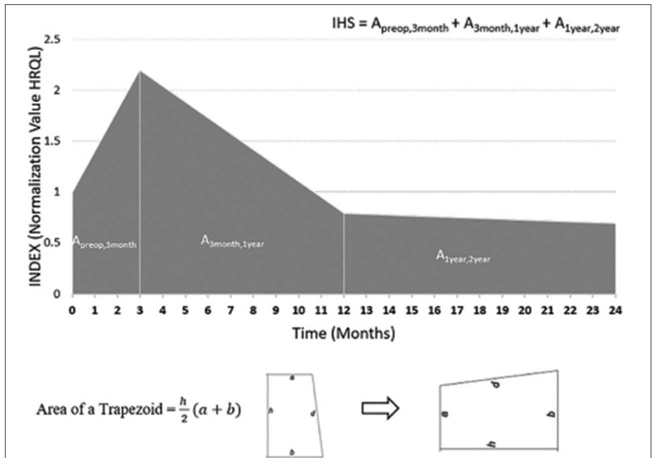


**Figure 1: Area graph representation of normalized HRQL scores and the integrated health state calculation. The change in time was calculated as months and is represented the "height" or "h" of the trapezoid, when calculating the area of each trapezoid: Area of a trapezoid = $\frac{h}{2}(a+b)$. The "y" values represent a given normalized HRQL value at each respective time point and represent a + b within the trapezoid area equation. The equations used for each patient was the following:**

**Area of a trapezoid = $\frac{h}{2}(a+b)$**

**Integrated Health State$_{1year}$ =**

$$\frac{\frac{3months}{2}\left(y_{preop}+y_{3month}\right)+\frac{3months}{2}\left(y_{3month}+y_{6month}\right)+\frac{6months}{2}\left(y_{6month}+y_{1year}\right)}{12months}$$

**Integrated Health State$_{2year}$ =**

$$\frac{\frac{3months}{2}\left(y_{preop}+y_{3month}\right)+\frac{3months}{2}\left(y_{3month}+y_{6month}\right)+\frac{6months}{2}\left(y_{6month}+y_{1year}\right)+\frac{12months}{2}\left(y_{1month}+y_{2year}\right)}{24months}$$

### Neurologic complications outcomes

28 (18%) patients experienced a total of 28 neurologic complications in the postoperative period, with 15 classified as major. When assessed by type, there were 7 radiculopathy, 6 motor deficits, 6 sensory deficits, 5 C5 motor deficits, 2 central neurodeficits, and 2 spinal cord deficits. Motor deficits were the most common major complication (8), 4 of which were C5 motor deficits. There were 3 major intraoperative complications and 5 major complications before discharge. In total, 4.6% of patients had neurologic complications before discharge. 13.7% of patients had neurologic complications occur before 30 days (7 major) and 18.3% before 90 days (12 major). 15% of neurocomplication patients went on to have revision surgery within 6 months and 32% within 2 years, for reasons including spinal stenosis and hardware failure.

**Table 1: Baseline demographic, surgical, and radiographic values**

| Baseline demographics | Mean |
|---|---|
| Age | 61.1±10.4 |
| Female (%) | 63 |
| BMI | 29.7±8.0 |
| CCI | 0.92±1.29 |
| Baseline surgical details | |
| Anterior approach (%) | 18 |
| Posterior approach (%) | 49 |
| Combined approach (%) | 33 |
| Levels fused | 8.1±4.6 |
| Operative time (min) | 531±275.5 |
| Estimated blood loss (cc) | 924.2±729.5 |
| Postoperative length of stay (days) | 7.5±10.0 |
| Baseline radiographic measurements | |
| CL | −7.0±21.5 |
| cSVA | 46.2±24.8 |
| C7-S1 SVA | 4.5±68.5 |
| PT | 20±11.3 |
| PI-LL | 1.8±17.7 |

CL - Cervical Lordosis, cSVA - C2-C7 sagittal vertical axis, SVA - Sagittal vertical axis, PT - Pelvic tilt, PI-LL - Pelvic incidence - lumbar lordosis, BMI - Body mass index, CCI - Charlson comorbidity index

There were no differences in baseline deformity between neurologic complication patients and nonneurologic complication patients (all $P > 0.05$). While baseline frailty status was not a significant predictor of experiencing a neurologic complication ($P = 0.91$), more invasive surgeries (odds ratio [OR]: 1.02 [1.00–1.03], $P = 0.007$) was a significant predictor of experiencing a neurologic complication.[16] Patients with initial diagnosis of degenerative cervical scoliosis (OR: 3.80 [0.51–28.1], $P = 0.19$), and those who received 3 column osteotomies (OR: 1.52 [0.61–3.83], $P = 0.37$) trended toward higher odds of having a neurologic complications [Table 3].

### Health related quality of life and integrated health state clinical outcomes

As compared to nonneurologic complication patients, neurologic complication patients had similar improvement in NDI and EQ5D scores but less improvement in mJOA scores postoperatively. However, when comparing IHS outcomes, there was no significant difference in NDI or EQ5D between groups, but a significant difference in mJOA (1.07 vs. 0.98, $P = 0.003$) at 1-year postoperative.

Of the various types of neurologic complications, patients who experienced spinal cord deficits or central neurologic deficits had the worst IHS outcomes of all complication types at 1 year [Tables 4]. Patients who experienced sensory deficits had the best EQ5D and mJOA IHS outcomes of all complication types.

In the 2-year analysis, there were no significant differences in IHS outcomes between neurologic complication and

**Table 2: Radiographic outcomes of neurologic complication and nonneurologic complication patients**

| | No neurologic complication | Neurologic complication | *P* |
|---|---|---|---|
| Baseline radiographic measurements | | | |
| CL | −7.1±19.5 | −4±26.2 | 0.553 |
| cSVA | 44±25.6 | 51±21.1 | 0.134 |
| TSCL | 37.4±19.7 | 38±21.2 | 0.883 |
| SVA | 4.7±64.5 | 7.1±79.9 | 0.872 |
| PT | 20±12 | 18.7±8.9 | 0.504 |
| PI-LL | 1.3±18.5 | 1.8±14.2 | 0.866 |
| 1-year postoperative radiographic measurements | | | |
| CL | 6.1±15.2 | 10.5±15.2 | 0.207 |
| cSVA | 41.2±19.5 | 39.7±11.2 | 0.642 |
| TSCL | 29.6±13.2 | 25.6±10.9 | 0.141 |
| SVA | 26.2±72.7 | 22.9±49.9 | 0.799 |
| PT | 20.3±12.7 | 17.8±9.1 | 0.287 |
| PI-LL | 2±19 | 3.4±13.5 | 0.696 |

CL - Cervical Lordosis, cSVA - C2-C7 sagittal vertical axis, SVA - Sagittal vertical axis, PT - Pelvic tilt, PI-LL - Pelvic incidence - lumbar lordosis, TSCL - T1 slope - CL noncomplication patients, however, complication patients trended toward worse NDI ($P = 0.263$) and worse mJOA outcomes [$P = 0.163$, Table 5].

### Case example

Figures 2 and 3 present the pre and postoperative radiographs of patients who underwent corrective surgery for CD. Patient 1 was diagnosed with C4-C7 degenerative kyphosis and underwent a C4-C7 anterior cervical discectomy and fusion. Postoperatively, she experienced nerve sensory deficits. Patient 2 was diagnosed with C3-C7 cervical spondylosis and underwent an uncomplicated C3-C7 anterior cervical discectomy and fusion. The calculation of both of their postoperative recovery kinetics and traditional outcomes can be seen in Table 6. When comparing their IHS totals versus their traditional scores, both patients had similar NDI IHS totals, despite patient 1 experiencing a postoperative complication. However, the traditional outcomes assessment only shows patient 2 achieving a larger pre to postoperative change in NDI score.

## DISCUSSION

Postoperative recovery is a defining period in CD surgery, as it plays an integral role in having a successful surgical experience. Recent studies have established recovery kinetics as a more encompassing view of a patient's postoperative clinical outcomes as compared to traditional static measures.[14,15] While little is understood of the effect of neurologic complications on a patient's recovery process, a better understanding of the rates, clinic affects, and postsurgery expectations of patient's experiencing neurologic complications are necessary for both patients and clinicians alike. The present investigation found that patients who experienced neurologic complications had worse recovery kinetics for the mJOA at 1-year postoperative and trended toward worse outcomes for the mJOA and NDI by 2 years. These results suggest that neurologic complications play a critical role as a negative driver of patient-reported outcomes in CD corrective surgery.

In a review of early complications following CD surgery, Smith *et al*. found new neurologic deficits to be the most common new complication following CD corrective surgery, at a rate of 13.5%.[2,17] The results of this investigation found a similar rate, 13.7%, which is also comparable to other previously reported values.[2,7,11] However, when assessing preoperative factors predictive of early complications, Smith *et al*. found no significant associations with the occurrence of early complications.[4] In contrast, when only considering neurologic complications, this investigation found that more invasive surgeries, the use of three column osteotomies, and preoperative diagnosis of degenerative cervical scoliosis were associated with experiencing a neurologic complication. High rates of complication in CD patients undergoing

**Table 3: Predictors of neurologic complications**

| Predictor | Odds of neurologic complication, *P* |
|---|---|
| Surgical invasiveness | 1.02 (1.00-1.03), 0.007 |
| Degenerative cervical scoliosis (2.6%) | 3.80 (0.51-28.1), 0.19 |
| 3 column osteotomy | 1.52 (0.61-3.83), 0.37 |

**Figure 2: Pre and 2-year postoperative radiographs of a patient who underwent a C4-C7 anterior cervical discectomy and fusion**

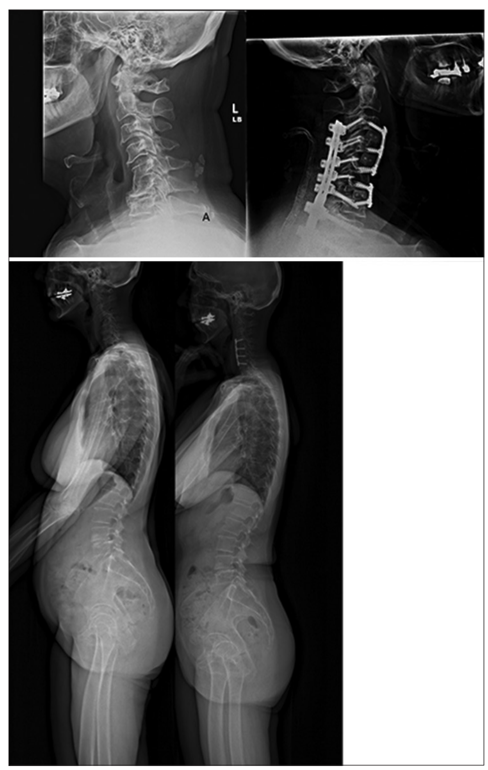

**Figure 3: Pre and 2-year postoperative radiographs of a patient who underwent a C3-C7 anterior cervical discectomy and fusion**

**Table 4: Paired t-test between baseline and follow-up scores for the neck disability index, EQ5D. and modified Japanese orthopedic association**

| Complication | Baseline | 3 months, *P* | 6 months, *P* | 1 year, *P* |
|---|---|---|---|---|
| NDI | | | | |
| Radiculopathy (7) | 48.2±12.0 | 47.6±18.8, 0.92 | 36.9±19.9, 0.44 | 33.7±19.3, 0.04 |
| Motor deficits (6) | 59.7±10.1 | 43.3±15.4, 0.06 | 44.0±23.2, 0.15 | 41.6±23.1, 0.17 |
| Sensory deficits (6) | 47.0±17.4 | 29.4±14.2, 0.07 | 30.0±11.6, 0.03 | 26.3±19.8, 0.03 |
| C5 motor deficits (5) | 47.8±5.9 | 56.1±12.4, 0.60 | 27.3±22.0, 0.28 | 34.4±20.1, 0.16 |
| Central neurodeficits (2) | 20.7±10.4 | 32.0±12.6, 0.04 | 24.3±3.3, 0.52 | 34.0±5.6, 0.03 |
| Spinal cord deficits (2) | 45.3±26.4 | 74.0±12.2, 0.03 | 48.0±8.5, 0.82 | 65.0±12.1, 0.56 |
| No neurologic complication | 48.6±19.4 | 42.7±20.2, 0.01 | 32.7±21.9, <0.001 | 37.8±21.7, <0.001 |
| EQ5D | | | | |
| Radiculopathy (7) | 0.76±0.03 | 0.70±0.04, 0.02 | 0.78±0.11, 0.73 | 0.80±0.03, 0.09 |
| Motor deficits (6) | 0.74±0.06 | 0.75±0.06, 0.88 | 0.78±0.06, 0.28 | 0.77±0.06, 0.84 |
| Sensory deficits (6) | 0.77±0.07 | 0.82±0.05, 0.09 | 0.80±0.04, 0.28 | 0.83±0.09, 0.09 |
| C5 motor deficits (5) | 0.75±0.05 | 0.75±0.04, 0.52 | 0.87±0.12, 0.38 | 0.78±0.08, 0.80 |
| Central neurodeficits (2) | 0.82±0.02 | 0.88±0.03, 0.15 | 0.77±0.06, 0.16 | 0.80±0.07, 0.65 |
| Spinal cord deficits (2) | 0.76±0.05 | 0.60±0.02, 0.06 | 0.74±0.09, 0.74 | 0.70±0.05, 0.83 |
| No neurologic complication | 0.73±0.07 | 0.76±0.08, 0.003 | 0.78±0.09, <0.001 | 0.78±0.08, <0.001 |
| mJOA | | | | |
| Radiculopathy (7) | 13.8±3.8 | 14.0±3.3, 0.70 | 14.7±3.1, 0.50 | 14.7±2.2, 0.47 |
| Motor deficits (6) | 14.0±1.7 | 12.4±2.3, 0.23 | 13.0±2.1, 0.03 | 12.5±1.9, 0.31 |
| Sensory deficits (6) | 15.4±2.9 | 15.5±2.6, 0.72 | 14.8±2.8, 0.70 | 14.2±2.8, 0.50 |
| C5 motor deficits (5) | 13.4±1.5 | 11.0±2.6, 0.55 | 15.7±1.2, 0.06 | 15.5±2.6, 0.04 |
| Central neurodeficits (2) | 14.5±0.71 | 17.0±2.5, 0.58 | 16.0±2.8, 0.74 | 14.0±2.4, 0.91 |
| Spinal cord deficits (2) | 13.5±3.5 | 7.0±2.3, 0.04 | 10.5±0.7, 0.41 | 10.5±3.5, 0.41 |
| No neurologic complication | 13.3±2.8 | 14.1±2.9, 0.02 | 14.4±2.9, <0.001 | 14.1±3.0, 0.10 |

NDI - Neck disability index, mJOA - Modified Japanese orthopedic association

**Table 5: Integrated health state outcomes at 1 year and 2-year postoperative**

| | No neurologic complication | Neurologic complication | *P* |
|---|---|---|---|
| 1-year outcomes | | | |
| NDI | 0.82±0.34 | 0.84±0.40 | 0.873 |
| EQ5D | 1.05±0.08 | 1.03±0.07 | 0.458 |
| mJOA | 1.07±0.14 | 0.98±0.08 | 0.003 |
| 2-year outcomes | | | |
| NDI | 40.0±18.4 | 34.6±15.4 | 0.263 |
| EQ5D | 1.04±0.07 | 1.06±0.10 | 0.619 |
| mJOA | 1.07±0.11 | 1.01±0.08 | 0.163 |
| **1-year outcomes by complication type** | | | |
| **Complication** | **NDI** | **EQ5D** | **mJOA** |
| Radiculopathy (7) | 0.83±0.32 | 1.00±0.04 | 0.96±0.04 |
| Motor deficits (6) | 0.72±0.28 | 0.98±0.06 | 0.91±0.05 |
| Sensory deficits (6) | 0.64±0.18 | 1.06±0.08 | 1.02±0.07 |
| C5 motor deficits (5) | 0.83±0.19 | 1.06±0.05 | 1.01±0.04 |
| Central neurodeficits (2) | 1.6±0.17 | 0.93±0.07 | 0.90±0.03 |
| Spinal cord deficits (2) | 2.22±0.52 | 0.91±0.06 | 0.89±0.05 |
| No neurologic complication | 0.82±0.34 | 1.05±0.08 | 1.07±0.14 |

NDI - Neck disability index, mJOA - Modified Japanese orthopedic association, EQ5D - EuroQol 5 dimension

3 column osteotomies have previously been reported.[17,18] The association found between neurologic complication occurrence, invasiveness, and osteotomies are likely due to the relatively high preoperative deformity of the entire study cohort and the need for more aggressive surgical procedures for correction.

The use of recovery kinetics for evaluating patient's postoperative periods has been employed previously. When comparing the outcomes of CD patients undergoing primary versus revision surgery, Segreto *et al*. found no differences in IHS scores between groups at 2-year postoperative.[15] In a population of cervical spondylotic myelopathy patients undergoing anterior or posterior surgery, Liu *et al*. found that recovery kinetics more accurately described the postoperative outcomes of patients than static scores did.[14] Similar conclusions can be drawn from this investigation, as the static mJOA outcomes at 1 year were comparable between neurologic complication and nonneurologic complication patients, however, neurologic complication patients had significantly worse IHS scores, a stark difference that was unappreciable through conventional outcomes assessments.

Within this study, certain neurologic deficits were associated with myelopathy and impacted patient outcomes following CD surgery. These findings build upon previous work that has established the critical role myelopathy and functional status play in having successful outcomes following surgery.[7,19-22] In a recent analysis of CD patients undergoing

**Table 6: Case examples of recovery kinetics calculation**

| | Baseline | Normalized 3 months | Normalized 6 months | Normalized 1 year | Normalized 2 years | IHS total |
|---|---|---|---|---|---|---|
| NDI | | | | | | |
| Patient 1 | 1 | 0.96 | 0.58 | 0.50 | 0.58 | 0.62 |
| Patient 2 | 1 | 1.22 | 0.57 | 0.57 | 0.30 | 0.61 |
| EQ5D | | | | | | |
| Patient 1 | 1 | 1.12 | 1.21 | 1.14 | 1.14 | 1.14 |
| Patient 2 | 1 | 1.03 | 1.14 | 1.04 | 1.14 | 1.08 |
| mJOA | | | | | | |
| Patient 1 | 1 | 1.09 | 1.09 | 1.0 | 1.18 | 1.07 |
| Patient 2 | 1 | 1.08 | 1.08 | 1.17 | 1.25 | 1.23 |

**Traditional baseline and 2-year outcomes**

| | Baseline | 2 years | Change |
|---|---|---|---|
| NDI | | | |
| Patient 1 | 52 | 30 | 22 |
| Patient 2 | 46 | 14 | 32 |
| EQ5D | | | |
| Patient 1 | 0.66 | 0.76 | 0.10 |
| Patient 2 | 0.76 | 0.86 | 0.10 |
| mJOA | | | |
| Patient 1 | 11 | 13 | 2 |
| Patient 2 | 12 | 15 | 3 |

NDI - Neck disability index, mJOA - Modified Japanese orthopedic association

ACDF procedures, Kim *et al*. found that despite restoring sagittal alignment within their cohort, there was no correlation with clinical outcomes.[13] Ailon *et al*. found no postoperative improvement in mJOA scores among patients undergoing CD corrective surgery.[6] The present analysis appreciated a similar lack of improvement in both traditional and integrated health scores for neurologic complication patients, however, patients who did not experience the occurrence of a neurologic complication were found to have significantly improved mJOA scores at both 1 and 2-year postoperative. In addition, both groups achieved similar deformity correction as there were no differences in radiographic parameters at baseline or 1 year between neurologic complication patients and noncomplication patients. These results underscore the importance of resolving or preventing motor and spinal cord deficits, as symptoms that persist in the postoperative period may play a prominent role in driving worse HRQL outcomes.

This study appreciates several limitations. The limited sample size of the study and relatively high loss to follow-up introduces the risk of selection bias. However, it should be noted that this prospective study was conducted at institutions with well-established support to ensure thorough and accurate reporting. These considerations highlight the difficulty in ensuring full participation within this cohort. In addition, this study relied on surgeon selection for enrollment, which may have been another source of bias unknowingly introduced. We also recognize the limitations of the HRQLs employed within our study. As there is no CD specific health questionnaire currently developed, it is difficult to fully and accurately assess the physical and mental disabilities within this population. The lack of a specific questionnaire may contribute to the lack of deformity correction and HRQL outcomes. However, despite these limitations, this prospective, multicenter study offers valuable insight into the postoperative recovery process of a vulnerable population undergoing surgical procedures with the potential for serious adverse events.

## CONCLUSIONS

This investigation assessed the 1 and 2-year clinical outcomes for CD patients who experienced neurologic complications using recovery kinetics, a more holistic reflection a patient's postoperative clinical recovery. Patients who experienced neurologic complications had worse recovery kinetics for the mJOA at 1-year postoperative and trended toward worse outcomes for the mJOA and NDI by 2 years, despite achieving similar deformity correction. These results suggest that the resultant myelopathy, motor deficit, and pain from postoperative neurologic compromise play a critical role as a negative driver of patient-reported outcomes in adult CD surgery.

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## Conflicts of interest

There are no conflicts of interest.

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