Original Article

Cervical and spinopelvic parameters can predict patient reported outcomes following cervical deformity surgery

ABSTRACT

Background: Recent studies have evaluated the correlation of health-related quality of life (HRQL) scores with radiographic parameters. This relationship may provide insight into the connection of patient-reported disability and disease burden caused by cervical diagnoses.

Purpose: To evaluate the association between spinopelvic sagittal parameters and HRQLs in patients with primary cervical diagnoses.

Methods: Patients ≥18 years meeting criteria for primary cervical diagnoses. Cervical radiographic parameters assessed cervical sagittal vertical axis, TS-CL, chin-to-brow vertical angle, C2-T3, CL, C2 Slope, McGregor's slope. Global radiographic alignment parameters assessed PT, SVA, PI-LL, T1 Slope. Pearson correlations were run for all combinations at baseline (BL) and 1 year (1Y) for continuous BL and 1Y modified Japanese Orthopaedic Association scale (mJOA) scores, as well as decline or improvement in those HRQLs at 1Y. Multiple linear regression models were constructed to investigate BL and 1Y alignment parameters as independent variables.

Results: Ninety patients included 55.6 ± 9.6 years, 52% female, 30.7 ± 7kg/m^2. By approach, 14.3% of patients underwent procedures by anterior approach, 56% posterior, and 30% had combined approaches. Average anterior levels fused: 3.6, posterior: 4.8, and mean total number of levels fused: 4.5. Mean operative time for the cohort was 902.5 minutes with an average estimated blood loss of 830 ccs. The mean BL neck disability index (NDI) score was 56.5 and a mJOA of 12.81. While BL NDI score correlated with gender (P = 0.050), it did not correlate with BL global or cervical radiographic factors. An increased NDI score at 1Y postoperatively correlated with BL body mass index (P = 0.026). A decreased NDI score was associated with 1Y T12-S1 angle (P = 0.009) and 1Y T10 L2 angle (P = 0.013). Overall, BL mJOA score correlated with the BL radiographic factors of T1 slope (P = 0.005), cervical lordosis (P = 0.001), C2-T3 (P = 0.008), C2 sacral slope (P = 0.050), SVA (P = 0.010), and CL Apex (P = 0.043), as well as gender (P = 0.050). Linear regression modeling for the prior independent variables found a significance of P = 0.046 and an R^2 of 0.367. Year 1 mJOA scores correlated with 1Y values for maximum kyphosis (P = 0.043) and TS-CL (P = 0.010). At 1Y, a smaller mJOA score correlated with BL S1 sacral slope (P = 0.014), pelvic incidence (P = 0.009), L1-S1 (P = 0.012), T12-S1 (P = 0.008). The linear regression model for those 4 variables demonstrated an R^2 of 0.169 and a P = 0.005. An increased mJOA score correlated with PI-LL difference at 1Y (P = 0.012), L1-S1 difference (P = 0.036), T12-S1 difference (0.006), maximum lordosis (P = 0.026), T9-PA difference (P = 0.010), and difference of T4-PA (P = 0.008).

Conclusions: While the impact of preoperative sagittal and cervical parameters on mJOA was strong, the BL radiographic

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factors did not impact NDI scores. PostOp HRQL was significantly associated with sagittal parameters for mJOA (both worsening and improvement) and NDI scores (improvement). When cervical surgery has been indicated, radiographic alignment is important for postoperative HRQL.

Keywords: Cervical deformity, health-related quality of life, patient report outcomes, radiographic parameters

INTRODUCTION

Musculoskeletal procedures are some of the most common odds ratio (OR) procedures performed, especially among patients over the age of 45. A significant portion of these patients suffers from some form of spine-related problem. Spinal fusion was the sixth most common procedure performed in the OR in 2014, with nearly a half-million of them performed each year. Spinal fusions alone account for $12 billion in aggregate costs for hospitals annually, which is the highest out of all OR procedures.[1] The number of spinal fusions performed each year increased by 70%, from 287,600 procedures in 2001 to 488,300 procedures in 2011.[2] Therefore, achieving quality and cost-effective outcomes with these procedures greatly benefits both hospitals and patients.

Previous studies have shown that treatment of cervical diagnoses can have a dramatic impact on health-related quality of life (HRQL). Studies have found that spinal surgery can effectively improve sleeping, daily activities, symptoms of discomfort, depression, distress, vitality, and sexual activity, thus improving quality of life.[3] This leads to the finding that quality-adjusted life years improved on average by 0.29 1 year (1Y) after surgery and 0.62 2 years after surgery.[4] Previous studies also demonstrate that certain patient characteristics including obesity and low mental health status may interfere with the improvement of HRQL following spinal surgery.[5,6] These studies suggest that, for many patients, spinal surgery can lead to a marked improvement of HRQL, especially when individual patient characteristics are taken into consideration.

In addition, existing research suggests that spinopelvic sagittal alignment plays a major role in outcomes following surgery of the cervical spine. Sagittal spinal parameters are interrelated due to the flexibility of the spine, so changes in one area often lead to progressive compensatory changes in other regions.[7] For this reason, it is important to look at both cervical and global alignment parameters. Previous studies indicate that cervical alignment plays a major role in clinical outcomes, and thus, patient-specific alignment parameters should be considered when customizing cervical interbody grafts for each spine surgery patient.[8] Furthermore, studies have found that under-correction of sagittal spine alignment may lead to pelvic recruitment and lower-limb flexion to compensate, leading to worse postoperative outcomes.[9] Finally, studies suggest that intraoperative spinal alignment measures are correlated with postoperative global alignment; therefore, these measures have significant utility in surgical planning.[10]

Given the importance of spinopelvic sagittal alignment in clinical outcomes after cervical spine surgery as well as the impact cervical diagnoses have on HRQL, it is natural to raise the question of how spinopelvic sagittal parameters correlate with HRQL. As the existing literature does not adequately address this question, this study intended to evaluate the association between spinopelvic sagittal parameters and HRQLs in patients with primary cervical diagnoses.

METHODS

Study inclusion and exclusion criteria

This was a retrospective analysis of consecutively enrolled patients greater than 18 years of age with primary cervical diagnoses undergoing cervical fusion by a single spine surgeon at an academic center. Institutional review board approval was obtained. Database inclusion criteria required scheduled elective multilevel posterior or anterior cervical fusion ending proximal to or distal to the cervicothoracic junction. Diagnoses included cervical disc herniation, spinal stenosis, spondylolisthesis, degenerative scoliosis, and adjacent segment disease. Study inclusion criteria required full baseline (BL) and 1Y HRQL and radiographic data. Patients with a prior cervical fusion or diagnoses of trauma, ankylosing spondylitis, rheumatoid arthritis or chronic autoimmune conditions, neoplasm, systemic infection, or preoperative spinal infection were excluded.

Data collection, radiographic, and health-related quality of life assessment

BL patient demographics and clinical data assessed included patient age, gender, body mass index (BMI), and Charlson Comorbidity Index (CCI). Surgical data collected included the number of levels fused, surgical approach, decompression and osteotomy type, as well as estimated blood loss (EBL) and total operative time. To assess the regional and global parameters associated with the spine, preoperative to 1Y full-length free-standing lateral spine radiographs were measured

with SpineView® (ENSAM, Laboratory of Biomechanics, Paris, France) software at a single academic center. Cervical radiographic parameters assessed included (cervical sagittal vertical axis: C2 plumbline offset from the posterosuperior corner of C7), T1 slope minus CL (TS-CL: mismatch between T1 slope and cervical curvature), chin-to-brow vertical angle, C2-T3 angle, C2-C7 lordosis (CL: angle between the C2 inferior end plate and the C7 inferior end plate), C2 Slope (C2S), McGregor's slope (MGS: Angle between the line from the posterosuperior aspect of the hard palate to the caudal portion of the opisthion and the horizontal), and CL Apex. Global radiographic alignment parameters assessed included pelvic tilt (PT: the angle between the vertical and the line through the sacral midpoint to the center of the two femoral heads), T1 slope (angle between the horizontal line and the T1 superior endplate), T12-S1 angle, T10 L2 angle, L1-S1 angle, S1 sacral slope, C2 sacral slope, T9-PA, T4-PA, maximum kyphosis, maximum lordosis, pelvic incidence, the mismatch between pelvic incidence and lumbar lordosis (PI-LL), and the sagittal vertical axis (SVA: C7 plumb line relative to the posterosuperior corner of S1).

Clinical outcomes, or HRQL metrics, utilized in this study included the modified Japanese Orthopedic Association scale (mJOA) and the neck disability index (NDI) collected at BL and up to 1Y. The NDI in this database was multiplied by two to obtain each patient's BL and follow-up score out of 100. The NDI is the most ubiquitous and strongly validated self-report measure for neck pain.[11] The questionnaire includes 10 sections related to how neck pain impacts the ability to manage daily activities. Each section is given a score from 0 to 5 and a higher score indicates more severe disability. On the other hand, the mJOA score is frequently used to assess physical disability in patients with cervical myelopathy, especially to judge the effectiveness of an intervention. To evaluate motor and sensory function, patients are asked to perform tasks such as walking.[12]

Statistical analysis

Demographic, clinical, and surgical data were assessed with descriptive analyses. After determining data followed a parametric distribution using the Shapiro–Wilk Normality test ($P = 0.15$, $P > 0.05$), Pearson correlations were run for all combinations of cervical and global radiographic alignment measures and continuous HRQLs (mJOA and NDI) at BL and 1Y, as well as worsening or improvement in the HRQLs. An improved NDI score at 1Y corresponds to a decrease in the patient-reported score at the follow-up, and an increase in score demonstrated a worsened neck disability score. The opposite was observed for the myelopathy severity HRQL. Worsening in mJOA scores was defined as a decrease in score from BL to 1Y, whereas improvement was an increased score at 1Y. Multiple linear regression models were constructed to investigate the factors as independent variables that correlated with the HRQLs at each time point and the change from BL to 1Y. Statistical analysis was performed using SPSS software (version 21.0 IBM, Armonk, NY, USA). All analyses were two-sided and the level of significance was set to $P < 0.05$.

RESULTS

Overall cohort characteristics

A total of 90 patients who underwent elective cervical fusion surgeries by a single surgeon were included in this study. The average age was 55.6 (standard deviation [SD] ± 9.6) years old, 52% of patients were female, and the average BMI was (SD ± 7) kg/m^2. The average CCI for the cohort was 0.71 ± 1.06, with the most common comorbidities of diabetes mellitus (29.8%), vascular disease (21.1%), and pulmonary disease (5.4%). The mean BL NDI score was 56.5 and mJOA of 12.81. BL cervical and global radiographic parameters are listed in Table 1.

Surgical characteristics

By surgical approach, 14% of patients underwent procedures by anterior approach (average levels fused 3.6), 56% posterior (4.8), and 30% had combined approaches (4.5). The mean operative time for the cohort was 902.5 minutes with an average EBL of 830 ccs.

Neck disability index and radiographic factors

While BL NDI score correlated with gender ($P = 0.050$), it did not correlate with BL global or cervical radiographic factors. An increased NDI score at 1Y postoperatively correlated with BL BMI ($P = 0.026$). A decreased NDI score was associated with 1Y T12-S1 angle ($P = 0.009$) and 1Y T10 L2 angle ($P = 0.013$).

Table 1: Mean baseline cervical and global radiographic parameters

Baseline cervical and global radiographic parameters	
Radiographic parameters	**Measurement**
Sacral slope	38.5°
Pelvic tilt	17.7°
Pelvic incidence	55.9°
Pelvic incidence minus lumbar lordosis	−1.9°
L1-S1 angle	58°
T4-T12 angle	−38.4°
T1 slope	25.6°
T1 slope minus cervical lordosis	25.1°
C2-C7 angle	2.9°
C2-C7 sagittal vertical axis	25.9 mm
C2 slope	21.7°
C7-S1 sagittal vertical axis	−3.9 mm

Modified Japanese orthopedic association scale and radiographic factors

Overall, BL mJOA score correlated with the BL radiographic factors of T1 slope ($P = 0.005$), cervical lordosis ($P = 0.001$), C2-T3 ($P = 0.008$), C2 sacral slope ($P = 0.050$), SVA ($P = 0.010$), and CL Apex ($P = 0.043$), as well as gender ($P = 0.050$). Linear regression modeling for the prior independent variables found a significance of $P = 0.046$ and an R^2 of 0.367. Year 1 mJOA scores correlated with 1Y values for maximum kyphosis ($P = 0.043$) and TS-CL ($P = 0.010$). At 1Y, a smaller mJOA score correlated with BL S1 sacral slope ($P = 0.014$), pelvic incidence ($P = 0.009$), L1-S1 ($P = 0.012$), T12-S1 ($P = 0.008$). The linear regression model for those 4 variables demonstrated an R^2 of 0.169 and a $P = 0.005$. An increased mJOA score correlated with PI-LL difference at 1Y ($P = 0.012$), L1-S1 difference ($P = 0.036$), T12-S1 difference (0.006), maximum lordosis ($P = 0.026$), T9-PA difference ($P = 0.010$), and difference of T4-PA ($P = 0.008$).

DISCUSSION

Primary cervical diagnoses are commonly treated through surgical intervention and when successful these interventions provide a marked improvement in HRQL. Surgical treatment of primary cervical diagnoses often utilizes radiographic alignment measures to inform the surgical approach and the targeted degree of correction during the surgery. The correlation between spinopelvic sagittal alignment parameters and HRQL is not well understood, though previous studies have suggested that these parameters can be used to improve clinical outcomes.

In this study, we examined the spinopelvic sagittal alignment parameters and HRQL measures reported by 90 patients who underwent elective cervical fusion surgeries by a single surgeon to study the relationship between sagittal alignment parameters and HRQL metrics. The HRQL metrics were assessed using NDI and mJOA measurements. Of interest is that the NDI primarily utilizes a self-reported scale where patients are asked to rate how much pain they experience while performing a given task. In contrast, the mJOA uses the ability to perform different tasks, such as walking on a flat surface compared to walking up a set of stairs, to assess a motor function of certain parts of the body, such as the lower extremities. As such, the NDI may be a better measure of how the patient subjectively experiences pain while doing a given task, whereas the mJOA may be a better measure of what the patient can objectively do.

Our study found that there were correlations between spinopelvic alignment parameters, other patient characteristics and NDI score at BL and after 1Y. While BL NDI score did not correlate with BL spinopelvic alignment parameters, the study found that a decreased NDI score was associated with T12-S1 and T10-L2 angles at 1Y after surgery. This suggests that restoring spinopelvic alignment through spine surgery may be beneficial in improving patient's self-reported pain with different activities. Moreover, one should consider how surgery and postsurgical rehabilitation will impact global alignment parameters, including possible compensatory changes in the alignment of the thoracolumbar region. An interesting finding in this study was the positive correlation between increased NDI at 1Y and BL BMI. This finding supports previous research suggesting that obese patients have worse HRQL measures after spine surgery than nonobese patients.[13] Awareness of this correlation can influence patient selection as well as discussions with the patient regarding the expected change in their quality of life. Patients with additional comorbidities require multifactorial solutions, and this suggests that it may be beneficial for spine surgeons to work with other members of an obese patient's health-care team to address the patient's weight to optimize their HRQL after spinal surgery.

Overall, our study found a stronger correlation between mJOA score and radiographic factors compared to other HRQL measures. BL mJOA score correlated with the BL radiographic factors of T1 slope ($P = 0.005$), cervical lordosis ($P = 0.001$), C2-T3 ($P = 0.008$), C2 sacral slope ($P = 0.050$), SVA ($P = 0.010$), and CL Apex ($P = 0.043$), as well as gender ($P = 0.050$). This suggests that radiographic measures are correlated with the degree of dysfunction a patient experiences which in combination with the physical exam can help inform the best method of treatment for a given patient. At 1Y after surgery a smaller mJOA score, indicating more severe dysfunction was correlated with BL measures of S1 sacral slope ($P = 0.014$), pelvic incidence ($P = 0.009$), L1-S1 ($P = 0.012$), and T12-S1 ($P = 0.008$). This suggests that BL radiographic findings can be used to help predict possible clinical outcomes after surgery and identify which patients are more likely to deteriorate and may need more aggressive monitoring. To improve function in patients with these BL radiographic findings, perhaps a greater emphasis can be placed on correcting these malalignments perioperatively. An increased mJOA score, indicating improved function, was correlated with PI-LL difference ($P = 0.012$), L1-S1 difference ($P = 0.036$), T12-S1 difference (0.006), maximum lordosis ($P = 0.026$), T9-PA difference ($P = 0.010$), and difference of T4-PA ($P = 0.008$) at 1Y. These significant differences in global parameters after 1Y in relation to increased function indicate that global alignment improves after cervical fusion

surgery, likely due to the relief of compensatory changes after the procedure. Since BL L1-S1 and T12-S1 correlated with smaller mJOA scores and an increased mJOA score correlated with a difference in these two parameters, finding ways to correct these parameters will greatly improve the efficacy of interventions to restore function. Given that previous studies suggest that some of these measures, such as maximum lordosis, can be improved with physical activity, such as extension exercises, it is worth considering how other modalities including physical therapy can be used in tandem with spinal surgery to improve patient outcomes.[14]

Our study is not without limitations. The retrospective nature of the study comes with accompanying limitations. Using data collected from one surgeon operating in an academic setting may not be representative of the average physician and average hospital where a primary cervical diagnosis patient receives treatment in the United States. Furthermore, a study of this nature cannot examine causality, and both sagittal spinal alignment parameters and HRQL may be influenced by another confounding factor such as the underlying spinal diagnoses for which the patient was receiving spinal fusion surgery. Nonetheless, to our knowledge, this is the largest retrospective cohort study examining the relationship between sagittal spinal alignment parameters and HRQL outcomes.

CONCLUSIONS

While the impact of preoperative sagittal and cervical parameters on mJOA was strong, the BL radiographic factors did not impact NDI scores. This may be partially explained by the fact that NDI measures a more subjective patient experience of how painful it is to perform a given task, whereas the mJOA measures what physical tasks a patient objectively can or cannot perform. The discrepancy here illustrates that while both pain and physical dysfunction are important, they may not be perfectly correlated. PostOp HRQL was significantly associated with sagittal parameters for mJOA (both worsening and improvement) and NDI scores (improvement). This suggests that when cervical surgery has been indicated, radiographic alignment is important for PostOp HRQL.

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Conflicts of interest

Peter G Passias MD – Reports personal consulting fees for Spinewave, Zimmer Biomet, DePuy Synthes, and Medicrea outside the submitted work.

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