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/m². 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 12.8. 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 R² 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 R² of 0.169 and a P = 0.005. An increased mJOA score correlated with PT-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 parameters on mJOA was weak, the BL radiographic

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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.[9,10] 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.
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. 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.

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/m². 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

| 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. 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 Medtrica outside the submitted work.

REFERENCES

1. McDermott KW, Freeman WJ, Elixhauser A. Overview of Operating Room Procedures During Inpatient Stays in U.S. Hospitals, 2014. Statistical Brief #233. In: Healthcare Cost and Utilization Project (HCUP) Statistical Briefs. Rockville (MD): Agency for Healthcare Research and Quality (US); December 2017.
2. Weiss AJ, Elixhauser A. Trends in Operating Room Procedures in U.S. Hospitals, 2001–2011. Statistical Brief #171. In: Healthcare Cost and Utilization Project (HCUP) Statistical Briefs. Rockville (MD): Agency for Healthcare Research and Quality (US); March 2014.
3. Räsänen P, Ohman J, Sintonen H, Rynänen OP, Koivisto AM, Blom M, et al. Cost-utility analysis of routine neurosurgical spinal surgery. J Neurosurg Spine 2006;5:204-9.
4. Parker SL, Chotai S, Devin CJ, Tetreault L, Mroz TE, Brodke DS, et al. Bending the cost curve-establishing value in spine surgery. Neurosurgery 2017;80:S61-9.
5. Horn SR, Segreto FA, Ramchandran S, Poorman GR, Sure A, Marascalchi B, et al. The influence of body mass index on achieving age-adjusted alignment goals in adult spinal deformity corrective surgery with full-body analysis at 1 year. World Neurosurg 2018;120:e533-45.
6. Diebo BG, Tishelman JC, Horn S, Poorman GW, Jalali C, Segreto FA, et al. The impact of mental health on patient-reported outcomes in cervical radiculopathy or myelopathy surgery. J Clin Neurosci 2015;2018;54;102-8.
7. Roussouly P, Pinheiro-Franco JL. Sagittal parameters of the spine: Biomechanical approach. Eur Spine J 2011;20 Suppl 5:578-85.
8. Goldschmidt E, Angriman F, Agarwal N, Trevisman M, Zhou J, Chen K, et al. A new piece of the puzzle to understand cervical sagittal alignment: Utilizing a novel angle δ to describe the relationship among T1 vertebral body slope, cervical lordosis, and cervical sagittal alignment. Neurosurgery 2020;86:446-51.
9. Passias PG, Jalali CM, Diebo BG, Cruz DL, Poorman GW, Buckland AJ, et al. Full-body radiographic analysis of postoperative deviations from age-adjusted alignment goals in adult spinal deformity correction and related compensatory recruitment. Int J Spine Surg 2019;13:205-14.
10. Oren JH, Tishelman JC, Day LM, Baker JF, Foster N, Ramchandran S, et al. Measurement of spinopelvic angles on prone intraoperative long-cassette lateral radiographs predicts postoperative standing global alignment in adult spinal deformity surgery. Spine Deform 2019;7:325-30.
11. Vernon H. The neck disability index: State-of-the-art, 1991-2008. J Manipulative Physiol Ther 2008;31:491-502.
12. Kato S, Oshima Y, Oka H, Chikuda H, Takeshita Y, Miyoshi K, et al. Comparison of the Japanese Orthopaedic Association (JOA) score and modified JOA (mJOA) score for the assessment of cervical myelopathy: A multicenter observational study. PLoS One 2015;10:e0123022.
13. Segreto FA, Passias PG, Lafage R, Lafage V, Smith JS, Line BG, et al. Incidence of acute, progressive, and delayed proximal junctional kyphosis over an 8-year period in adult spinal deformity patients. Oper Neurosurg (Hagerstown) 2020;18:75-82.
14. Weiner MT, Oakley PA, Dennis AK, Shapiro DA, Harrison DE. Increasing the cervical and lumbar lordosis is possible despite overt osteoarthritis and spinal stenosis using extension traction to relieve low back and leg pain in a 66-year-old surgical candidate: A CBP® case report. J Phys Ther Sci 2018;30:1364-9.