

# Risk-benefit assessment of major versus minor osteotomies for flexible and rigid cervical deformity correction

## ABSTRACT

**Introduction:** Osteotomies are commonly performed to correct sagittal malalignment in cervical deformity (CD). However, the risks and benefits of performing a major osteotomy for cervical deformity correction have been understudied. The objective of this retrospective cohort study was to investigate the risks and benefits of performing a major osteotomy for CD correction.

**Methods:** Patients stratified based on major osteotomy (MAJ) or minor (MIN). Independent *t*-tests and Chi-squared tests were used to assess differences between MAJ and MIN. A sub-analysis compared patients with flexible versus rigid CL.

**Results:** 137 CD patients were included (62 years, 65% F). 19.0% CD patients underwent a MAJ osteotomy. After propensity score matching for cSVA, 52 patients were included. About 19.0% CD patients underwent a MAJ osteotomy. MAJ patients had more minor complications ( $P = 0.045$ ), despite similar surgical outcomes as MIN. At 3M, MAJ and MIN patients had similar NDI, mJOA, and EQ5D scores, however by 1 year, MAJ patients reached MCID for NDI less than MIN patients ( $P = 0.003$ ). MAJ patients with rigid deformities had higher rates of complications (79% vs. 29%,  $P = 0.056$ ) and were less likely to show improvement in NDI at 1 year (0.95 vs. 0.54,  $P = 0.027$ ). Both groups had similar sagittal realignment at 1 year (all  $P > 0.05$ ).

**Conclusions:** Cervical deformity patients who underwent a major osteotomy had similar clinical outcomes at 3-months but worse outcomes at 1-year as compared to minor osteotomies, likely due to differences in baseline deformity. Patients with rigid deformities who underwent a major osteotomy had higher complication rates and worse clinical improvement despite similar realignment at 1 year.

**Keywords:** Fixed deformity, flexible deformity, osteotomy, pedicle subtraction osteotomy, rigid deformity, vertebral column resection

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## INTRODUCTION

Sagittal alignment and balance are intricately linked, and together have a profound impact on health-related quality of life (HRQL). The range of normal values of sagittal alignment including cervical lordosis, thoracic kyphosis, lumbar lordosis, and pelvic incidence have been linked to one another via a “chain of correlation” to create the optimal alignment and balance which is unique for each individual patient.<sup>[1]</sup> Glassman *et al.* demonstrated that at increasing degrees of positive sagittal balance patients have improvement in HRQL outcomes.<sup>[2]</sup>

Specific to the cervical spine, sagittal imbalance due to cervical spine deformity (CD) leads to an increase in effort and energy expenditure to maintain an upright posture. CD can severely limit patients' quality of life as it can restrict horizontal gaze, limit eating and ambulation, and cause Pain and neurologic dysfunction.<sup>[3,4]</sup> Trauma, metabolic bone disease, ankylosing spondylitis, iatrogenic malalignment, and age-related degeneration are all potential causes of cervical sagittal imbalance. Sagittal imbalance can be either focal with maintained global alignment or globally imbalanced with a C7 plumb line >2 cm. Several attempts have been made to classify CD types and stratify surgical intervention along these lines. Importantly, these can lead to either flexible or rigid deformities.

Surgical techniques that have been developed over time have specific indications for the management of CD. Techniques to address CD range from minor procedures such as multilevel anterior cervical discectomy and fusion and/or corpectomy and facet osteotomies to major surgical interventions including osteotomies such as pedicle subtraction osteotomy (PSO) and vertebral column resection (VCR). Approaches for deformity corrective surgery are also quite variable: including anterior only, posterior only, anterior-posterior, posterior-anterior, anterior-posterior-anterior, and posterior-anterior-posterior options.<sup>[5,6]</sup> Determining the optimal procedure for a particular deformity can be challenging as the ideal is to restore balance without overcorrection, and minimizing surgical morbidity.

Achieving deformity correction to normal values may appear ideal on the surface however extensive surgical intervention comes at a cost. Major three-column resection osteotomies have a complication rate of over 50%, and there is a poor understanding of the long-term benefits and risks of these major osteotomies compared to minor osteotomies. While major osteotomies offer a larger degree of deformity correction, at a certain degree the maximum quality of life

attained begins to plateau and regress due to increased complications and risk of overcorrection. The goal of this study was to assess the risks and benefits of major versus minor osteotomies for flexible and rigid cervical deformity correction.

## METHODS

### Data source

This study is a retrospective review of a prospectively collected database of CD patients enrolled from 13 sites within the United States. Internal Review Board approval was obtained at each participating site before study initiation and informed consent was given by each included patient. Inclusion criteria for the database were patients ages  $\geq 18$  years, and radiographic evidence of CD at baseline assessment, defined as the presence of at least 1 of the following: cervical kyphosis (C2–7 Cobb angle  $> 10^\circ$ ), cervical scoliosis (C2–7 coronal Cobb angle  $> 10^\circ$ ), C2–7 sagittal vertical axis (cSVA)  $> 4$  cm, or chin-brow vertical angle (CBVA)  $> 25^\circ$ . CD patients meeting radiographic inclusion with available baseline and 1-year follow-up data were included in this study. Patients with active tumors or infections were excluded from the study.

### Data collection

Demographic and clinical data collected included patient age, sex, body mass index (BMI), prior cervical surgery, and Charlson Comorbidity Index. Surgical data collected included operative time, estimated blood loss, surgical approach, off-label use of bone morphogenetic protein 2, osteotomy use and the number of osteotomies, levels fused, and instrumentation used.

Patients were evaluated using full-length free-standing lateral spine radiographs (36" long-cassette) at baseline and 1-year postoperative follow-up visit. Radiographs were analyzed using dedicated and validated software (SpineView<sup>®</sup>; ENSAM, Laboratory of Biomechanics, Paris, France) at a single center with standard techniques.<sup>[7-9]</sup> Measured cervical spine parameters included cSVA (offset from the C2 plumbline and the postero-superior corner of C7), C2–C7 lordosis (CL: Cobb angle between C2 inferior endplate and C7 inferior endplate), T1 slope minus CL (TS–CL: Mismatch between T1 slope and cervical lordosis), and CBVA (angle subtended between the vertical line and the line from the brow to the chin). Measured spinopelvic parameters included: sagittal vertical axis (SVA: C7 plumb line relative to the posterior-superior corner of S1), pelvic incidence minus lumbar lordosis (PI–LL: Mismatch between pelvic incidence and lumbar lordosis), and pelvic tilt (PT: Angle between the vertical and the line through the sacral midpoint to the center of the two femoral heads).

### Patient stratification

Patients were categorized based on undergoing a major osteotomy (MAJ) defined as either a PSO or VCR or a minor osteotomy (MIN). The flexibility of the deformity was assessed using C2–C7 lordosis and T1S change > 10° between flexion and extension. A sub-analysis was performed on patients with fixed/rigid (< 10° difference between flexion and extension) and nonfixed/flexible (> 10° change between flexion and extension) alignment for cervical lordosis for both major and minor deformities.

### Statistical analysis

Propensity score matching (PSM) was performed controlling for baseline cSVA to generate two groups with similar baseline deformity, with one group who had a major osteotomy and one group with only minor osteotomy. Independent *t*-tests for continuous variables and Chi-squared tests for categorical variables were used to assess differences between MAJ and MIN. Two-sided *P* < 0.05 were considered statistically significant. All analyses were performed using All analyses were performed using SPSS software (IBM Corp. IBM SPSS Statistics for Windows, v23.0. Armonk, NY, USA).

## RESULTS

### Patient demographics

137 CD patients were included (61.6 years old, 65.2% female, BMI 29.2 kg/m<sup>2</sup>). The most common diagnoses for these CD patients were degenerative kyphosis (48.2%), stenosis or myelopathy (20.0%), and iatrogenic kyphosis (14.1%). 30.3% of patients had depression, 29.2% had a history of smoking, and 14.6% had osteoporosis. About 38.6% of patients had prior cervical spine surgery. There were 26 patients (19.0%) who underwent a major (MAJ) osteotomy (20 PSO, 6 VCR). Major osteotomy locations ranged from C4-T4 with the most common occurrences T1 and T2 (8 patients, and 4 patients).

After PSM, there were 26 MAJ and 26 min patients. MAJ and MIN had no differences in any baseline radiographic parameters, with the exception of cSVA (MAJ: 62.5 mm, MIN: 42.0 mm, *P* = 0.002). There were no significant differences in age gender, or BMI between patients who underwent a MAJ or MIN osteotomy during their primary surgery [all *P* > 0.05, Table 1]. Frailty scores did not differ between MAJ and MIN patients, as well as other comorbidities, including smoking status, diabetes, osteoporosis, and depression [all *P* > 0.05, Table 1].

### Surgical details and complications

MAJ patients trended toward more minor complications compared to MIN patients (50% vs. 23%, *P* = 0.083), however, there were no differences in levels fused (11.1 vs. 9.8, *P* = 0.274), blood loss (1200cc vs. 1087cc, *P* = 0.91),

operative time (484.0 vs. 565.2 *P* = 0.83), or any postoperative complication as compared to MIN patients [73% vs. 62%, *P* = 0.385, Table 2].

### Pre- and post-operative radiographic alignment compared between MAJ and MIN

There were significant differences in preoperative T1 slope and cervical lordosis between MAJ and MIN patients after the PSM was performed controlling for baseline cSVA [both *P* < 0.05, Table 3]. Postoperatively, MAJ and MIN achieved similar cervical and global sagittal alignment (all *P* > 0.05).

### Health-related quality of life scores

At 3M postoperative, MAJ and MIN patients had similar NDI, mJOA, and EQ5D scores, however by 1 y postoperative MAJ patients reached MCID for NDI less than MIN patients [7.7% vs. 42.3%, *P* = 0.003, Table 4].

### Flexible and rigid cervical deformities

There were 9 (38%) MAJ osteotomy patients with flexible deformity assessed by C2–C7 CL and 17 (65.0%) MAJ patients with rigid deformity. For the MIN osteotomy patients, 9 (38%) patients had flexible deformities and 17 (65.0%) had fixed deformities at baseline.

For flexible deformity patients, there were no differences in minor complications, major complications, or reoperation rates between MAJ and MIN osteotomy patients (all *P* > 0.05).

**Table 1: Demographic and clinical factors compared between patients undergoing a major or minor osteotomy**

| Baseline demographics factors | Mean ± SD    |              | <i>P</i> |
|-------------------------------|--------------|--------------|----------|
|                               | Major (n=26) | Minor (n=26) |          |
| Age (years)                   | 60.5±9.7     | 59.8±12.0    | 0.844    |
| Gender (female %)             | 63.2         | 52.6         | 0.372    |
| BMI (kg/m <sup>2</sup> )      | 28.3±7.1     | 31.6±8.5     | 0.221    |
| Frailty score                 | 0.417±0.10   | 0.417±0.11   | 0.997    |
| Smoking status                | 27.8         | 31.3         | 0.560    |
| Diabetes                      | 10.5         | 0.0          | 0.243    |
| Osteoporosis                  | 15.8         | 10.5         | 0.500    |
| Depression                    | 26.3         | 36.8         | 0.364    |

SD - Standard deviation, BMI - Body mass index

**Table 2: Surgical factors compared between major and minor osteotomy patients**

| Surgical factors                            | Major (n=26) | Minor (n=26) | <i>P</i> |
|---|--------------|--------------|----------|
| Levels fused                                | 11.1±3.2     | 9.8±4.9      | 0.274    |
| Estimated blood loss (cc)                   | 1200±623     | 1087±342.2   | 0.914    |
| Operative time (min)                        | 565.2±342.2  | 484±346.0    | 0.826    |
| Intra-operative major complication rate (%) | 1 (5.3)      | 0            | 0.500    |
| Intra-operative any complication rate (%)   | 3 (15.8)     | 2 (10.5)     | 0.500    |
| Any complication rate (%)                   | 62           | 73           | 0.654    |

**Table 3: Radiographic alignment compared between major and minor osteotomy patients both pre- and 1 year post-operatively**

| Radiographic parameter       | Preoperative |              |       | Postoperative |              |       |
|------------------------------|--------------|--------------|-------|---------------|--------------|-------|
|                              | Major (n=26) | Minor (n=26) | P     | Major (n=26)  | Minor (n=26) | P     |
| Pelvic tilt (°)              | 20.3±13.7    | 22.5±10.1    | 0.518 | 18.7±13.0     | 21.0±9.2     | 0.543 |
| PI-LL (°)                    | -1.6±20.8    | 2.5±16.2     | 0.438 | -3.1±23.3     | 3.5±19.3     | 0.365 |
| T4-T12 thoracic kyphosis (°) | -44.8±21.0   | -42.5±12.8   | 0.635 | -47.2±19.9    | -46.7±13.3   | 0.938 |
| SVA (mm)                     | 2.3±66.9     | -9.6±81.0    | 0.565 | 11.6±84.9     | 19.4±76.1    | 0.777 |
| T1 slope (°)                 | 45.9±17.4    | 32.8±16.4    | 0.007 | 40.9±15.0     | 40.1±13.7    | 0.862 |
| TS-CL (°)                    | 41.4±18.5    | 45.6±20.2    | 0.435 | 33.1±12.2     | 33.4±15.3    | 0.942 |
| C2-C7 lordosis (°)           | 4.5±21.6     | -12.8±26.4   | 0.013 | 8.4±21.3      | 6.6±18.0     | 0.794 |
| cSVA (mm)                    | 62.5±17.4    | 60.7±18.1    | 0.712 | 49.7±14.1     | 50.1±14.6    | 0.935 |
| C2-T3 angle (°)              | -19.6±24.8   | -24.3±27.7   | 0.523 | -5.8±24.3     | -3.5±16.7    | 0.747 |
| C2-T3 SVA (mm)               | 111.4±30.3   | 95.3±30.7    | 0.063 | 86.9±21.7     | 92.5±20.8    | 0.450 |
| C2 Slope (°)                 | 43.7±21.2    | 46.9±20.8    | 0.580 | 31.7±14.2     | 33.6±16.0    | 0.722 |

Significance was set at  $P < 0.05$ . cSVA: C2-C7 sagittal vertical axis

**Table 4: Health-related quality of life scores compared between major and minor osteotomy patients both pre- and post-operatively**

| HRQOL metric | Time point                          | Major (n=26) | Minor (n=26) | P     |
|--------------|-------------------------------------|--------------|--------------|-------|
| NDI          | Baseline                            | 50.8±16.9    | 51.1±19.7    | 0.953 |
|              | 1 year postoperative                | 47.3±23.8    | 31.1±21.7    | 0.040 |
|              | Δ Baseline to 1 year                | -3.5±1.7     | -20.0±7.2    | 0.009 |
|              | Percentage meeting 1 year NDI MCID  | 8            | 42           | 0.003 |
| mJOA         | Baseline                            | 13.7±2.6     | 13.7±2.5     | 0.967 |
|              | 1 year postoperative                | 15.1±2.6     | 14.6±2.8     | 0.596 |
|              | Δ Baseline to 1 year                | +1.4±1.9     | +0.9±3.46    | 0.882 |
|              | Percentage meeting 1 year mJOA MCID | 12           | 19           | 0.452 |
| EQ5D         | Baseline                            | 0.73±0.1     | 0.73±0.1     | 0.939 |
|              | 1 year postoperative                | 0.77±0.1     | 0.79±0.1     | 0.400 |
|              | Δ Baseline to 1 year                | +0.04±0.06   | +0.06±0.09   | 0.138 |
|              | Percentage Meeting 1 year EQ5D MCID | 8            | 8            | 1.00  |

Significance was set at  $P < 0.05$ . NDI - Neck disability index, mJOA - Modified Japanese Orthopaedic Association, EQ5D - EuroQol Five Dimensions, MCID - Minimum clinically important difference

There were no differences in HRQL outcomes as both groups showed similar rates of improvement in NDI, EQ5D, and mJOA (all  $P > 0.05$ ). In addition, there were no differences in achieving radiographic alignment between the groups at 1 year (all  $P > 0.05$ ).

In the analysis of rigid deformity patients, MAJ osteotomy patients had higher rates of complications (79% vs. 29%,  $P = 0.056$ ) and were less likely to show improvement in NDI at 1 year (0.95 vs. 0.54,  $P = 0.027$ ). However, both groups had similar reoperation (7% vs. 0%,  $P > 0.05$ ) and sagittal realignment rates at 1 year (all  $P > 0.05$ ).

## DISCUSSION

The cervical deformity is a complex and crippling array of pathology, representing varied structural drivers and causing the decreased quality of life.<sup>[10,11]</sup> Cervical osteotomies are capable of providing powerful deformity correction at the cost of high complication rates.<sup>[12]</sup> While widely used in thoracolumbar deformity, the applications, utility, and

complications of osteotomies in CD have only recently been explored.<sup>[13,14]</sup>

This study demonstrates that patients with CD who underwent minor osteotomies were able to achieve the same correction, with improved NDI, as those who underwent major osteotomies. Furthermore, those with rigid deformities who underwent MAJ osteotomy had higher rates of complications and were less likely to improve in NDI than those who underwent MIN osteotomy, despite achieving similar sagittal realignment outcomes at 1 year.

In regards to deformity correction, normative values for cervical lordosis are established, however, the relationship between the restoration of alignment, HRQL, and their clinical significance remains unclear.<sup>[15,16]</sup> Similar to our study, Sabou *et al.* found that when used to manage fixed flexion deformities of the cervical spine in patients with ankylosing spondylitis, cervical osteotomies including pedicle subtraction osteotomies resulted in the restoration of horizontal gaze and sagittal balance as well as in



improvement in HRQL.<sup>[17]</sup> While not statistically significant, a trend toward an increase in the mean C2–C7 lordosis and decrease in mean cSVA was observed in this study in both MAJ and MIN groups postoperatively. Furthermore, the mismatch between TS-CL, which has been suggested to better reflect sufficient cervical lordosis, also decreased in both groups indicating improved cervical lordosis. Interestingly, there was no difference in the complication rates between the MAJ and MIN groups overall, in contrast to previous literature citing high complication rates for major cervical osteotomies.<sup>[12,18]</sup>

Our study demonstrated similar improvements in mJOA, and EQ5D scores amongst both groups at all points; however, at 1-year after surgery, there was a significant difference in NDI for MAJ patients with fewer reaching MCID than MIN patients. Given the same deformity correction, it may follow that the increased invasiveness of osteotomies lessens the improvement that may be achieved through the same correction obtained without osteotomies, or perhaps fewer levels fused.

Management of rigid versus flexible deformity may require different treatment strategies.<sup>[16,19]</sup> Ankylosed, rigid deformities may require larger osteotomies for correction, while flexible deformities may be corrected with the anterior release with or without posterior fusion. This study found no differences in complication or reoperation rates between MAJ or MIN osteotomy patients with flexible deformities. Conversely, MAJ patients with rigid deformities had higher overall complication rates and were less likely to improve in their NDI scores versus MIN osteotomy patients despite similar realignment outcomes at 1 year. These findings suggest that, while some rigid deformities need major osteotomies or they are likely to remain grossly under-corrected, the clinical recovery of these patients is worse. This is likely due to the morbidity of the surgery, but also in part related to greater baseline disability.

A strength of this study is its prospective multicenter design that standardized the collection of detailed clinical and radiographic data. This allowed a broad spectrum of cervical deformities treated by multiple surgeons across multiple institutions to be included. A limitation is that clinical outcomes following CD surgery have not been well explored, and no CD-specific HRQL exists. Passias *et al.* found no clear relationship between improvements in Ames radiographic modifiers and improvements in HQRLs (mJOA, EQ-5D., and NDI).<sup>[20]</sup> In addition, when adjusted for cofounders, these HRQLs were not strongly correlated with each other. Therefore any interpretation of HRQLs in this population must be made with caution. Another limitation is that rigid

deformities are more likely to require major osteotomies, and there may not be the option to employ a minor osteotomy. The limited number of patients that were included despite the multicenter design can also be considered a limitation. Due to the limited number of patients, several types of osteotomies were combined in the MAJ group. Further work with a larger patient cohort is needed to continue the investigation into which osteotomies are optimal for rigid and flexible deformity correction.

## CONCLUSIONS

Selecting the appropriate surgery for the appropriate patient is paramount for deformity surgery. Overall, the same correction was achieved with and without osteotomies, with those who did not receive major osteotomies having improved NDI. While the clinical benefit of correction remains to be tightly defined, some rigid deformities require osteotomy to obtain correction. This study suggests patients with rigid cervical deformity may benefit from major osteotomies as part of their correction, they are less likely to show clinical improvement as compared to patients treated with minor osteotomies.

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## Conflicts of interest

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