Clinical Neurology and Neurosurgery 169 (2018) 71–76

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Does postoperative PI-LL mismatching affect surgical outcomes in thoracolumbar kyphosis associated with ankylosing spondylitis patients?

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ARTICLE INFO

Keywords:
Ankylosing spondylitis
Thoracolumbar kyphosis
Sagittal alignment
Spino-pelvic parameters
Health related quality of life
Surgery planning

ABSTRACT

Objective: To investigate if pelvic incidence (PI) and lumbar lordosis (LL) mismatching affects surgical outcomes for ankylosing spondylitis (AS) related kyphosis following 1-level lumbar pedicle subtraction osteotomy (PSO).
Patients and methods: AS patients with thoracolumbar kyphosis, who underwent 1-level lumbar PSO from March 2006 and February 2014 in our institution, were retrospectively reviewed. The radiographic measurements and health-related quality of life (HRQoL) scores, including Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) for pain, were recorded at baseline and the last follow-up. Patients were divided into 2 groups according to PI-LL matching or not postoperatively (Match Group, Mismatch Group), and comparison of the aforementioned parameters between the two groups was performed.
Results: Seventy patients were enrolled with a mean age of 34.60 ± 9.45 years (range, 17 yrs.–59 yrs.). Among them, 44 were included in the Match Group and 26 in the Mismatch Group. At baseline, patients in the Match Group had larger LL ($p = 0.014$) and smaller pelvic tilt (PT, $p < 0.001$) than patients in the Mismatch Group. At the last follow-up, along with larger LL ($p = 0.004$) and smaller PT ($p = 0.001$), Match Group patients also had significantly smaller sagittal vertical axis (SVA, 3.31 cm vs 6.27 cm, $p = 0.001$) than those in the Mismatch Group. Seventy-five percent (33/44) of the patients in the Match Group had a SVA < 5 cm at the last follow-up, while in the Mismatch Group, only 35% (9/26) of the patients did. However, no significant difference was found between the two groups regarding HRQoL scores.
Conclusion: Patients with postoperative PI-LL matching were more likely to have a better correction of SVA; they also tended to have a smaller preoperative PT. However, PI-LL mismatching didn't affect HRQoL scores at the last follow-up, which was different from the results of previous studies in the settings of ASD.

1. Introduction

As a chronic inflammatory rheumatic disease, ankylosing spondylitis (AS) is characterized by its tendency to affect the axial skeleton, causing progressive ossification of the spinal ligament and may eventually lead to a rigid spine. In the advanced stages of AS, when thoracolumbar kyphosis causes severe restriction of daily activities and psychological burden to these patients, a lumbar pedicle subtraction osteotomy (PSO) is commonly recommended as an effective treatment. In lumbar PSO, 1-level correction can be up to 40°, restoring proportional lumbar lordosis (LL) for ideal postoperative sagittal alignment [1].

Significant relationships were found between radiographic parameters and clinical outcomes in AS patients [2–5]. Shin et al. established the relationships between sagittal spino-pelvic parameters and preoperative health-related quality of life (HRQoL) scores in AS patients by revealing that sagittal vertical axis (SVA) and sacral slope (SS) significantly predicted Oswestry Disability Index (ODI), Visual Analogue Scale (VAS) and Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) scores and that SVA and LL predicted SRS-22 scores [2]. Furthermore, Debarge et al. emphasized the importance of the pelvic incidence (PI) in balancing severe kyphosis: AS patients with a higher PI were in need of a larger amount of correction than those with a lower PI. They suggested that pelvic parameters, especially PI, should be taken in account to determine the correction angle required to restore sagittal balance [6,7]. Therefore, both spinal and pelvic parameters are essential to surgical decision-making for AS patients.

Pelvic incidence and lumbar lordosis mismatch (PI-LL), a parameter combining the spine and the pelvis, is of great value for assessing sagittal alignment in the settings of adult spinal deformity (ASD) [8,9,10]. In 2013, Schwab et al. reported that ASD patients with PI-LL mismatching had 4.2-fold greater risk of pelvic retroversion and 10.9-fold

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https://doi.org/10.1016/j.clineuro.2018.04.006
Received 9 February 2018; Received in revised form 28 March 2018; Accepted 2 April 2018
Available online 03 April 2018
0303-8467/

greater risk of positive SVA [8]. Accordingly, postoperative PI-LL machining or not, along with other sagittal spino-pelvic parameters, could be used to predict patients' disability and quality of life after surgery. However, it remains unclear if PI-LL mismatching affects surgical outcomes in AS patients with thoracolumbar kyphosis. Therefore, the purpose of this study was to clarify the relationship between spino-pelvic parameters and HRQoL scores in AS patients who underwent 1-level PSO for thoracolumbar kyphosis, especially focusing on the clinical relevance of PI-LL matching.

2. Material and methods

This retrospective analysis of AS patients with thoracolumbar kyphosis between March 2006 and February 2014 was conducted at one single institution and was approved by the institutional review broad. Informed consent was obtained from every patient included in the study. The inclusion criteria were: (1) underwent one level PSO; (2) clear visualization of the femoral heads on the full-length standing lateral radiographs of the spine and pelvis; (3) with a minimum of 2-year follow-up, and (4) preoperative and the last follow-up HRQoL questionnaires were available. Patients with previous spinal surgery, spinal fractures, pseudarthrosis or contracted deformity of the hip were excluded from this study. Out of 179 hospitalized AS patients, 70 patients (65 males and 5 females) that met the above-mentioned inclusion criteria were enrolled in this study, with a mean age of 34.35 ± 9.45 years (range, 17–59 years). The mean follow-up was 46.97 ± 18.36 months (range, 24–119 months.). The apex of the kyphosis was located at T10 in 2 cases, T11 in 3 cases, T12 in 18 cases, L1 in 29 cases, L2 in 13 cases, L3 in 4 cases and L4 in 1 case. For surgical decision-making, the routine preoperative planning was mainly based on the desired correction angle estimated from lateral radiographs. When the required correction was within 40°, single level PSO was recommended. Intraoperatively, if the correction accomplished by closing wedge osteotomy (CWO) was inadequate, the surgery would be converted into closing-opening wedge osteotomy (COWO) [11]. Because of the adjustable opening of the anterior cortex in COWO, an extra 10° correction can be achieved in this procedure. In the current study, all patients underwent 1-level lumbar PSO by using CWO or COWO. Osteotomy was performed at L1 in 17 cases, L2 in 42 cases and L3 in 11 cases.

Full-length free-standing lateral spine radiographs (36-in cassette) taken at baseline, postoperatively and at the last follow-up were obtained and analyzed using a professional and validated software (Nemaris, Inc., New York, NY, USA). Patients were instructed to stand upright with their hips and knees fully extended, their arms flexed, and their hands rested at the level of the shoulders [12]. Sagittal radiographic measurements included: (1) global kyphosis (GK, the angle between the superior endplate of the maximally tilted upper end vertebra and the inferior endplate of the maximally tilted lower end vertebra) [13]; (2) thoracic kyphosis (TK, the angle between the superior endplate of the T5 vertebra and the inferior endplate of the T12 vertebra) [14]; (3) lumbar lordosis (LL, the angle between the superior endplate of T12 and S1, positive when the curve is kyphotic and negative when the curve is lordotic) [13]; (4) sagittal vertical axis (SVA, the distance measured between the C7 plumb line (C7PL) and the posterosuperior corner of S1 vertebra, positive when the C7PL is anterior to the posterosuperior corner of S1 and negative when the C7PL is posterior to the posterosuperior corner of S1) [11]; (5) pelvic tilt (PT, the angle between the vertical line and the line joining the middle of the sacral plate and the hip axis, positive when the hip axis is located anterior to the middle of the sacral plate and negative when the hip axis is located posterior to the middle of the sacral plate) [15]; (6) sacral slope (SS, the angle between the sacral plate and the horizontal line) [15], and (7) pelvic incidence (PI, the angle between the perpendicular of the sacral plate and the line joining the middle of the sacral plate and the hip axis) [15]. PI-LL was calculated by adding the values of PI and LL. Because LL was negative when the lumbar spine was lordotic, a smaller absolute value of PI-LL would indicate a better matching of PI and LL. Completed ODI and VAS for pain were used for HRQoL assessment.

Based on the study of Schwab et al. [8], all patients of our study were divided into 2 groups according to the postoperative PI-LL value. The Match Group consisted of patients with a PI-LL value between −10° and 10°, and the Mismatch Group was composed of patients with a PI-LL mismatch larger than 10°. Comparison of demographic, radiographic and HRQoL data was performed between groups at baseline and at the last follow-up. Within each group, changes in radiographic and HRQoL parameters between baseline and the last follow-up were also evaluated.

To describe continuous variables, mean and standard deviation were used, and for categorical variables, frequency analyses was applied. For comparison between baseline and the last follow-up, a paired *t*-test analysis was performed while comparison between the two groups were conducted by using an unpaired *t*-test analysis. The statistical analysis was performed using SPSS version 22.0 software (SPSS Inc., Chicago, IL). For all analysis, a P value smaller than 0.05 indicated statistical significance.

3. Results

Out of 70 enrolled patients, 44 were included in the Match Group and 26 in the Mismatch Group. Comparison of demographics between two groups showed that patients in the Match Group were about the same age as those in the Mismatch Group (34.09 vs 35.46 years, $p = 0.562$). And no significant difference was found in gender proportion of the two groups ($p = 0.381$).

At baseline, comparison of radiographic parameters between the two groups demonstrated that patients in the Match Group had larger LL (−2.45° vs 6.58°, $p = 0.014$), smaller PT (34.09° vs 43.23°, $p < 0.001$) and PI-LL (40.98° vs 56.46°, $p < 0.001$) than patients in the Mismatch Group. No other significant difference was found in the rest of the parameters. As for HRQoL measurements, patients in both groups had similar ODI and VAS scores (Table 1).

When compared with patients in the Mismatch Group at the last follow-up, patients in the Match Group still had larger LL (−43.39° vs −35.54°, $p = 0.004$), smaller PT (22.11° vs 29.54°, $p = 0.001$) and PI-LL (−0.18° vs 12.58°, $p < 0001$). In addition, a significant difference of SVA between the two groups were also found at the last follow-up: patients in the Match Group had a smaller SVA than those in the Mismatch Group (3.31 cm vs 6.27 cm, $p = 0.001$). Seventy-five percent (33/44) of the patients in the Match Group had a SVA < 5 cm, while in the Mismatch Group, only 35% (9/26) of the patients did. And 48% (21/44) of the patients had a PT < 22° in the Match Group, while 23% (6/26) in the Mismatch Group did. Comparison of clinical scores revealed no significant difference between groups, in neither ODI nor VAS scores (Table 1).

Comparison between baseline and the last follow-up was performed within each group respectively. Patients in both groups had significant improvement in all the radiographic measurements and HRQoL scores after surgery, except for the TK (Match Group: 44.70° vs 45.18°, $p = 0.792$; Mismatch Group: 44.96° vs 40.65°, $p = 0.080$) and PI (Match Group: 43.41° vs 43.20°, $p = 0.704$; Mismatch Group: 49.85° vs 48.00°, $p = 0.060$) (Table 1). In addition, comparison of the changes in the aforementioned parameters between the two groups demonstrated that patients' improvement from baseline to the last follow-up was up to a similar extent for both groups (Table 2).

No significant difference was found between immediate postoperative and the last follow-up values of all the radiographic parameters. The mean loss of correction of GK were 2.24° in the Match Group and 2.77° in the Mismatch Group ($p = 0.779$). The mean loss of correction of LL were 1.39° in the Match Group and 3.82° in the Mismatch Group ($p = 0.137$). and that of SVA were 1.34 mm in the