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Research Article

Does laminectomy Affect Spino-Pelvic Balance in Lumbar Spinal Stenosis? A Study Based on Eos® X Ray Imaging System

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Abstract

Purpose: Lumbar spinal stenosis (LSS) is a degenerative disorder, causing forward bending of trunk and pelvic retroversion with consequent loss of lumbar lordosis; surgical treatment is intended to enlarge the canal and foramina and decompress the nerve roots. The purpose of our study is to analyse if and to what extent facets-sparing laminectomy affects the spino-pelvic balance.

Methods: Spino-pelvic balance was analyzed before and after surgery through EOS® X-Ray Imaging System on 26 patients. Parameters considered were: thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS). Clinical data were expressed in numeric values through Oswestry Disability Index (ODI), Visual Analogue Scale (VAS), modified Japanese Orthopaedic Association scoring system (mJOA).

Results: Significant SS decrease and PT increase were noticed after surgery, without modification in LL, axial vertebral rotation (AVR) and the general alignment. Pain and disability had a significant improvement, as represented by decrease of scores in VAS and ODI scales and increase in mJOA functional scale.

Conclusion: The most important parameter seems to be a congruence between pelvic and spinal parameters in order to achieve an economic posture with physiologic position of the axis of gravity. According to literature, a standard SB is not defined.

Keywords: Lumbar Spinal Stenosis; Sagittal Balance; EOS System; Spino-Pelvic Parameters

Introduction

LSS is a frequent disorder in the elderly and the most common reason for patients over 65 years to undergo spinal surgery. The narrowing of the lumbar canal is due to a combination of factors as disk degeneration, hypertrophy of yellow ligament and facet joints, osteophytes and spondylolisthesis. Surgical treatment is intended to enlarge the canal and foramina to decompress the nerve roots with different possible strategies: laminectomy, bilateral or unilateral laminotomy, splitting of spinous processes [1]. Our purpose is to analyse if and to what extent the conventional facets-sparing laminectomy affects the spino-pelvic balance, evaluated, pre- and post-operatively, through EOS® X-Ray Imaging System [2,3].

Materials and Methods

Patient population

Twenty-six patients (8 female, 18 male; average age 69.9, range 65 - 80) with symptomatic LSS underwent facet-preserving laminectomy in a span period of 3 months. Inclusion criteria were: an almost 6 months history of neurogenic claudication; grade C or D stenosis according to Schizas scale on MRI images [4]; no other co-morbidities or conditions that could affect spino-pelvic parameters, like spondylolisthesis, instability at flexion-extension X-ray exam. Patient's clinical conditions were assessed through ODI [5], VAS [6], mJOA [7]. The clinical evaluation was performed 2 days before and 6 months after surgery (Table 1). Ten patients had 2 levels lumbar stenosis, 16 patients 3 levels.

Imaging evaluation

All the patients, before surgery, underwent 1,5T MRI of lumbar spine and flexion-extension radiographs in standing position. EOS® 2D/3D acquisition and 3D reconstructions with ster EOS 3D software (EOS Imaging, France), obtained preoperatively and 6 months after surgery, have been used to calculate the spino-pelvic balance parameters and the axial vertebral rotation (AVR) for each vertebra (Figure 1). Spino-pelvic balance was evaluated according to the following parameters: TK, LL, PI, PT, SS and the difference between PI and LL. TK is defined as the angle between the upper endplate of T4 vertebrae and lower endplate of T12 vertebrae. LL is the angle between the sacral endplate and the upper endplate of L1 vertebra. PI is the angle between a line drawn from the centre of the femoral head axis to the midpoint of the sacral plate and the perpendicular to the sacral plate. PI defines the relative orientation of the sacrum versus iliac bone. PT is the angle between a line drawn from the centre of the femoral head axis to the midpoint of the sacral plate and the vertical. SS refers to sagittal inclination of the sacral endplate and is defined as the angle between the endplate of S1 and the horizontal; PT and SS are directly related by the geometrical equation PI = PT+SS. The difference between PI and LL angle (PI-LL) quantifies the mismatch between pelvic morphology and lumbar curve; spino-pelvic alignment is considered satisfactory when PI-LL is below the 10° threshold [8]. The vertebra orientation in the space is represented by a vector (AVR) in order to simplify the visualization and to allow mathematical quantification (Figure 2). The AVR is based on known vertebral landmarks; it appears as a

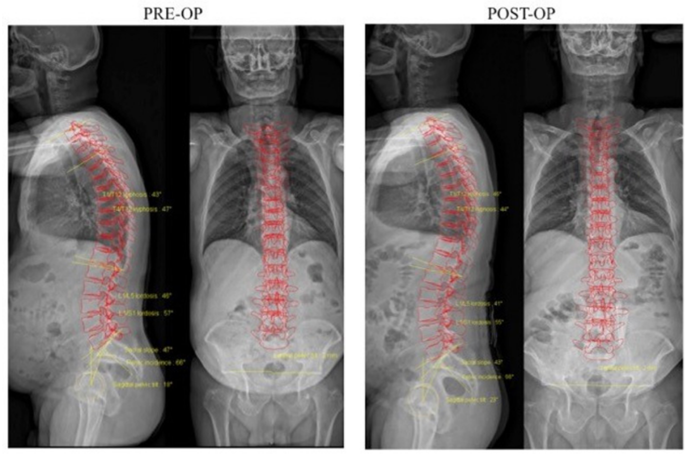

Figure 1: EOS 3D reconstruction, on which sterEOS 3D software automatically calculates the pelvic and spinal parameters of the sagittal balance (LL,TK, SS, PI, PT).

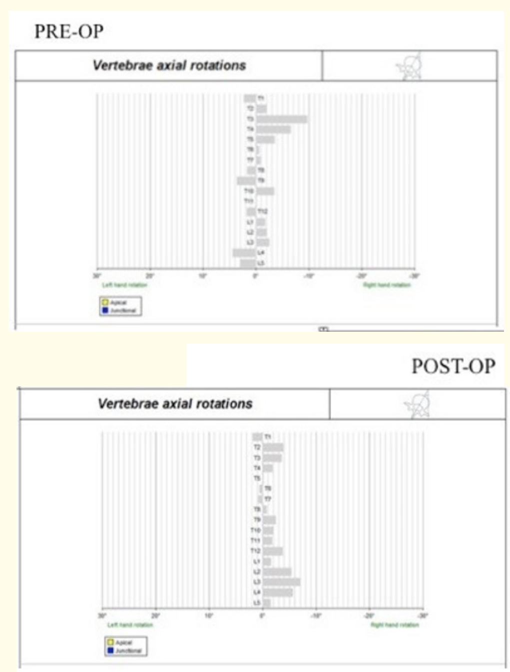

Figure 2: Pre and post-operative diagram of vertebrae axial rotation.

line starting at the midpoint of the straight connecting the two pedicular centroids, parallel to the upper endplate at the level of the pedicles, terminating at the ventral surface of the vertebral body. Therefore, AVR represents the axis of the vertebra in its sagittal median axis and its length is proportional to its size. The AVRs are placed in a coordinate system: a line connecting the two acetabular centres forms the X axis of the coordinate system, the Y axis is perpendicular to the coronal, and Z axis is a perpendicular to the horizontal plane crossed each other and the X axis in the midpoint of the interacetabular straight. Calibration scale of the coordinate system is based on interacetabular distance. After AVRs are placed inside this calibrated coordinate system, the coordinates of each vector point can be determinate in all three planes using basic vector algebra [9]. In this study, we focused only on the vertebral vector projection in the axial plane (Figure 3).

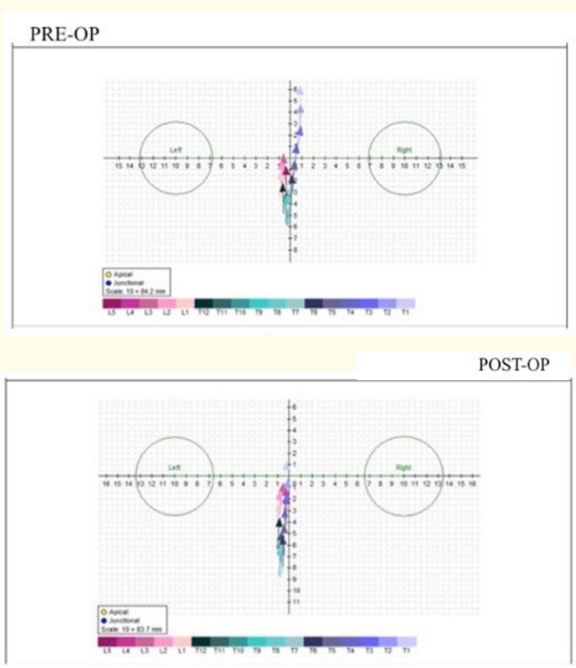

Figure 3: Pre and post-operative view from above of vertebral vectors.

Statistical analysis

Statistical analyses were performed using Stata software (version 13; Stata Corp LP, College Station, TX). Before each analysis, the Shapiro Wilk test was used to assess the normality of distribution of variables. If normality assumption was satisfied, parametric tests were used (Student's t-test, linear regression analysis), otherwise, non-parametric equivalent tests were employed. Results were considered significant if $p < 0.05$.

Results

In all cases normality assumption was satisfied, so parametric tests were used. For each parameter mean and standard deviation were calculated, before and 6 months after surgery. We obtained the following results using Student's t-test for paired data:

- TK (pre-operative 37.42° (mean) ± 10.45° (standard deviation) vs post-operative 37.38° ± 11.20°, p = 0.29); LL (50.19° ± 13.54° vs 47.08° ± 12.08°, p = 0.10); PI (53.03° ± 10.79° vs 53.62° ± 10.57°, p = 0.59).
- SS significantly decreased after surgery (39.58° ± 10.40° vs 36.81° ± 10.39°, p = 0.03).
- PT significantly increased after surgery (13.50° ± 7.27° vs 16.73° ± 7.84°, p = 0.002).

In our series post-operative PI - LL value was 6,54°< 10°. Pre and post-operative axial vertebral rotation (AVR) of each vertebra (T1 - L5), automatically calculated by sterEOS 3D software based on reconstructed 3D models, did not show statistically significant results. VAS and ODI significantly decreased after surgery (respectively: 6.58 ± 1.30 vs 3.16 ± 0.71, p < 0.05; 48.46 ± 12.67 vs 21.92 ± 6.31, p < 0.05 Student's t-test for paired data). mJOA significantly increased after surgery (9.04 ± 1.78 vs 12.77 ± 1.68, p < 0.05 Student's t-test for paired data).

Discussion

The gold standard treatment for symptomatic LSS is a facet-preserving laminectomy [1]. Controversy continues about the extent of resection required to effectively decompress the spinal canal: as narrowing occurs predominantly at the interlaminar region, due to arthrosis of facet joints, disc bulging and ligamentous hypertrophy, resection of the whole vertebral arch may not be necessary: an interemilaminar or undercutting unilateral laminectomy can be alternatively performed to decompress the spinal canal. Extensive damage to paraspinous muscles and resection of the posterior bone and ligaments could increase postoperative pain and long-term instability [10]: surgical techniques sparing posterior midline structures have been recently proposed with the aim of preserving spinal stability [11], although clear evidences are still lacking. As most of translational and rotational resistance is provided by vertebral disc and zygapophyseal joints and the force exerted by posterior ligaments during flexion is small when compared to back muscles [12], spinal stability is minimally affected by conventional laminectomy. Suzuki., *et al.* noticed that patients with LSS usually exhibit a forward bending of trunk and a pelvic retroversion with consequent loss of LL [13]: this posture increases available space in the spinal canal, allowing relief from back pain and claudication. Large portion of flat-back deformities is postural and thus reversible, although long periods of altered posture may lead to degenerative atrophy and hyposthenia of the paraspinal muscles. FuJii., *et al.* showed a reactive sagittal alignment change after spinous process splitting, especially in patients with poor preoperative alignment [14], probably related to resolution of compensatory posture. In Hikata., *et al*. study, preoperative sagittal imbalance improved after surgery, suggesting reversibility of degenerative changes in extensor muscles [15]. Jeon., *et al.* showed that decompressive laminectomy caused posterior migration of C7PL, increase of the LL and restore of upright posture due to improvement of pain and function [16]. However, we believe that restoration of SB is not an essential parameter in evaluation of short-term clinical outcome after surgery: similarly, Bayerl., *et al.* demonstrated that imbalanced patients benefit from decompression to the same degree as patients with normal balance at 1-year follow-up [17]. The average SS in asymptomatic adult subjects has been reported to be 41° ± 8° [8]; this parameter is affected by patient's position. In our series SS significantly decreased after surgery ($p = 0.03$) (39.58° ± 10.40° vs 36.81° ± 10.39°). Pelvic tilt (PT) is also a dynamic parameter, changing through rotation of the pelvis about the hip axis. Positive values of PT denote posterior rotation of the pelvis (retroversion), and negative values an anterior rotation (antiversion) [9]. PT increases over childhood, being smaller in children than in adolescents (4° in 7 years old, 8° in 13 years old subjects); PT in asymptomatic adults has been reported to be 13°±6° [18]. We observed a significantly increased PT after surgery ($p = 0.002$) (13.5° ± 7.27° vs 16,73° ± 7.84°), while no modification in the LL and the general alignment was noticed (post-operative PI-LL = 6,54°). Morphology and orientation of lumbar spine and pelvis are usually strictly related: in an asymptomatic adult, a high correlation has been demonstrated between LL and SS (r: [0.65;0.86]), while that between LL and PI is slightly weaker (r: [0.60;0.69]). No correlation between LL and the PT has been reported [8]. Unlike literature data [16], we observed a slight, though not statistically significant, reduction in LL after laminectomy, however not causing a global misalignment (post-operative PI-LL = 6,54°.), probably related to weakness and degenerative atrophy of paraspinal muscle secondary to patient age and long period of forward bending posture. The EOS device and ster EOS 3D reconstruction software brought a strikingly new possibility in study of degenerative spine pathology, completing data obtained from CT scan acquired in supine position with coronal and sagittal curves relative to upright position [19,20]. The EOS System allows simultaneous capture of upright full body, at low radiation doses, in a spatially calibrated way, thus avoiding positioning problems that can distort a proper 3D reconstruction. Image quality is optimized, providing clear anatomical landmarks for proper 3D reconstruction. The vertebral vector is a mathematical entity characterized by its length and spatial direction and projecting on each of the planes with its specific angle [9]. Pre and postoperative AVR of each vertebra are calculated by ster EOS 3D software based on reconstructed 3D models: we did not obtain statistically significant differences after surgery. Only a limited number of studies investigated the effects of surgical decompression on adjacent levels. According to Zander., *et al.* laminectomy has only a negligible effect on the intersegmental forces in the facet joints of the segments above [21]. Similarly, Bisschop., *et al*. found that a single level laminectomy alters segmental biomechanical behavior without affecting adjacent segments [22]. Delank., *et al.* found that adjacent levels were not substantially affected,even after facetectomy [23]. On the contrary, Cardoso., *et al.* found that adjacent instability occurs after a more extensive decompressive surgery [24]. In our experience, a significant improvement in clinical outcome was noticed, more than restoration of spino-pelvic alignment. In fact VAS and ODI significantly decreased after surgery ($p < 0.05$ for both) while JOA significantly increased ($p < 0.05$). Such evaluation scores are currently applied in clinical practice, as they offer an immediate and easily comparable numeric value. mJOA score gives an immediate overview on neurological status; it needs to be performed by a physician as it includes objective parameters. VAS and ODI evaluations provide complementary information about subjective perception of pain and its impact on daily activities and quality of life. In our experience, combination of objective and subjective evaluation offers a better comprehension of clinical outcome.

Conclusion

In our opinion, the facet-preserving laminectomy has any effect on AVR and an insignificant repercussion on SB. Anyway, a standard SB does not exist among the normal population [25], while congruence between pelvic and spinal parameters in order is crucial to achieve an economic posture placing the axis of gravity in a physiologic position [8]. This is only a preliminary study on a small number of patients and therefore requires further studies correlating level and number of lamina removed. Probably the short follow up could be a weak point, although a longer time of observation could detect the progression of the degenerative cascade, being most of the patients affected over 65 years old.

Compliance with Ethical Standards

No founding were received for the present study. All the authors declare that they have no competing interest in relation with the article. All procedures performed were in accordance with the institutional ethical standards and with the 1964 Helsinki declaration and its later amendments. Informed consent was obtained from all individual participants included in the study.

Declarations

Funding

The authors did not receive any founding for this research.

Conflicts of Interest/Competing Interests

The authors declare that they have no conflicts of interest or competing interest in relation with the article.

Ethics Approval

Not applicable.

Consent to Participate

Patients gave their informed consent to surgical procedure and to inclusion in the study.

Consent for Publication

Patients included gave their consent for publication of data and radiological images.

Availability of Data and Material

Data are stored in hospital repository in accordance with European GDPR. Due to privacy and ethical concerns, the data cannot be made available.

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