ORIGINAL ARTICLE
DEGENERATIVE
http://dx.doi.org/10.1590/S1808-185120242303283025

LUMBAR MOBILITY AS A PREDICTOR OF POST-ARTHRODESIS ALIGNMENT VIA POSTERIOR APPROACH

MOBILIDADE LOMBAR COMO PREDITOR DO ALINHAMENTO PÓS-ARTRODESE POR VIA POSTERIOR

MOVILIDAD LUMBAR COMO PREDICTOR DEL ALINEAMIENTO POSTARTRODESIS POR VÍA POSTERIOR

LUAN DINIZ DE ARAUJO[1], EMILIANO NEVES VIALLE[1], PAULO HENRIQUE SILVA MEIRA[1]

1. Pontifícia Universidade Católica do Paraná, Hospital Universitário Cajuru, Orthopedics and Traumatology Service, Spine Surgery Group, Curitiba, PR, Brazil.

ABSTRACT

Objective: To predict lumbar spine flexibility by analyzing the difference in lumbar lordosis between orthostatic and supine positions. Methods: A retrospective analysis was conducted on patients undergoing interbody fusion and posterior fixation surgery between 2013 and 2019 due to degenerative diseases of the lumbar spine. All patients were over 18 years old, and pre- and post-operative weight-bearing X-rays and pre-operative magnetic resonance imaging were obtained. The difference between lumbar lordosis in standing X-rays and magnetic resonance imaging was calculated as lordosis delta and compared to post-operative radiographic outcomes. Results: The study involved 49 patients, with the most approached level being L4-L5 (49.0%). The Roussouly type 3 of lumbar lordosis was the most common (53.1%). Disc degeneration syndrome (DDS) was the predominant diagnosis (83.7%). The Pearson correlation between lordosis delta and post-operative lumbar lordosis was significantly positive. Conclusion: This study establishes a correlation between lumbar lordosis delta and post-operative radiographic outcomes, suggesting its utility in the pre-operative assessment of lumbar spine flexibility. ***Level of Evidence IV; Retrospective Observational Study.***

Keywords: Spondylosis; Spondylolisthesis; Posture; Arthrodesis; Lumbar Lordosis; Preoperative Procedure.

RESUMO

Objetivo: Predizer a flexibilidade da coluna lombar analisando a diferença da lordose lombar entre as posições ortostática e supina. Métodos: Análise retrospectiva de pacientes submetidos à cirurgia de artrodese intersomática e fixação posterior entre 2013 a 2019 devido a doenças degenerativas da coluna lombar. Todos os pacientes apresentavam mais de 18 anos de idade, radiografias em ortostase pré e pós-operatórias e ressonância magnética pré operatória. A diferença entre a lordose lombar nas radiografias em pé e na ressonância magnética foi calculada como delta lordose, e comparada ao resultado radiográfico pós-operatório. Resultados: O estudo envolveu 49 pacientes. O nível mais abordado foi o L4-L5 (49,0%), e o tipo 3 de Roussouly de lordose lombar foi o mais comum (53,1%). A síndrome de degeneração discal (DDS) foi o diagnóstico predominante (83,7%). A correlação de Pearson entre o delta lordose e a lordose lombar pós operatória foi significativamente positiva. Conclusão: O estudo estabelece uma correlação entre o delta da lordose lombar e os resultados radiográficos pós-operatórios, sugerindo sua utilidade na avaliação pré-operatória da flexibilidade da coluna lombar. ***Nível de Evidência IV; Estudo Observacional Retrospectivo.***

Descritores: *Espondilose; Espondilolistese; Postura; Artrodese; Lordose Lombar; Assistência Pré-Operatória.*

RESUMEN

Objetivo: Predecir la flexibilidad de la columna lumbar analizando la diferencia de lordosis lumbar entre las posiciones ortostática y supina. Métodos: Análisis retrospectivo de pacientes sometidos a cirugía de artrodesis intersomática y fijación posterior entre 2013 y 2019 por enfermedades degenerativas de la columna lumbar. Todos los pacientes eran mayores de 18 años, tenían radiografías ortostáticas pre y postoperatorias y resonancias magnéticas preoperatorias. La diferencia entre la lordosis lumbar en las radiografías de pie y la RM se calculó como lordosis delta, y se comparó con el resultado radiográfico postoperatorio. Resultados: En el estudio participaron 49 pacientes. El nivel más frecuentemente abordado fue L4-L5 (49,0%), y la lordosis lumbar tipo 3 de Roussouly fue la más frecuente (53,1%). El síndrome de degeneración discal (SDD) fue el diagnóstico predominante (83,7%). La correlación de Pearson entre la lordosis delta y la lordosis lumbar postoperatoria fue significativamente positiva. Conclusión: El estudio establece una correlación entre el delta de lordosis lumbar y los resultados radiográficos postoperatorios, lo que sugiere su utilidad en la evaluación preoperatoria de la flexibilidad de la columna lumbar. ***Nivel de Evidencia IV; Estudio Observacional Retrospectivo.***

Descriptores: *Espondilosis; Espondilolistesis; Postura; Artrodesis; Lordosis Lumbar; Cuidados Preoperatorios.*

Study conducted by the Hospital Universitário Cajuru, Curitiba, PR, Brazil.
Correspondence: Luan Diniz de Araujo. 260, Coronel Pedro Scherer Sobrinho Street, Cristo Rei, Curitiba, PR, Brazil. 80050-470. luandin@gmail.com

Received on 02/06/2024 accepted on 07/19/2024
Reviewed by: Erasmo Abreu Zardo

INTRODUCTION

Degenerative lumbar diseases are one of the most common causes of disability, affecting about 266 million people annually.[1] It is common, with the degeneration of the spine, for there to be changes in the spinopelvic parameters of patients.[2] Currently, we know that to maintain proper sagittal alignment after surgery and to expend less energy while walking, it is necessary to adjust lumbar lordosis according to pelvic incidence.[3,4]

During the preoperative evaluation, spine surgeons usually request X-rays of the patients, which are normally performed in the standing position, and magnetic resonance imaging – which is performed in the supine position. The use of dynamic radiographs (in flexion and extension) has limitations due to the lack of standardization of the exam and the limitation of mobility due to the patient's pain.

The literature already describes how this change in position in imaging exams alters some spinopelvic parameters.[5] Therefore, the purpose of this study is to seek a predictor of lumbar spine flexibility through the difference in lumbar lordosis in standing and supine positions to assist spine surgeons in the preoperative planning of their patients.

METHODOLOGY

Study subjects

This is a retrospective study using a database of patients who underwent surgical treatment for lumbar degenerative diseases from 2013 to 2019. The study was approved by the Institution's Ethics and Research Committee (089852/2013).

The inclusion criteria for patients were: (1) patients over 18 years of age, (2) diagnosis of degenerative lumbar disease, (3) pre- and post-operative standing lumbar spine X-ray, (4) pre-operative lumbar spine MRI, and (5) undergoing interbody fusion in the lumbar spine with complementary posterior fixation at one or two levels.

The exclusion criteria were: (1) patients with other non-degenerative pathologies, (2) lack of preoperative lumbar spine X-rays or magnetic resonance imaging, and (3) incomplete medical history. All images were evaluated using the *Picture archiving and communication system* (PACS) of the institution's radiology service. We performed radiographic and resonance measurements using Surgimap software (Nemaris Inc., New York, USA).

Study methods

In all patients, standing radiography was standardized, with anteroposterior and lateral views, including the femoral head in the preoperative and immediate postoperative periods. Magnetic resonance imaging was performed in the supine position. The spinopelvic parameters were evaluated in the pre- and postoperative radiographs. The lumbar lordosis was evaluated in the magnetic resonance imaging exams, as well as in the pre and post-operative radiographs.

Lumbar lordosis (LL) was measured using the Cobb angle between the upper endplate of the L1 vertebra and the upper endplate of the S1 vertebra; segmental lordosis was measured using the Cobb angle between the upper endplate of the upper operated vertebra and the lower endplate of the lower operated vertebra. The pelvic incidence (PI) was measured as an angle between a line from the center of the femoral head to the center of the upper plateau of S1 and a line perpendicular to the upper plateau of S1 coming out of the center of this plateau. The *sacral slope* (SS) was evaluated from the angle resulting from a line on the S1 plateau and a line parallel to the ground. The delta lumbar lordosis (DLL) was calculated from the difference between the lumbar lordosis in preoperative radiographs and the lumbar lordosis in magnetic resonance imaging. In contrast, delta segmental lordosis (DLS) was evaluated by the difference in segmental lordosis in preoperative radiographs and segmental lordosis in magnetic resonance imaging. The sagittal alignment was evaluated by the PI-LL formula, where the patient was considered aligned when PI-LL $\leq$10.

Statistical analysis

The statistical analysis in this study involved the assessment of the central tendency of continuous variables and determining linear relationships between variables using the Pearson correlation test. The measure of central tendency, represented by the arithmetic mean, was calculated for each continuous variable, providing an indication of the central location of the data distribution. Furthermore, the Pearson correlation test was employed to quantify the strength and direction of linear relationships between pairs of continuous variables. This test assesses the linear correlation between two variables, providing a correlation coefficient that ranges from -1 to 1, where values close to 1 indicate a strong positive correlation, values close to -1 indicate a strong negative correlation, and values close to 0 suggest a weak or no correlation between the variables in question.

RESULTS

The study involved a total of 49 patients, with 25 females and 24 males. Regarding the operated levels, it was observed that in 24 cases (49.0%), the treated level was L4-L5, followed by L5-S1 in 19 cases (38.8%) and, finally, L4-L5-S1 in 6 cases (12.2%). As for the type of lumbar lordosis, Roussouly type 3 was the most frequent, occurring in 26 cases (53.1%), followed by type 2 in 12 cases (24.5%), type 1 in 6 cases (12.2%), and type 4 in 5 cases (10.2%), as shown in Figure 1. The most common diagnosis among patients was symptomatic disc degeneration (SDD), present in 41 cases (83.7%), while the other 8 cases were of degenerative spondylolisthesis.

The central tendency measures of continuous variables, such as age, number of levels addressed, pre and postoperative segmental and global lumbar lordosis values, as well as *sacral slope* and DLL and DLS, are in Table 1. It is observed that the average age of the patients was 42 years, with an average of 1 level addressed. The preoperative and postoperative segmental lordosis averages were 17° and 13°, respectively. For lumbar lordosis, the preoperative and postoperative averages were 52° and 43°. The corresponding values in the preoperative magnetic resonance were 27° for segmental lordosis and 38° for lumbar lordosis. The average DLL was 14°, while the average DLS was -10°.

The Pearson correlation test results indicated a statistically significant correlation between the preoperative and postoperative lordosis difference measures, both in the global aspect (DLL) and segmental (DLS). This correlation was positive in both cases, as shown in Table 2 and Figures 2 and 3. These findings suggest that the higher the preoperative DLL value, the greater the postoperative LL gain.

DISCUSSION

The definition of the ideal lumbar lordosis after a lumbar spine arthrodesis is a process that requires meticulous planning, taking into account spinopelvic alignment and various radiographic parameters. However, this planning does not always guarantee perfect execution, as the assessment of spinal flexibility is not

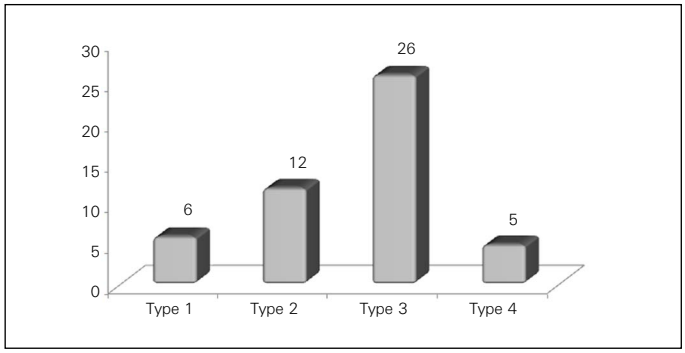

Figure 1. Distribution of patients regarding the type of lumbar lordosis (Roussouly).

Table 1. Central tendency measures of continuous (numerical) variables.

Descriptive Statistics					
Variable	**N**	**Minimum**	**Maximum**	**Average**	**Standard Deviation**
Age	45	30	58	42	8
Number of levels	49	1	2	1	0.3
Segmental lumbar lordosis – Preoperative	49	2	44	17	12.4
Segmental lumbar lordosis – Postoperative	49	2	38	13	8.1
Global lumbar lordosis – Preoperative	49	14	72	52	13.0
Global lumbar lordosis – Postoperative	49	15	66	43	9.4
Segmental lumbar lordosis - MRI	49	10	41	27	8.0
Global lumbar lordosis - MRI	49	20	58	38	9.5
Sacral Slope – Preoperative	49	19	50	36	8.7
Sacral Slope – Postoperative	49	10	51	32	9.0
Delta lumbar lordosis	49	-12	46	14	11.1
Delta segmental lordosis	49	-33	16	-10	13.0
Difference in postoperative lumbar lordosis with preoperative lumbar lordosis (X-ray)	49	-30	27	-8	12.7
Difference in postoperative segmental lordosis with preoperative segmental lordosis (X-ray)	49	-27	9	-4	7.9

Table Caption 1: MRI: magnetic resonance imaging; X-ray: radiography; N = number of patients.

Table 2. Pearson Correlation Test Results for comparison between variables.

Variable	Correlation Coefficient R	Value p
Preoperative DLL vs. postoperative DLL	0.639	0.000*
Preoperative DLS x Postoperative DLS	0.670	0.000*

Table Caption 2: DLL: Delta lumbar lordosis; DLS: Delta segmental lordosis; The correlation coefficient (R) measures the strength and direction of the linear relationship between two variables. Varies from -1 to 1, where R = 1: Perfect positive correlation (as one variable increases, the other also increases). R = -1: Perfect negative correlation (as one variable increases, the other decreases). R = 0: Absence of linear correlation; The p-value indicates the statistical significance of the observed correlation. A low p-value (usually < 0.05) suggests that the correlation is not due to chance, increasing confidence in the observed relationship.

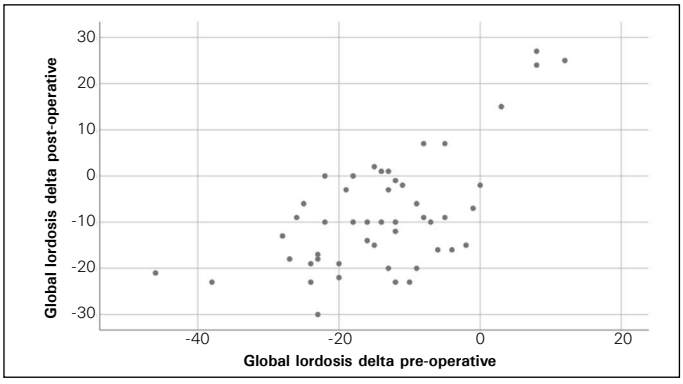

Figure 2. Relationship between Preoperative Global Lordosis Delta and Postoperative Global Lordosis Delta.

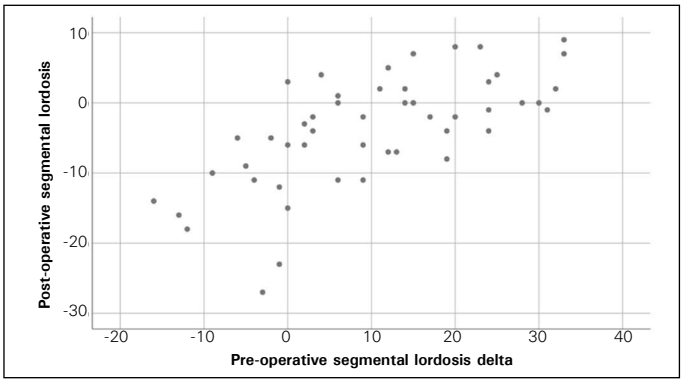

Figure 3. Relationship between Preoperative Segmental Lordosis Delta and Postoperative Segmental Lordosis Delta.

yet fully standardized in the literature. Often, the use of dynamic radiographs is limited by patient pain, and their execution can vary according to the method used.[6,7]

Columns with greater mobility tend to require less invasive surgical interventions than rigid columns. These stiffer columns may benefit from approaches such as osteotomies of the posterior elements and wide discectomies, aiming to achieve the necessary results for proper sagittal alignment.

The literature presents several radiographic factors to define lumbar instability, however, few studies focus on defining the degree of mobility or flexibility of the degenerative spine. According to Fong et al., a translation greater than or equal to 3.5 mm and an angulation greater than or equal to 11º measured on standing radiographs can be classified as mobile segments in cases of degenerative spondylolisthesis. In 1990, Boden and Wiesel cited in their study that this translation could be considered stable when it reached values less than 3 mm and, although not definitive, reported that the greatest angulation between the vertebrae in rigid segments was 7º. Elmose et al. conducted a study in which they sought signs in magnetic resonance imaging that suggest instability in cases of degenerative spondylolisthesis and lumbar spinal canal stenosis and suggested that, in magnetic resonance imaging, unstable segments may present: a translation greater than 3 mm when compared to radiography, bilateral facet angulations greater than or equal to 46º, bilateral facet effusion greater than or equal to 1.5 mm, and disc height index greater than or equal to 13%.[8,9]

The results of our work contrast with the findings of the study by Fan et al., whose research indicated that magnetic resonance imaging is capable of presenting lumbar lordosis values similar to those obtained by standing radiographs. Furthermore, they identified a minimal difference between the values of the sacral slope and the kyphosis of the thoracolumbar junction, suggesting that magnetic resonance imaging can accurately assess the sagittal alignment of patients. It is important to note that these specific parameters were not the subject of our analysis.[10]

In our study, we observed an average of 14º difference in lumbar lordosis between preoperative X-ray images and magnetic resonance imaging. This difference aligns with the results found by Xu et al. where magnetic resonance imaging tends to underestimate the values of sagittal alignment parameters in patients, emphasizing the need to use preoperative lumbar spine radiography to obtain more accurate assessments.[11]

Additionally, the study conducted by Sharma et al. provides valuable insight by investigating the relationship between spinal

flexibility and facet degeneration. Although our focus is distinct, there is agreement between the results of both studies regarding the flexibility of the lumbar spine. This highlights the usefulness of magnetic resonance imaging as a reliable tool in the assessment of flexible deformities, something that aligns with what Sharma et al. observed. This also reinforces the importance of properly assessing the flexibility of deformities before surgery, intending to provide better long-term results.[12]

Our study aims to fill a gap in the literature, specifically to assist in the decision of the ideal surgical strategy. We consider that comparing the standing and lying down positions may be an alternative since standing X-rays and MRI are part of the standardized preoperative evaluation of these patients.

RESULTS

The statistically significant correlation between pre- and postoperative lumbar lordosis measurements, as evidenced in our study, suggests that DLL can be considered an indicator of lumbar spine flexibility in candidates for arthrodesis for degenerative lumbar diseases. This relationship demonstrates particular relevance in preoperative evaluation, assisting surgeons in determining spinal flexibility and thus facilitating the selection of the most appropriate surgical techniques and degree of invasiveness for each case.

Considering the multifactorial nature of disc degeneration, it is crucial to recognize the limitations of our study, including the sample size and the retrospective design, limiting the application of this concept to the preoperative planning of the analyzed patients. Therefore, we recommend that future studies adopt larger samples and prospective designs to establish a more robust understanding of the relationship between DLL and lumbar spine flexibility.

Another limitation is that some radiology services place cushions under the knees of patients with pain for greater comfort during the MRI scan, which, according to the study by Simonovich et al., reduces lumbar lordosis in the scan by approximately 5º. This variable cannot be taken into consideration in this study, as it is a retrospective study and we do not have information on how the magnetic resonance exams of the evaluated patients were performed.[13]

Our findings significantly impact clinical practice and surgical planning in patients with lumbar degenerative diseases. Including DLL in the preoperative assessment can enhance decision-making, helping surgeons identify patients benefitting from specific surgical interventions.

CONCLUSION

This study demonstrated that the DLL is correlated with the radiographic outcomes of postoperative lumbar arthrodesis. A higher DLL indicates greater spine flexibility, which may reduce the need for additional invasive procedures during surgery. These results highlight the importance of preoperative assessment of spinal flexibility, including DLL, for a more personalized and effective approach to surgery for lumbar degenerative disorders.

ACKNOWLEDGMENTS

To AOSpine Latin America and the AOSLA Degenerative Study Group for supporting the realization of this study.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS: The author Luan Diniz de Araujo contributed to the development of the work with the literature review, data collection and analysis, project and manuscript writing. The author Emiliano Neves Vialle contributed with literature review and project writing, study design, data analysis, manuscript review. The author Paulo Henrique Silva Meira contributed to the literature review, data review, and manuscript writing.

REFERENCES

1. Ravindra VM, Senglaub SS, Rattani A, Dewan MC, Härtl R, Bisson E, et al. Degenerative Lumbar Spine Disease: Estimating Global Incidence and Worldwide Volume. Global Spine J. 2018;8(8):784-94. doi:10.1177/2192568218770769.
2. Barrey C, Roussouly P, Perrin G, Le Huec JC. Sagittal balance disorders in severe degenerative spine. Can we identify the compensatory mechanisms?. Eur Spine J. 2011;20(Suppl 5):626-33. doi:10.1007/s00586-011-1930-3.
3. Schwab F, Ungar B, Blondel B, Buchowski J, Coe J, Deinlein D, et al. Scoliosis research society-schwab adult spinal deformity classification: A validation study. Spine (Phila Pa 1976). 2012;37(12):1077-82. doi:10.1097/BRS.0b013e31823e15e2.
4. Le Huec JC, Thompson W, Mohsinaly Y, Barrey C, Faundez A. Sagittal balance of the spine. Eur Spine J. 2019;28(9):1889-905. doi:10.1007/s00586-019-06083-1.
5. Park SA, Kwak DS, Cho HJ, Min DU. Changes of spinopelvic parameters in different positions. Arch Orthop Trauma Surg. 2017;137(9):1223-32. doi:10.1007/s00402-017-2757-0.
6. Pourahmadi M, Sahebalam M, Dommerholt J, Delavari S, Mohseni-Bandpei MA, Keshtkar A, et al. Spinopelvic alignment and low back pain after total hip arthroplasty: a scoping review. BMC Musculoskelet Disord. 2022;23:250. doi:10.1186/s12891-022-05154-7.
7. Fong AM, Duculan R, Endo Y, Carrino JA, Cammisa FP, Sama AA, et al. Instability Missed by Flexion-Extension Radiographs Subsequently Identified by Alternate Imaging in L4-L5 Lumbar Degenerative Spondylolisthesis. Spine (Phila Pa 1976). 2023;48(3):E33-9. doi:10.1097/BRS.0000000000004483.
8. Boden SD, Wiesel SW. Lumbosacral segmental motion in normal individuals. Have we been measuring instability properly?. Spine. 1990;15(6):571-6. doi:10.1097/00007632-199006000-00026.
9. Elmose SF, Oesterheden Andersen M, Sigmundsson FG, Carreon LY. Magnetic Resonance Imaging Proxies for Segmental Instability in Degenerative Lumbar Spondylolisthesis Patients. Spine (Phila Pa 1976). 2022;47(21):1473-82. doi:10.1097/BRS.0000000000004437.
10. Fan X, Xue D, Pan Z, Wang Y. Comparison of sagittal spinal alignment on standing plain x-rays and supine MRI in degenerative lumbar disease. Front Surg. 2023;10:1103952. doi:10.3389/fsurg.2023.1103952.
11. Xu C, Yin M, Mo W. Correlation and Differences in Lumbopelvic Sagittal Alignment Parameters Between Lumbar Radiographs and Magnetic Resonance Images. Global Spine J. 2022;12(1):79-84. doi:10.1177/2192568220947049.
12. Sharma A, Pourtaheri S, Savage J, Kalfas I, Mroz TE, Benzel EC, et al. The utility of preoperative magnetic resonance imaging for determining the flexibility of sagittal imbalance. Clin Neurosurg. 2018;83(3):465-70. doi:10.1093/neuros/nyx431.
13. Simonovich A, Nagar Osherov A, Linov L, Kalichman L. The influence of knee bolster on lumbar spinal stenosis parameters on MR images. Skeletal Radiol. 2020;49(2):299-305. doi:10.1007/s00256-019-03287-w.