11º CONGRESSO NACIONAL DE BIOMECÂNICA
A. P. G. Castro, C. Pina, P. R. Fernandes, C. Santos, J. Folgado & A. Amaro (Eds)
Sesimbra, Portugal, 21-22 de Fevereiro, 2025

EVALUATION OF LUMBAR DISC HERNIATION USING IMAGE SEGMENTATION AND MODELLING

I. F. Mendes [1], N. Cristino[2], R. Fernandes[3,4], A. P. G. Castro[1,5]

[1] ESTSetúbal, Instituto Politécnico de Setúbal, Portugal

[2] Serviço de Neurocirurgia, Hospital da Luz Setúbal, Portugal

[3] ESS, Instituto Politécnico de Setúbal, Portugal

[4] LBMF, CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, Portugal

[5] IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal

ines.fernandes.mendes@estudantes.ips.pt; nuno.remedio.cristino@hospitaldaluz.pt; rita.fernandes@ess.ips.pt; andre.castro@estsetubal.ips.pt;

KEYWORDS: Spine, low back pain, lumbar disc hernia and image segmentation.

1 INTRODUCTION

Lumbar disc herniation (LDH) is the most common diagnosis among degenerative diseases of the lumbar spine, altering its biomechanical behaviour. The usual clinical manifestation is lumbar pain that radiates to the lower limb (sciatica), and it might be associated with sensory and motor disturbances. It is the main cause of spinal surgery in the adult population [1]. Although symptoms and severity may vary, lumbar degenerative diseases are theoretically associated with biomechanical deficiencies in the spinal muscles, resulting in energy-consuming gait patterns and, subsequently, a deterioration in gait quality and capacity [2]. Other symptoms, such as low back pain and radiating leg pain, are the main symptoms of LDH and affect the patient's daily activities and quality of life [3]. Using medical imaging methods, such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT), it is possible to perform a three-dimensional reconstruction of the functional units of the lumbar spine, allowing for an in-depth study of the spine and enabling the surgeon to plan the surgical technique.

This study aims to characterise the qualitative/quantitative parameters obtained from manual measurement of different imaging techniques (MRI, CT, Standing and Functional X-Ray) and the quantitative parameters extracted from 3D biomechanical models developed from segmentation (ITK-Snap), in order to correlate them with the patient's clinical manifestations.

2 METHODOLOGY

A total of 10 patients were recruited at the Neurosurgery Department of Hospital da Luz Setúbal, between April and September 2024. Patients' clinical data, including age, gender, height, weight, body mass index (BMI), treatment group and pain intensity and laterality, were collected and prospectively recorded. Functional disability and quality of life was quantified with clinical validated scales – Numeric Pain Rating Scale (NPRS) and Oswestry Disability Index (ODI).

The sample consisted of 6 women and 4 men, all of them diagnosed with LDH according to clinical and imaging criteria. The same patient can have more than one affected disc and, as such, we studied 14 different affected discs in 4 different levels: L2-L3 (1), L3-L4 (3), L4-L5 (4) and L5-S1 (6). Patients had an average of 53.80 ± 12.19 years, with a weight of 87.30 ± 24.29 kg and an average BMI of 30 ± 6.46. The patients were divided between conservative treatment (3 of them) and surgical groups (7). In terms of pain laterality, 5 patients had left, 4 had right and 1 had

bilateral symptoms. Relevant morphological parameters were manually extracted from the original exams, including disc and vertebral heights, plus intervertebral and lordotic angles.
The dataset consisted of 3 measurements for each parameter of each imaging modality (MRI, CT, Standing and Functional X-Ray images), but it must be highlighted that only 4 of the patients had the complete set of scans. 3D models of patient's lumbar spines were then generated based on MRI and CT scans, using the open-source medical imaging segmentation software ITK-Snap.

3 RESULTS AND DISCUSSION

Table 1 shows the average (plus standard deviation) measurements of disc height, assessed from MRI and CT scans in the sagittal plane. Comparing the quantitative outputs of the two tests performed with the patient in the supine position, where MRI was used as the diagnostic test for LDH and CT was used for segmentation purposes, disc height (sagittal and coronal planes), disc length and intervertebral angle (coronal plane) in CT were lower in 95%, 80% and 87.5% of the cases, respectively, when compared to the same parameters in MRI. When comparing MRI to Standing X-ray, all parameters (except disc height on coronal plane), have higher values in X-Ray than those taken from MRI. These were not expected, as the change from the prone to the standing position should lead to compression of the discs and, consequently, a reduction in the variables measured on Standing X-Ray. Finally, when comparing the CT scan with the 3D model, the disc height in the 3D model is lower than in 2D in 85% of the cases, while vertebral height is higher in 3D in 80% of them, when comparing with 2D.

Table 1 – Average disc height assessed from MRI and CT scans in the sagittal plane.

	MRI			CT		
Disc	**Anterior (mm)**	**Central (mm)**	**Posterior (mm)**	**Anterior (mm)**	**Central (mm)**	**Posterior (mm)**
L1-L2	10.32 ± 1.84	11.48 ± 0.91	7.19 ± 1.24	7.42 ± 1.84	9.04 ± 1.01	3.05 ± 0.70
L2-L3	11.45 ± 1.02	11.09 ± 0.85	7.66 ± 0.19	8.08 ± 1.59	8.93 ± 1.68	3.97 ± 0.90
L3-L4	11.14 ± 1.84	12.90 ± 1.73	7.79 ± 1.14	10.60 ± 1.45	10.54 ± 0.95	4.89 ± 1.23
L4-L5	13.62 ± 1.41	13.13 ± 1.09	7.83 ± 1.52	11.43 ± 2.28	9.96 ± 2.46	5.12 ± 1.26
L5-S1	11.31 ± 2.14	10.01 ± 2.68	7.06 ±0.33	9.11 ± 2.22	6.86 ± 1.27	4.81 ± 1.21

4 CONCLUSIONS

This study suggests that the diagnosis of LDH is more accurate if based on the clinic and a combination of the various imaging modalities. 3D models for biomechanical simulation will also benefit from a better understanding of the differences intrinsic to each imaging modality.

ACKNOWLEDGMENTS

This work was supported by FCT, through project LAETA Base Funding (DOI: 10.54499/UIDB/50022/2020).

REFERENCES

[1] L. Vialle, E. Vialle, J. Henao, and G. Giraldo, "Lumbar Disc Herniation," *Rev. Bras. Ortop. (English Ed.*, vol. 45, no. 1, pp. 17–22, 2010, doi: 10.1007/s12178-017-9441-4.

[2] P. Natarajan, R. D. Fonseka, L. W. Sy, M. M. Maharaj, and R. J. Mobbs, "Analysing Gait Patterns in Degenerative Lumbar Spine Disease Using Inertial Wearable Sensors: An Observational Study," *World Neurosurg.*, vol. 163, pp. e501–e515, 2022, doi: 10.1016/j.wneu.2022.04.013.

[3] K. Lee, E. S. Kim, B. Jung, S. W. Park, and I. H. Ha, "Association between pain and gait instability in patients with lumbar disc herniation," *J. Int. Med. Res.*, vol. 49, no. 8, pp. 1–9, 2021, doi: 10.1177/03000605211039386.