ORIGINAL RESEARCH

Magnetic resonance morphometry of the lumbar spinal canal in Zenica - Doboj Canton in Bosnia and Herzegovina

Belma Jaganjac[1,2], Amina Džidić-Krivić[3,4], Hakija Bečulić[5,6], Armin Šljivo[7], Emir Begagić[8], Adis Šišić[1]

[1]Department of Emergency Medicine, Cantonal Hospital Zenica; [2]Department of Histology and Embryology, School of Medicine, University of Zenica; [3]Department of Neurology, Cantonal Hospital Zenica; [4]Department of Physiology, School of Medicine, University of Zenica; [5]Department of Neurosurgery, Cantonal Hospital Zenica, [6]Department of Anatomy, School of Medicine, University of Zenica; [7]Department of Emergency Medicine, University Clinical Centre Sarajevo, Sarajevo; Bosnia and Herzegovina, [8]Department of General Medicine, School of Medicine, University of Zenica

ABSTRACT

Aim To investigate morphometric determinants of lumbar canal in patients treated in Cantonal Hospital Zenica, and their variation according to gender.

Methods Morphometry of lumbar spinal canal was assessed in 52 patients treated at the Department of Neurosurgery of Cantonal Hospital Zenica in the period between September 2022 and November 2022. Data were collected retrospectively: anteroposterior and transverse diameter of lumbar vertebrae and intervertebral discs, as well as anteroposterior diameter of the spinal canal.

Results Gender appeared to be an important morphometric determinant, since it significantly differed when it comes to lumbar vertebral anteroposterior and transverse diameter, being mostly larger in males.

Conclusion This study increases anatomical knowledge of the vertebras and spinal canal of the lumbar region. Therefore, the measured dimensions of the lumbar vertebrae and spinal canal could be used as a baseline point for evaluation of patients presenting with low back pain and potential spinal canal stenosis.

Key words: morphometry, spine, spinal canal, Torg-Pavlov ratio

Corresponding author:
Belma Jaganjac
Department of Emergency Medicine,
Cantonal Hospital Zenica
Crkvice 67, 72 000 Zenica,
Bosnia and Herzegovina
Phone: +387 61 045 932
E-mail: belma.jaganjac@gmail.com
ORCID ID: 0009-0002-3520-7418

Original submission:
26 December 2022;
Revised submission:
03 February 2023;
Accepted:
07 May 2023
doi: 10.17392/1575-23

Med Glas (Zenica) 2023; 20(2):263-268

INTRODUCTION

One of the leading causes of disability in the world is low back pain. In the period between 1990-2017 life with disability (YLDs) increased from 42.5 to 64.9 million, respectively (1,2). The highest increase of the prevalence of this entity was noted in the low-income and middle- income countries (2). This disease has become a growing burden for healthcare system, and it is one of the main reasons for work absence in the population (2,3). It is a common medical condition, frequently occurring with non-specific signs and symptoms (4,5). Disc herniation in the lumbar region of the spine is one of the most common causes of lower back pain. It can lead to morphological changes in the spinal canal such as stenosis of the canal or narrowing of the lateral recess and neural foramen (6,7). The spinal canal is made up of vertebral foramina, which protect spinal cord. Spinal cord ends at the level of L2 vertebra with its caudal part called conus medullaris (8,9).

The aim of this study was to evaluate the lumbar spinal canal morphometry in correlation with patients' gender and calculating the Torg-Pavlov ratio (TPR). In general, scientific data collected on the topic of lumbar spinal stenosis are still insufficient and not homogeneous, in the population of the Balkans, especially Bosnia and Herzegovina (B&H). The data obtained in this study may also be useful to the surgeon in establishing a threshold value in the diagnosis of lumbar spinal stenosis and deciding whether conservative or surgical treatment is necessary. This therefore leads to a more complete and accurate diagnosis, treatment and rehabilitation for the patient.

MATERIALS AND METHODS

Patients and study design

For this retrospective, descriptive, analytical study, data were collected in the period between September and November 2022. Morphometry of lumbar spinal canal was assessed in 52 patients who were admitted to the Department of Neurosurgery of the Cantonal Hospital Zenica. The observed variables were age, gender and body mass index (BMI), and morphometric characteristics of the spinal canal of the lumbar spine. Patients with lower back pain with suspected stenosis of the lumbar part of the spinal canal diagnosed by magnetic resonance imaging (MRI) were included in the study. MRI images of patients who did not have an indication for surgery were used. Exclusion criteria were previous lumbar spine surgery, massive lumbar disc herniation, expansive vertebral lesions, scoliosis, kyphosis and spondylolisthesis of lumbar spine.

The study was conducted with the approval of the Ethics Committee of the Cantonal Hospital Zenica. All patients signed informed consents.

Methods

While undergoing the MRI (Siemens MagnetomAvanto 1,5 T, Erlangen, German), the patients were positioned in the prone position. Weight and height of the patients and their BMI were collected from medical history of patients.

The measuring was done on MRI images found in digital radiology imaging system IMPAX (Agfa Healthcare Impax, version 6.5.3.2525, Mortsel, Belgium), which allows direct measuring of anatomical structures necessary for the study in all planes. The analysis and measurement (in mm) of each recording were carried out by researchers with monitoring by a specialist neurosurgeon. The standard study protocols were applied on the lumbosacral spine region (MRI 1,5 T; T1 and T2 sequences).

The measurement on all levels of the lumbosacral spine (L1 - L5) and their belonging intervertebral discs (L1/L2 – L5/S1) was done, as well as the anteroposterior diameter of spinal canal on the level of belonging intervertebral disc. Measurements of anteroposterior diameter of vertebral body and anteroposterior diameter of spinal canal were taken for the study. The anteroposterior diameter of the lumbar vertebral body was measured between the midpoints of their superior and inferior endplates (9). The anteroposterior diameter of the spinal canal was measured from the posterior surface of the body of the vertebra to the closest point of the corresponding spinal laminar line (Figure 1) (9). The Torg-Pavlov ratio TPR was calculated by dividing the anteroposterior diameter of the spinal canal and the anteroposterior diameter of the vertebral body (9).

Statistical analysis

Mean and standard deviation (SD) values of the examined variables were presented. The normality of the distribution was analysed with the Kolgomorov-Smirnov test. The Student T test

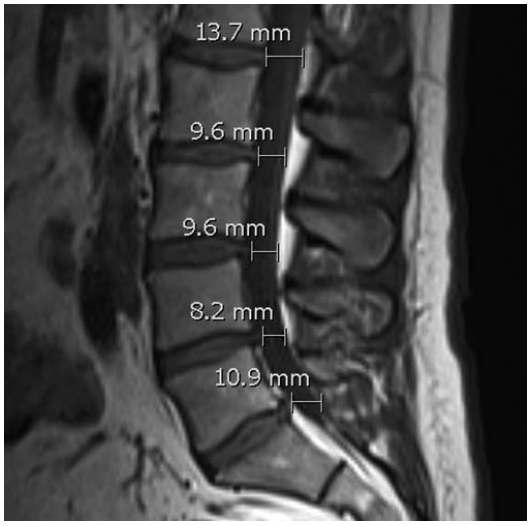

Figure 1. Anteroposterior diameter of the spinal canal measured on MRI (axial T2 view): 1 – level of L1/L2 intervertebral disc (Department of Neurosurgery, Cantonal Hospital Zenica, 2017.)

was used to determine statistically significant differences in variables with a normal distribution. The non-parametric Mann-Whitney U test was used to determine statistically significant differences for variables with deviations from the normality of the distribution. Statistical significance was set at $p \leq 0.05$.

RESULTS

The study included 52 patients. After the exclusion of three patients according to the exclusion criteria, the final sample consisted of 49 patients, 25 (51.0%) males and 24 (49.0%) females. A mean age was 58.8±10.1years (ranging from 31 to 74 years); BMI mean of 25.7±4.6 (ranging from 18.5 to 31.6) was found. There was no measurable significant difference in age ($p>0.05$) and BMI ($p>0.05$) in relation to gender.

L1 vertebrae of males showed significantly ($p<0.05$) larger vertebrae and intervertebral disks compared to females. The results in males were as follows: anteroposterior 29.9 (±3.1) mm and transverse 41.5 (±3.8) mm diameter of the vertebrae and anteroposterior 39.0 (±3.1) mm and transverse 53.8 (±4.7) mm diameter of the intervertebral disks, and in females: anteroposterior 27.0 (±2.5) mm and transverse 38.1 (±3.6) mm diameter of the vertebrae and anteroposterior 35.9 (±3.0) mm and transverse 49.0 (±3.2) mm diameter of the intervertebral disks. On the L4 level of the lumbar spine, mean anteroposterior 32.0 (±3.1) mm and transverse 44.5 (±4.5) mm diameter of the vertebrae, and anteroposterior 43.2 (±5.0) mm diameter of the intervertebral disk were measured.

Table 1. Anthropometric measures among male and female patients who underwent MRI imaging

Variable		Mean (±SD) Males (N=25)	Mean (±SD) Females (N=24)	p
Age (years)		58.7 (±11.0)	58.8 (±9.4)	>0.05
BMI		25.8 (±6.0)	25.7(±2.7)	>0.05
Vertebra	**Diameter** (mm)			
	AP	29.9 (±3.1)	27.0 (±2.5)	0.001
	Transverse	41.5 (±3.8)	38.1 (±3.6)	<0.001
	AP spinal canal	13.6 (±2.2)	14.0 (±2.3)	>0.05
L1	AP intervertebral disc L1/L2	39.0 (±3.1)	35.9 (±3.0)	0.001
	Transverse intervertebral disk L1/L2	53.8 (±4.7)	49.0 (±3.2)	<0.001
	TPR	0.6 (±0.1)	0.6 (±0.1)	>0.05
	AP	31.4 (±2.8)	28.2 (±3.5)	0.001
	Transverse	43.1 (±3.9)	39.7 (±3.7)	0.004
	AP spinal canal	11.6 (±2.9)	11.5 (±2.9)	>0.05
L2	AP intervertebral disk L2/L3	40.6 (±3.9)	38.2 (±4.6)	0.001
	Transverse intervertebral disk L2/L3	57.6 (±5.0)	52.7 (±4.4)	>0.05
	TPR	0.7 (±0.1)	0.6 (±0.1)	>0.05
	AP	33.0 (±3.2)	30.0 (±2.8)	0.001
	Transverse	44.8 (±4.0)	41.7 (±3.9)	0.008
	AP spinal canal	10.4 (±3.1)	9.9 (±3.8)	>0.05
L3	AP intervertebral disk L3/L4	43.3 (±4.8)	40.5 (±3.4)	0.026
	Transverse intervertebral disk L3/L4	58.1 (±6.6)	55.9 (±4.7)	>0.05
	TPR	0.6 (±0.1)	7.0 (±4.1)	>0.05
	AP	32.0 (±3.3)	31.0 (±2.6)	0.032
	Transverse	46.0 (±5.0)	43.0 (±3.4)	0.022
	AP spinal canal	10.8 (±3.6)	10.4 (±3.3)	>0.05
L4	AP intervertebral disk L4/L5	44.7 (±5.6)	41.6 (±3.9)	0.029
	Transverse intervertebral disk L4/L5	61.8 (±6.5)	56.5 (±3.5)	0.001
	TPR	0.7 (±0.1)	6.0 (±2.3)	>0.05
	AP	32.8 (±4.4)	30.6 (±3.9)	>0.05
	Transverse	47.0 (±6.5)	44.6 (±4.7)	>0.05
	AP spinal canal	12.0 (±3.2)	13.0 (±3.2)	>0.05
L5	AP intervertebral disk L5/S1	43.8 (±4.4)	40.1 (±5.5)	0.013
	Transverse intervertebral disk L5/S1	59.0 (±7.0)	55.6 (±5.1)	>0.05
	TPR	0.6 (±0.1)	4.5 (±1.4)	>0.05

SD, standard deviation; AP, anteroposterior; BMI, body mass index; TPR, Torg – Pavlov ratio

Statistically significant differences within the values of the anteroposterior diameter of the vertebral body between males and females were confirmed for the L1 ($p=0.001$), L2 ($p=0.001$), L3 ($p=0.001$) and L4 ($p=0.032$) levels. Statistically noteworthy differences were found for the transverse diameter at the same levels as for the anteroposterior diameter. The anteroposterior diameter of the spinal canal had no significant differences in relation to gender categories. The

anteroposterior diameter within the individual intervertebral levels differed at all levels: L1/L2 (p=0.001), L2/L3 (p=0.001), L3/L4 (p=0.026), L4/L5 (p= 0.029), and L5/S1 (p=0.013). The transverse diameter at the level of the intervertebral disc was statistically significantly diverse only at the L1/L2 (p=0.001) and L5/S1 (p=0.05).

DISCUSSION

Data about lumbar spine morphometry are essential for the assessment of low back pain and lumbar spinal stenosis (LSS) (9). It is also important for understanding the biomechanics of the spine as well as surgical interventions (10). There are many studies which investigated the morphometry of vertebra and spinal canal, mostly in western population (4,8). They were mostly conducted by using cadavers or osteological specimens. Sample sizes of these studies were adequate, but they did not show the differences of diameters between the patient's gender. More recently computed tomography and magnetic resonance imaging have been used for evaluation of spinal morphometry and they have shown to be superior to cadaveric studies, as well as x-ray ones. Diameter of the spinal canal varies within the spine regions with its width being the largest in the lumbar region. The highest diameter measured was at the point of L5 vertebra being around 17.5 mm (5,9).

Research has shown that the size of lumbar vertebra is dependent on age, gender, race and level, and it is associated with degenerative lumbar pathologies, which are the risk factors that clinicians should observe in patients while deciding on the adequate treatment for low back pain (10).

In a study conducted on the Indian population, anteroposterior diameter of the spinal canal gradually decreased from Th12 to L4 and marginally increased at L5 (9). The results of this study show also that AP diameter of spinal canal decreased from L1 to L3 in both males and females, but it slowly increased at the levels of L4-L5, indicating that the first three levels of lumbar spine should be carefully observed in patients with low back pain symptoms. Transverse diameter of the vertebral bodies was higher in males than in females on all levels of the lumbar spine. Also, the results of the study conducted on the Indian population noted greater values of all measured diameters in males, which was also the case in our study (9).

AP diameter of the spinal canal was larger in females only at the L1 and L5 level, while in the rest of the vertebras of the lumbar spine it remained larger in males. A study conducted on the Pakistani population showed greater spinal canal diameters in males, with a significant statistical difference at the level of L5, as well as dimensions of the vertebra, both anteroposterior and transverse diameter (11). Furthermore, Alam et al. (11) found that the anteroposterior and transverse diameter of the intervertebral disk was larger in males at all levels of the lumbar spine than in females. On the opposite, TPR was noted to be bigger on the levels of L2 and L3 in females than in males in same study (11). In a comparative study, Wang et al. (12) analysed the differences in the morphological characteristics of the spinal canal between the Chinese and Indian populations; the AP diameter of the spinal canal for all levels of the lumbar spine in their study was smaller compared to our results. The reason for these differences is the morphometric contrast between the observed populaces (13). El-Rakhawy et al. (14) stated that there are differences in AP diameter in relation to gender groups at the L2, L3, and L4 levels, which partially coincides with the results of our study. Namely, statistically significant differences in AP diameter were observed at all levels except for L5.

Analysing the transverse diameter of the spinal canal, Amoon-Kuofi et al. (15) concluded that its length increased from L1 to L5 level, which is also the case with the results of our study for both gender categories. Similar results were obtained by Postacchini et al. (16), and Eisenstein et al. (17) in cadaveric studies.

Regarding the transverse diameter, our study results support the existence of a significant difference between males and females for L1-L4 levels, which is consistent with the findings of Tacareta et al. (18) in the population of Türkiye.

The values of the TPR were without significant deviations in men and women in our findings, which is opposite to the results described by Qudsieh H et. al. (19). Interestingly, TPR could be used as a predictive factor for lumbar spinal stenosis since significant association of the TPR and occurrence of spinal canal stenosis at L2, L3, L4, and L5 (20-21) was found. Previous research on the TPR ratio supports its predictive value

when it comes to lumbar spinal stenosis. Even more, Lee et al. (22) reported that the values of the TPR of the lumbar spine are correlated with the same ratio of the cervical spine in patients with diagnosed stenosis.

Ultimately, knowing the morphometric characteristics of the lumbar part of the spinal canal has its clinical implications. A significant increase in the number of degenerative spine diseases in the world requires a better understanding of diagnostic methods so that the outcome of the disease can be predicted. The total prevalence of degenerative diseases increased by 27.3% (23). The importance of morphometric measurements of the spinal canal is crucial in the evaluation of spinal stenosis (24-26), and as the most significant indicator of spinal stenosis. Eisenstein et al. (17) state that AP is the most important diameter in the evaluation of spinal canal stenosis. The role of the TPR has been confirmed by several studies (27-29), and accordingly, it is necessary to consider it as a diagnostic indicator and predictive value of the outcome when it comes to lumbar canal stenosis.

The limitations of this study are a small number of patients and the subjective nature of measurement taken by IMPAX tools. An additional possible limitation is reflected in the evaluation that focused exclusively on radiological diagnostics (MRI) without the inclusion of data on symptoms and clinical indicators.

This study increased anatomical knowledge of the vertebras and spinal canal in the lumbar region in a sample population taken from patients in Zenica-Doboj Canton, Bosnia and Herzegovina. The dimensions of the lumbar vertebrae and spinal canal that were collected could be used as a baseline point for evaluation of patients presenting with low back pain and potential spinal canal stenosis. Also, the findings from the study could be used in the evaluation of patients with spinal stenosis. Therefore, it is necessary to continue research in the context of the clinical applicability of the described parameters in the process of evaluation and eventual prediction of the operative outcome.

FUNDING

No specific funding was received for this study.

TRANSPARENCY DECLARATIONS

Competing interest: None to declare.

REFERENCES

1. Wu A, March L, Zheng X, Huang J, Wang X, Zhao J, Blyth FM, Smith E, Buchbinder R, Hoy D. Global low back pain prevalence and years lived with disability from 1990 to 2017: estimates from the Global Burden of Disease Study 2017. Ann Transl Med 2020; 8:299.
2. Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, Hoy D, Karppinen J, Pransky G, Sieper J, Smeets RJ, Underwood M. Lancet Low Back Pain Series Working Group. What low back pain is and why we need to pay attention. Lancet 2018; 391:2356-67.
3. Schwill C. Rückenschmerzen in der Hausarztpraxis: Der spezifische Rückenschmerz (Back pain in the primary care setting: Specific back pain) [in German]. Internist (Berl) 2021; 62:34-46.
4. Kaydu A, Andan İ, Deniz MA, Bilge H, Başol Ö. Examination of spinal canal anatomy with MRI measurements in lumbar disc herniation patients: an anesthesiologist viewpoint. Anesth Essays Res 2021; 15:38-44.
5. Peabody T, Das JM. Anatomy, Back, Vertebral Canal. StatPearls. https://www.ncbi.nlm.nih.gov/books/NBK557587/#_NBK557587_pubdet_ (25 February 2023)
6. Katz JN, Zimmerman ZE, Mass H, Makhni MC. Diagnosis and Management of Lumbar Spinal Stenosis: A Review. JAMA. 2022;327:1688-1699.
7. Bharadwaj UU, Ben-Natan AR, Huang J, Pedoia V, Chou D, Majumdar S, Link TM, Chin CT. Evaluation of 2 Novel Ratio-Based Metrics for Lumbar Spinal Stenosis. AJNR Am J Neuroradiol 2022; 43:1530–8.
8. Lee JH, Kang KC, Kim KT, Kim YC, Chang TS. Extent and characteristic of relationships in canal dimension and canal body ratio between cervical and lumbar spine. Sci Rep 2021; 11:18471.
9. Suk KS, Kim KT, Lee JH, Lee SH, Kim JS, Kim JY. Reevaluation of the Pavlov ratio in patients with cervical myelopathy. Clin Orthop Surg 2009; 1:6-10.
10. Yadav U, Singh V, Bhargava N, Kumar Srivastav A, Neyaz Z, Phadke RV, Mishra P. Lumbar Canal Diameter Evaluation by CT Morphometry-Study of Indian Population. Int J Spine Surg 2020; 14:175-81.
11. Alam MM, Waqas M, Shallwani H, Javed G. Lumbar morphometry: a study of lumbar vertebrae from a Pakistani population using computed tomography scans. Asian Spine 2014; 8:421-6.
12. Wang TM, Shih C. Morphometric variations of the lumbar vertebrae between Chinese and Indian adults. Acta Anat (Basel) 1992; 144:23-9.
13. Chazono M, Tanaka T, Kumagae Y, Sai T, Marumo K. Ethnic differences in pedicle and bony spinal canal dimensions calculated from computed tomography of the cervical spine: a review of the English-language literature. Eur Spine J 2012; 21:1451-8.

14. El-Rakhawy M, El-Shahat AE-R, Labib I, Ehaz A. Lumbar vertebral canal stenosis: concept of morphometric and radiometric study of the human lumbar vertebral canal. Anatomy 2010;4:51–62.
15. Amonoo-Kuofi HS, Patel PJ, Fatani JA. Transverse diameter of the lumbar spinal canal in normal adult Saudis. Acta Anat (Basel) 1990; 137:124-8.
16. Postacchini F, Ripani M, Carpano S. Morphometry of the lumbar vertebrae. An anatomic study in two caucasoid ethnic groups. Clin Orthop Relat Res 1983; 172:296-303.
17. Eisenstein S. The morphometry and pathological anatomy of the lumbar spine in South African negroes and caucasoids with specific reference to spinal stenosis. J Bone Joint Surg Br 1977; 59:173-180
18. Tacar O, Demirant A, Nas K, Altindağ O. Morphology of the lumbar spinal canal in normal adult Turks. Yonsei Med J 2003; 44:679-685.
19. Qudsieh H, Al-Rawashdeh I, Daradkeh A, Abualnadi T, Al Tah B. Variation of Torg-Pavlov ratio with age, gender, vertebral level, dural sac area, and ethnicity in lumbar magnetic resonance imaging. J Clin Imaging Sci 2022; 12:53.
20. Abbas J, Peled N, Hershkovitz I, Hamoud K. The role of vertebral morphometry in the pathogenesis of degenerative lumbar spinal stenosis. Biomed Res Int. 2021; 2021:7093745.
21. Bajwa NS, Toy JO, Ahn NU. Application of a correlation between the lumbar Torg ratio and the area of the spinal canal to predict lumbar stenosis: a study of 420 postmortem subjects. J OrthopTraumatol 2013; 14:207-12.
22. Lee JH, Kang KC, Kim KT, Kim YC, Chang TS. Extent and characteristic of relationships in canal dimension and canal body ratio between cervical and lumbar spine. Sci Rep 2021; 11:18471
23. Parenteau CS, Lau EC, Campbell IC, Courtney A. Prevalence of spine degeneration diagnosis by type, age, gender, and obesity using Medicare data. Sci Rep 2021; 11:5389.
24. Akar E, Somay H. Comparative morphometric analysis of congenital and acquired lumbar spinal stenosis. J Clin Neurosci 2019; 68:256-61.
25. Akar E, Toprak F, Öğrenci A. The relationship between bone canal diameter and facet tropism in cases of lumbar spinal stenosis. J Neurosci Rural Pract 2022; 13:641-6.
26. Bečulić H, Skomorac R, Jusić A, et al. Impact of timing on surgical outcome in patients with cauda equina syndrome caused by lumbar disc herniation. Med Glas (Zenica) 2016; 13:136-41
27. Moon MS, Choi WR, Lim HG, Lee SY, Wi SM. Pavlov's ratio of the cervical spine in a Korean population: a comparative study by age in patients with minor trauma without neurologic symptoms. Clin Orthop Surg 2021; 13:71-5.
28. Kong L, Bai J, Zhang B, Shen Y, Tian D. Predictive factors of symptomatic lumbar canal stenosis in patients after surgery for cervical spondylotic myelopathy. Ther Clin Risk Manag 2018; 14:483-8.
29. Song KJ, Choi BW, Kim SJ, Kim GH, Kim YS, Song JH. The relationship between spinal stenosis and neurological outcome in traumatic cervical spine injury: an analysis using Pavlov's ratio, spinal cord area, and spinal canal area. Clin Orthop Surg 2009; 1:11-8.