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Original article

Morphometric Study of the Lumbar Spinal Canal in the Normal Libyan Population using Computed Tomography

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Abstract
Precise measurements of the lumbar vertebrae are crucial for spinal surgery and for the placement of medical devices. When the stenosis in the vertebral canal or intervertebral foramen exists, it can press on nerves, leading to symptoms like low back pain or radicular pain (pain radiating down the leg). This study aimed to measure the mid-sagittal diameter and interpedicular distance of the lumbar spinal canal by analyzing computed tomography (CT) scans. This study on 113 Libyan patients (84 males, 29 females) with an age range between 18 to 60 years of age utilized computed tomography (CT) scans to determine the normal values of the midsagittal diameter and interpedicular distance in the normal Libyan population. The study sample included 113 patients, with 74.33% being male (84) and 25.67% female (29). The range of midsagittal diameter at all levels was (10.2-29.1mm). The narrowest level was L3. It is found that L5, the lowest lumbar vertebra, had the largest midsagittal diameter among all the lumbar vertebrae measured, averaging 17.61 mm (with a range of 11.1 to 29.1 mm). The range of interpedicular distance at all levels was (15.6-42.4 mm). The measurement of the lumbar vertebrae showed a steady increase in the interpedicular distance from L1 to L5. Only a small percentage of patients, specifically 3.1%, were found to have a statistically significant midsagittal diameter. The findings of this research could have important clinical implications for surgeons and medical professionals. CT scans provide crucial data, which, when combined with accurate measurements, form the basis for anatomical studies.
Keywords. Lumbar Vertebrae, Spinal Canal, Morphometry, Interpedicular Distance, Midsagittal Diameter.

Introduction

The lumbar vertebrae, positioned between the thoracic and sacral regions, are composed of five segments (L1-L5). The first lumbar vertebral foramen contains the conus medullaris of the spinal cord, while lower foramina contain the cauda equine and spinal meninges that are biggest/hardest of all sections [1]. Lumbar vertebrae are irregularly shaped bones consisting of a large vertebral body and posterior elements including the pedicles and lamina. The spinal canal is bordered anteriorly by the vertebral bodies and discs and posteriorly by the laminae and ligamenta flava. The anterior wall which made up of the back of the vertebral bodies and the intervertebral discs' annulus, all covered in the midline by the posterior longitudinal ligament, which gets wider over each disc. The laminae's uppermost parts and the ligamenta flava form the posterior wall [2]. The spinal canal's rigid bony walls normally maintain a minimal free space around its contents, crucial for tension-free movement. Therefore, the canal's normal size is vital, as an abnormal reduction can lead to lower back pain [3]. Factors like age, weight, body stature, ethnic differences [4], and even environmental influences (e.g., low birth weight, low socioeconomic status) have been linked to spinal canal size [5]. The transverse diameter (interpedicular distance) is considered a reliable measure of canal size [6]. Lumbar spinal canal stenosis, often related to progressive vertebral degeneration [7], is indicated by a sagittal diameter of ≤15 mm, with ≤12 mm strongly suggesting stenosis; normal sagittal diameters range from 15 to 25 mm [8]. According to Haig et al [9], lumbar spinal stenosis frequently causes back and lower extremity pain, often accompanied by other neurological symptoms. While precise data on lumbar spinal canal dimensions is limited, these measurements are vital for spinal surgeries and instrumentation like pedicle screws [10].

Previous research has primarily used X-rays [11,12] or CT scans [13], with only a few studies examining cadavers [14-16]. To prevent pain due to lumbar spinal canal or intervertebral foramen stenosis, which can compress neural structures during a dorsal approach in patients undergoing spinal surgery, accurate measurements of the size of the spinal canal are necessary [17]. This study was conducted to measure the mid-sagittal diameter and interpedicular distance of the lumbar spinal canal using CT scans in a healthy Libyan population using CT images.

Methods

Subjects

This study employed a retrospective design and was conducted using 113 randomly selected abdominal CT images retrieved from the radiological archive of Dar Al-Shifa Hospital (DSH). The sample consisted of Libyan patients, both male and female, with a total of 84 males and 29 females. The age of the participants ranged

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between 18 and 60 years. The inclusion criteria required that patients had undergone CT scans encompassing the vertebral levels from L1 to S1, were within the specified age range, and presented with a lumbar spine that appeared normal on the CT images. Conversely, the exclusion criteria eliminated patients younger than 18 years or older than 60 years, as well as those with pathological fractures of the lumbar vertebrae, scoliosis, or other spinal deformities. Additionally, cases were excluded if demographic data such as age or gender were missing, or if the CT images were deemed inappropriate or of inadequate quality. A considerable number of cases were excluded based on these criteria to ensure the reliability and validity of the study sample.

Technique

Radiant DICOM Viewer 2021 software visualized medical CT images in the mid-sagittal, interpedicular has been used to visualize the lumbar canal. The CT images were stored in a computer system with features like enhancement, magnification, rotation, and a measuring tool. To measure the distance between two points, a user would position a cursor at the first reference point, drag it to the second, and then release the mouse button. The system would then display the distance, representing the actual size within the lumbar spinal canal on that particular CT slice.

Measurement Method

A total of 565 lumbar vertebrae, ranging from L1 to L5, were examined from 113 patients in order to measure the midsagittal diameter and the interpedicular distance. The primary objective of this investigation was to establish normative values for these parameters within the Libyan population. From the cross-sectional images of each vertebra, two specific measurements were obtained. The interpedicular distance, also referred to as the transverse diameter, was defined as the distance between the inner edges of the two pedicles of a single vertebral body, representing the maximum transverse dimension of the spinal canal. The midsagittal diameter, or anteroposterior diameter, was determined by measuring the distance from the posterior border of the vertebral body to the lamina at the midline, thereby representing the maximum anteroposterior dimension of the canal from the posterior surface of the vertebral body to the junction of the laminae.

Statistical analysis

Data were analyzed using SPSS version 26 (IBM, Armonk, NY, USA). Mean, standard deviation (SD), range, and Student's t-test were used. A P-value < 0.05 was considered statistically significant.

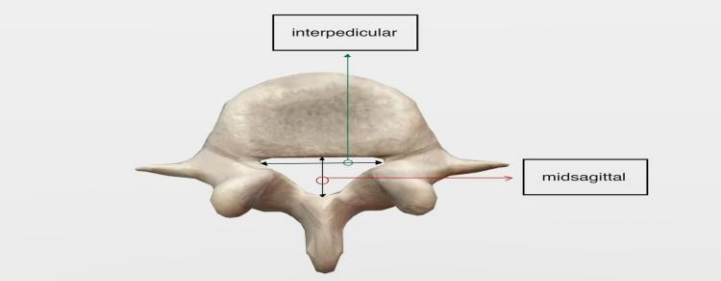

Figure 1. Illustrations showing the methods of measuring the interpedicular distance and midsagittal diameter

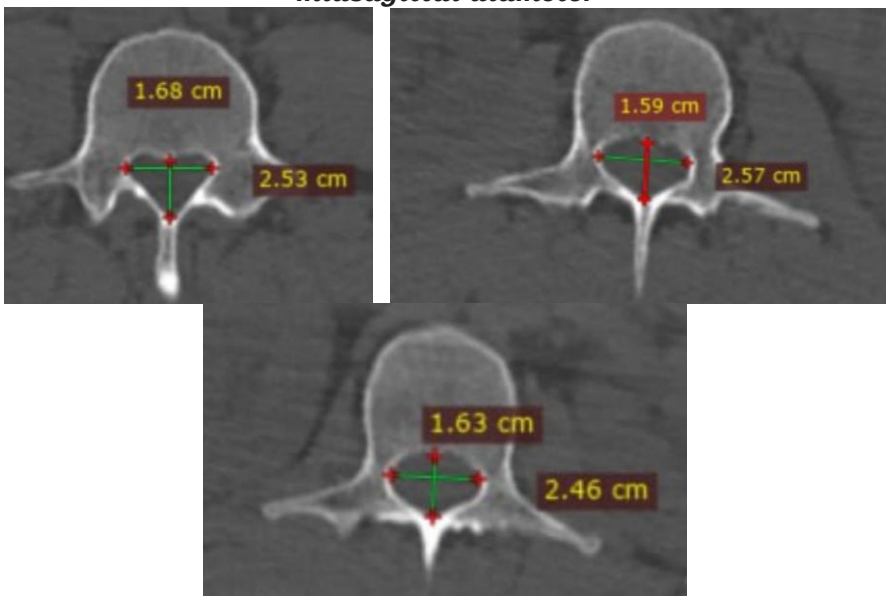

Figure 2: CT image showing the methods of measuring the interpedicular distance (Transverse diameter) and midsagittal diameter (Anteroposterior diameter) of male & female

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Ethical considerations
Ethical approval was obtained from the Libyan International University Ethics Committee. All procedures adhered to ethical research standards.

Study period
The study was conducted over 9 months, from October 2024 to July 2025.

Results
Midsagittal Diameter
A totla of 113 patients (84 males and 29 females; Table 1) underwent CT scanning to measure their midsagittal diameter (Table 2). Data are presented as mean±SD (range) for each vertebral level to all patients (Table 3). Analysis showed that L3 is the narrowest and L5 has the largest. Notably, we observed a distinct pattern: the midsagittal diameter decreased from L1 to L3, reaching its minimum at L3, and then increased toward L5.

Table 1. Frequencies of sex

Sex	Counts	% of Total
Male	84	74.4%
Female	29	25.6 %

Table 2. Midsagittal Diameter (mm) of lumber vertebrae at L1-L5

Vertebra	Mean Midsagittal Diameter (Range), mm
L1	16.2 (10.8-24) mm
L2	15.76 (10.5-28) mm
L3	15.1 (10.5-23) mm
L4	15.41 (10.2-23.5) mm
L5	17.61 (11.1-29.1) mm

Interpedicular Distance
The Interpedicular distance was measured, and data are presented as mean ± SD (range) from L1 to L5 for all patients (Table 3). The measurement showed a steady increase in the interpedicular distance from L1 to L5, ranging from 15.6 to 42.4 mm (Table 4).

Table 3. The mean of all lumbar vertebrae (Interpedicular-midsagittal)

Variables		RL1inter	RL1Mids	RL2Inter	RL2Mids	RL3Inter	RL3Mids	RL4inter	RL4Mids	RL5inter	RL5Mids
N	Valid	113	111	113	113	113	113	113	113	113	112
	Missing	0	2	0	0	0	0	0	0	0	1
Mean		25.29	16.21	25.74	15.76	27.19	15.10	29.71	15.41	33.39	17.61
Std. Deviation		2.13	2.02	2.94	2.60	2.96	2.35	3.41	2.48	4.36	3.29
Range		11.80	13.20	16.50	17.50	16.40	12.50	21.60	13.30	26.80	18.00

Table 4. Interpedicular Diameter (mm) of lumber vertebrae at L1-L5

Vertebra	Mean Interpedicular Diameter (Range), mm
L1	25.28 (20.1-31.9) mm
L2	25.74 (19.8-36.3) mm
L3	27.19 (19.3-35.7) mm
L4	29.71 (19.2-40.8) mm
L5	33.39 (15.6-42.4) mm

Sex Comparison
No statistical differences were observed between males and females for any vertebral level ($P > 0.05$) (Table 5).

Table 5. Comparison of lumber spinal canal (Mean Interpedicular & midsagittal) between males and females

Vertebra	Male (mean±SD)	Female (mean±SD)	Significant
L1-Inter	25.43±2.22	24.84±1.79	0.194
L1-Mids	16.18±1.8	16.26±2.57	0.858
L2-Inter	25.87±3.13	25.36±2.28	0.42

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L2-Mids	15.6±2.61	16.23±2.54	0.148
L3-Inter	27.42±3.15	26.53±2.19	0.162
L3-Mids	15.08±2.42	15.15±2.14	0.888
L4-Inter	29.82±3.55	28.38±3.01	0.549
L4-Mids	15.64±2.6	14.75±1.97	0.98
L5-Inter	33.68±4.12	32.53±4.95	0.222
L5-Mids	17.71±3.3	17.32±3.31	0.584

Discussion

Computed tomography (CT) offers a validated, straightforward, and standardized approach for accurately measuring the spinal canal directly from scan data. This method is utilized to establish normal values for the midsagittal diameter and interpedicular distance within the lumbar spinal canal. By analyzing the configuration of the canal, CT scans can confidently assist in diagnosing lumbar spinal stenosis [18]. When studying human vertebrae, the accuracy and representativeness of the data depended on the number of samples measured. As several researchers [12,13,16] have demonstrated, assessing a few samples cannot provide adequate and reliable information. To truly understand the complexities of vertebral measurements, a larger series of samples is always necessary. In addition, older methods made it tough to get accurate information. For example, using cadaver specimens was problematic because it was hard to find enough of them, and they underwent changes after death that affected their dimensions.

Early studies relying on plain radiographs were also difficult to interpret, often leading to errors [19]. The range of midsagittal diameter at all levels was (10.2-29.1 mm), mean 16.2 in L1, 15.76 in L2, 15.10 in L3, which is the narrowest one, 15.41 in L4, 17.6 in L5, which is the largest one. Interestingly, we observed a specific pattern: the midsagittal diameter actually decreased from L1 down to L3, reaching its narrowest point there, and then began to increase again as it approached L5. This "hourglass" or "V-shaped" pattern, where the canal narrows mid-lumbar and then widens, is a common anatomical finding in many populations [19-21]. These findings are consistent with the data reported by Aly T & Amin O, AkI & Zidan, Lee et al., and Hinck et al [19-22]. The hourglass shape was explained by the fact that the lower end of the lumbar enlargement of the spinal cord is located at L1, which is the transitional area from the thoracic spine to the thin lumbar spine [23].

In the present study L5, had the largest midsagittal diameter among all the lumbar vertebrae measured, averaging 17.61 mm, the findings of the study inconsistent with those of previous studies on Egypt (19,20) and Korea [21] Lee et al [21], Eisenstein [24], and Amonoo-Kuofi [25] reported that L1 vertebra had the largest midsagittal diameter among all measured lumbar vertebrae. In this study, the interpedicular distance across the lumbar vertebrae (L1 to L5) ranged from 15.60 mm to 42.44 mm. This measurement consistently increased from L1 to L5, a finding that aligns with previous research by Aly T & Amin O [19], Lee et al [21], and Zhou et al [26].

In the present study, there was no significant distinction between males and females in any of the two dimensions ($p > 0.05$). A statistically significant was observed when comparing the midsagittal diameter values from the current study with those reported by Aly T & Amin O [19] and Akl and Zidan [20]. This indicates that the observed differences between the two studies are unlikely to be due to random chance. The discrepancies observed can be attributed to several factors. Firstly, there's a difference in the measurement instruments used: the current study utilized CT scans, while other research relied on plain radiographs. Secondly, the current measurements were taken from living humans via CT, whereas other research measured non-living specimens, which are susceptible to postmortal changes that could alter their dimensions. In this study, 3.1% of the participants had a midsagittal diameter below the normal threshold (10.2 mm), suggesting marginal bony stenosis, whereas the lower limit of normal is 12 mm [12]. Eisenstein [24] reported that this marginal skeletal stenosis might predispose patients to cauda equina compression.

Conclusion

The range of midsagittal diameter at all levels was (10.2-29.1mm). The narrowest level was L3. On the other hand, the L5, the lowest lumbar vertebra, had the largest midsagittal diameter among all the lumbar vertebrae measured, averaging 17.61 mm. The range of interpedicular distance at all levels was (15.6-42.4 mm). The measurement of the lumbar vertebrae showed a steady increase in the interpedicular distance from L1 to L5. The findings of this research could have important clinical implications for surgeons and medical professionals. CT scans provide crucial data, which, when combined with accurate measurements, form the basis for anatomical studies.

Recommendations

This research should be supplemented with data from diverse geographic regions of Libya to create a more comprehensive representation of the national population. Additionally, these findings underscore the necessity for further investigation into the contributing factors behind anatomical variations relevant to lumbar puncture procedures.

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Limitations

Our study acknowledges three primary limitations: the number of participants was small, which may restrict the generalizability of our findings. Also, the CT scans used in the study were of poor quality, which may have affected the accuracy of anatomical measurements. Further, the study cohort was predominantly male, with a very small number of female participants, limiting our ability to analyze potential.

Conflict of interest. Nil

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