Original Article

Morphometric Analysis of Lumbar Vertebrae for Identification of Intervertebral Spaces During Spinal Anesthesia: An Osteological Study

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Abstract

Background: Accurate identification of lumbar intervertebral spaces is essential for successful spinal anesthesia. Variations in lumbar vertebral morphology influence needle placement and the safety of neuraxial procedures. Despite their clinical importance, osteological morphometric data on the Indian population remain limited. This study evaluated the morphology of lumbar vertebrae with reference to identification of intervertebral spaces for spinal anesthesia. **Material and Methods:** A descriptive osteological study was conducted on 68 intact adult dry lumbar vertebrae (L1–L5) obtained from the Department of Anatomy, Santosh Medical College, Ghaziabad. Vertebral body transverse diameter, anteroposterior diameter, vertical height, and vertebral canal dimensions were measured using a digital Vernier caliper. Each measurement was recorded three times, and the mean value was used for analysis. Statistical analysis was performed using SPSS version 30.0, with results expressed as mean ± standard deviation. **Results:** Vertebral body dimensions increased progressively from L1 to L5. The mean transverse diameter increased from 41.2 ± 2.8 mm at L1 to 52.1 ± 3.8 mm at L5, while the anteroposterior diameter increased from 28.9 ± 1.9 mm to 35.2 ± 2.7 mm. Vertebral body height also increased across successive lumbar levels. Conversely, the anteroposterior diameter of the vertebral canal decreased from 17.5 ± 1.5 mm to 14.8 ± 1.2 mm, whereas the transverse canal diameter increased. **Conclusion:** Progressive morphometric changes in lumbar vertebrae from L1 to L5 have important clinical implications for accurate localization of intervertebral spaces during spinal anesthesia and may improve procedural success while reducing complications.

Keywords: Lumbar vertebrae; morphometry; spinal anesthesia; vertebral canal; intervertebral space; osteology.

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Introduction

The lumbar spine plays a vital role in maintaining posture, supporting body weight, and permitting movement while protecting the spinal cord and cauda equina.[1] Because of its unique anatomy and accessibility, it is also the preferred site for neuraxial procedures such as spinal anesthesia. The lumbar vertebrae are characterized by large vertebral bodies, broad spinous processes, and a relatively spacious vertebral canal, all of which contribute to their functional and clinical significance.[2]

Spinal anesthesia is widely used for surgeries involving the lower abdomen, pelvis, perineum, and lower limbs because it provides rapid onset of anesthesia, effective analgesia, and fewer systemic complications than general anesthesia.[3] Successful administration depends on accurate identification of the lumbar intervertebral space, usually at the L3–L4 or L4–L5 level, below the termination of the spinal cord. Failure to identify the correct level can lead to multiple needle attempts, failed blocks, neurological injury, post-dural puncture headache, and increased patient discomfort.[4]

The morphology of the lumbar vertebrae varies considerably among individuals owing to differences in age, sex, ethnicity, and biomechanical loading. Morphometric characteristics such as vertebral body dimensions, vertebral canal size, pedicle morphology, and spinous process orientation influence both spinal biomechanics and the ease of performing spinal anesthesia. Detailed knowledge of these anatomical variations is therefore essential for anesthesiologists, spine surgeons, and anatomists, as it contributes to safer procedures and improved clinical outcomes.[5]

Traditionally, lumbar intervertebral spaces are identified using surface anatomical landmarks, particularly Tuffier's line. However, previous studies have demonstrated that this landmark does not always correspond accurately to the intended vertebral level, increasing the risk of incorrect needle placement. Although ultrasound guidance has improved the precision of lumbar level identification, its routine use remains limited in many healthcare settings because of equipment availability, cost, and operator

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expertise. Consequently, a sound understanding of lumbar vertebral morphology continues to be fundamental for safe neuraxial procedures.[6]

Despite numerous morphometric studies conducted worldwide, anatomical variations differ across populations, and osteological data from the Indian population remain relatively limited. Population-specific morphometric information is important because it provides clinicians with reliable anatomical reference values that may improve the accuracy of spinal anesthesia and reduce procedure-related complications.[7]

Therefore, the present study was undertaken to evaluate the morphometric characteristics of adult lumbar vertebrae (L1–L5) and assess their relevance in the identification of intervertebral spaces for spinal anesthesia.

Materials and Methods

Study Design and Setting: A descriptive osteological study was conducted in the Department of Anatomy, Santosh Medical College, Ghaziabad, Delhi NCR, India, over a period of 24 months.

Study Specimens: A total of 68 adult dry human lumbar vertebrae (L1–L5) were obtained from the Osteology Bone Room, Department of Anatomy, Santosh Medical College, Ghaziabad, India, and included in the study. Ethical approval was obtained from the Institutional Ethics Committee of Santosh Medical College before commencement of the study, which was conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion Criteria

- Fully ossified adult dry lumbar vertebrae (L1–L5).
- Intact vertebrae with clearly identifiable anatomical landmarks.

Exclusion Criteria

- Vertebrae showing fractures or other physical damage.
- Vertebrae with congenital anomalies.
- Vertebrae exhibiting deformities or pathological changes.

Morphometric Assessment: Each vertebra was identified and oriented in the standard anatomical position before measurement. Linear dimensions were recorded in millimetres using a digital Vernier caliper. Each parameter was measured three times by the same observer, and the mean value was used for analysis.

1. Vertebral body transverse diameter: Maximum horizontal distance between the lateral borders of the vertebral body.
2. Vertebral body anteroposterior diameter: Maximum distance between the anterior and posterior surfaces of the vertebral body in the midsagittal plane.
3. Vertebral body height: Vertical distance between the superior and inferior endplates of the vertebral body.
4. Vertebral canal anteroposterior diameter: Midline distance from the posterior surface of the vertebral body to the anterior surface of the vertebral arch.
5. Vertebral canal transverse diameter: Maximum distance between the medial surfaces of the pedicles.
6. Intervertebral notch length: Anteroposterior distance between the anterior and posterior margins of the intervertebral notch.
7. Spinous process length: Distance from the base of the spinous process at its junction with the vertebral arch to its tip.
8. Spinous process height: Maximum supero - inferior dimension of the spinous process.
9. Spinous process thickness: Maximum transverse thickness measured at the midpoint of the spinous process.
10. Spinous process direction: Orientation of the spinous process relative to the horizontal plane, recorded as horizontal or oblique.

Statistical Analysis: Data were analyzed using IBM SPSS Statistics version 30.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. One-way analysis of variance (ANOVA), Student's t-test, Chi-square test, and Fisher's exact test were applied where appropriate. A p-value <0.05 was considered statistically significant.

Results

Figure 1: Transverse Diameter of Body of Vertebrae

Figure 2: Antero Posterior Diameter of Body of Vertebra

Figure 3: Height of Vertebra Measured

Figure 4: Intervertebral Notch Measured

Figure 5: Antero - Posterior Diameter of Vertebral

Figure 6: Transverse Diameter of Vertebral

Figure 7 : Central Thickness of Spinous Process

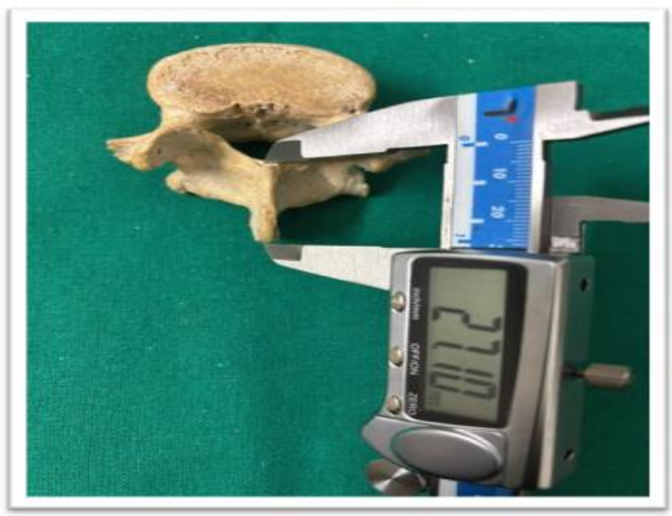

Figure 8 : Length of Spinous Process

Figure 9: Height of Spinous Process.

Table 1: Distribution of Lumbar Vertebrae According to Vertebral Level

Vertebral Level	Frequency (n)	Percentage (%)
L1	14	20.6
L2	13	19.1
L3	14	20.6
L4	14	20.6
L5	13	19.1
Total	68	100

Table 2: Morphometric Measurements of Vertebral Body Across Lumbar Levels

Level	Transverse Diameter (mm) Mean ± SD	Min	Max	AP Diameter (mm) Mean ± SD	Min	Max	Height (mm) Mean ± SD	Min	Max
L1	41.2 ± 2.8	37.5	46.1	28.9 ± 1.9	26.1	32.4	22.5 ± 1.7	19.8	25.2
L2	43.5 ± 2.9	39.4	48.2	30.4 ± 2.1	27.3	34.1	23.4 ± 1.9	20.5	26.3
L3	46.8 ± 3.2	42.1	52.5	32.1 ± 2.2	28.9	35.8	24.1 ± 2.0	21.1	27.5
L4	49.3 ± 3.5	44.5	55.8	33.8 ± 2.5	30.1	38.2	25.2 ± 2.1	22.0	28.9
L5	52.1 ± 3.8	46.8	59.1	35.2 ± 2.7	31.5	40.1	25.9 ± 2.3	22.8	30.1

Table 3: Morphometric Measurements of Vertebral Canal Across Lumbar Levels

Level	Canal AP Diameter (mm) Mean ± SD	Min	Max	Canal Transverse Diameter (mm) Mean ± SD	Min	Max
L1	17.5 ± 1.5	14.8	20.1	25.8 ± 2.2	22.4	29.5
L2	16.8 ± 1.4	14.2	19.2	26.5 ± 2.3	23.1	30.2
L3	16.2 ± 1.4	13.9	18.8	27.9 ± 2.5	24.5	32.1
L4	15.5 ± 1.3	13.1	17.9	29.4 ± 2.6	25.9	34.0
L5	14.8 ± 1.2	12.5	17.2	30.8 ± 2.8	27.1	35.9

Table 4: Morphometric Measurements of the Spinous Process Across Lumbar Levels

Level	Length (mm) Mean ± SD	Min	Max	Height (mm) Mean ± SD	Min	Max	Thickness (mm) Mean ± SD	Min	Max
L1	28.5 ± 2.5	23.5	33.5	13.01 ± 1.17	10.9	14.8	5.4 ± 0.8	3.8	7.0
L2	29.8 ± 2.7	24.4	35.2	14.77 ± 1.22	12.9	16.8	5.6 ± 0.8	4.0	7.2
L3	31.6 ± 2.9	25.8	37.4	16.21 ± 1.31	13.8	17.9	6.1 ± 0.9	4.3	7.9
L4	33.5 ± 3.1	28.5	39.5	19.96 ± 1.46	17.8	22.1	6.9 ± 1.0	5.0	8.9
L5	30.9 ± 2.8	26.5	36.5	17.36 ± 1.24	14.8	19.4	7.2 ± 1.1	5.5	9.4

Table 5: Morphometric Measurements of the Intervertebral Notch

Level	Anteroposterior Length (mm) Mean ± SD	Min	Max
L1	8.4 ± 1.1	6.8	10.5
L2	8.9 ± 1.2	7.1	11.2
L3	9.5 ± 1.3	7.8	12.0
L4	10.2 ± 1.4	8.5	13.1
L5	11.1 ± 1.6	9.1	14.2

Table 6: Distribution of Spinous Process Orientation According to Vertebral Level

Vertebral Level	Horizontal n (%)	Oblique n (%)
L1	2 (14.3)	12 (85.7)
L2	3 (23.1)	10 (76.9)
L3	8 (57.1)	6 (42.9)
L4	11 (78.6)	3 (21.4)
L5	12 (92.3)	1 (7.7)

Table 7: Correlation Between Vertebral Body and Vertebral Canal Dimensions

Variables	Correlation Coefficient (r)	p-value
Body Transverse vs Canal AP	-0.65	<0.001
Body Transverse vs Canal Transverse	+0.71	<0.001
Body AP vs Canal AP	-0.59	<0.001

Table 8: Regional Comparison Between Upper and Lower Lumbar Spine (Student's t-test)

Parameter	Upper Lumbar (Mean ± SD)	Lower Lumbar (Mean ± SD)	p-value
Body Transverse	42.4 ± 3.0	50.7 ± 3.9	<0.001
Body AP	29.7 ± 2.2	34.5 ± 2.7	<0.001
Canal AP	17.1 ± 1.5	15.1 ± 1.3	<0.001
Canal Transverse	26.2 ± 2.3	30.1 ± 2.7	<0.001
Spinous Length	29.2 ± 2.6	32.2 ± 3.2	<0.001
Spinous Thickness	5.5 ± 0.8	7.1 ± 1.1	<0.001
Notch Length	8.7 ± 1.2	10.7 ± 1.6	<0.001

A total of 68 adult lumbar vertebrae were examined, with an almost equal distribution across all lumbar levels.

A consistent trend of increasing vertebral body size was observed from L1 to L5, as the mean transverse diameter increased from 41.2 ± 2.8 mm to 52.1 ± 3.8 mm, the anteroposterior diameter from 28.9 ± 1.9 mm to 35.2 ± 2.7 mm, and the vertebral body height from 22.5 ± 1.7 mm to 25.9 ± 2.3 mm.

In contrast, the anteroposterior diameter of the vertebral canal decreased from 17.5 ± 1.5 mm at L1 to 14.8 ± 1.2 mm at L5, whereas its transverse diameter increased from 25.8 ± 2.2 mm to 30.8 ± 2.8 mm.

The spinous process length increased from 28.5 ± 2.5 mm at L1 to 33.5 ± 3.1 mm at L4 before decreasing slightly to 30.9 ± 2.8 mm at L5, while its thickness increased steadily from 5.4 ± 0.8 mm to 7.2 ± 1.1 mm.

Similarly, the intervertebral notch length increased from 8.4 ± 1.1 mm at L1 to 11.1 ± 1.6 mm at L5. A gradual change in spinous process orientation was also noted, with oblique processes predominating at L1 (85.7%) and horizontal processes becoming more common at L5 (92.3%).

Correlation analysis showed a significant negative association between vertebral body transverse diameter and vertebral canal anteroposterior diameter ($r = -0.65$, $p < 0.001$) and a significant positive association with vertebral canal transverse diameter ($r = 0.71$, $p < 0.001$). Furthermore, comparison between the upper and lower lumbar spine demonstrated significant regional differences in all measured parameters ($p < 0.001$), indicating distinct morphometric adaptations of the lower lumbar vertebrae.

Discussion

The present osteological study evaluated the morphometric characteristics of adult lumbar vertebrae (L1–L5) with emphasis on their relevance for identification of intervertebral spaces during spinal anesthesia. The vertebral specimens were almost equally distributed among all lumbar levels, allowing reliable inter level comparisons. Similar comprehensive evaluation of lumbar vertebrae has been reported by Megala et al.8 and Khatiwada et al.9, who included vertebrae from all lumbar levels in their morphometric analyses.

The present study demonstrated a progressive increase in vertebral body dimensions from L1 to L5. The transverse diameter increased from 41.2 ± 2.8 mm at L1 to 52.1 ± 3.8 mm at L5, while the anteroposterior diameter increased from 28.9 ± 1.9 mm to 35.2 ± 2.7 mm. Vertebral body height also increased steadily towards the lower lumbar vertebrae. These findings are consistent with the systematic review by Bonczar et al,[5] who reported progressive enlargement of vertebral body dimensions from the upper to lower lumbar spine. Similar observations have also been described by Ali and Azu et al,[10] in South Indian and South African populations, respectively. Such enlargement reflects the increasing biomechanical demands placed on the caudal lumbar vertebrae, which bear greater body weight.

In contrast to vertebral body dimensions, the anteroposterior diameter of the vertebral canal decreased progressively from L1 to L5, whereas the transverse diameter increased. Comparable findings have been reported by Banik and Rajkumari,[11] Nayak et al,[12] and Bonczar et al,[5] demonstrating a characteristic remodeling of the lumbar vertebral canal. This pattern of sagittal narrowing with transverse widening may represent an anatomical adaptation that preserves neural accommodation despite increasing vertebral size and is clinically important during neuraxial interventions and in the evaluation of lumbar spinal stenosis.

The posterior vertebral elements also showed characteristic morphometric changes. Spinous process length increased from L1 to L4 with a slight reduction at L5, whereas spinous process height and thickness increased progressively towards the lower lumbar vertebrae. Similar morphometric trends have been described by Megala et al.8 and Nayak et al.[12] The intervertebral notch also became progressively larger from L1 to L5, consistent with the observations of Khatiwada et al,[9] who reported enlargement of structures associated with the neural passage in the lower lumbar spine. These findings are relevant during spinal procedures, as enlargement of posterior elements influences needle trajectory and intervertebral space accessibility.

Statistically significant differences were observed in vertebral body dimensions, vertebral canal dimensions and spinous process orientation across lumbar levels ($p < 0.001$). Significant correlations were also identified between vertebral body and canal dimensions, with vertebral body transverse diameter demonstrating a negative correlation with canal anteroposterior diameter and a positive correlation with canal transverse diameter. Similar coordinated morphometric remodeling has been emphasized by Bonczar et al.[5] Furthermore, comparison between upper and lower lumbar vertebrae demonstrated significantly larger vertebral body and posterior element dimensions in the lower lumbar region, findings that agree with those reported by Azu et al,[13] and reflect functional adaptation to increasing mechanical stress.

Overall, the present study demonstrates consistent morphometric variation across lumbar vertebrae, characterized by progressive enlargement of vertebral body and posterior element dimensions, transverse widening of the vertebral canal, reduction in its anteroposterior diameter, and increasing horizontal orientation of spinous processes toward the lower lumbar spine. These findings provide clinically relevant anatomical information that may improve the accuracy of lumbar intervertebral space identification, facilitate safer spinal anesthesia, and assist spine surgeons during preoperative planning and instrumentation.

Conclusion

The present osteological study demonstrated significant level-dependent variations in the morphometry of lumbar vertebrae (L1–L5). Vertebral body dimensions increased progressively from the upper to the lower lumbar vertebrae, reflecting adaptation to increasing biomechanical load. In contrast, the vertebral canal exhibited a gradual reduction in anteroposterior diameter with a corresponding increase in transverse diameter, indicating characteristic remodeling of the lumbar canal. Progressive changes in the posterior vertebral elements and spinous process orientation further highlighted the anatomical differences among lumbar levels. These morphometric variations have important clinical implications for spinal anesthesia, as they influence accurate identification of lumbar intervertebral spaces, needle trajectory, and procedural safety. The findings provide baseline morphometric data for the North Indian population and may assist anesthesiologists, spine surgeons, and radiologists in improving the accuracy of lumbar interventions. Furthermore, these data contribute to the existing anatomical literature and may serve as a reference for future radiological, cadaveric, and clinical studies aimed at enhancing the safety and success of neuraxial procedures.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Sassack B, Carrier JD. Anatomy, Back, Lumbar Spine.In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2026 Jan-
2. Olawin AM, Das JM. Spinal Anesthesia. [Updated 2022 Jun 27]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-.
3. Hunie M, Fenta E, Kibret S, Teshome D. The Current Practice of Spinal Anesthesia in Anesthetists at a Comprehensive Specialized Hospital: A Single Center Observational Study. Local Reg Anesth. 2021 Mar 31;14:51-56. doi: 10.2147/LRA.S300054. PMID: 33833567; PMCID: PMC8020134.
4. Alam Z, Syed MU, Siddiqui TA, Gunturi A, Reddy B, Alam Z, Rahman AA. Spinal lesions: a comprehensive radiologic overview. Front Radiol. 2025 Jun 27;5:1577840. doi: 10.3389/fradi.2025.1577840. PMID: 40654524; PMCID: PMC12245835.
5. Bonczar, Michał & Koszewski, Jan & Czarnota, Wiktor & Bonczar, Martyna & Ostrowski, Patryk & Możdżeń, Kamil & Murawska, Agnieszka & Hajdyła, Paweł & Walocha, Andrzej & Walocha, Ewa & Walocha, Jerzy & Koziej, Mateusz. (2024). The morphology of the lumbar vertebrae: a systematic review with meta-analysis of 1481 individuals with implications for spine surgery. Surgical and Radiologic Anatomy. 47. 10.1007/s00276-024-03509-4.
6. Kim H, Won D, Chang JE, Lee JM, Ryu JH, Min SW, Jun K, Row HS, Hwang JY. Ultrasound assessment of the anatomic landmarks for spinal anesthesia in elderly patients with hip fracture: A prospective observational study. Medicine (Baltimore). 2019 Jul;98(27):e16388. doi: 10.1097/MD.0000000000016388. PMID: 31277196; PMCID: PMC6635173.
7. Mitra SR, Datir SP, Jadhav SO. Morphometric study of the lumbar pedicle in the Indian population as related to pedicular screw fixation. Spine (Phila Pa 1976). 2002 Mar 1;27(5):453-9. doi: 10.1097/00007632-200203010-00004. PMID: 11880829.
8. Megala S, Paventhan B, Subbulakshmi G, Amudha G. Clinical anatomy of the lumbar spine: a morphometric and radiological approach in a South Indian population. Int J Pharm Clin Res. 2024;16(7):1379–84.
9. Khatiwada S, Sudhin B, Pandey N, Shrestha I, Dhungel D. Morphometric study of lumbar vertebral pedicles. J Chitwan Med Coll. 2021;11:46–51. doi:10.54530/jcmc.315.
10. Ali SJ. Morphometric study of lumbar vertebrae in South Indian population. Biosci Biotechnol Res Commun. 2020;13(8):358–62. doi:10.21786/bbrc/13.8/163.
11. Banik S, Rajkumari A. Morphometric analysis of lumbar vertebrae and its applied clinical importance. Int J Anat Res. 2019;7:6381–6. doi:10.16965/ijar.2019.122
12. Nayak G, Panda S, Chinara PK. Morphometry of lumbar spine: a holistic comparative study between typical and atypical lumbar vertebrae. Int J Anat Radiol Surg. 2020;9(2):AO05–AO09. doi:10.7860/IJARS/2020/43367:2535.
13. Nayak G, Panda S, Chinara PK. Morphometry of lumbar spine: a holistic comparative study between typical and atypical lumbar vertebrae. Int J Anat Radiol Surg. 2020;9(2):AO05–AO09. doi:10.7860/IJARS/2020/43367:2535.