Research Article

LOCATING L4-L5 INTERVERTEBRAL SPACE AND ITS RELATION TO INTERCRISTAL LINE USING USG AMONG INDIAN POPULATION. A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Accurate identification of the L4–L5 intervertebral space is crucial for safe neuraxial anesthesia. The conventional palpation method using Tuffier's (intercristal) line is widely practiced; however, anatomical variations may lead to incorrect level identification. Ultrasound (USG) offers a more reliable alternative for precise localization, particularly in populations with variable anthropometry.

Aim: To evaluate the accuracy of palpation-based identification of the L4–L5 intervertebral space using the Tuffier's line and to assess its relationship with demographic and anthropometric factors using ultrasound guidance among the Indian population.

Methods: This prospective observational analytical study was conducted over 12 months at a tertiary care hospital in Mumbai. A total of **85 adult participants** undergoing preanesthetic evaluation were enrolled. Demographic variables and anthropometric measurements including weight, height, BMI, sitting height, and hip circumference were recorded. The L4–L5 interspace was identified using both palpation (Tuffier's line) and ultrasound guidance. The distance between the palpated Tuffier's line and the ultrasound-confirmed L4–L5 interspace was measured. Statistical analysis included descriptive statistics, correlation analysis, and appropriate tests of significance.

Results: Accurate alignment of the palpated Tuffier's line with the ultrasound-confirmed L4–L5 interspace was observed in only **3.5%** of participants, while **96.5%** showed misalignment. The mean distance between the Tuffier's line and the L4–L5 interspace was **4.3 ± 1.7 cm**, with a maximum displacement of **9 cm**. The Tuffier's line most commonly corresponded to the **L3–L4 (42%)** and **L2–L3 (40%)** interspaces. Significant correlations were observed between the distance of the L4–L5 interspace from the Tuffier's line and **weight, sitting height, and hip circumference**, whereas **age, sex, and BMI** did not show significant associations.

Conclusion: Palpation-based identification of the L4–L5 intervertebral space using the Tuffier's line is unreliable in the Indian adult population. Ultrasound guidance significantly improves accuracy and should be considered a valuable adjunct for neuraxial anesthesia, especially in patients with varying anthropometric profiles.

Keywords: Tuffier's line; L4–L5 intervertebral space; Ultrasound guidance; Neuraxial anesthesia; Anthropometry; Indian population.

INTRODUCTION

Neuraxial anaesthesia is one of the most commonly performed regional anaesthetic techniques in modern anaesthesia practice, particularly for obstetric, orthopedic, urological, and lower abdominal surgeries. Accurate identification of lumbar intervertebral spaces is crucial for the safe and effective administration of spinal and epidural anaesthesia, as incorrect level identification may result in inadequate block, failed procedures, or rare but serious neurological complications [1]. Traditionally, the **intercristal line (Tuffier's line)**—an imaginary line joining the highest points of the

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iliac crests—has been used as an external anatomical landmark to identify the L4 vertebral level or the L4–L5 interspace during palpation-based techniques [2].

Classical anatomical teaching suggests that Tuffier's line intersects the spine at the level of the L4 spinous process or the L4–L5 interspace. However, several cadaveric, radiological, and clinical studies have demonstrated substantial variability in this relationship, influenced by factors such as age, sex, posture, ethnicity, and body habitus [3,4]. Misidentification of lumbar levels using surface landmarks alone has been reported in up to 50–70% of cases, even among experienced anaesthesiologists, raising concerns regarding the reliability of palpation-based techniques [5].

The introduction of **ultrasound (USG) guidance** in regional anaesthesia has significantly enhanced the accuracy of anatomical localization. Ultrasound allows real-time visualization of vertebral structures, including spinous processes, laminae, interlaminar spaces, and the sacrum, thereby enabling precise identification of lumbar interspaces before needle insertion [6]. Several studies have shown that ultrasound-guided identification of lumbar interspaces is superior to palpation alone, particularly in patients with obesity, abnormal spinal anatomy, or poorly palpable landmarks [7].

Anthropometric parameters such as **weight, height, body mass index (BMI), sitting height, and hip circumference** have been shown to influence vertebral anatomy and surface landmark relationships. Increased adiposity, altered pelvic morphology, and changes in spinal curvature may shift the position of Tuffier's line relative to lumbar vertebrae, potentially leading to systematic errors during palpation-based localization [8]. Despite this, most routine clinical practices continue to rely on palpation without accounting for individual anthropometric variability.

Ethnic and population-specific anatomical variations further complicate the reliability of standard anatomical assumptions. Studies conducted in Western populations may not be directly applicable to the Indian population due to differences in body proportions, pelvic anatomy, and nutritional status [9]. Limited Indian data suggest that the position of Tuffier's line may frequently correspond to higher lumbar levels (L3–L4 or even L2–L3) rather than the traditionally assumed L4–L5 level, highlighting the need for population-specific evaluation [10].

Given the widespread use of neuraxial anaesthesia in India and the potential risks associated with incorrect lumbar level identification, it is essential to systematically evaluate the relationship between the L4–L5 intervertebral space and Tuffier's line using ultrasound guidance. Furthermore, understanding the influence of age, sex, and anthropometric factors on this relationship can help refine clinical practice, improve procedural safety, and promote the integration of ultrasound as a standard adjunct in preprocedural spinal assessment.

This study aimed to accurately locate the L4–L5 intervertebral space using ultrasound guidance and to evaluate its relationship with the traditionally palpated Tuffier's line in the Indian adult population. The objectives were to compare palpation-based and ultrasound-guided identification of the L4–L5 interspace and to assess the influence of demographic and anthropometric factors such as age, sex, weight, body mass index, sitting height, and hip circumference on the variability of this relationship. The findings of this study are expected to improve the accuracy of neuraxial anesthesia by highlighting the limitations of surface landmark techniques and supporting the routine use of ultrasound guidance, particularly in individuals with altered body habitus, thereby enhancing procedural safety and clinical outcomes.

MATERIALS AND METHODS
This prospective observational analytical study was conducted after obtaining approval from the Institutional Ethics Committee at a tertiary care hospital in Mumbai. The study was carried out over a period of **12 months** following ethics approval. Written informed consent was obtained from all participants prior to enrollment.

The study population comprised adult patients attending the **pre-anesthetic evaluation clinic (Anaesthesia OPD),** a tertiary care hospital in Mumbai. A total of **100 participants** were recruited using a **consecutive sampling method**. The sample size was calculated based on a correlation sample size formula using an expected correlation coefficient (r) of **0.3**, derived from previous studies, with a confidence level of **95% ($Z\alpha = 1.96$)** and power of **80% ($Z\beta = 0.84$)**. To account for possible dropouts, an additional 10–15% was added to the calculated sample size.

Demographic and anthropometric data including **age, sex, weight, height, sitting height, body mass index (BMI), and hip circumference** were recorded for all participants in a predesigned case record form. Depending on surgical requirements, patients requiring regional anesthesia were included for ultrasound assessment.

Initially, the **intercristal line (Tuffier's line)** was identified by palpation by the attending anesthesiologist, defined as the line joining the highest points of the iliac crests on both sides, and marked on the patient's back (Ti). Subsequently, ultrasound examination was performed using a **curvilinear probe** with a depth setting of **8–10 cm**, under strict aseptic precautions.

The ultrasound probe was first placed transversely over the sacral region and moved in a **cephalad direction**, identifying and marking each spinous process up to the thoracic region. A line connecting these spinous processes was drawn and

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labeled as **Ta**. The intersection point of the palpated intercristal line (Ti) and the ultrasound-identified spinous process line (Ta) was marked and designated as **Tai**.

Next, the probe was positioned in the **parasagittal plane**, approximately **3 cm lateral to the midline**, and tilted to obtain an oblique view of the laminae. The first lamina identified above the sacrum was labeled as **L5**, and successive laminae were identified cranially up to L1. The midpoint between the L4 and L5 laminae was marked as the **L4–L5 intervertebral space**. The **distance between Tai and the ultrasound-identified L4–L5 interspace** was measured in centimeters and recorded.

All measurements were documented systematically. Statistical analysis was performed using appropriate software. Continuous variables were expressed as **mean and standard deviation**, while categorical variables were expressed as **frequencies and percentages**. Correlation between anthropometric variables and the distance between the L4–L5 interspace and Tuffier's line was assessed using **Pearson correlation analysis**. Comparison between groups was performed using **unpaired t-test** and **ANOVA**, wherever applicable. A **p-value < 0.05** was considered statistically significant.

RESULT

A total of **100 adult patients** undergoing pre-anaesthetic evaluation were included in this prospective observational study. The **mean age** of the study population was **40.28 ± 13.39 years**, with the majority belonging to the **30–45-year age group (36.5%)**, followed by **18–30 years (30.6%)**. Males constituted **63.5%** of participants, indicating a male predominance. Most participants had a **normal BMI (18.5–24.9 kg/m²)**, accounting for **62.4%**, while **23.5%** were overweight and **8.2%** were obese.

Ultrasound assessment revealed a marked discrepancy between palpation-based identification of the L4–L5 intervertebral space and its true anatomical location. Accurate localization of the L4–L5 interspace at the level of the palpatory Tuffier's line was observed in only **3.5%** of cases, while **96.5%** showed misalignment. The **mean distance** between the palpatory Tuffier's line and the ultrasound-identified L4–L5 interspace was **4.3 ± 1.7 cm**, with a **median distance of 4 cm (IQR: 3–5 cm)**. The maximum observed deviation was **9 cm**, highlighting substantial anatomical variability.

Analysis of vertebral level alignment demonstrated that the Tuffier's line most commonly corresponded to the **L3–L4 interspace (42%)**, followed by the **L2–L3 interspace (40%)**. Only **3%** of participants had the Tuffier's line aligned with the true **L4–L5 interspace**, while **15%** showed no consistent alignment with standard lumbar interspaces, emphasizing the unreliability of palpation alone for accurate lumbar level identification.

Statistical analysis revealed that **weight (r = 0.220, p = 0.043)** and **hip circumference (r = 0.472, p = 0.002)** had a **significant positive correlation** with the distance between the L4–L5 interspace and the Tuffier's line. In contrast, **age (p = 0.341)**, **sex (p = 0.757)**, **BMI (p = 0.133)**, and **sitting height (p = 0.148)** did not show a statistically significant association. These findings indicate that increased body habitus, particularly greater weight and hip circumference, significantly influences the positional discrepancy between the palpatory landmark and the actual L4–L5 interspace.

Table 1. Demographic and Anthropometric Profile of Study Participants (n = 100)

Variable	Category / Mean ± SD	n (%)
Age (years)	40.28 ± 13.39	—
	18–30	26 (30.6)
	30–45	31 (36.5)
	45–60	22 (25.9)
	>60	6 (7.1)
Sex	Male	54 (63.5)
	Female	31 (36.5)
BMI (kg/m²)	<18.5	5 (5.9)
	18.5–24.9	53 (62.4)
	25–29.9	20 (23.5)
	≥30	7 (8.2)

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Table 2. Ultrasound-Based Localization of L4–L5 Interspace and Relationship with Tuffier's Line

Parameter	Result
Accurate palpation of L4–L5 at Tuffier's line	3 (3.5%)
Inaccurate palpation	82 (96.5%)
Mean distance of Tuffier's line from L4–L5 (cm)	4.3 ± 1.7
Median distance (IQR)	4 (3–5)
Maximum observed distance (cm)	9.0
Most common vertebral level of Tuffier's line	L3–L4 (42%)
Second most common level	L2–L3 (40%)
Tuffier's line at true L4–L5 level	3%
Unaligned with standard lumbar levels	15%

Table 3. Test of Significance: Association Between Anthropometric Factors and Distance of L4–L5 from Tuffier's Line

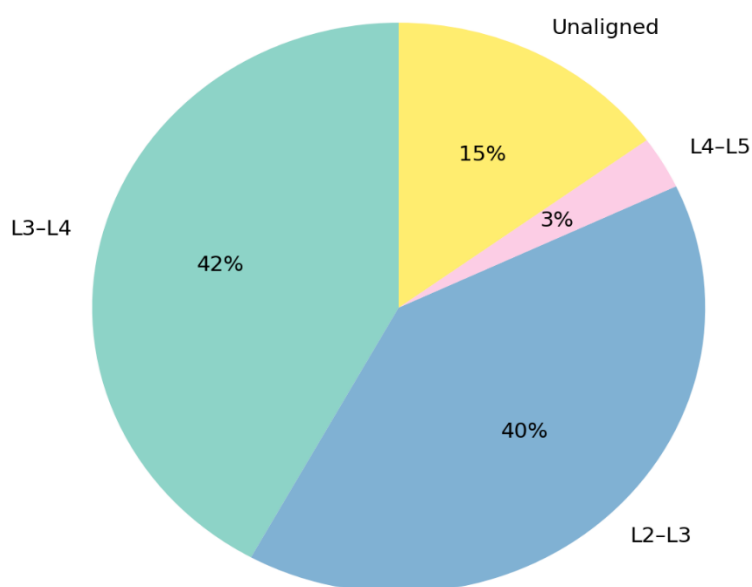| Variable	Test Applied	Value	p-value	Interpretation
Sex vs distance	Unpaired t-test	—	0.757	Not significant
BMI vs distance	One-way ANOVA	—	0.133	Not significant
Weight vs distance	Pearson correlation ($r = 0.220$)	—	0.043	**Significant**
Sitting height vs distance	Pearson correlation ($r = 0.158$)	—	0.148	Not significant
Hip circumference vs distance	Pearson correlation ($r = 0.472$)	—	0.002	**Significant**
Age vs distance	Pearson correlation ($r = 0.104$)	—	0.341	Not significant

Figure 1: Variation of Tuffler's Line with Respect to Intervertebral Spaces (n= 85)

DISCUSSION

In the present prospective observational study, ultrasound-based localization of the L4–L5 intervertebral space demonstrated a substantial discrepancy from the traditionally palpated Tuffier's line. Accurate alignment of the palpatory Tuffier's line with the true L4–L5 interspace was observed in only **3%** of participants, whereas **96.5%** showed misalignment. The mean distance between the palpated Tuffier's line and the ultrasound-identified L4–L5 interspace was **4.3 ± 1.7 cm**, highlighting the unreliability of surface landmark techniques in the Indian adult population.

These findings are consistent with those reported by **Broadbent et al.**, who demonstrated that palpation-based identification of lumbar interspaces was inaccurate in nearly **50–70%** of cases when validated against imaging modalities

[11]. Similarly, **Schlotterbeck et al.** reported frequent misidentification of lumbar levels using anatomical landmarks, particularly in patients with altered body habitus [12]. Compared to these studies, the degree of inaccuracy observed in the present study appears even higher, possibly reflecting ethnic, anthropometric, and population-specific anatomical variations.

The present study found that the Tuffier's line most commonly corresponded to the **L3–L4 interspace (42%)**, followed by **L2–L3 (40%)**, while alignment with L4–L5 was rare **(3%)**. These findings closely mirror observations by **Chakraverty et al.**, who reported that the intercristal line frequently crossed the spine at higher lumbar levels than traditionally assumed, most commonly at L3–L4 [13]. Indian studies using ultrasound and MRI have similarly shown cranial displacement of the Tuffier's line in a majority of adults, reinforcing the limited reliability of palpation-based methods in this population [14].

Anthropometric analysis in this study demonstrated that **weight (r = 0.220, p = 0.043)** and **hip circumference (r = 0.472, p = 0.002)** were significantly correlated with increased distance between the Tuffier's line and the L4–L5 interspace. In contrast, **age, sex, BMI, and sitting height** did not show statistically significant associations. These findings align with those of **Kim et al.**, who reported that increased body mass and pelvic dimensions significantly altered surface landmark accuracy during neuraxial procedures [15]. The stronger correlation observed with hip circumference in the present study suggests that pelvic anatomy may play a more critical role than generalized adiposity in determining landmark displacement.

Several ultrasound-based studies have emphasized the superiority of sonographic guidance in accurately identifying lumbar interspaces. **Furness et al.** demonstrated that pre-procedural ultrasound significantly improved the accuracy of lumbar puncture level identification and reduced the number of attempts and complications [16]. Likewise, **Perlas et al.** highlighted that ultrasound provides a reliable, reproducible method for neuraxial landmark identification, particularly in patients with difficult anatomy [17]. The findings of the present study further strengthen this evidence, especially in the context of Indian patients, where anatomical variability appears pronounced.

From a clinical safety perspective, incorrect identification of lumbar interspaces has important implications. Higher-than-intended needle insertion levels increase the risk of spinal cord or conus medullaris injury, particularly in adults where the conus may extend as low as L2–L3. **Reynolds** reported catastrophic neurological complications following spinal anesthesia attributed to unintentional high-level needle placement based on incorrect surface landmark identification [18]. The present study's observation that only **3%** of palpation-based identifications correctly matched the L4–L5 interspace underscores the potential risk associated with exclusive reliance on anatomical landmarks.

Overall, when compared with existing literature, this study confirms that palpation-based identification of the L4–L5 interspace is highly unreliable in the Indian population and that anthropometric factors—particularly weight and hip circumference—significantly influence this discrepancy. Ultrasound guidance provides a more accurate and safer alternative for neuraxial procedures and should be increasingly incorporated into routine anaesthetic practice, especially in patients with non-ideal anatomy.

CONCLUSION
This prospective observational study demonstrates that palpation-based identification of the L4–L5 intervertebral space using the Tuffier's line is highly unreliable in the Indian adult population. Accurate alignment of the palpated intercristal line with the ultrasound-confirmed L4–L5 interspace was observed in only **3%** of participants, with the majority showing cranial displacement of the landmark, most commonly at the **L3–L4 (42%)** and **L2–L3 (40%)** levels. Anthropometric factors such as **weight, sitting height, and hip circumference** showed significant correlation with the degree of displacement, while age, sex, and BMI did not demonstrate a consistent association. These findings highlight substantial anatomical variability and underscore the superiority of **ultrasound guidance** over surface landmark techniques for accurate localization of lumbar interspaces, thereby enhancing the safety and precision of neuraxial anesthesia.

LIMITATIONS
The study has certain limitations that should be acknowledged. First, it was conducted at a **single tertiary care center**, which may limit the generalizability of the findings to other populations or clinical settings. Second, although ultrasound provides accurate localization, **inter-observer variability** was not formally assessed, as all measurements were performed by a limited number of trained anesthesiologists. Third, the study population consisted of adults presenting for pre-anesthetic evaluation, and the findings may not be directly applicable to **pregnant patients, pediatric populations, or patients with spinal deformities**. Finally, radiological confirmation using MRI or CT was not performed, and ultrasound was considered the reference standard.

RECOMMENDATIONS
Based on the findings of this study, **routine reliance on palpation-based identification of lumbar interspaces should be discouraged**, particularly in patients with higher body weight or altered pelvic anatomy. **Pre-procedural ultrasound guidance** should be increasingly incorporated into routine anesthetic practice for neuraxial blocks to improve accuracy,

reduce needle-related complications, and enhance patient safety. Future research should focus on **multicentric studies with larger sample sizes**, inclusion of special populations such as obstetric and obese patients, and assessment of **learning curves and inter-observer reliability** of ultrasound-guided techniques. Incorporation of ultrasound training into **anesthesiology residency programs** is also recommended to standardize practice and improve clinical outcomes.

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