Research Square

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A Dual-landmark Palpation Protocol Integrating the Intercristal and PSIS Lines for Improved L3/4 Interspinous Space Localization

Xiaotong Yi
The Third Affiliated Hospital of Guangzhou Medical University
Liping He
The Third Affiliated Hospital of Guangzhou Medical University
Yanli Tang
The Third Affiliated Hospital of Guangzhou Medical University
Tianyin Gao
The Third Affiliated Hospital of Guangzhou Medical University
Xianbao Liu
The Third Affiliated Hospital of Guangzhou Medical University
Shouping Wang
The Third Affiliated Hospital of Guangzhou Medical University
Wenhua Zhang
Wenhuazhangoo@126.com
The Third Affiliated Hospital of Guangzhou Medical University

Research Article

Keywords: The posterior superior iliac spine, Localization, Intercristal line, L3/4 interspinous space, Neuraxial anesthesia

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10631516/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Palpation-based L3/4 localization using the intercristal line is often inaccurate. This two-phase study quantified the position of the L3/4 interspinous space relative to the posterior superior iliac spine (PSIS) line in pregnant women, and developed and validated a novel palpation protocol.

Methods

We enrolled 642 parturients. Phase 1 measured PSIS-to-L3/4 and PSIS-to-intercristal line (PI) distances, analyzed their spatial relationship, and developed a palpation protocol stratified by PI distance into three categories. Phase 2 compared the accuracy of the resulting dual-landmark protocol against the conventional intercristal line method, using ultrasound confirmation.

Results

The L3/4 distance (8.0 ± 0.92 cm) correlated with maternal height and PI distance (8.2 ± 1.25 cm), but not with other anthropometrics. The PI-to-L3/4 (I-L) distance averaged − 0.1 ± 1.10 cm and was strongly correlated with PI distance. A PI-stratified protocol was developed: select the interspace at/below the PI line if PI ≥ 9 cm; at/above if PI ≤ 7 cm; for PI 7–9 cm, apply a 6.5–10 cm window from the PSIS line, selecting the single interspace within it or the most caudal if multiple are present. In Phase 2, the protocol achieved 95.7% accuracy, significantly outperforming the conventional method (69.1%).

Conclusions

A dual-landmark (PSIS/PI) palpation protocol provides significantly more accurate and reliable L3/4 localization than the conventional intercristal line method in parturients.

Clinical trial registration

ClinicalTrials.gov, NCT06711601. Registered 18 November 2024, https://clinicaltrials.gov/study/

Key message

- The intercristal (Tuffier's) line frequently results in inaccurate localization of the L3/4 interspace, particularly in pregnant women, leading to spinal level misidentification.

- A dual-landmark palpation protocol, utilizing both PSIS and PI lines, achieves superior accuracy in locating the L3/4 interspinous space compared to the traditional single-line method.

The dual-landmark protocol achieved 95.7% accuracy in L3/4 localization, significantly outperforming the conventional single-landmark method, and offers a simple, bedside-adoptable alternative that could reduce neuraxial block failure and complications.

Introduction

Neuraxial anesthesia for cesarean delivery or vaginal birth requires precise identification of the L3/4 intervertebral space. The intercristal (Tuffier's) line is the most common anatomical landmark[1–3]. however, it aligns with vertebral bodies rather than interspinous spaces, creating a fundamental mismatch between surface anatomy and the needle target[3, 4]. Furthermore, its accuracy is affected by obesity, degenerative changes, and patient positioning[5–7]. In late pregnancy, this line often corresponds to L3 or L3/4, prompting many clinicians to intentionally select a space below the palpated line to avoid the risk of spinal cord injury from an inadvertently high puncture at L2/3[8, 9]. To avoid the risk of spinal cord injury from an inadvertently high puncture at L2/3, many clinicians intentionally select an interspace below the palpated intercristal line. While this strategy enhances safety, it paradoxically increases the risk of mistaking L4/5 for L3/4, potentially leading to failed or inadequate anesthesia.

The posterior superior iliac spine (PSIS) is a stable bony landmark with a consistent relationship to the sacrum. Previous studies have demonstrated that the PSIS line most commonly intersects the S2 spinous process in approximately 81% of individuals, suggesting its potential as a reliable baseline for vertebral level identification[10–13]. Although it provides a reliable caudal baseline, difficulty palpating the lower lumbar spaces (L4/5 and L5/S1) due to adipose tissue often limits its utility for sequential upward identification of the target space.

To address these limitations, we hypothesized that a stable quantitative relationship exists between the PSIS and the L3/4 interspinous space (L3/4 distance). We proposed that by utilizing ultrasound to define this numerical range, anesthesiologists could bypass unreliable lower palpation and directly target L3/4. Furthermore, we hypothesized that integrating the PI distance (from PSIS to the intercristal line) with the PSIS line into a dual-landmark approach would achieve precise and reliable L3/4 localization.

Methods

Study Registration and Ethical Oversight

This prospective observational study was approved by the Institutional Review Board of The Third Affiliated Hospital of Guangzhou Medical University on August 26, 2024 (approval number: Linlun-Shen-Yanbei [2024] No. 328). The study was registered with ClinicalTrials.gov (NCT06711601) on November 18, 2024. The first participant was enrolled on December 1, 2024, and the last participant completed the study on December 30, 2025. Written informed consent was obtained from all participants prior to enrollment.

Participant Recruitment and Study Design

We enrolled parturients aged 22–45 years with singleton gestations of 37–42 weeks scheduled for epidural or combined spinal-epidural analgesia. Exclusion criteria included a BMI ≥ 40 kg/m^2 (to minimize palpation-related variability), a history of lumbar surgery or structural deformity (e.g., scoliosis, spondylolisthesis, or vertebral compression fractures), inability to maintain the flexed lateral decubitus position, voluntary withdrawal, and unexpected anatomical abnormalities identified during screening.

Participants were placed in the flexed lateral decubitus position with head support and maximal flexion of the neck, back, buttocks, and knees. An assistant stabilized the patient to maintain alignment. The PSIS line was identified and marked by two anesthesiologists following a three-step protocol: visual localization of the skin dimple, palpatory confirmation of the bony prominence, and final skin marking. Similarly, the PI line was identified and marked by bilateral palpation of the iliac crest summits. Subsequently, two reference points were defined: point PSIS (intersection of the PSIS line with the midline) and point PI (intersection of the PI line with the midline). Three distances were calculated: L3/4 distance (L3/4 midpoint to point PSIS), PI distance (point PI to point PSIS), and I-L distance (L3/4 midpoint to point PI).

Using a convex array probe (Versana Active™, 4C-RS; GE Healthcare, Wauwatosa, WI, USA), ultrasound localization proceeded as follows: the probe was initially angled at 45° along the superior iliac crest to visualize the caudal hyperechoic ilium, then moved medially to identify the L5 transverse process. After rotating parallel to the spine, it was slid cephalad to locate the L4 transverse process. The L3/4 interspace was subsequently identified by aligning its interlaminar space horizontally with the superior margin of the L4 transverse process[14, 15].

Phase 1: Observational study

We aimed to quantify the L3/4 and PI distances and to evaluate the correlation of the L3/4 distance with maternal anthropometrics and the PI distance. A specialist anesthesiologist performed the ultrasound-guided L3/4 localization. Subsequently, a trained anesthesiologist executed palpation and marking, with distance measurements then taken jointly by the two anesthesiologists and a specialized nurse. All measurements were performed in duplicate, and the mean was used for subsequent analysis.

Phase 2: Validation Study

Based on an interim analysis of Phase 1 data, we established the following decision protocol for L3/4 interspinous space localization:

1. PI ≥ 9 cm: Select the interspace at or immediately below the PI line.
2. PI ≤ 7 cm: Select the interspace at or immediately above the PI line.
3. PI 7–9 cm: Apply a 6.5–10 cm target window from the PSIS point.

- – If one interspace lies within this window, select it.

- – If multiple interspaces are present, choose the most caudal one.

We employed a modified intercristal line palpation protocol (adapted from Kim et al.[16]), selecting either the interspace intersected by the line or the one immediately caudal to it. To prevent bias, an attending anesthesiologist performed an initial ultrasound to identify the true L3/4 space (this finding was concealed). Two blinded anesthesiologists then independently palpated the L3/4 interspinous space: one using the PSIS and PI line (markings removed afterward) and the other using the PI line, who was also blinded to the ultrasound result. We collected participant characteristics and recorded the intersected vertebral level and palpation accuracy for analysis.

Outcome Measures

The primary outcome was the accuracy of L3/4 localization using the dual-landmark protocol in Phase 2 (proportion correct by ultrasound). Secondary outcomes included: (1) L3/4 and PI distances in Phase 1; (2) associations of L3/4 distance with maternal anthropometrics and PI distance; (3) I-L distance and its association with PI distance; and (4) performance of the PI-stratified protocol.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics 26.0. Continuous variables are presented as mean ± SD. Stepwise multiple linear regression evaluated associations between L3/4 distance and PI distance plus maternal anthropometrics (age, height, weight, waist circumference). The chi-square test compared proportions between groups. Sample size for Phase 2 was based on an estimated discordant pair proportion of 27% (from Phase 1 pilot data). Using a two-sided McNemar test ($\alpha = 0.05$, power = 90%), a minimum of 87 paired observations was required (PASS 15.0); we enrolled 230 participants, providing > 99% power. Statistical significance was defined as two-tailed $p < 0.05$.

Result

After excluding eight women in whom the target interspinous space was unpalpable, 642 of the initially recruited 650 participants were included in the final analysis. Table 1 summarizes their baseline characteristics.

Table 1
Baseline characteristics of the study participants (mean ± SD).

Phase1 (n = 412)	Age (year)	Gestational age (Week)	Height (cm)	Weight (Kg)	Waist circumstance (cm)	BMI (kg/m^2)
	32 ± 4.0	**39 ± 1.3**	**159 ± 5.2**	**67 ± 8.7**	**100 ± 6.6**	**27 ± 3.1**
Phase2 (n = 230)	32 ± 3.9	38 ± 0.9	160 ± 5.6	67 ± 8.3	99 ± 8.4	26 ± 3.0

Mean L3/4 distance was 8.0 ± 0.92 cm (range 5.5–10.5; 94.7% within 6.5–10 cm). Mean PI distance was 8.2 ± 1.25 cm (range 4.8–12; 97.1% within 6–11 cm) (Fig. 1).

Figure 1. The histograms show that most measurements clustered near the mean (L3/4: 8.0 cm; PI: 8.2 cm), with 94.7% of L3/4 values within 6.5–10.0 cm and 97.1% of PI values within 6.0–11.0 cm. This narrow distribution indicates that, despite individual variability, these anatomical landmarks offer a predictable reference for epidural space localization.

In stepwise regression, maternal height and PI line distance were significant predictors of L3/4 distance ($R^2 = 0.293$). PI distance had a larger coefficient (0.361 vs. 0.028 for height; both $p < 0.05$); weight, age, and abdominal circumference were excluded (all $p > 0.05$). Detailed results are shown in Table 2.

Table 2
Stepwise Multiple Linear Regression: L3/4 Distance vs. Maternal Height and PI Line Distance (n = 412)

Model (line)	Unstandardized Coefficients		95.0% Confidence Interval for B		Standardized Coefficients (Beta)	Sig. (p-value)
	B	Standard Error	Lower Bound	Upper Bound		
Constant	0.586	1.169				0.617
PI-line	0.361	0.031	0.3	0.423	0.489	< 0.05
Height	0.028	0.007	0.014	0.043	0.160	< 0.05

- L distance (L3/4 position minus PI position) was − 0.1 ± 1.10 cm (range − 3.1 to 3.5 cm). A linear regression revealed a negative correlation between I-L and PI distances. The inflection point occurred at approximately 8 cm (Fig. 2). This pattern formed the basis of the PI-stratified protocol.

Figure 2. The regression equation is $Y = - 0.6179X + 4.915$ ($R^2 = 0.49$), indicating a negative correlation. The I-L distance crosses zero at PI ≈ 8 cm. For PI < 8 cm, I-L is typically positive (L3/4 superior to the PI line); for PI > 8 cm, I-L is typically negative (L3/4 inferior to the PI line). This relationship informs the PI-stratified protocol.

The L3/4 distances, stratified by PI distance (≥ 9 cm, 7–9 cm, or ≤ 7 cm), are summarized in Table 3. The stratification of interspinous space distribution by intercristal line is shown in Table 4. The non-linear fit of L3/4 distance probability distributions, stratified by PI Distance, is shown in Fig. 3.

Table 3
L3/4 Distance Stratified by PI Line (n = 412)

PI Line	Mean ± SD (cm)	ange (Min–Max)(cm)	Skewness	Kurtosis	Total
≤ 7 cm	7.4 ± 0.87	5.5–9.5	-0.01	-0.763	93
7–9 cm	7.9 ± 0.71	6.0–10.0	-0.02	0.304	194
≥ 9 cm	8.6 ± 0.90	6.0–10.5	0.03	-0.214	125

Table 4
Interspinous Space Distribution Stratified by PI Distances (≤ 7 cm, 7–9 cm, ≥ 9 cm) for Phase 1 (n = 412) and Phase 2 (n = 230)

Trail	≤ 7 cm			7–9 cm			≥ 9 cm			
	L2/3	L3/4	L4/5	L2/3	L3/4	L4/5	L2/3	L3/4	L4/5	total
Phase 1	5	86	2	0	190	4	6	110	9	412
Phase 2	3	61	2	2	115	0	1	44	2	230

Figure 3 The y-axis represents relative frequency, and the x-axis represents the L3/4 distance.

In Phase 2 (n = 230), our dual-landmark palpation protocol achieved significantly higher accuracy for L3/4 interspace localization compared to the conventional single line method (Table 5).

Table 5
Dual-Landmark Protocol Versus Conventional Palpation for L3/4 Interspace Identification (n = 230)

Protocol	L4/5	L3/4	L2/3
PI line-only	70 (30.4%)	159(69.1%)	1(0.4%)
Dual-landmark	4 (1.7%)	220(95.7%)	6(2.6%)

Discussion

Our study revealed that L3/4 distance was correlated with height and PI distance. but not with age, weight or abdominal circumference. Furthermore, a linear relationship was identified between the PI distance and the I-L distance. Based on this relationship, we developed a novel three-category protocol (PI distance: ≤7 cm, 7–9 cm, ≥ 9 cm) for L3/4 localization, which was validated in Phase 2 with an accuracy of 95.7%.

Body weight is traditionally considered a factor affecting L3/4 localization in overweight populations, largely because subcutaneous tissue thickness displaces the PI line cephalad[4, 17]. In contrast, we found no correlation between L3/4 distance and maternal weight or abdominal circumference, likely attributable to the PSIS serving as a more stable landmark less influenced by adiposity. However, the evidence regarding the impact of obesity on lumbar localization in pregnant women remains inconsistent, possibly due to variations in iliac crest palpation technique or protocol across studies[5, 9, 17, 18].

Vertebral disc dehydration and age-related height loss have been linked to L3/4 localization accuracy in women over 50, but this association is generally absent in younger populations[19]. In our cohort of parturients aged 22–40 years, maternal age showed no correlation with L3/4 distance. Nevertheless, maternal height demonstrated a positive, albeit weak, correlation (B = 0.028), consistent with findings from a prior study in term pregnant women[17]. The clinical relevance of this height-related effect appears negligible within the studied range. However, it may warrant consideration in parturients taller than 175 cm.

Imaging studies have confirmed that the position of the intercristal line follows a normal distribution when measured in vertebral segments rather than as an absolute distance [8, 17]. but the distribution of the L3/4 distance has remained unclear. To our knowledge, this is the first study to demonstrate that the L3/4 distance, measured from the PSIS line in the flexed lateral decubitus position, also follows a normal distribution. This finding clarifies how the L3/4 distance varies across the population and enables more precise analysis of its relationship with the PI line.

The linear I-L vs. PI relationship helps define the L3/4 interspinous space position relative to the PI line. Using 8 cm as a threshold (Fig. 2): when PI distance > 8 cm, L3/4 typically lies below the intercristal line and deviates farther as PI distance increases; when PI distance < 8 cm, L3/4 generally lies above and shifts farther as PI distance decreases. Based on these findings, we developed a simple, clinically practical protocol that accommodates this variability.

When the PI distance is ≤ 7 cm (93/412), the L3/4 interspinous space is typically at or above the PI line (I-L < 3 cm). In the uncommon event (5.4%, 5/93) that L3/4 lies below the line, selecting the space above risks misidentifying L2/3 as L3/4. Since no L3/4 distance exceeded 9.5 cm in this range (range 5.5–9.5 cm; 0/93), a measured distance ≥ 9.5 cm warrants ultrasound confirmation.

When the PI distance is ≥ 9 cm (125/412), the L3/4 interspinous space is typically at or below the PI line. However, when L3/4 lies above (7.2%, 9/125), selecting the space below risks misidentifying L4/5 as L3/4. Given the L3/4 range of 6.0-10.5 cm, a measured distance ≤ 6.5 cm (2/125) or ≥ 10.5 cm (5/125) warrants ultrasound confirmation to avoid incorrect level identification.

When the PI distance is 7–9 cm (194/412), the L3/4 interspace is most often within ± 2 cm of the PI line, making a simple above/below strategy unreliable. However, 94.7% (390/412) of L3/4 distances fell

within 6.5–10 cm (97.9% in the 7–9 cm PI subgroup), forming a high-probability window. If a single interspinous space lies within this window, it can be reliably identified as L3/4; if multiple are present, the most caudal one is selected. This stratified approach demonstrated high reliability in Phase 2.

Phase 2 confirmed a 95.7% success rate for L3/4 localization using this protocol. While most misidentified levels could be excluded based on the normal L3/4 distance range, a subset of cases, particularly those with extreme L2/3 values overlapping the normal L3/4 range, could not be reliably filtered by distance criteria alone and warrant further investigation.

Conclusion

In summary, This study first established the PSIS line as an anatomical baseline to quantify both the L3/4 and PI distances, revealing a linear relationship between them. By integrating these measurements, we developed and validated a dual-land palpation protocol and validated its superiority over the conventional method relying solely on the PI line.

Abbreviations

PSIS
The posterior superior iliac spine
PI
PSIS-to-intercristal line
I-L
PI-to-L3/4

Declarations

Authors and Affiliations

The Department of Anesthesiology and Perioperative Services, Guangdong Provincial Key Laboratory of Major Obstetric Diseases; Guangdong Provincial Clinical Research Center for Obstetrics and Gynecology; The Third Affiliated Hospital of Guangzhou Medical University, Guangzhou, 510150,China.

Xiaotong Yi, Liping He, Yanli Tang, Tianyin Gao, Xianbao Liu, Shouping Wang, Wenhua Zhang.

Contributions

Conceptualization: Wenhua Zhang and Xiaotong Yi; Data acquisition: Xiaotong Yi, Liping He, Yanli Tang and Tianyin Gao,; Formal Analysis:Wenhua Zhang; Writing—Original Draft: Wenhua Zhang and Xiaotong Yi; Writing—Review & Editing: All authors.

Corresponding authors

Correspondence to Wenhua Zhang.

Ethics declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of The Third Affiliated Hospital of Guangzhou Medical University on August 26, 2024 (approval number: Linlun-Shen-Yanbei [2024] No. 328). The study was registered with ClinicalTrials.gov (NCT06711601) on November 18, 2024.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Funding

No funding received.

Author Contribution

Conceptualization: Z. and Y.; Data acquisition: Y., H., T. and G.,; Formal Analysis:Z.; Writing—Original Draft: Z. and Y.; Writing—Review & Editing: All authors.

Acknowledgments

We are grateful to Prof Ziqing Hei (Department of Anesthesiology, The Third Affiliated Hospital of Sun Yat-sen University) for his critical comments during manuscript preparation, and all the authors thank Prof Lan Jiang and Jiayun Zhang (Department of Medical Imaging, The Third Affiliated Hospital of Guangzhou Medical University) for his kind help during the course of the study.

Data availability

The deidentified participant data, study protocol, and statistical analysis plan will be made available from the corresponding author upon reasonable request.

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Figures

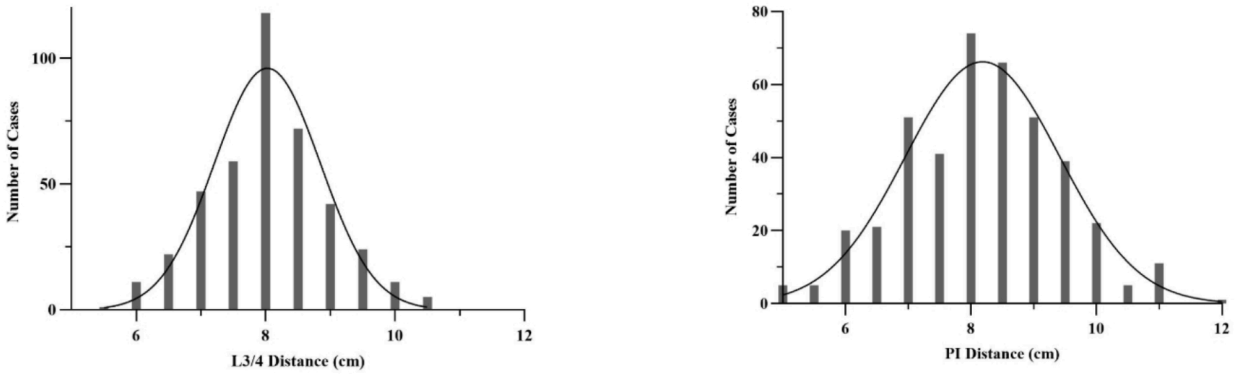


Figure 1

Fitted Distributions of L3/4 and PI Distances (n=412).

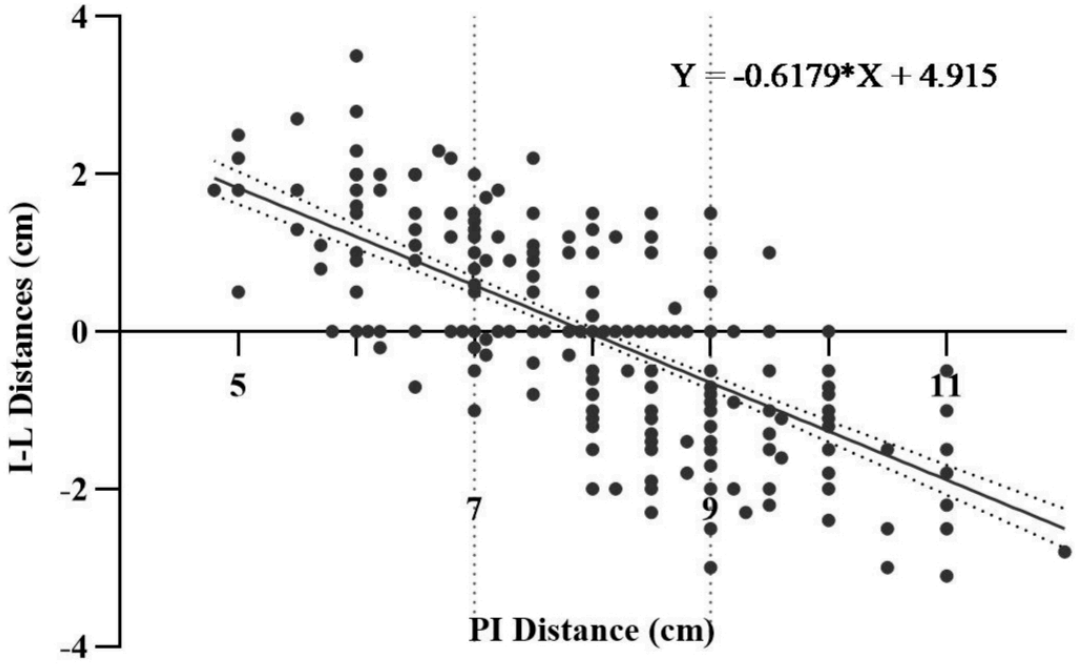


Figure 2

Scatter Plot with Linear Fit of I-L Distance Against PI Distance (R^2 = 0.49).

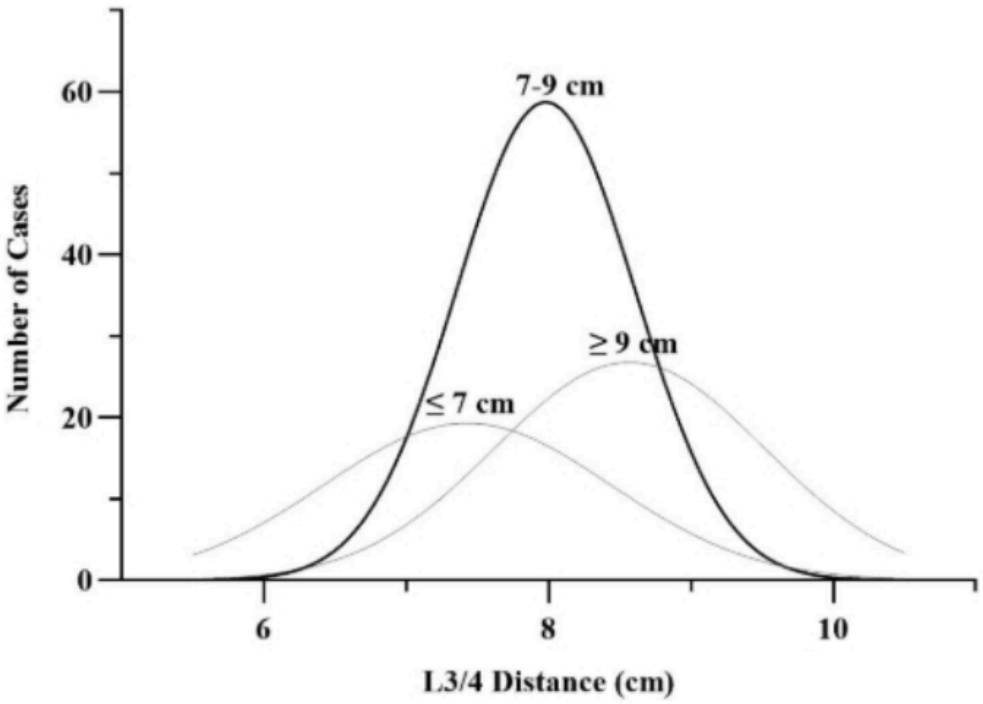


Figure 3

Distribution of L3/4 Distances across PI Distance Strata (n=412)