Section Editor: **Cynthia A. Wong**

Ultrasound Assessment of the Vertebral Level of the Intercristal Line in Pregnancy

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Conferencia Zacatecas

BACKGROUND: The intercristal line is known to most frequently cross the L4 spinous process or L4-5 interspace; however, it is speculated to be positioned higher during pregnancy because of the exaggerated lumbar lordosis. Clinical estimation of vertebral levels relying on the use of the intercristal line has been shown to often be inaccurate. We hypothesized that the vertebral level of the intercristal line determined by palpation would be higher than the level determined by ultrasound in pregnant women.

METHODS: Fifty-one term pregnant patients were recruited. Two experienced anesthesiologists performed estimates of the position of the intercristal line by palpation. Using ultrasound, another anesthesiologist who was blinded to the clinical estimates, determined the position of the superior border of the iliac crest in the transverse and longitudinal planes and then identified the lumbar vertebral levels. The vertebral level at which the clinical estimates of the intercristal line crossed the spine was recorded and compared with the ultrasound-determined level of the superior border of the iliac crest.

RESULTS: The clinical estimates of the spinal level of the intercristal line agreed with the ultrasound measurement 14% of the time (14 of 101; 95% confidence interval [CI]: 8%, 22%). The clinical estimates were 1 level higher than the ultrasound measurement 23% of the time (23 of 101; 95% CI: 16%, 32%) and $>$1 level higher 25% of the time (25 of 101; 1-tailed 95% CI: $>$18%). The distribution of the clinical estimates found clinicians locating the intercristal line at L3 or L3-4 54% of the time (54 of 101; 95% CI: 44%, 63%) and at L2-3 or higher 27% of the time (27 of 101; 1-tailed 95% CI: $>$20%).

CONCLUSION: The anatomical position of the intercristal line was at L3 or higher in at least 6% of term pregnant patients using ultrasound. Clinical estimates were found to be $\geq$1 vertebral level higher than the anatomical position determined by ultrasound at least 40% of the time. This disparity may contribute to misidentification of lumbar interspaces and increased risk of neurologic injury during neuraxial anesthesia. (Anesth Analg 2011;113:559–64)

The imaginary horizontal line connecting the superior aspect of the posterior iliac crests, known as Tuffier's line, Jacoby's line, or the intercristal line, has long been used as an anatomical landmark for the estimation of vertebral levels during placement of neuraxial anesthesia. This is not just an interesting anatomical landmark; it is an issue of great concern for patient safety. Correct identification of vertebral levels is essential to avoid needle trauma to the spinal cord during these procedures. There are numerous reports of major morbidity when the vertebral level is misidentified during the placement of spinal block.[1,2] These cases, although rare, continue to occur and incorrect identification of the vertebral level can have dire and permanent consequences. In addition to the neurologic consequences, the cephalad extent of sensory blockade is related to the level at which injection is performed.[3,4]

In 1899, Jacoby described the line joining the top of the iliac crests as passing through the L4 vertebral body, and this observation has subsequently been verified multiple times.[5,6] It is speculated that, during pregnancy, the intercristal line is positioned higher than the L4 or L5 vertebral levels.[7] Clinical estimation of the intercristal line using anatomical landmarks may be inaccurate. The aim of this study was to compare the vertebral levels of clinical estimates of the intercristal line with the level determined by ultrasound in term pregnant women. We hypothesized that the vertebral level of the intercristal line determined by palpation would be higher than the level determined by ultrasound.

METHODS

After receiving approval from the IRB, 51 term pregnant patients gave informed written consent and were enrolled before placement of neuraxial blockade for cesarean or

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Accepted for publication April 28, 2011.

This report was previously presented, in part, at the Society for Obstetric Anesthesia and Perinatology Annual Meeting 2010 and the American Society of Anesthesiologists' Annual Meeting, 2010.

This report describes a cross-sectional observational study. The authors state that the report includes every item in the STROBE checklist for cross-sectional observational studies.

The authors declare no conflicts of interest.

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Reprints will not be available from the authors.

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DOI: 10.1213/ANE.0b013e318222abe4

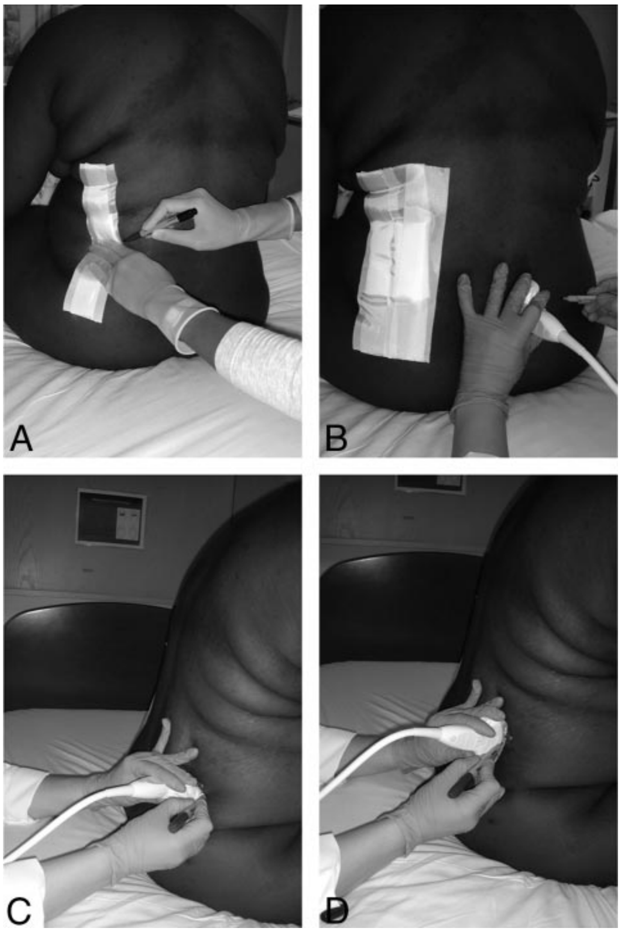

Figure 1. A, Second clinical estimate of the iliac crest level performed with the observer blinded to the first clinical estimate. B, Ultrasonographer scanning the lumbar spine while blinded to both clinical estimates of the iliac crest level. C, Ultrasonographer scanning the iliac crest in the transverse plane. D, Scanning the iliac crest in the longitudinal plane.

Figure 2. Ultrasound image of the L5 lamina–paramedian longitudinal view, centered. L4 to L1 levels were identified in a similar manner by moving cephalad.

vaginal delivery. Convenience sampling was used. Patients in labor who had numerical rating scale (scored 0 to 10) pain scores >4 or who were perceived to be unable to cooperate with positioning were excluded. Other exclusion criteria were body mass index (BMI) >45 kg/m^2, previous spine surgery, and known spinal deformities.

Patients were positioned sitting to one side of a level stretcher with the neck, back, and hips flexed and feet supported by a foot rest. The hips were positioned with the weight distributed evenly between both sides. An assistant stood facing the patient, helping to maintain her position while monitoring the fetal heart rate. Two senior anesthesiologists, after palpating both iliac crests, consecutively marked the skin with an erasable pen at the estimated level of the intercristal line in each patient. The marks were placed on the left side. Each mark was concealed with a folded 4″ × 4″ woven gauze swab and tape, so that each was blinded to the other's estimation (Fig. 1A). One of 2 anesthesiologists, who were experienced ultrasonographers, scanned the lumbar area in the same flexed position. The ultrasonographer was also blinded to the marks (Fig. 1B).

A portable GE Healthcare® LOGIQ P5® (Waukesha, WI) ultrasound system, fitted with a 4-MHz curved array probe, was used to determine the vertebral and iliac crest levels. The probe was applied in the paramedian longitudinal plane to visualize the sacrum and the interlaminar spaces individually.

The interlaminar space between L5 and the sacrum was first identified. The L5 level was marked on the skin at the midpoint of the probe by positioning the L5 lamina in the center of the screen (Fig. 2). The L4 to L1 levels were identified and marked in a similar manner moving cephalad.

The highest point of the iliac crest posteriorly was visualized by ultrasound in both the longitudinal and transverse planes (Fig. 3, A and B). A skin marking was made corresponding to the superior border in both views to verify the position in 2 different planes (Fig. 1, C and D). The ultrasound probe was maintained perpendicular to the skin throughout the examination to minimize measurement error. Scans were performed on the right side to maintain blinding of the examiner.

Using a 30-cm ruler with an embedded spirit level, the vertebral level that corresponded to the position of the intercristal line determined by ultrasound was recorded. If the line was between the marks for vertebral laminae, the level was recorded as the corresponding interspace. The marks for the clinical estimates of the intercristal line were uncovered, and in a similar manner, the corresponding vertebral levels were noted (Fig. 4).

The primary outcome was the determination of the level of agreement between the 2 clinical estimates of the intercristal line by palpation and the levels determined by ultrasound. Descriptive data were reported for the demographic characteristics as means and standard deviations. The frequency, percent, and 2-sided (unless otherwise noted) 95% confidence bounds for a multinomial distribution[8] were reported for the intercristal line position determined by ultrasound. To test the hypothesis that there was no difference between the palpated level and the ultrasound level, we coded the levels as L1 = 1, L1-2 = 1.5, L2 = 2, and so on. The coded data were entered into a general linear mixed regression model (SAS PROC MIXED) to determine

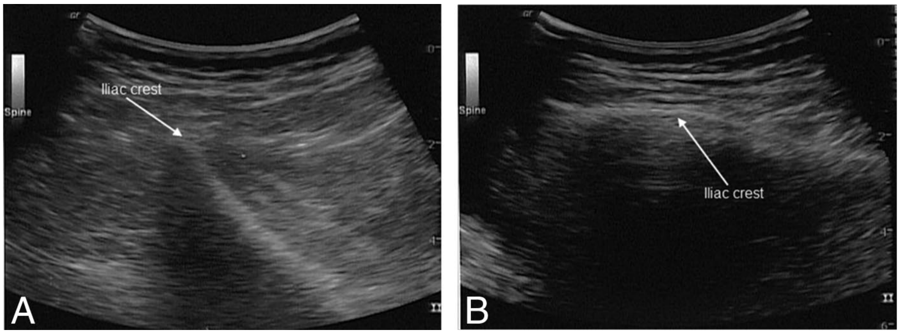

Figure 3. Ultrasound images of the iliac crest (A) longitudinal to the long axis and (B) transverse to the long axis.

Figure 4. Clinical estimates of iliac crest level, when uncovered, shown to be at the L2 vertebral level in this patient. The iliac crest level by ultrasound was found to be at L3-4.

Table 1. Iliac Crest Level Determined by Ultrasound

Ultrasound (n = 51)			
Level	**No.**	**%**	**95% CI**
L5[a]	4	8	3, 18
L4-5[b]	5	10	4, 21
L4[a]	31	61	47, 73
L3-4[b]	5	10	4, 21
L3[a]	4	8	3, 18
L2-3[b]	1	2	0, 10
L2[a]	1	2	0, 10

CI = confidence interval.
[a] Lamina.
[b] Interspace.

the level of agreement between the 2 clinical estimates of the intercristal line with the ultrasound measure while controlling for the clustering of measurements within a patient. The model specified the coded level of the clinical estimate as the dependent variable and the ultrasound-determined level as the independent variable. In this analysis, the intercept was random. A variance component covariance matrix was chosen. The analysis also computed 95% confidence intervals (CIs) about the intercept and slope parameters. If the clinical estimates and ultrasound measures are similar, the CI for the slope includes one and the CI for the intercept includes zero.

Correlations between the demographic characteristics (age, gestational age, and BMI) and the disparity between clinical estimates and ultrasound determination of the intercristal line were computed to determine whether there was a significant relationship. Separate general linear mixed-model regression analyses were used to compute the regression of the disparity between clinical estimates and ultrasound measures on age, gestational age, and BMI, using a random intercept with a variance component covariance structure. The correlation coefficient was computed using the equation, $r = S_x\beta/S_y$, where S_x is the standard deviation of the independent variable (age, gestational age, or BMI), S_y is the standard deviation of the dependent variable, and β is the estimated regression coefficient for the independent variable. S_y is adjusted for the clustering caused by multiple measures in the same patient by taking the square root of the residual variance in the covariance matrix of a general linear mixed model, with discrepancy between the clinical estimates and ultrasound measure as the dependent variable and no independent variable, using a variance component covariance structure. Fisher r to z transformations were used to calculate 95% CIs.

A sample-size analysis for the primary outcome showed that a sample size of 50 would provide a power of 80% to detect a medium effect size of 0.5 for a 1-sided t test at the 0.05 level. Effect size represents the difference in means (in this study, clinical estimates versus ultrasound determination of vertebral level of the intercristal line) divided by the standard deviation.[9] SAS 9.2 software (SAS Institute, Inc., Cary, NC) was used for all analyses. The 0.05 probability level was used to determine statistical significance.

RESULTS

Fifty-one patients were enrolled. In 1 patient, a protocol violation occurred; the second clinical estimate was not performed. The mean ± SD of age, gestational age, and BMI were 29 ± 6 years, 39 ± 1 week, and 33 ± 6 kg/m^2, respectively. The vertebral levels at which the intercristal line intersected the vertebral column as assessed by ultrasound are found in Table 1.

The clinical estimates of the spinal level of the intercristal line agreed with the ultrasound measurement 14% of the time (14 of 101; 95% CI: 8%, 22%). The clinical estimates were 1 level higher than the ultrasound measurement 23% of the time (23 of 101; 95% CI: 16%, 32%) and >1 level higher 25% of the time (25 of 101; 1-tailed 95% CI: >18%). The distribution of the clinical estimates (Fig. 5) found clinicians locating the intercristal line at L3 or L3-4 54% of the time (54 of 101; 95% CI: 44%, 63%) and at L2-3 or higher 27% of the time (27 of 101; 1-tailed 95% CI: >20%).

The regression of the clinical estimates on the ultrasound measurement (Fig. 6) demonstrated no agreement:

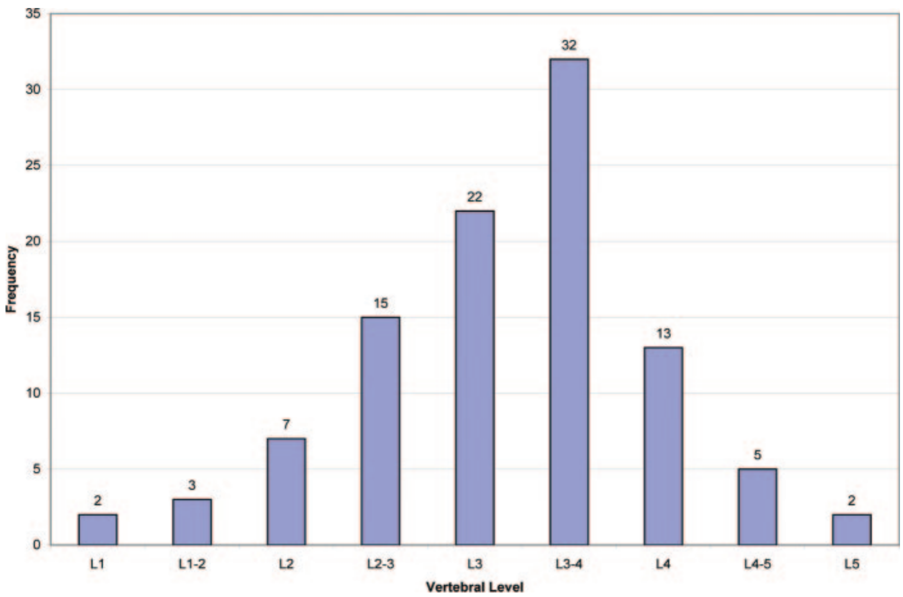

Figure 5. Distribution of the clinical estimates of the intercristal line by palpation.

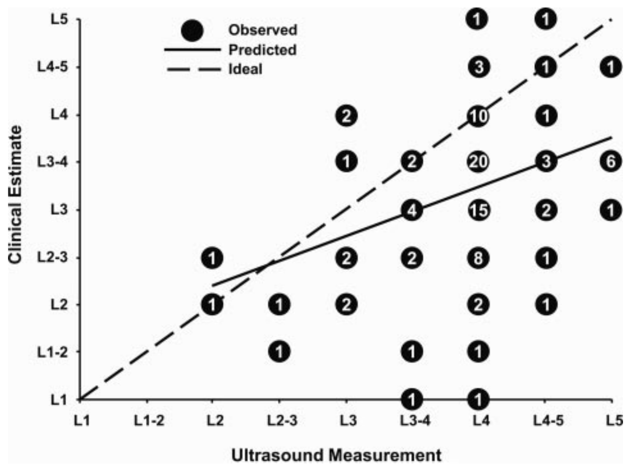

Figure 6. Scatter diagram of clinical estimates of the intercristal line by palpation and ultrasound with regression line. Numbers in the circles represent the number of observations.

Table 2. Correlation of Demographic Data with the Disparity Between Clinical Estimates and Ultrasound Determination of the Intercristal Line

Correlations with disparity between clinical estimates and ultrasound-determined level			
Variable	*r*	*P* value	95% CI
Maternal age	0.16	0.27	−0.12, 0.42
Gestational age	0.12	0.42	−0.16, 0.38
BMI	−0.07	0.62	−0.34, 0.21

BMI = body mass index; CI = confidence interval.

the intercept was significantly different from zero (intercept = 1.09; 95% CI: 0.09, 2.10), and the slope was significantly lower than one (slope = 0.53; 95% CI: 0.28, 0.78). No significant correlation was found among age, gestational age, and BMI and the difference between the clinical estimates and the ultrasound-determined level (Table 2).

DISCUSSION

Based on a review of the literature, this is the first study identifying the vertebral level of the intercristal line by ultrasound in pregnant patients. Clinical estimation using anatomical landmarks has been shown to be inaccurate compared with imaging by magnetic resonance imaging (MRI), radiograph, and ultrasound.[10–13] In a fluoroscopy study of 75 patients in the prone position, the intercristal line corresponded to the L4 or L4-5 level in 87% of patients, whereas the levels determined by palpation in the same group of patients were found to be at L3 or L3-4 in 77% of patients.[11] Researchers conducting a similar analysis using ultrasound in nonpregnant patients reported that the level of the intercristal line palpated clinically corresponded to the L3-4 level in 73% of cases.[12] Whitty et al.[14] reported that in 32% of patients, the vertebral level identified clinically was at least 1 interspace higher than the level located by ultrasound. We found the clinical estimate of the intercristal line to be at least 1 level higher than the ultrasound determination in at least 40% of patients (1-tailed 95% CI). Thus, we also found that practitioners frequently enter a higher interspace than intended during neuraxial anesthesia.[10,13,14]

The position of the intercristal line is distributed in a normal manner and is reported to range from as low as the L5-S1 interspace to as high as the L3-4 interspace in nonpregnant patients.[15] The position of the conus medullaris also follows a normal distribution.[16] Saifuddin et al.[17] described a range from the middle third of T12 vertebral body to L3. In MRI studies of 690 consecutive patients, Kim et al.[16] reported that the conus medullaris tended to be lower in females compared with males. The conus has also been reported to lie at L2 or L2-3 in 32% of Africans compared with 20% of Europeans.[13] A high-positioned intercristal line may lead to misidentification of vertebral interspaces, and in conjunction with a low-lying conus medullaris, would be expected to increase the risk of neurologic injury.

Because clinicians are frequently incorrect in their estimates of the vertebral interspace, we believe the practice of using the L2-3 interspace during the performance of spinal anesthesia in obstetric patients is inappropriate. Of 7 reports of conus injury described by Reynolds,[1] 6 occurred in obstetric patients receiving spinal or combined spinal epidural blocks, most believed to be at the L2-3 interspace. Furthermore, the American Society of Anesthesiologists' Closed Claims database reported that 2 spinal cord injuries that resulted in paraplegia were attributable to direct injection into the spinal cord.[18]

In our sample of pregnant women, we determined the intercristal line by ultrasound to be at L3 or above in at least 6% of patients (1-tailed 95% CI). This is in contradistinction to nonpregnant patients, in whom the intercristal line determined by radiograph coincided with the L4 spinous process or the L4-5 interspace in 79% of patients but was as high as the L3-4 interspace in only 4% of patients.[6] Shiraishi and Matsumura[5] conducted a radiograph study of a small sample of nonpregnant females in the flexed position and found none with an intercristal line level above L4. This difference may be secondary to an accentuation of the lumbar lordosis and difficulty flexing the lumbar spine during pregnancy.[7] Pelvic lordosis and pelvic incidence (the angle between the line perpendicular to the superior plate of the first sacral vertebra at its midpoint and the line connecting this point to the middle axis of the femoral heads)[19] have been shown to be directly related to the projection of the intercristal line.[20]

For patients with severe edema or obesity, greater difficulty may be encountered in palpation of the intercristal line through thick subcutaneous tissue. In our study, BMI did not correlate with a greater disparity between the clinical estimates and ultrasound-determined levels. The large width of the CIs for the correlation coefficients indicates that our sample size was insufficient to provide an accurate measure of the correlation among BMI, maternal age, and gestational age and the disparity between clinical estimates and ultrasound-determined levels.

The accuracy of ultrasound in identifying the correct intervertebral level was previously compared with lumbar radiograph in 50 nonpregnant subjects.[21] Seventy-one percent accuracy was reported using ultrasound, compared with 30% with palpation ($P < 0.001$).[21] No studies have compared ultrasound with a "gold standard" technique such as MRI or radiograph for the identification of the iliac crest, and this is a limitation of our study conclusions. Further studies are needed to validate the use of ultrasound for scanning of the spine and iliac crest. Another limitation of this study is that we did not consider the presence of lumbosacral transitional vertebrae (either a sacralized L5 or a lumbarized S1).[16,22] This may have affected the accuracy of determination of vertebral levels; however, recognition is difficult without the use of radiography.[16] Errors in measurement could have occurred because of variations in positioning during examination, but small differences in the degree of flexion of the spine are unlikely to have had a significant effect on our findings.[23]

Ultrasound is more accurate than palpation in correctly identifying the lumbar interspaces and decreases the number of attempts required to perform a block.[24] Although it may be inferior to radiologic imaging,[25] it is far more practical when the exposure to radiation and cost involved in using radiographs, computed tomography, and MRI are considered. The same ultrasound equipment used by obstetricians is suitable for scanning of the lumbar spine and therefore the purchase of additional equipment may be unnecessary.

Because of the devastating and permanent complications resulting from spinal cord injection, we advocate greater use of ultrasound to verify the position of the iliac crests and vertebral levels in obstetric patients. This may improve safety, particularly in patients with abnormal spinal anatomy and in the morbidly obese, in whom difficulty may be encountered in palpating anatomical landmarks.

DISCLOSURES

Name: Allison J. Lee, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Allison J. Lee has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
Name: J. Sudharma Ranasinghe, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: J. Sudharma Ranasinghe has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
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Attestation: Jules Marie Chehade has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
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Contribution: This author helped analyze the data and write the manuscript.
Attestation: David J. Birnbach has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

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