

Ultrasound assessment of the vertebral level of the palpated intercrystal (Tuffier's) line

Évaluation par échoguidage du niveau vertébral de la ligne de Tuffier

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Abstract

Purpose Identification of a particular vertebral level by clinical landmark palpation is inaccurate. This study uses ultrasound imaging to assess the vertebral level at which the palpated intercrystal line occurs in subjects clinically positioned to receive a neuraxial technique.

Methods Following Research Ethics Board approval and informed written consent, 114 adult subjects were seated in the position used clinically for placement of a neuraxial block. A single investigator marked the skin where the palpated intercrystal line crossed the spinous processes. A 2–5 MHz curved ultrasound probe in paramedian orientation was advanced cephalad from the sacrum, counting the ultrasound-visualized intervertebral levels until the skin marking was encountered. The weight, height, waist circumference, body mass index, and age of the volunteers were recorded. These physical characteristics and relationship to the ultrasound-measured palpated intercrystal line were assessed using the Chi square and Tukey Honestly Statistically Different tests.

Results Using ultrasound, the palpated intercrystal line was identified at the L3-4 interspace in 83 (73%), at L4-5 in 16 (14%), and at L2-3 in 15 (13%) of volunteers, respectively. Those with a palpated intercrystal line at L2-3 were taller (mean difference 7.8 cm, 95% confidence interval 2.6–13.0 cm) and more likely to be male (22% vs

6%; $P = 0.016$) than those imaged with a palpated intercrystal line at L3-4 or below.

Conclusions According to ultrasound, the palpated intercrystal line falls at the L3-4 interspace, or below, in the majority of subjects positioned for neuraxial block in the sitting position. A palpated intercrystal line at L2-3 was more likely in tall and male individuals.

Résumé

Objectif L'identification d'un niveau vertébral par palpation de repères cliniques est une technique imprécise. Cette étude a fait usage d'imagerie par ultrason pour évaluer le niveau vertébral auquel apparaît la ligne de Tuffier chez des patients cliniquement positionnés pour recevoir une technique neuraxiale.

Méthode Après avoir obtenu l'approbation du Comité d'éthique de la recherche et le consentement éclairé des patients, 114 patients adultes ont été assis dans la position utilisée en clinique pour réaliser un bloc neuraxial. Un seul chercheur a marqué la peau à l'endroit où la ligne de Tuffier croisait l'apophyse épineuse. Une sonde d'échoguidage courbe de 2-5 MHz en orientation paramédiane a été avancée vers le haut depuis le sacrum en comptant les niveaux intervertébraux visualisés par ultrasons jusqu'au niveau de la marque sur la peau. Le poids, la taille, le tour de taille, l'indice de masse corporelle et l'âge des volontaires ont été enregistrés. Ces caractéristiques physiques et leur association à la ligne de Tuffier mesurée par échoguidage ont été évaluées par un test de Chi carré.

Résultats La ligne de Tuffier a été localisée au niveau de l'espace intervertébral L3-4 chez 83 (73 %) volontaires, au niveau L4-5 chez 16 (14 %) volontaires et au niveau L2-3 chez 15 (13 %) volontaires. Les volontaires chez lesquels la ligne de Tuffier se situait à L2-3 étaient plus grands

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(différence moyenne 7,8 cm, intervalle de confiance 95 % 2,6–13 cm) et plus probablement de sexe masculin (22 % vs 6 %; $P = 0,016$) que les volontaires chez lesquels la ligne de Tuffier se situait à L3-4 ou plus bas.

Conclusion La ligne de Tuffier se situe au niveau de l'espace intervertébral L3-4 ou plus bas chez la majorité des individus placés en position assise pour recevoir un bloc neuraxial. Une ligne de Tuffier au niveau L2-3 était plus probable chez les individus de grande taille et de sexe masculin.

The intercrystal (Tuffier's) line is a clinical landmark defined as a horizontal line connecting the superior aspect of the posterior iliac crests. It is routinely used to locate the level of the body of L4 prior to performing a subarachnoid or epidural block. Identifying a particular intervertebral level for neuraxial techniques by clinical palpation is inaccurate.^{1,2} Reports of spinal cord injuries and neurologic sequelae from neuraxial techniques based on Tuffier's line have been noted.³ Magnetic resonance imaging (MRI) and radiography studies highlight possible explanations for the unanticipated injuries incurred at presumed "safe" levels of needle insertion, including (1) differences in the vertebral level of the palpated intercrystal line vs the imaged (or anatomic) intercrystal line⁴; and (2) significant interpatient variation of the vertebral level at which spinal cord termination (conus medullaris) occurs.⁵

As ultrasound technology becomes more accessible to the clinician, it holds great potential to facilitate neuraxial anesthesia for the anesthesiologist and patient. In the obstetric population, ultrasound reliably predicts pre-puncture lumbar epidural space depth,⁶ enhances patient satisfaction with the epidural insertion process, and decreases needle insertion attempts.⁷ Moreover, ultrasound improves accuracy in selecting a particular vertebral interspace vs palpation-based techniques.⁸ To our knowledge, ultrasound has not been reported to assess the vertebral level of the palpated intercrystal line in the non-obstetric population. This cross-sectional study uses ultrasound to determine the vertebral level at which the palpated intercrystal line occurs in volunteers clinically positioned for neuraxial techniques. Based on previous studies assessing palpated intercrystal line as measured by radiography,⁴ we hypothesized that the level of the palpated intercrystal line would correspond to the L3-4 vertebral interspace in the majority of subjects, as measured by ultrasound.

Methods

The Ottawa Hospital Research Ethics Board approved both the study and the advertisements used for recruitment.

Informed, written consent was obtained from all participants. Study subjects consisted of pre-admission unit patients and allied healthcare staff at the Ottawa Hospital. Recruitment was facilitated through advertisements located throughout the Ottawa Civic Hospital. Exclusion criteria included age <18 yr, pregnancy, and inability to maintain clinical positioning for a neuraxial technique.

The age, height, weight, and waist circumference of the participants were directly measured by a single observer (C.P.), and body mass index (BMI) was then calculated. With volunteers in clinical position for neuraxial blockade (seated on a stool with feet on a footrest and neck, hips, and back flexed), the superior aspect of the iliac crests was palpated from behind. A horizontal skin mark was created with an erasable pen at the level of the palpated iliac crest. A SonoSite® MicroMAXX® (Bothell, WA, USA) ultrasound using a C60e 2–5 MHz 60-mm broadband curved array probe was applied in a paramedian orientation to the spine. Following sonographic identification of the sacrum, the ultrasound probe was advanced cephalad, counting the vertebral interspaces until the middle of the probe intersected with the horizontal skin marking of the palpated intercrystal line. The interspace at that level was determined to be the ultrasound-measured palpated intercrystal line. If the palpated intercrystal line intersected the cephalad half of the spinous process, the intervertebral level cephalad to the spinous process was recorded. Similarly, if the palpated intercrystal line intersected the caudad half of the spinous process, the intervertebral level caudad to the spinous process was recorded. If the palpated intercrystal line intersected the middle of the spinous process, the intervertebral level caudad to the spinous process was recorded.

The primary objective of the study was to use ultrasound to characterize the location of the palpated intercrystal line. The secondary outcome of the study was to investigate physical features (sex, age, height, mass, BMI, and waist circumference) as potential predictors of intercrystal line location. On the basis of a previous study,⁴ we expected palpation of the intercrystal line to identify the L3-4 interspace in 75% of participants. We considered a 95% confidence interval with expected half-width $\leq 50\%$ to be a sufficiently precise estimate for this proportion, yielding a required sample size of approximately 100. As such, this was our target sample size.

Subjects were divided into three groups based on the lumbar interspace identified on ultrasound (L2-3, L3-4, and L4-5). To ensure a family-wise Type 1 error rate of 5% for each characteristic of interest we used Tukey's Honestly Statistically Different (HSD) test to make pair-wise comparisons of the physical characteristics (age, height, mass, BMI, and waist circumference) between the groups. Pearson's Chi square test with a Bonferroni adjustment of the resulting P values ($3 \times P$) was used to make pair-wise

comparisons of the sex ratio between groups. No additional adjustment was employed to account for the multiple variables compared between the groups.

Results

One hundred and fourteen consenting subjects (64 females and 50 males) were entered in the study. The palpated intercrystal line was found at the L3-4 interspace in 83 of 114 (73%; 95% confidence interval 64% to 80%) subjects. Demographic characteristics are displayed in Table 1. Males were taller, heavier, and had greater waist circumferences than females. The age of the volunteers ranged from 24 to 88 yr and did not differ between sexes. Individuals with a palpated intercrystal line at the L2-3 interspace were more frequently male (Table 2) and taller (Table 3). Table 3 highlights the relationship identified between physical characteristics and intercrystal line height.

Discussion

This cross-sectional analysis study used ultrasound to assess the vertebral level of the palpated intercrystal line in volunteers positioned for a neuraxial technique. Our findings are consistent with recent clinical studies evaluating the palpated level of the intercrystal line by radiography,⁴ i.e., the majority of subjects have a palpated intercrystal line at L3-4.

Commonly used anesthesia texts cite the intercrystal line as “crossing the body of L4 or the L4-5 interspace”^{9,10} and

Table 1 Physical characteristics of subjects

Physical characteristic	Male (n = 50)	Female (n = 64)	P value
Age (yr)	45.3 ± 13.7	45.8 ± 13.7	0.85
Height (cm)	175.8 ± 7.8	162.3 ± 6.5	<0.001
Weight (kg)	83.4 ± 14.7	67.6 ± 14.6	<0.001
Body mass index (kg · m ⁻²)	27.0 ± 4.7	25.8 ± 6.0	0.25
Waist circumference (cm)	93.9 ± 14.7	82.3 ± 14.2	<0.001

Table 2 Distribution of palpated intercrystal line levels by sex

	Ultrasound-imaged intercrystal line level			Total
	L2-3 Number (%)	L3-4 Number (%)	L4-5 Number (%)	
Female	4 (6%)	50 (78%)	10 (16%)	64
Male	11 (22%)*	33 (66%)	6 (12%)	50
Total	15 (13%)	83 (73%)	16 (14%)	114

* P < 0.02 male vs female (Chi square test)

Table 3 Physical characteristics of subjects with different palpated intercrystal line levels

Physical characteristics	L2-3 (n = 15)	L3-4 (n = 83)	L4-5 (n = 16)
Age (yr)	38 ± 10	46 ± 15	48 ± 15
Height (cm)	175 ± 9*	167 ± 9	168 ± 14
Weight (kg)	78 ± 16	74 ± 17	75 ± 16
Body mass index (kg · m ⁻²)	26 ± 5	26 ± 6	27 ± 6
Waist circumference (cm)	87 ± 16	87 ± 16	89 ± 13

Data expressed as mean ± standard deviation

* Tukey Honestly Statistically Different (HSD), P = 0.01 compared with L3-4 and L4-5

do not differentiate between the palpated and imaged intercrystal line when describing performance of a subarachnoid or epidural block. This difference is important to consider as the palpated, not the imaged, intercrystal line forms the basis for initiating neuraxial attempts in clinical practice. Given that up to 10% of the population has a spinal cord proper extending caudal to L2,⁵ the potential for hazard from erroneously placed needles based on inaccurate surface anatomical relationships exists and has manifested in patient morbidity.³ Despite the risk of nerve injury with subarachnoid approaches, a recent study has demonstrated that permanent neurologic sequelae are extremely rare (0.9–1.2 cases per 100,000) and supports the overall safety record of central neuraxial anesthetic techniques.¹¹

We have potentially identified a clinically important subset of patients in whom the palpated intercrystal line occurred at L2-3, i.e., males and taller individuals. Our results parallel work by Kim *et al.* who used MRI to demonstrate a more cephalad position of the imaged intercrystal line in males compared with females.¹² A recent publication by Snider *et al.* also supports our findings that the intercrystal line is more cephalad in males than in females.¹³ Spino-pelvic morphological dissimilarity between males and females may account for the observed difference in vertebral level of the palpated intercrystal line. Legaye *et al.* identified that the pelvic incidence angle—“the angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to the middle axis of the femoral heads”—is significantly greater in males than in females.¹⁴ Subsequently, Horduna and Legaye reported a highly significant, positive correlation between the magnitude of the pelvic incidence angle and a more cephalad intercrystal line location by radiography.¹⁵ Taken together, these studies may provide an anatomic explanation for the greater proportion in our study of males-to-females with a more cephalad ultrasound-confirmed palpated intercrystal line.

Fifteen subjects (13.2%) had their palpated intercrystal line at the L2-3 interspace. This cephalad location of the intercrystal line raises the possibility of needle placement in

close proximity to the termination of the spinal cord should a clinician assume that the intercrystal line corresponds to the L3-4 interspace. Subjects with a palpated intercrystal line sited at L2-3 were more frequently male (Table 2) and taller (Table 3) than those sited at L3-4 or below. As male subjects were taller than females, we considered the use of logistic regression to determine if both height and sex were independent predictors of cephalad placement of the palpated intercrystal line. Peduzzi *et al.* state that logistic regression models require a minimum of ten events for each variable entered into the model to prevent overestimation of effects.¹⁶ We had considered sex, height, and weight as candidate variables *a priori* requiring a minimum of 30 instances of a palpated intercrystal line identified at L2-3 for regression modelling. As there were only 15 cases of a palpated intercrystal line identified at L2-3 by ultrasound, logistic regression was not performed. To our knowledge, little research has been conducted investigating the role of patient height and sex of the patient in determining the level of the palpated intercrystal line. Further studies are warranted to assess the possible risk to which taller and/or male patients may be exposed during neuraxial techniques.

It is important to note the limitations of our study. First, a single investigator assessed both the palpated intercrystal line and ultrasound-measured vertebral levels. The lack of blinding introduces the potential of bias when recording results. Second, we did not document the incidence in our study population of lumbo-sacral transitional vertebrae (LSTV), commonly referred to as “sacralization of the L5 vertebra” or “lumbarization of the S1 vertebra”. Given that the incidence of LSTV has been reported as high as 5–15%,¹⁷ a similar proportion of participants in our study who may possess this anatomical aberration may affect the accuracy of ultrasound confirmation of the palpated intercrystal line. Although Kim *et al.* showed with MRI that sacralization patients have more cephalad imaged intercrystal lines and conus medullaris compared with lumbarization or non-LSTV patients, there was no difference in the “margin of safety”—distance between the intercrystal line and the conus medullaris—among subjects with sacralization, lumbarization, or normal anatomy.¹²

In conclusion, this cross-sectional study used paramedian neuraxial ultrasonography to assess the intervertebral level at which the palpated intercrystal line occurred in non-obstetric subjects clinically positioned for a neuraxial technique. We found that the majority of subjects had an ultrasound-confirmed palpated intercrystal line at L3-4. However, further research is required to determine the importance of physical factors, particularly height and sex, when considering location of needle placement for a neuraxial technique.

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Competing interests None declared.

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