An ultrasound-assisted approach facilitates spinal anesthesia for total joint arthroplasty

Une approche par ultrason facilite l'anesthésie rachidienne pour arthroplastie totale

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Abstract

Purpose Spinal anesthesia can be challenging in patients undergoing total joint arthroplasty because of poorly palpable surface landmarks and age-related changes in the lumbar spine. We hypothesized that pre-procedural ultrasound imaging would be effective in identifying the lumbar intervertebral spaces and would provide an accurate measure of the depth to the intrathecal space.

Methods Fifty patients undergoing elective total joint arthroplasty were recruited in this prospective descriptive study. Using a curved-array 2–5 MHz transducer, the lumbar spine was imaged in two views, i.e., longitudinal parasagittal (LP) and transverse midline (TM). The intervertebral levels were identified by counting upwards from the sacrum. The locations of the interlaminar spaces were identified by visualizing the ligamentum flavum–dura mater complex and the posterior aspect of the vertebral body. The needle insertion point for a midline approach was determined from the ultrasound examination and was marked on the skin of the patient's back.

Results The mean patient age was 67 ± 10 yr, and 46% of the patients had a body mass index $>30 \text{ kg} \cdot \text{m}^{-2}$. Surface landmarks were difficult or impossible to palpate in 38% of the patients. The scan quality on the LP and TM views was adequate or better in 100 and 98% of the patients, respectively. Dural puncture was achieved with one needle insertion attempt and within two needle insertion attempts in 84% and 98% of the patients, respectively. The ultrasound-measured depth to the intrathecal space correlated well with the actual needle insertion depth (concordance correlation coefficient = 0.82, accuracy 0.95, precision 0.86), with a tendency to overestimate the depth by just 2.1 ± 5.4 mm.

Conclusions Ultrasound imaging of the lumbar spine provides clinically useful information that can facilitate spinal anesthesia in the older orthopedic patient population.

Résumé

Objectif L'anesthésie rachidienne peut présenter certains défis chez les patients subissant une arthroplastie totale en raison de repères de surface peu palpables et des changements dans la colonne lombaire liés à l'âge. Nous avons émis l'hypothèse que l'imagerie par ultrason avant l'intervention serait efficace pour identifier les espaces intervertébraux lombaires et fournir une mesure précise de la profondeur jusqu'à l'espace intrathécal.

Méthode Cinquante patients subissant une arthroplastie totale non urgente ont été recrutés dans cette étude descriptive prospective. À l'aide d'une sonde à déphasage courbe de 2–5 MHz, nous avons obtenu des images de la colonne lombaire à partir de deux vues, soit une vue longitudinale parasagittale (LP) et une vue transversale médiane (TM). Les niveaux intervertébraux ont été identifiés en comptant vers le haut depuis le sacrum. Les emplacements des espaces interlaminaires ont été identifiés

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en visualisant le complexe ligament jaune / dure-mère et le côté postérieur du corps vertébral. Le point d'insertion de l'aiguille pour une approche médiane a été déterminé à partir de l'examen par échoguidage et a été marqué sur la peau du dos du patient.

Résultats L'âge moyen des patients était de 67 ± 10 ans, et 46 % des patients avaient un indice de masse corporelle $> 30 \text{ kg}\cdot\text{m}^{-2}$. Il était difficile ou impossible de palper les repères de surface chez 38 % des patients. La qualité des images pour les vues LP et TM était adéquate ou meilleure chez 100 % et 98 % des patients, respectivement. La ponction durale a été réalisée avec une tentative d'insertion de l'aiguille et une ou deux tentatives d'insertion de l'aiguille chez 84 % et 98 % des patients, respectivement. La profondeur de l'espace intrathécal mesurée par échoguidage était bien corrélée avec la profondeur réelle d'insertion de l'aiguille (coefficient de corrélation de concordance = 0,82, exactitude 0,95, précision 0,86), avec une tendance vers la sur-estimation de la profondeur de seulement $2,1 \pm 5,4 \text{ mm}$.

Conclusion L'imagerie par ultrason de la colonne lombaire procure des informations cliniquement utiles qui peuvent faciliter l'anesthésie rachidienne chez une population de patients âgés en orthopédie.

Spinal anesthesia is a common technique in patients undergoing total joint arthroplasty. These patients are often elderly, obese, or both, and these factors have been shown to contribute to technical difficulties with central neuraxial blockade.^{1–3} A pre-procedural ultrasound scan of the lumbar spine has been shown to be of benefit in guiding lumbar epidural insertion in obstetric patients.^{4–7} However, there is limited data evaluating the potential role of ultrasound imaging of the spine in non-obstetric adult patients. We therefore conducted an observational cohort study in patients undergoing total joint arthroplasty to ascertain: (1) the accuracy and precision with which the ultrasound scan could predict the depth to the intrathecal space (ITS); (2) the ease to which relevant anatomical landmarks for spinal anesthesia could be visualized using a systematic ultrasound scanning technique; and (3) if the ultrasound scan could accurately determine a site for successful needle insertion and dural puncture.

Methods

Following approval of the research ethics board of University Health Network and after obtaining written informed consent from all participants, 50 patients were enrolled in this prospective cohort study. Included in the study were patients aged 50 or older who were scheduled to

undergo elective total hip or knee arthroplasty under spinal anesthesia. Patients who had undergone previous spinal surgery were excluded from the study. A single experienced operator [K.J.C.], who had previously performed several hundred landmark-guided and 30–35 ultrasound-assisted spinal anesthetics (prior to study initiation), performed the clinical and ultrasound examination as well as the spinal anesthetic in each patient.

Routine monitors (non-invasive blood pressure, 3-lead ECG, oximetry) were applied and peripheral intravenous access was established. All patients were placed in a sitting position throughout the procedure. The patient's back was examined prior to ultrasound scanning to assess the ability to palpate surface anatomical landmarks (iliac crests, spinous processes, and interspinous gaps) using a 4-point scale: easy, moderate, difficult, and impossible. The L3–4 intervertebral level was also estimated from the intercrystal line as the imaginary horizontal line across the top of the iliac crests.

Pre-puncture ultrasound imaging in all patients was performed using a Philips HD11XE (Philips, Bothell, WA, USA) ultrasound unit and a low-frequency (2–5 MHz) curved array transducer. Depth and gain settings were adjusted, as necessary, to optimize image quality in each patient. We followed the systematic ultrasound scanning protocol described below.

Ultrasound imaging protocol

Longitudinal parasagittal (LP) scan

The transducer was oriented longitudinally and placed over the lumbosacral spine in a parasagittal plane approximately 2 cm lateral to the midline (Fig. 1). The transducer was angled toward the midline to direct the ultrasound beam through the interlaminar spaces so as to visualize the interior of the vertebral canal. The sacrum was identified as a continuous hyperechoic line (Fig. 1). The transducer was then moved cephalad to identify the individual lumbar intervertebral spaces from L5/S1 to L2/3. The position of each level was determined by imaging the ligamentum flavum–dura mater complex (LF/D) and the posterior aspect of the vertebral body (PVB) through the respective interlaminar space, and each position was marked on the skin of the patient's back. The LF/D and the PVB appeared as bright hyperechoic lines on ultrasound (Fig. 1) and represented the posterior and anterior limits of the ITS, respectively. In our experience, the ligamentum flavum and dura mater cannot be consistently differentiated in this patient population; hence, we chose to regard them as a single sonographic structure. Using the ultrasound unit's built-in electronic calliper, the depth from the skin to the anterior aspect of the LF/D and the depth from skin to the

Fig. 1 Longitudinal parasagittal (LP) scan. The transducer is placed lateral to the midline and angled medially. The transducer is moved in a cephalad-caudad direction to identify successive lumbar interlaminar spaces through which the ligamentum flavum–dura mater complex (LF/D) and the posterior aspect of the vertebral body (PVB) may be visualized. The intrathecal space lies in-between the LF/D (not visible at L5–S1) and the PVB. The intervertebral level to which the interlaminar space corresponds is determined by counting upwards from the sacrum. By placing an interlaminar space in the centre of the image, its position can be marked on the skin as shown

posterior aspect of the PVB were measured at each intervertebral level whenever they were visible.

Transverse midline (TM) scan

Following the parasagittal scan, the transducer was rotated 90° and centred on the patient's midline to obtain transverse views of the neuraxis. The transducer was moved in a cephalad-caudad direction between the spinous processes of the L2 and L5 vertebrae. The spinous processes appeared as short hyperechoic lines with vertical linear acoustic shadowing beneath. Interlaminar spaces were identified as soft tissue acoustic windows that allowed imaging of deeper midline structures such as the LF/D and the PVB (Fig. 2). The articular processes of the facet joints and the transverse processes of each vertebra were also identified (Fig. 2). The intervertebral level to which each interlaminar space corresponded was confirmed using the skin markings made during the earlier LP scan. The depth from skin to the LF/D,

Fig. 2 Transverse midline (TM) scan. The transducer is placed in the midline (ML) and moved in a cephalad-caudad direction. Deeper structures are visible through the acoustic soft tissue window in-between the spinous processes. These include the articular processes of the intervertebral facet joints (FJ), the transverse processes (TP), the ligamentum flavum–dura mater complex (LF/D), and the posterior aspect of the vertebral body (PVB). The intrathecal space lies between the two latter structures. The position of the neuraxial midline and the interlaminar space can be marked as shown. The intersection of the vertical and horizontal lines marks the appropriate site for needle insertion

ITS, and PVB were determined at each intervertebral level whenever they were visible (as described above). In addition, we calculated the depth from the skin to the midpoint of the ITS as follows: depth to ITS = (depth to LF/D) + $\frac{1}{2}$ (depth to PVB – depth to LF/D). The location of the neuraxial midline and the L2/3, L3/4, and L4/5 intervertebral levels were marked on the skin (Fig. 2).

Both LP and TM scan quality were graded using an objective 4-point scale as follows: 4 = very good, LF/D and PVB clearly visible at all three intervertebral levels; 3 = good, LF/D or PVB visible at ≥ 2 levels; 2 = adequate, LF/D or PVB visible at one level; and 1 = inadequate, LF/D or PVB not visible at any intervertebral level.

Needle insertion

Following the ultrasound scan, the operator marked three possible needle insertion points for a midline approach to dural puncture. These corresponded to the intersections of

Fig. 3 **a** The intervertebral levels are indicated by horizontal skin markings and are marked based on both the longitudinal parasagittal (LP) and the transverse midline (TM) scans. The neuraxial midline is indicated by vertical lines and is marked based on the TM scan. The difference between the position of the neuraxial midline at L4/5 and the two higher levels is due to lumbar scoliosis in this patient. The

needle insertion points are marked by extending the vertical and horizontal lines so that they intersect. **b** Spinal needle and introducer inserted into the intrathecal space in the midline at L2/3. Cephalad angulation of the needle can be estimated from the cephalad angulation of the transducer required to visualize the ligamentum flavum–dura and posterior aspect of the vertebral body on the TM scan

the skin marks indicating the neuraxial midline (identified in the TM scan) and the L2/3, L3/4, and L4/5 intervertebral levels (identified from information obtained in both the LP and the TM scans) (Fig. 3). The intervertebral level used for the initial attempt was selected based on the relative ease with which the LF/D and/or the PVB could be visualized on the TM scan. The spinal anesthetic was performed with a 25G, 90 mm Whitacre needle inserted through a 20G introducer needle (MED-RX[®] spinal anesthesia kit, Benlan Inc., Oakville, ON, Canada). If the ultrasound-measured depth to the PVB exceeded 75 mm, a 25G, 120 mm Sprotte needle (Pajunk[®], Geisingen, Germany) was used. Needle re-direction was defined as angulation of the introducer needle without withdrawing it from the skin. Needle re-insertion was defined as complete withdrawal followed by re-insertion of the introducer needle at a different entry point on the skin. The number of needle insertion and re-direction attempts required for successful entry into the ITS was recorded by a research fellow. If the ITS was not entered after three needle insertion attempts at the same intervertebral level, a second level was attempted. Once good backflow of cerebrospinal fluid had been obtained, 3 mL of plain 0.5% bupivacaine was injected. The depth from skin to spinal needle tip was calculated by measuring the length of needle protruding from the skin surface and subtracting this measurement from the overall length of the needle. Successful spinal

anesthesia was defined as a sensory level to pinprick at T10 or higher within 30 min of local anesthetic injection.

Statistical analysis

Statistical calculations were performed with SPSS[®] 16.0 for Windows[®] (SPSS Inc., Chicago, IL, USA) and STATA[®] 9.2 for Macintosh[®] (StataCorp., College Station, TX, USA) software. Descriptive statistics were calculated using mean (SD) for continuous data, median (lower-upper quartiles [range]) for ordinal data, and percentages for discrete variables.

We analyzed the agreement between actual needle insertion depth and the ultrasound-measured depth to the LF/D, ITS, and PVB using the concordance correlation coefficient (CCC) and Bland–Altman analysis. The CCC represents the variation of the linear relationship between two variables from the 45° line of perfect agreement passing through the origin.^{8,9} The CCC analysis provides a measure of precision which corresponds to the Pearson correlation coefficient, and it also delivers a measure of accuracy. The assumption of normal distribution of the differences was checked by the Shapiro–Wilk *W*-test for normal data.

The required sample size of 50 patients was calculated using a reference population CCC of 0.88, as reported in a previous study⁴ to test the null hypothesis (one-tailed) of

poor correlation between the ultrasound-measured depth to the ITS and the measured needle depth (ND) (correlation coefficient ≤ 0.7). A type I error and type II error of 5% (α) and 20% (β) were assumed, respectively.

Results

From February to November, 2008, 50 patients were screened for inclusion. All 50 patients consented to participate and completed the study assessments. Patient demographics are summarized in Table 1. Nearly half of the subjects (46%) were obese (body mass index [BMI] $>30 \text{ kg} \cdot \text{m}^{-2}$), and anatomical landmarks for spinal anesthesia were difficult or impossible to palpate in 38% of patients (Table 1). Only 18% of patients aged ≥ 70 yr had difficult or impossible landmarks, compared with 79% of patients with a BMI $\geq 35 \text{ kg} \cdot \text{m}^{-2}$ (Table 2).

The L5/S1 to L2/3 intervertebral levels were identified in all patients on the LP scan. The intercrystal line between the iliac crests (which were impalpable in four patients) corresponded to the L3/4 level in 72% (33/46), to the L2/3 level in 26% (12/46), and to the L4/5 level in 2% (1/46) of patients.

The quality of the LP and TM scans was very good in 14 (28%) and 6 (12%) patients, good in 30 (60%) and 32 (64%) patients, adequate in 6 (12%) and 11 (22%) patients, and inadequate in 0 (0%) and 1 (2%) patients, respectively.

Table 1 Patient demographics ($n = 50$). Values are expressed as mean (SD) and number (proportion)

Age (yr)	67 (10)
Height (cm)	168 (9)
Weight (kg)	88 (21)
BMI ($\text{kg} \cdot \text{m}^{-2}$)	31.4 (7.6)
No. of patients, BMI > 30	23 (46%)
No. of patients, BMI > 35	14 (28%)
No. of patients, BMI > 40	6 (12%)
Gender	
Male	23 (46%)
Female	27 (54%)
Type of surgery	
TKR	33 (66%)
THR	17 (33%)
Ease of landmark palpation	
Easy	12 (24%)
Moderate	19 (38%)
Difficult	16 (32%)
Impossible	3 (6%)

BMI body mass index; TKR total knee replacement; THR total hip replacement

The grade of scan quality was significantly higher on the LP scan compared with the TM scan (3 [3–4] vs 3 [2.75–3], $P = 0.022$). The frequency with which the LF/D and the PVB were seen at each intervertebral level is displayed in Fig. 4. The PVB was more easily visualized than the LF/D. Of the three intervertebral levels, L2/3 tended to afford the best visibility of LF/D and PVB, particularly on the TM scan.

As a result, the L2/3 level was chosen most frequently for needle insertion (20 patients), followed by L3/4 (17 patients) and L4/5 (13 patients). Successful spinal anesthesia was achieved in all patients at the first chosen intervertebral space. The ITS was entered with a single needle insertion attempt in 84% (42/50) of patients. Needle re-direction was not required in 62% (26/42) of these patients. The median number of needle insertion attempts and overall needle re-directions required for successful dural puncture was 1 (1–1 [1–3]) and 0 (0–3 [0–9]), respectively. Only one patient required three needle insertion attempts for successful dural puncture. Whether patients were aged ≥ 70 yr, had a BMI $\geq 35 \text{ kg} \cdot \text{m}^{-2}$, or had anatomical landmarks that were difficult or impossible to palpate, subgroup analysis showed a high first-attempt success rate of entry into the ITS (79–86%) (Table 2). Five patients (10%) required the use of a 120 mm needle.

The actual ND required to enter the ITS correlated well with both the measured depth to the ITS and the PVB. The CCC was 0.82 (95% confidence intervals [CI] 72–91%) and 0.82 (95% CI 71–89%) for depth to the ITS and the PVB, respectively. The accuracy and precision of correlation were identical for both parameters, being 0.95 and 0.86, respectively. Correlation of the ND with the depth to the LF/D was not as good, the CCC being 0.59 (95% CI 43–72%) with an accuracy of 0.73 and a precision of 0.81. The depth to the ITS and the PVB tended to overestimate the ND by 2.1 (5.4) and 2.5 (5.2) mm, respectively (Fig. 5). Depth to the LF/D, on the other hand, tended to underestimate the ND by 7.6 (6.2) mm.

Discussion

The results of our study suggest that ultrasound-assisted spinal anesthesia in the older orthopedic population presenting for total joint arthroplasty is both feasible and potentially useful in identifying the lumbar intervertebral spaces and providing an accurate measure of the depth to the ITS. Many of these patients are either elderly or obese, which are both factors associated with poor quality of surface landmarks.^{1,2} Landmark quality, in turn, is the most significant predictor of difficult central neuraxial blockade.^{1,10} Also, neuraxial block may be more difficult in the elderly because of a reduced ability to flex the

Table 2 Selected outcomes for patients subgrouped by age ≥ 70 yr, body mass index (BMI) ≥ 35 , and ease of palpation of surface landmarks. Data are reported as n (%)

	Surface landmarks		Needle insertion attempts			Needle redirection attempts		
	Easy/moderate	Difficult/impossible	1	2	3	0	1–2	3–6
BMI ($\text{kg} \cdot \text{m}^{-2}$)								
≥ 35 ($n = 14$)	3 (21%)	11 (79%)	11 (79%)	3 (21%)	0	5 (36%)	3 (21%)	6 (43%)
< 35 ($n = 36$)	28 (78%)	8 (22%)	31 (86%)	4 (11%)	1 (3%)	21 (58%)	8 (22%)	7 (19%)
Age (yr)								
≥ 70 ($n = 17$)	14 (82%)	3 (18%)	14 (82%)	2 (12%)	1 (6%)	11 (65%)	4 (24%)	1 (6%)
< 70 ($n = 33$)	17 (52%)	16 (48%)	28 (85%)	5 (15%)	0	15 (45%)	7 (21%)	11 (33%)
Surface landmarks								
Difficult/impossible ($n = 19$)	–	–	16 (84%)	2 (11%)	1 (5%)	7 (37%)	5 (26%)	7 (37%)
Easy/moderate ($n = 31$)	–	–	26 (84%)	5 (16%)	0	19 (61%)	6 (19%)	6 (19%)

Fig. 4 Visibility of the ligamentum flavum–dura mater complex (LF/D) and posterior aspect of the vertebral body (PVB) at each intervertebral level. The PVB was visible more often than the LF/D, especially on the transverse midline (TM) scan. Visibility of the LF/D and the PVB tended to be better on the longitudinal parasagittal (LP) scan compared with the TM scan **Fig. 5** Bland–Altman analysis of the difference between **a** needle depth (ND) and depth to the ligamentum flavum/dura mater complex (LF/D); **b** needle depth (ND) and depth to the middle of the intrathecal space (ITS); and **c** needle depth (ND) and depth to the posterior aspect

of the vertebral body (PVB). The dashed lines represent the mean difference and the 95% confidence intervals (95% CI) for the mean difference

lumbar spine.³ The mean age of our study cohort was 67 yr; 46% of patients were obese and 38% had poorly palpable or impalpable landmarks. Despite this, we had a

100% success rate of spinal anesthesia using a midline approach at the first intervertebral level selected. In addition, dural puncture was achieved with one needle

insertion attempt in 84% of patients and within two attempts in 98% of patients. The high first-attempt success rates were observed even in patients who were elderly, obese, or who had landmarks that were difficult or impossible to palpate. This success rate compares favourably with published rates (62–68 and 81–89%, respectively) for successful neuraxial block in the general population within one and two needle insertion attempts.^{1–3,11} Only one patient in our study required three needle insertion attempts for success; he was not particularly obese (BMI 33.7 kg · m⁻²), but he had narrow interspaces with steeply sloping spinous processes, which accounted for the difficulty. This was apparent during the TM scan where steep cephalad angulation of the transducer was required to visualize the LF/D and the PVB.

Pre-procedural ultrasound imaging has yielded similar benefits when applied to obstetric epidural catheter insertion: it increases success rates amongst novices⁵; it reduces needle insertion attempts^{12,13} and block-associated pain¹³; and it increases patient satisfaction.¹³ However, the use of ultrasound to assist central neuraxial blockade in other patient populations has been limited. This is probably because the traditional landmark-guided technique is regarded as being relatively efficacious, and also because ultrasound imaging of the lumbar spine in adults has hitherto been regarded as being difficult. The relevant anatomical structures (ligamentum flavum, dura mater, and thecal sac) lie relatively deep below the skin surface, are encased by bony vertebrae, and can only be accessed through narrow soft-tissue windows. The depth also means a low-frequency transducer must be used for adequate penetration, which, in turn, means lower image resolution. Nevertheless, if the structures of the vertebral canal can be visualized on ultrasound, the same window that allows ultrasound beam penetration will also allow needle penetration. Stiffler *et al.*¹⁴ evaluated the utility of ultrasound in identifying relevant anatomical structures (spinous processes and ITS) for lumbar puncture. They used a low-frequency curved array transducer to scan the spine in the sagittal and parasagittal (but not transverse) planes. They were only able to visualize relevant structures on ultrasound in 74% of patients who had a BMI > 30, and they concluded that the usefulness of ultrasound was inversely related to BMI. There is no published data on whether age is related to ultrasound image quality of the spine. In contrast, we were able to visualize LF/D or PVB at one or more intervertebral levels on the LP scan in all patients, and on the TM scan in all but one patient. In this latter patient (who had a BMI of 42.7 kg · m⁻² and impalpable landmarks), we were still able to identify and mark the bony midline and the interspinous gaps using the TM scan. Successful dural puncture in the midline was achieved after two needle insertion attempts.

Although it has been suggested that only a TM scan is necessary when performing pre-puncture imaging for a midline approach to neuraxial blockade,⁴ we recommend including a LP scan in all patients for three reasons. First, the LP scan allowed us to easily identify and mark the lumbar intervertebral levels by counting upwards from the sacrum. These marks were subsequently useful in confirming the level of the interlaminar spaces identified on the TM scan, especially in patients where the spaces were narrow or close together. It has been shown repeatedly that clinical estimation of the lumbar intervertebral level using surface landmarks, such as the intercrystal line, is inaccurate.^{15–21} Our results are consistent with previous studies in that, when an error does occur, the actual intervertebral level tends to be higher than presumed, rather than lower.^{16–21} It should be noted, however, that ultrasonographic determination of intervertebral level has not been fully validated against more definitive imaging methods.^{19,22}

Second, the LP scan generally affords better visibility of the LF/D and the PVB than the TM scan, an observation that was also made by Grau *et al.*²³ The interspinous space is narrowed by the anatomic changes of aging (loss of vertebral height, osteophyte formation, and decreased ability to flex the lumbar spine),³ and this can make it challenging to visualize the LF/D or the PVB on the TM scan. Where this is the case, the LP scan may be used instead to mark the intervertebral level for needle insertion. Finally, it is also possible to mark out a paramedian approach to the ITS using the information from the LP scan, although we did not have to resort to this approach in our cohort of patients.

Needle insertion depth and the requirement for a longer needle to reach the ITS can also be predicted by ultrasound. The measured depth to both ITS and PVB correlated well with ND, with a tendency to overestimate ND by a mean of only 2–2.5 mm. This minor discrepancy is not unexpected, given that the antero-posterior diameter of the thecal sac may range from 6 to 12 mm^{24,25} and a variable degree of tissue compression by the transducer occurs during scanning.

There are several limitations to our study. First, as this was an observational study, no conclusions can be drawn about the superiority of ultrasound-assisted spinal anesthesia compared with the surface landmark-guided technique. Second, the results reported in this study were obtained by a single experienced operator and may limit the reproducibility of these results. Further research into the learning curve associated with ultrasound-assisted central neuraxial blockade is warranted. Third, the technique is limited by the fact that needle insertion is not guided by ultrasound in real-time, but rather by skin markings made with the assistance of ultrasound (hence

our preference for the term *ultrasound-assisted* rather than *ultrasound-guided* spinal anesthesia). At present, most ultrasound transducers do not have markings to indicate their midline, nor do they provide precision regarding the origin of beam emanation. Therefore, an inherent degree of inaccuracy may exist when marking a needle insertion point on the skin. Nevertheless, we find that this imprecision diminishes with experience. In addition, the process of scanning conveys to the operator the subtle adjustments in needle trajectory (particularly the degree of cephalad angulation) that are required to enter the interlaminar space, thus increasing the likelihood of success. Finally, we did not study the efficacy of ultrasound scanning when patients are placed in the lateral decubitus position. The tendency for the soft tissue of the back to sag downwards in this position could potentially diminish the accuracy of skin marking.

In conclusion, pre-procedural ultrasound imaging in the older orthopedic patient undergoing total joint arthroplasty is feasible and provides useful anatomical information. The required ND can be predicted and the intervertebral level accurately determined. More importantly, ultrasound is capable of identifying the precise location of an interlaminar space through which a needle may be advanced, thus facilitating successful central neuraxial blockade.

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Conflicts of interest None declared.

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