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Anatomical landmarks based assessment of intravertebral space level for lumbar puncture is misleading in more than 30%

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Abstract

Bacground. The anatomical landmark which is used to identify the correct level for lumbar puncture is the line connecting both iliac crests. This crosses the vertebra column at the level of the L4–L5 intervertebral space or L4 vertebra. It can be difficult to determine in a group of orthopaedic patients due to chronic orthopaedic disorders, chronic pain, overweight, or difficulties with positioning for lumbar puncture.
The objective of this study was to determine if identification of intervertebral space by a physical exam differs from that of an ultrasound assessment.
Methods. Adult patients scheduled for lower limb surgery under spinal block were enrolled in this study. The intervertebral space suitable for lumbar puncture was determined by physical exam by an anaesthetist in the sitting or lateral position. This was followed by a lumbar ultrasound. Primarily, a transducer was placed in paramedian sagittal view followed by transverse interlaminar view to confirm the identification of the interlaminar spaces. The 'counting-up' approach starting with the L5–S1 space was applied.
Results. One hundred and twenty two patients (122) were included in this study. Lumbar intervertebral spaces were identified by ultrasound in all cases. There was concordance of intervertebral space identification (between clinical and ultrasound examination) in 78 cases (64%). Mean deviation of inacuracy was one intervertebral space with no statistical difference among cephalad and caudal direction. There were no statistically significant differences fund in terms of demographic data (sex, age, height, weight, or BMI), positioning for lumbar puncture, or intervertebral space chosen for the puncture between the concordant and the nonconcordant identification groups. The only statistically significant difference found was the difference in the years of experience of the anaesthetist performing the clinical assessment and puncture.
Conclusions. The concordance rate between clinical examination and using assessment of intervertebral space identification for lumbar puncture is 64% among patients undergoing lower limb surgery. No special parameters were found which could make an anaesthetist aware that a patient is at greater risk of inadequate intervertebral space level assessment. Spinal ultrasound can reduce the incidence of inappropriate lumbar puncture level in orthopaedic patients.

Key words: level of lumbar puncture, orthopedia, spinal anaesthesia, ultrasound, ultrasound guided regional anaesthesia

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Spinal anaesthesia (SA) has been successfully used for orthopaedic surgery for years. It provides high-quality muscle relaxation; its analgesic effect is predictable and the time needed to obtain effective block short.

In everyday clinical practice, the intervertebral space for central block of the lumbar spine is chosen after identifying the L4 location based on anatomical landmarks. The intercristal line, called the Tuffier`s line, intersects the spine at the level of L4 vertebra or L4–L5 intervertebral space [1, 2] and is a relevant reference point to choose the intervertebral space for regional anaesthesia. In spinal anaesthesia cases, this line allows to determine the safe puncture level, considering the fact that the medullary cone in adults is located at the level of the lower edge of L1 vertebral body [1, 2, 3].

The identification of lumbar puncture levels according to this traditional method is not accurate in some groups of patients, e.g. elderly patients undergoing orthopaedic procedures with coexisting chronic spinal degenerative changes and deformities, limited joint mobility, overweight and resultant difficulties in optimal anaesthesia positioning. The above factors are likely to result in the unintended level of lumbar puncture [4, 5].

In recent years, the use of ultrasonography has been increasingly common in anaesthetic practice, thanks to which patient's anatomic structures can be non-invasively and objectively evaluated [6, 7]. Ultrasound imaging is used to locate peripheral plexi and nerves, to determine the level of intervertebral spaces and to estimate the depth of epidural and spinal spaces. The available literature data demonstrate that in many cases the intervertebral space determination based on anatomical landmarks differs from ultrasound-guided identification [8–12].

The aim of the present study was to compare prospectively the differences between anatomical landmarks-based and ultrasound-controlled determinations of spinal structures. The intervertebral space level chosen for spinal anaesthesia was evaluated.

METHODS

The study was approved by the Bioethics Committee of the Medical University of Warsaw and included patients undergoing orthopaedic surgical procedures within the lower extremities. The inclusion criteria were the age over 18 years, scheduled procedures under spinal anaesthesia and patients` consent to participate in the study. Patients with thigh and hip fractures were excluded as the forced position during ultrasound imaging would cause additional discomfort likely to adversely affect the assessment.

Once patients were transported to the operative suite and routine monitoring (ECG, non-invasive arterial blood measurement, pulse oximetry) was initiated, the intervertebral space for lumbar puncture was determined. Patients were placed in the sitting or lateral recumbent position depending on the preferences of an anaesthesiologist. The anaesthesiologist determined the intervertebral space level intended to be punctured based on anatomical landmarks — the line joining the iliac crests. The level chosen was distinctly highlighted on the skin. Immediately after the puncture level determination, another anaesthesiologist performed ultrasound imaging of the lumbar spine in three projections: transverse, lateral sagittal and oblique sagittal. The spaces were counted in a cephalad direction, starting from the junction between the last lumbar vertebra with the sacrum, based on visualization of spinous processes and interlaminar spaces. The examination was carried out using the Logiq e (GE) 4C–RS device, the frequency range of 2–5 MHz. After ultrasound assessment, spinal anaesthesia was carried out in a typical manner and the scheduled procedure continued.

The data were collected using Numbers 09, version 2.1 (Apple Inc.) and statistically analysed by STATISTICA 9.1 software (StatSoft, Tulsa, USA). The results were presented as a mean (parametric variables) or a median (non-parametric variables) ± SD. The statistical significance of differences between two groups was evaluated by the Mann-Whitney *U* test (non-parametric variables) or *Student's t*-test (parametric variables). The regression analysis was applied to evaluate the correlation between a dichotomous variable and quantitative features. Relations of qualitative data were assessed by the χ^2 test of independence. The significance of fraction differences was checked using the test of differences in structural indices. $P < 0.05$ was considered as statistically significant.

RESULTS

One hundred and twenty three patients (78 women and 44 men) were enrolled in the study; data regarding 122 anaesthetic procedures were analysed (one case was excluded due to incomplete data). The demographic characteristics of the study group were presented in Table 1.

Spinal anaesthetic procedures were carried out in the sitting or lateral recumbent position; the intervertebral spaces determined anatomically included L2–L3, L3–L4, and L4–L5. L3–L4 was most frequently selected for lumbar puncture (in 93 cases — 76%), followed by L4–L5 (in 23 — 19%), and L2–L3 (in 6 cases — 5%) (Tab. 2).

Twenty physicians, including 13 (65%) specialists in anaesthesiology and intensive therapy and 7 (35%) residents in anaesthesiology, were involved in the study. The characteristics of physicians, together with the degree of speciality and years of professional experience, were presented in Table 3.

Lumbar intervertebral spaces were identified in 122 patients (100%), using both the anatomical landmarks and ultrasound guidance. The agreement in both methods was observed in 78 cases (64%) whereas the concordance in 44 (36%). Compared to ultrasound imaging, anatomical identification

Table 1. Demographic data of the study population

Parameter	$\bar{x}$ ± SD
Female/Male	78/44
Age (years)	60.8 ± 16.8
Height (cm)	167.0 ± 9.3
Body weight (kg)	77.8 ± 16.7
BMI (kg m^{-2})	27.9 ± 5.23

BMI — *body mass index*

Table 2. Block methods

Parameter	Number of patients (%)
Sitting position	109 (89%)
Lateral recumbent position	13 (11%)
L3–L4 puncture	93 (76%)
L4–L5 puncture	23 (19%)
L2–L3 puncture	6 (5%)

Table 3. Professional experience of the physicians involved

Parameter	Total ($\bar{x}$ ± SD)
Number of physicians	20
Specialists	13
Non-specialists	7
Experience (years) [$\bar{x}$ ± SD]	8.7 ± 5.8

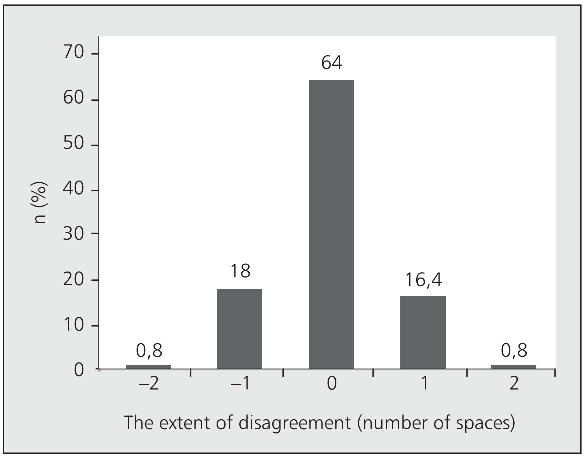

Figure 1. Disagreement of intervertebral space determination between the anatomical and ultrasound method. The x-axis values denote the difference by a given number of intervertebral spaces, negative values — in a caudal direction, positive values — in a cephalad direction

was too caudal by one space in 22 cases (18%) and too cephalad in 20 cases (16.4%); the differences by two spaces were found in two cases, one in either direction (0.8%) (Fig. 1).

Anthropometric and demographic data in the groups of patients with consistent and inconsistent results of intervertebral space determinations based on anatomical landmarks and ultrasound imaging were listed in Table 4. The intergroup differences in parameters were not statistically significant.

The other parameters likely to affect the differences in anatomic and ultrasound determinations of the intervertebral space level were listed in Table 5. The only statistically significant correlation was found between the length of professional training vs. agreement in clinical and ultrasound-guided identifications (P = 0.013). Identifications carried out by physicians with longer professional experience were more commonly consistent with ultrasound-guided determinations.

DISCUSSION

The use of ultrasound imaging in regional anaesthesia is increasingly popular as the technique enables objective assessment of anatomical structures and direct visual monitoring of the block performed. The ultrasound guidance is of particular interest for peripheral blocks, where the identification of nervous structures based only on anatomical landmarks does not guarantee sufficiently precise location of nervous structures and provision of high-quality and

Table 4. Comparison of anthropometric and demographic data in groups of patients with consistent vs. inconsistent results of intervertebral space determinations

Parameter	Agreement ($\bar{x}$ ± SD)	Disagreement ($\bar{x}$ ± SD)	Statistical significance
Age (years)	60.7 ± 17.4	60.9 ± 15.8	NS
Height (cm)	166.2 ± 9.3	168.2 ± 9.3	NS
Weight (kg)	77.6 ± 16.9	78.1 ± 15.0	NS
BMI (kg m^{-2})	28.0 ±5.7	27.5 ± 4.3	NS

BMI — *body mass index*; NS — *non-significant differences*

Table 5. Parameters affecting the agreement between clinical and ultrasound determinations of intervertebral space levels

Parameter	Agreement	Disagreement	Statistical significance
Female	54	24	NS
Male	24	20	
Sitting position	69	40	NS
Lateral recumbent position	9	4	
Specialist	34	15	NS
Non-specialist	44	29	
Professional experience (years) [$\bar{x}$ ± SD]	9.7 ± 5.9	6.8 ± 5.26	P = 0.013

predictable anaesthesia. Until recently, central blocks were addressed to differently. Considering the fact that traditional methods based on the knowledge of anatomy and anatomical landmarks are sufficient to provide effective central blocks in the majority of cases, and that ultrasound imaging of the spine in adults is difficult due to numerous bone structures, ultrasound of this region was not so widely used as for peripheral blocks. Recently, however, many studies demonstrated benefits of this method for central blocks, particularly in pregnant women [8–12]. All the authors indicated the differences in determinations based on physical examination and ultrasound imaging in that group of patients.

Margarido and co-workers [8], who studied 90 pregnant women, found the differences between the intercristal line identified by palpation and the actual Tuffier`s line. The median of the puncture level was L2–L3 with a standard deviation by one intervertebral space cephalad and the variance between L1–L2 and L4–L5 [8].

According to the study conducted by the authors from Miami, the mean identification error was one intervertebral space in a cephalad direction in 23% and more than one in 25% of cases [9]. In another study involving 99 pregnant patients, Schlotterbeck and colleagues demonstrated that the accuracy of determination was only 36%; predominantly, in a too cephalad direction (49%) as compared to a too caudal direction observed only in 15% of cases [11]. Still another study with 121 parturients revealed that US evaluation was consistent with the physical evaluation only in 55% of cases; in 32% of patients, the insertion site was at least one space higher than that in US imaging [12]. Moreover, the agreement of determinations was compared in the group of obese patients and those with normal BMI. The consistent results were found in 53% of non-obese patients (too cephalad in 40%) and in 49% of obese patients (too cephalad in 51%) [10].

According to Schlotterbeck, none of the parameters potentially biasing determination outcomes, e.g. the type of anaesthesia, indications, timing, experience of anaesthesiologists, spinal structural anomalies or BMI, affected the number of discrepancies [11].

The Medline database does not include any publications comparing the intended puncture level determined by palpation and by ultrasound in patients undergoing orthopaedic surgical procedures.

The use of ultrasound for visualisation of spinal structures requires the knowledge indispensible for proper interpretation of spinal sonograms. While visualising the individual structures in the transverse section, the median line and posterior dural lamina depth have to be determined. In many cases, US imaging does not allow to distinguish the individual structures surrounding the spinal canal posteriorly, which are called "the posterior complex" and consist of the yellow ligament, the posterior dural lamina and the epidural space between them (Fig. 2).

The transverse projection enables visualisation of the median line by showing the shadow projected by the spinous process, the transverse processes and the depth of epidural space. With the transducer placed about 2–3 cm laterally to spinous processes in the sagittal section the transverse processes from L3 to L5 are easy to identify, i.e. shadows producing what is referred to as "the trident sign" (Fig. 3).

By moving and rotating the transducer slightly more medially, the tubercles, corresponding to the inferior and superior articular processes, are visualised (Fig. 4).

By rotating the transducer further medially, the saw-tooth image is obtained corresponding to laminae and interlaminar spaces through which the "posterior complex" can be identified, hence the depth of the dural posterior lamina determined (Fig. 5).

The present study demonstrated the disagreement between the clinical and ultrasound-assisted determination of the intervertebral space level in 36% of patients undergoing orthopaedic procedures. None of the patient-dependent (demographic, anthropometric) factors or the technique

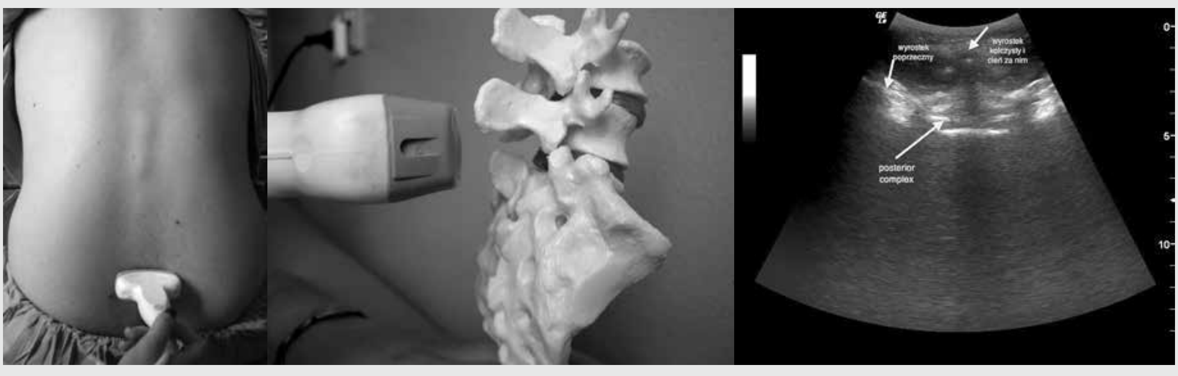

Figure 2. Transverse projection. US images of individual structures and "posterior complex". The epidural space is located at the depth of 4 cm

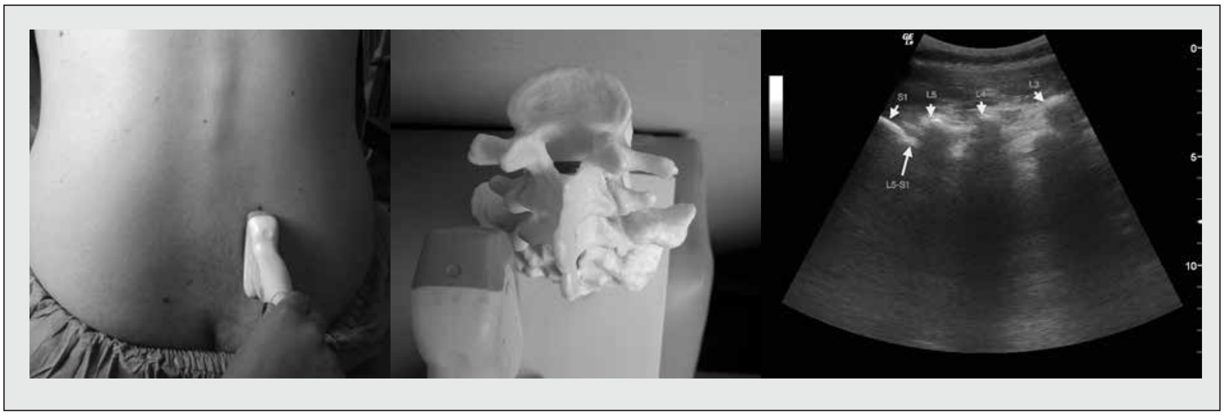

Figure 3. Lateral sagittal projection 3–4 cm laterally to the median line. The trident sign — shadows of transverse processes of L5–L3

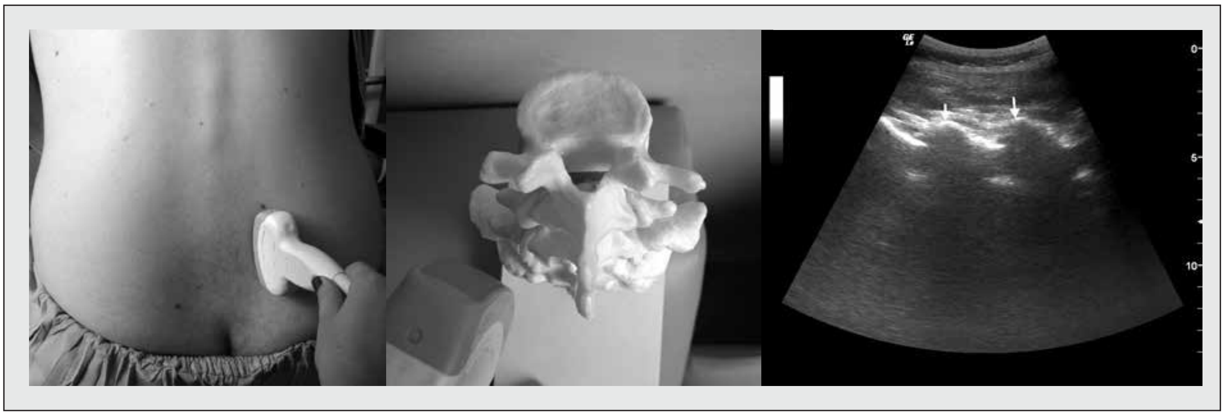

Figure 4. Lateral sagittal projection of the articular processes (2–3 cm laterally to the median line). Articular processes (arrows)

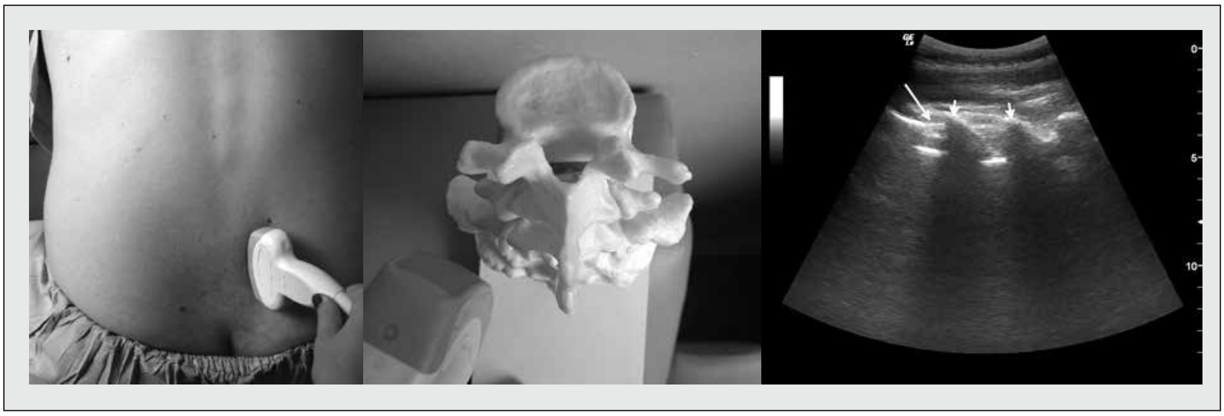

Figure 5. Oblique sagittal projection. The saw-tooth image (short arrows) corresponding to laminae and intervertebral foramina. A long arrow — the "posterior complex" (the epidural space is located at the depth of 4 cm)

of block (sitting or recumbent position) was shown to significantly affect the agreement of determination. The only parameter increasing the agreement rate was longer experience of anaesthesiologists (in the group with consistent versus inconsistent determinations — 9.7 and 6.8 years of experience, respectively; $P = 0.013$). Interestingly, the speciality degree in anaesthesiology per se did not affect the accuracy of determination.

Our results confirm the high frequency of inaccurate identifications based on traditional anatomy methods described in the literature. The agreement of clinical and ultrasound determinations observed in our study was comparable to the results presented by Whitty and colleagues yet higher compared to that of Schlotterbeck [11, 12].

The majority of differences involved one intervertebral space, with too caudal or too cephalad levels of puncture being equally common (16.4% and 18%, respectively). The difference by two intervertebral spaces was found only in 1.6% of patients. In none of the study cases the difference was more than two spaces.

The limitation of our study was relatively short experience of the authors in performing ultrasound examinations of the lumbar spine. Moreover, the anaesthesiologist performing ultrasound imaging was not blinded as to the results of palpation-based determination performed by another anaesthesiologist. It should be assumed that in a certain percentage of cases, ultrasound-guided identification was likely not to correspond to the actual anatomic structure. Therefore, it should be more appropriate to say that the clinical identification was different from the ultrasound-guided one rather than that it was improper.

Routine ultrasound examinations before lumbar punctures are not recommended [13]. They require additional time, availability of devices and appropriate skills of those conducting the imaging. There are no study data demonstrating that the ultrasound-guided method increases the safety of lumbar puncture. Many studies devoted to recommendations for the ultrasound use for central blocks emphasise its beneficial effects in children; nonetheless, according to large scale-literature surveys, further studies are required [14]. Moreover, there are no studies explicitly defining the benefits of ultrasound imaging in adults, except for cases in which the identification might be difficult (obesity, post-surgery spine or abnormal spine structure — scoliosis) [15, 16].

The present study results do not demonstrate that the differences in identification of intervertebral spaces increase the anaesthesia-related risk. None of our patients with different anatomical and ultrasound determinations had any complications. Motor block was delayed in one case and one spinal block failed — both cases were in the agreement group. The above information, however, do not allow far-reaching conclusions due to a small size of the population involved.

The patients included were not at high risks of difficulties in identification of intervertebral spaces due to obesity or severe deformities. Nevertheless, the percentage of failed anatomy-based identifications in the study population was high (over 30%), which confirms relatively poor precision and high failure rates of determinations based exclusively on anatomical landmarks. Since the peripheral block methods do evolve, it seems that routine objective non-invasive ultrasound-guided determinations for central blocks should be considered.

CONCLUSIONS

In patients undergoing lower limb surgical procedures, the intervertebral space levels determined by palpation are consistent with ultrasound levels in 64% of cases.

Longer professional experience of anaesthesiologists performing determinations was found to be significantly correlated with higher agreement rates.

Patient-related factors (demographic and anthropometric), positions during anaesthesia, and speciality in anaesthesiology were not of a prognostic value to estimate the risks of improper identification of intervertebral space level.

Most commonly, anatomical and ultrasound identifications differed by one intervertebral space, both in a cephalad and caudal direction.

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