Ultrasound imaging facilitates subarachnoid blockade in patients with difficult surface anatomic landmarks

Ahmed M. Abd El-Hamid[a], Ali M. Hasan[b], M. Hamed Abd El-fattah[a], Ali M. Elnabtity[b], Gamal A. Abo Elenein[c]

[a]Anesthesia Department, Benha University, Benha, [b]Anesthesia Department, Zagazig University, Zagazig, [c]Radiology Department, Alazhar University, Cairo, Egypt

Correspondence to Ahmed M. Abd El-Hamid, MD, Anesthesia Department, Benha University, Egypt
e-mail: bashaahmad@yahoo.com

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Background

Ultrasound imaging of the spine has recently been proposed to facilitate identification of the anatomic landmarks for subarachnoid blockade. This study assessed the accuracy and precision of the ultrasound-guided subarachnoid blockade over the conventional surface landmark-guided technique in patients with difficult surface anatomic landmarks undergoing elective orthopedic lower limb surgery.

Patients and methods

This prospective, randomized controlled study was conducted on 60 patients with difficult surface anatomic landmarks for subarachnoid block, scheduled for elective orthopedic lower limb surgery. These patients were randomly allocated into two equal groups: group LM in which subarachnoid block was performed using the conventional surface landmark-guided technique and group US in which subarachnoid block was performed using the ultrasound. The primary outcome was the rate of successful dural puncture on the first needle insertion attempt. The secondary outcomes included number of needle redirection, number of repeated needle insertion, number of failed attempts, time taken to establish landmarks, and time taken to perform the spinal anesthesia.

Results

Successful dural puncture on the first needle insertion attempt was achieved in 21 (70%) patients in group US and in eight (26.7%) patients in group LM ($P < 0.001$), whereas the number of patients requiring needle redirection in group US was seven (23.3%), which was significantly less than in group LM in which half of the patients required needle redirection after the first insertion of the needle. The number of patients requiring repeated needle insertions in group LM was three-fold the number of patients in group US [six (20%) vs. two (6.7%), respectively]. There was only one failed attempt in group LM. The mean time taken to establish anatomic landmarks was highly significantly longer in group US than in group LM (5.7 ± 0.93 vs. 2.27 ± 1.23 min, respectively; $P < 0.001$). There was a highly significant reduction in the time required to perform the spinal anesthesia in group US (5.01 ± 0.78 min) than in group LM (7.75 ± 0.96 min; $P < 0.001$).

Conclusion

Ultrasound-guided approach is a reliable and effective method in patients in whom technical difficulty is expected.

Keywords:
difficult anatomic landmarks, subarachnoid blockade, ultrasound imaging

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Introduction

Subarachnoid blocks are generally daily practice procedures for anesthesiologists [1]. The use of the traditional, landmark-guided technique in subarachnoid block can be extremely challenging in patients with difficult surface anatomic landmarks [2]. The surface landmarks may be absent, indistinct, or distorted in many adult patients because of obesity, previous spinal surgery, deformity, or degenerative changes of aging. Obesity, in particular, affects more than 30% of the adult population [3] and as many as 50% of patients presenting for joint surgery [4,5].

Although severe spinal deformities may make epidural or spinal puncture impossible, lesser degrees of scoliosis, kyphosis, kyphoscoliosis, and increased lumbar lordosis or disk disease usually allow satisfactory access to the epidural or subarachnoid space. However, the resulting block may fail or produce only patchy analgesia [6]. Moderately severe scoliosis may be associated with persistent unilateral epidural analgesia, and kyphosis frequently predisposes to an excessively high level of sensory block [7].

Reducing the technical difficulty of neuroaxial blockade is desirable because multiple needle insertion attempts may increase the risk of complications such as postdural puncture headache, paresthesia, and epidural hematoma [1,8]. Ultrasound of the lumbar spine may facilitate successful central blockade in such patients by indicating the presence and location of a soft tissue window into the vertebral canal [9]. Several studies on neuroaxial anesthesia have found that puncture processing performed under ultrasound guidance is easier and more effective than that performed without such guidance; thus, ultrasound imaging techniques are being developed for clinical practice [6].

This study aimed to estimate the accuracy and precision of ultrasound-guided subarachnoid blockade over the conventional surface landmark-guided technique in patients with difficult surface anatomic landmarks undergoing elective orthopedic lower limb surgery.

Patients and methods

After local ethical committee approval and patients informed written consent, this prospective, randomized, and controlled study was conducted on 60 patients, 21 men and 39 women, ASA I and II, and ages ranging between 36 and 67 years, with difficult surface anatomic landmarks (iliac crests, spinous processes, interspinous spaces) for spinal anesthesia. These patients were scheduled for elective orthopedic lower limb surgery with subarachnoid bock.

Patients were considered to have difficult surface anatomic landmarks when they had one or more of the following parameters:

(1) Poorly palpable or impalpable spinous processes.
(2) BMI greater than 35 kg/m^2.
(3) Moderate to severe lumbar scoliosis on clinical examination.
(4) Previous lumbar spinal surgery.

The quality of the surface landmarks was graded according to the overall ease with which these landmarks could be palpated (four-point scale: grade I = easy, grade II = moderate, grade III = difficult, and grade IV = impossible).

Patients unable to provide informed consent or with any contraindications to spinal anesthesia were excluded from the study. These patients were randomly allocated by sealed envelope assignment into two equal groups:

Group LM (30 patients) (the control group): spinal anesthesia was performed using the conventional surface landmark-guided technique.

Group US (30 patients) (the study group): spinal anesthesia was performed using the ultrasound-guided technique.

The procedures were performed for all patients in the sitting position with a 22-G spinal needle and a midline approach between L3–L4 or L4–L5 interspaces. Standard monitors (five-lead ECG, NIBP, and pulse oximetry) were applied, wide-bore intravenous access was established, and preoperative ringer lactate 15 ml/kg was given as preload.

In patients randomized into group LM, the surface anatomic landmarks were palpated to determine the location of the neuroaxial midline and lumbar intervertebral space. If dural puncture was unsuccessful after four needle insertion attempts, the trial was considered failed. Once dural puncture was achieved and confirmed by backflow of cerebrospinal fluid from the needle hub, a standard intrathecal anesthetic solution of 15 mg heavy bupivacaine 0.5% was injected.

Ultrasound imaging of the lumbar spine was performed in group US by an anesthesiologist and a radiologist using ultrasound machine (Chison L45607S; China) with curved-array probe (7.5 MHz). The probe was oriented longitudinally to obtain a parasagittal oblique view of the lumbosacral spine, in which the interlaminar spaces were identified and marked by counting upward from the sacrum. The probe was then rotated 90° to obtain a transverse view of the lumbar spine. The interspinous and interlaminar spaces were identified by visualizing the intrathecal space between the ligamentum flavum–dura mater complex and the posterior aspect of the vertebral body. The midline (interspinous ligament) and the location of each interlaminar space were marked on the skin. The intersection of these two markings was used to guide a midline approach to spinal anesthesia, which was performed in a manner similar to that described for group LM.

Success of the spinal anesthesia was determined by a motor (grade 3 of modified Bromage scale) and sensory (by pin-prick technique) block to the T7 dermatome or higher.

Motor block was assessed by the modified Bromage scale in which 0 = no paralysis, 1 = able to move the knee, 2 = unable to flex knee, and 3 = unable to move any part of the lower limb.

The primary outcome was the rate of successful dural puncture on the first needle insertion attempt. The secondary outcomes included the following:

(1) Number of needle redirection: It was defined as any change in the needle's direction that did not involve complete withdrawal of the needle from the patient's skin.

(2) Number of repeated needle insertion: It was defined as the number of needle's insertions after complete withdrawal of the spinal from the patient's skin.
(3) Number of failed attempts.
(4) Time taken to establish landmarks: In group LM, this was defined as the period between beginning when the operator first touched the patient and ending when the operator declared the examination complete. In group US, this was defined as the period between beginning when the probe was first placed on the patient and ending when the operator declared the examination complete.
(5) Time taken to perform the spinal anesthesia: It was defined as the period between the first insertion of the needle used to infiltrate skin with local anesthetic and withdrawal of the spinal needle after injection of the anesthetic solution into the intrathecal space.

We based the sample size calculation on the primary outcome of successful dural puncture on the first needle insertion attempt.

Statistical analysis

Statistical analysis was performed using SPSS version 16. Normally distributed outcome data were presented as mean ± SD and were compared between groups using the independent-measures *t*-test. Qualitative data were presented as numbers and percentages and were compared between groups using the χ^2-test, the Fisher exact test, or the *Z*-test. *P*-value less than 0.05 was considered statistically significant, whereas *P*-value less than 0.01 was considered statistically highly significant.

Results

Sixty patients completed the study. Their demographic characteristics are summarized in Table 1. There was no significant difference between the groups with respect to age, sex, height, weight, BMI, and ASA physical status.

There was no significant difference between the groups with respect to spine abnormalities and the ease of palpation of surface landmarks (Table 2).

Successful dural puncture on the first needle insertion attempt was achieved in 21 (70%) patients in group US and in eight (26.7%) patients in group LM ($P < 0.001$) (Table 3).

In group US, the number of patients requiring needle redirection was seven (23.3%), which was significantly less than in group LM in which half of the patients required needle redirection after the first insertion of the needle (Table 3).

The number of patients requiring repeated needle insertion in group LM was three-fold the number of patients in group US [six (20%) vs. two (6.7%), respectively] (Table 3).

Table 1 Demographic characteristics of patients

Parameter	Group US	Group LM	Test of significance	*P*-value
Age (year)	50.4 ± 6.08	52.4 ± 8.54	$t = 1.08$	0.28
Sex (♂ : ♀)	10 : 20	11 : 19	$\chi^2 = 0.073$	0.79
Height (cm)	166.3 ± 8.17	168.2 ± 9.8	$t = 0.79$	0.43
Weight (kg)	107.4 ± 9.8	109.6 ± 7.47	$t = 0.99$	0.32
BMI (kg/m²)	38.9 ± 3.31	40.17 ± 3.08	$t = 1.45$	0.15
ASA (I : II)	23 : 7	21 : 9	$\chi^2 = 0.34$	0.56

Data are presented as mean ± SD, whereas *n* values are provided for sex and ASA.

Table 2 Spine abnormalities and ease of palpation of surface landmarks

Spine abnormalities	Group US	Group LM	Fisher's exact test	*P*-value
None	22 (73)	25 (83)	Modified $\chi^2 = 3.001$	0.22
Scoliosis	5 (15)	1 (3)		
Previous spinal surgery	3 (12)	4 (13)		
Ease of palpation of surface landmarks				
Grade I (mild)	3 (8)	1 (2)	Modified $\chi^2 = 4.14$	0.24
Grade II (moderate)	9 (30)	4 (15)		
Grade III (difficult)	13 (43)	17 (57)		
Grade IV (impossible)	5 (18)	8 (27)		

Data are presented as *n* (%).

Table 3 Ease of performance of spinal anesthesia

Successful dural puncture	Group US	Group LM	Test of significance	*P*-value
On first needle attempt	21 (70)	8 (26.7)	$Z = 3.35$	< 0.001
Number of needle redirection	7 (23.3)	15 (50)	$Z = 2.14$	0.03
Number of repeated needle insertion	2 (6.7)	6 (20)	$Z = 1.5$	0.12
Number of failed attempts	0	1 (3.3)	$Z = 1.008$	0.31
Time to establish landmarks (min)	5.7 ± 0.93	2.27 ± 1.23	$t = 12.1$	< 0.001
Time to perform spinal anesthesia (min)	5.01 ± 0.78	7.75 ± 0.96	$t = 11.36$	< 0.001

Data are presented as *n* (%); *Significant; **Highly significant.

There was only one failed attempt in group LM (Table 3).

The mean time taken to establish anatomic landmarks was highly significantly longer in group US than in group LM (5.7 ± 0.93 vs. 2.27 ± 1.23 min, respectively; $P < 0.001$) (Table 3).

There was a highly significant reduction in the time required to perform the spinal anesthesia in group US (5.01 ± 0.78 min) than in group LM (7.75 ± 0.96 min; $P < 0.001$) (Table 3).

Discussion

The introduction of ultrasound to guide neuraxial anesthesia into clinical practice was relatively slow compared with peripheral nerve blocks or central venous catheterization. This could be because of the technical difficulties posed by the bony structures surrounding the spinal cord and its dura that blocks the path of the ultrasound beam. Many anesthetists are reluctant to change their conventional landmark technique, particularly with most studies showing no change in the success rate between ultrasound-guided and the landmark techniques.

The difficulty of neuroaxial blockade in most studies is assessed by two main parameters: the number of needle manipulations required for success and the time taken to perform the block. Of the two, the former is more important because multiple needle insertions are an independent predictor of complications [1]. Ultrasound imaging of the lumbar spine in different scanning planes facilitates the identification of the anatomic landmarks necessary for appropriate subarachnoid space location. The present study used the transverse approach for identification of anatomic landmarks, which was suggested by Cristian *et al.* [10] who found that ultrasound single-screen method, using the transverse approach, can be a reliable guide to facilitate epidural insertion. In addition, the same authors suggested that ultrasound may be helpful in reducing the number of attempts during needle insertion compared with the conventional palpatory technique, which was in agreement with our study.

In the present study, the success rate of the first attempt in the ultrasound group was about 70%, as ultrasound provides reliable information about the location of the correct intervertebral space; the number of puncture attempts and the number of puncture sites were significantly reduced. These results correlate with that of Chin *et al.* [3] who reported that ultrasound imaging significantly improves the success rate of puncture at the first puncture site in patients with difficult surface anatomic landmarks. In addition, Grau *et al.* [4] and Nomura *et al.* [5] reported the superiority of ultrasound imaging in improving the success rate of lumbar puncture and the success rate of the first attempt.

Finally, although there was a highly significant reduction in the time required to perform the spinal anesthesia in group US (5.01 ± 0.78 min) than in group LM (7.75 ± 0.96 min; $P < 0.001$), we do not consider this clinically significant when weighted against the benefits of the technique in this selected population of patients.

Conclusion

Ultrasound-guided approach is a reliable and effective method in patients in whom technical difficulty is expected.

Acknowledgements

Conflicts of interest
None declared.

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