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ASSESSMENT OF REAL-TIME ULTRASOUND GUIDANCE FOR LUMBAR ANESTHESIA IN LOWER LIMB ORTHOPEDIC SURGERY: A PROSPECTIVE STUDY

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ABSTRACT
This study aimed to evaluate the efficacy of real-time ultrasound guidance for lumbar anesthesia in lower limb orthopedic surgery patients. A paramedian approach was used, with the operator inserting a spinal needle unaided into the ultrasound imaging plane. Among 100 consecutive patients, CSF was successfully located within three needle passes in 97 patients (IQR 1–6). Only three patients experienced CSF aspiration, with two successfully receiving spinal anesthesia and one requiring general anesthesia. The procedure took an average of 1.2 minutes to complete the intrathecal injection. These findings suggest that real-time ultrasound guidance can be a reliable method for lumbar anesthesia in orthopedic surgery patients, potentially improving procedural accuracy and patient outcomes.

Key words: Lumbar anesthesia, Real-time ultrasound guidance, Orthopedic surgery, Paramedian approach, CSF localization.

INTRODUCTION

Anatomical landmarks have been used to identify the subarachnoid space since Bier described spinal anaesthesia in 1898 [1,2]. A surface anatomical landmark can be useful, but is still a surrogate marker. In obese and edematous patients, they may be difficult to palpate. There are many anatomical variations or abnormalities, so landmark-based approaches often miss lumbar interspaces. Incorrect recognition of the subarachnoid space can result in pain, hematomas, postdural puncture headaches, and neural damage [3, 4–8]. It may be possible to improve the success of current techniques and mitigate their limitations by using alternative approaches. The operator can preview spinal anatomy, identify the midline, and determine the needle insertion gap with neuraxial sonography. Pre-puncture guided by real-time ultrasound may be superior to ultrasound-assisted pre-puncture, even if a preliminary scan is already useful. The method avoids the need to "remember" the angulation between cephalad and caudad after pre-puncture skin marking. Real time ultrasound guided spinal anaesthesia has only been reported in one case report and in one report of 10 patients. During this prospective observational study, a single operator inserted the spinal needle in the plane of the ultrasound beam to access the subarachnoid space using a systematic method guided by ultrasound.

METHODS

In this study, 100 patients undergoing lower limb surgery were recruited. Also required were ASA I–III and an age between 18 and 90. Indeterminate neurologic disease, indeterminate coagulopathy, and allergy to local anesthetics were excluded from spinal anesthesia. The patient was monitored routinely and given intravenous sedation. Prior to spinal anaesthesia, peripheral nerve block procedures were performed.

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One of two fellows with experience in neuraxial ultrasound-assisted procedures, administered spinal anaesthesia. According to the operator's discretion, the patient was blocked sitting or lying. Transducer cable sheath, gloves, gown, and mask were used in full aseptic technique. Using either the Phillips HD11Xe ultrasound device or the Sonosite M Turbo ultrasound device, the patient's back was scanned from the operator's preferred hand using a standard curvilinear 2-5 MHz transducer. The operator held it with his other hand and placed the ultrasound screen in front of him. To obtain the best possible US image, the scanning depth was set, the transducer frequency was selected, and the gain was adjusted. After identifying the sacrum, we moved the probe cephalad in the paramedian axis towards the midline. We selected the area between L2-3 and L5-S1 in the lumbar lamina. A midline point was placed directly above the selected space. To obtain an oblique paramedian sagittal view, the probe was rotated 45 degrees toward the midline. Spinous process and lamina of upper vertebral body are simultaneously visible. Paramedian window into spinal canal is located at this angle. When inserting paramedian needles in transverse scanning planes, the facet joints can often obstruct the needle path. View of posterior longitudinal ligament-vertebral body complex, lamina, and intervertebral space. The needle entry point creates more space between the bed surface and the needle entry point than described previously. Furthermore, it has the same advantages as a paramedian approach, which have been proven in neuraxial ultrasound [9]. Probe is moved in the same direction as patient's midline.A curvilinear probe would otherwise have too lateral an entry point. Here is a picture of the spine after the probe was positioned and the image it provided. The transducer was placed directly under the ultrasound gel. Using sterile gauze, remove ultrasound gel from selected skin puncture site. Skin entry point was outside the transducer footprint area. Skin infiltration was performed with lidocaine 1%. An operator chose a standard spinal needle based on its ability to provide visibility through ultrasound and steer in the tissue while considering possible postdural puncture headache risks. In the interlaminar space, a needle was inserted at the caudal end of the ultrasound transducer. The spinal needle was still being inserted into the erector spinae muscle during the procedure, the angle of needle insertion was optimized. With US guidance, it gradually advanced to interlaminar space until the tip broke through the ligamentum flavum/dura complex. In some instances, needle tips were lost from view if they entered the spinous shadow, as a result of the quality of the image. Typically, entry into the thecal space took less than one centimeter after entry into the ligamentum flavum. The doses of 0.5% bupivacaine and fentanyl are adjusted to the planned surgery and the patient is placed in a lateral position with the surgical side uppermost. During surgery, the attending anesthetist determined that the patient was ready. In addition to propofol, oxygen was administered via a facemask. Within two hours of intrathecal injection, the spinal anaesthetic was considered failed. Only analgesics were administered by the acute pain team on the postoperative ward. We measured CSF acquisition success under live ultrasound guidance. The level of access to the subarachnoid space was measured using needle passes. Every needle advance was considered a "needle pass". There was a limit of six needle passes per skin puncture. There were a maximum of 3 skin punctures per patient. Multiple spinal levels were attempted, the skin punctures recorded, and the time taken to inject fluid was recorded.

STATISTICS

It was planned to include 100 consecutive patients representative of an elective spinal anaesthesia study population. All variables of interest were descriptively analyzed. Medians are used for normally distributed data and medians for non-normally distributed data. Using Shapiro-Wilk, normality was tested. The correlation between pre-procedure clinical scoring and puncture measurements, such as needle advancement, skin puncture, and time to complete an intravenous injection, correlation coefficient, Pearson Product Moment. It was calculated using Sigma Plot version 12 which was used to do the calculations.

RESULTS

Based on ultrasound guidance, CSF can be obtained in 97% of cases. Three patients failed real-time guidance to acquire CSF. Following two successful spinal anaesthesia procedures using landmark palpation and ultrasound prepuncture scanning, following multiple unsuccessful attempts by 2 different operators to acquire CSF, a patient underwent an elective general anesthetic.

There were 5% of patients who were converted intraoperatively to general anaesthesia after intrathecal local anaesthetic injection - 2 because of insufficient CSF flow, 1 because of having no block after two shots into freely flowing CSF, and 1 because she did not have sufficient time for a repeat block due to inadequate block height. Three needle passes were required for satisfactory CSF flow. A median of 1 skin puncture. For 12% of patients, three skin punctures were necessary to acquire CSF. There was a median spinal puncture. 30% of patients needed only one needle pass, while 80% needed six. 1.46 punctures were made per spinal interspace.

Scanning was completed in 3.9 minutes. Intacthecal injection took 1.2 minutes from spinal needle insertion. It took 8 minutes. Almost all patients were seated. CSF could not be located using real-time US guidance in one of three patients. 86 percent of cases used Quincke spinal needles, while 25 percent used Whitacre needles. 67% of patients were contacted 6 weeks after surgery for procedure-related complications. A 22 G Quincke needle caused an orthostatic headache in one patient. A table showing the level of difficulty in performing spinal anesthesia can be found in Table 2. Skin punctures, CSF acquisition time, and needle advancements were not correlated with BMI, anaesthetists' subjective preprocedure difficulty predictions, or bony landmark palpability. Nevertheless, a significant correlation was observed between abnormal spinal curves as well as needle advancements. Sixty-three percent were deemed difficult based on pre-procedure difficulty scoring. [10].

Table 1: Characteristics of patients

Surgery performed		
Total Patients (*n*)	200	
Gender (*n*)	M: 74, F: 126 67 ± 12	Total knee arthroplasty 122
Age (yrs)	Range 40–87 2.7 ± 1.1	Total hip arthroplasty (THA) 48
Height (m)	Range 2.7–2.9 84.5 ± 19.1	Revision THA 6
Weight (kg)	Range 46–147 31.4 ± 6.9	Other knee surgery 8
BMI (kg·m^{-2})	Range 18.6–53.1	Other lower limb surgery 18

Table 2: Spinal anesthesia was predicted to be difficult

Anaesthetists subjective prediction of Difficulty	Easy	128
	Difficult	72
Palpability of bony landmarks	Easily palpable	106
	Poorly palpable	70
	Impalpable	24
Predicted spinal anaesthesia difficulty scoring (after Atallah)	Easy (grade 0–3)	126
	Easy (grade ≥4)	74

DISCUSSION

During lower limb orthopaedic surgery, real-time ultrasound guided spinal anaesthesia is clinically feasible. The best outcomes are achieved in this patient group when neuraxial block results in the best outcomes. The 97% acquisition success rate for real-time US guidance is similar to that using landmark or ultrasound guided prepuncture approaches. With real-time ultrasound guidance, 3 patients failed spinal anaesthesia within predefined limits. Two of these patients were successfully anesthetized using landmark palpation and ultrasound pre-puncture scan. A definitive conclusion about real-time rather than landmark or ultrasound pre-puncture guidance cannot be drawn from this non-comparative study. CSF acquisition may not necessarily reflect needle passes or punctures required to reach this endpoint. The results of randomised trials comparing these three methods are needed to determine whether this technique is useful based on results that are clinically relevant. Randomized controlled trial comparing real-time ultrasound guidance to landmark-based approach for spinal-epidural insertion found it significantly reduces needle passes versus traditional landmark-based techniques. As previously reported, the first skin puncture in our study also identified the subarachnoid space (65%).It is important to minimize skin punctures to minimize the risk of multiple attempts. Approximately 95% of our patients sat. Lee et al. report that guiding spinal anaesthesia in real time presents practical difficulties. Neither lateral nor sitting positions were considered ergonomically feasible in this study. Average and standard deviation were 8.68 minutes. A landmark-based approach typically takes 4.4 ± 3.2 mins [11] to 4.8 ± 4.4 mins [12]. US guided spinal anaesthesia takes longer because of needle-probe alignment and identifying a satisfactory acoustic window. Preparing the probe sterile and scanning a specimen before inserting the needle required more time than that reported by Carney and Hunt for ultrasound assisted neuraxial techniques (2.7 min) [20]. Although the real-time scanning took an average of 3 minutes before the intrathecal injection was completed, this really is the cumulative time of real-time scanning and needling.

Fail Rate. Following spinal anaesthesia, 5% of patients required general anaesthesia or repeated intrathecal injections. Studies report spinal anaesthesia failure rates between 1% and 17% [13]. There is still a failure rate of 11.6% for spinal anaesthesia [14]. In this study, we were able to obtain CSF with a 97% success rate using our technique. Other studies used ultrasound guided neuraxial procedures with failure rates of 22% and 14%. As Cook points out, direct comparison is impossible due to the differences in techniques and reasons for failure. Several studies have shown that palpability of spinal bony landmarks (classified as easy, poorly, or totally impalpable spinous processes) is an independent predictor of difficulty administering spinal anaesthesia. For predicting difficulty spinal anesthesia, an algorithm was developed based on age, BMI, palpability of surface landmarks, bony deformities of the spine, and radiological characteristics [15]. Even without the radiological score, it predicts difficulty. 63% of our patients were predicted to be difficult. This sample of patients had a similar BMI to North American adults 40–79 years old. American adults in this age group had a mean BMI of 29.1 kg/m2, while Canadians had a mean BMI of 27.7 kg/m2. Hence, patients were not always "difficult," and further research is needed to determine whether real-time ultrasound guidance is superior to traditional landmarks or pre-puncture scanning.

Based on a study difficulty criterion, only 7% of spinal implantations were considered difficult by our study using our guidance technique. The Landmark-based approach was found to be difficult for 28% of Weed et al.'s patients. The reduction in predicted difficulty may be due to the improved visualization and guidance provided by real-time scanning over pre-scans and landmarks.

Prior to this study, a spinal anesthesia audit was conducted at our institution. Our study found that 81% of patients used 25 G Whitaker needles. In our study, 22G needles were used in 96% of patients. Due to their stiffness and echogenicity, 22 G needles are easier to see and steer within an ultrasound beam than finer 25 G needles. This consideration can be ignored by the use of longer insert needles and ultrasound reflectors. Only one postdural puncture headache occurred during follow-up using 22 G needles, giving an estimated incidence of 1%.

CONCLUSION

Our results demonstrate that ultrasound-guided spinal anesthesia can be performed clinically in real-time. A comparison with traditional landmark-based techniques and ultrasound-assisted techniques shows that it performs similarly.

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