Minimum Effective Anaesthetic Volume of Ropivacaine 0.5% for Sciatic Nerve Block in Arthroscopic Knee Surgeries

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Research article

ABSTRACT

Ultrasound and nerve-stimulation guidance (double-guidance) may help to exactly locate the injection and minimize the amount of local anaesthetics required. This clinical investigation aimed to estimate the minimum effective anaesthetic volume (MEAV) of ropivacaine 0.5% required to block the sciatic nerve at the subgluteal injection under double-guidance for arthroscopic knee surgery. The Dixon and Massey up-and-down sequential method was used to determine the MEAV of ropivacaine 0.5% necessary for double-guided subgluteal sciatic nerve block. This study included 26 patients between the ages of 18 and 48 years old. The starting dose was set at 16ml, which was decreased by 1.0ml if the block succeeded and increased by 1.0ml if the block failed. After the injection of local anaesthetic, sensory and motor function of the tibial and common peroneal nerve were assessed by a blinded observer every 5 minutes for 35 minutes. It was demonstrated that effective volume in 90% of cases (EV90) of ropivacaine 0.5% was 13.0 ml (95% CI 12.6–15.0). The 50% effective volume (EV50) of ropivacaine 0.5% was 12.3ml (95% CI 11.8–12.8). Therefore, perineural injection of ropivacaine 0.5% 13.0ml could provide successful subgluteal sciatic nerve block in 90% of patients undergoing arthroscopic knee surgery.
INTRODUCTION

Peripheral sciatic nerve block is commonly performed to provide intraoperative anaesthesia and postoperative analgesia for lower limb surgeries. Since multiple blocks are usually required, minimizing volumes of local anaesthetics in each nerve block is desirable to reduce the risk of toxicity and to advance postoperative motor function recovery \cite{1}. However, if the dose is too low, high rates of block failure will result \cite{1, 2}. Ultrasound (US)-guided peripheral nerve blocks allow for visual verification of the relationship between sciatic nerve and local anaesthetic (LA). Nerve stimulation (NS) guidance may help to specifically determine the motor function of the nerve and help prevent intraneural injection of LA. This clinical investigation aimed to estimate the minimum effective anaesthetic volume (MEAV) of ropivacaine 0.5% required to block the sciatic nerve at subgluteal injection under guidance of ultrasound with nerve stimulation in 90% patients.

METHODS

The Research and Ethics Committee of Shenzhen Second People’s Hospital and the First Affiliated Hospital of Shenzhen University approved this study. Written informed consent was obtained for each patient. The study was registered in Chinese Clinical Trial Registry. Chictr.org.cn/index.aspx: ChiCTR-ONC-16008025.

Patients with an American Society of Anesthesiologists (ASA) physical status I or II, age 18-48 yr, body mass index (BMI) 20-30 who were scheduled for arthroscopic meniscus or cruciate ligaments repair of knee were eligible for study inclusion. Exclusion criteria included patient refusal, pregnancy, history of diabetes mellitus, neuropathic or neuromuscular disease, coagulopathy, or skin infection at the site of needle insertion.

Blood pressure, continuous electrocardiogram and pulse oximetry was monitored for all patients using standard, non-invasive monitoring techniques. Prior to surgery, an IV infusion of acetated Ringer’s solution was started for each patient. Nasal cannula oxygen inhalation was applied at 1-2L.min⁻¹. All patients received midazolam 0.03mg.kg⁻¹ and fentanyl 1.5ng.kg⁻¹ intravenously for anxiolysis. Combined lumbar plexus block and subgluteal sciatic nerve block were performed to achieve anaesthesia and postoperative analgesia for all patients scheduled for arthroscopic knee surgery.

Under guidance of both US and NS, lumbar plexus blockade was performed using a posterior paravertebral approach at the L4-5 vertebral level. Patients were positioned in the lateral decubitus position with the hip and knees flexed and the side to be anaesthetized ipsilateral to the lateral approach, with the contralateral side toward the table. The Ultrasound scan was performed using a low-frequency, 5–2 MHz, curved array transducer with a MicroMaxx Ultrasound System (Sonosite Inc., Bothell, WA, USA). The US transducer was positioned approximately 3–4 cm lateral and parallel to the lumbar spine, with its orientation marker directed cranially. The transducer was then moved caudally, while still maintaining the same orientation, until the sacrum and the L5 transverse process were visible, with the other lumbar transverse processes also identified. The transducer was positioned with its center aimed at the middle of the L4-5 transverse process interspace, where the roots of the lumbar plexus are normally seen as longitudinal hyperechoic structures in the posterior aspect of the psoas muscle. Under full aseptic conditions, a Stimuplex A®, 120 mm, 22-gauge insulated nerve block needle (Stimuplex D®, Braun Medical, Melsungen, Germany) was inserted in the short axis of the ultrasound transducer (out-of-plane technique) and connected to the nerve stimulator (Stimuplex® B.Braun Medical, Melsungen AG, Germany). Stimulation was started with a current of 1 mA at a frequency of 1 Hz. Proximity of the needle to the plexus was determined by the threshold required to elicit quadriceps contraction. When contraction was achieved between 0.3 and 0.5 mA at
2Hz the needle was assumed to be appropriately located. After confirming negative aspiration, 20 ml of 0.5% ropivacaine was injected.

The dose of 16ml 0.5% ropivacaine administered to the first patient for sciatic block was chosen based on the results of Jeong et al [1]. The volume of ropivacaine 0.5% for subsequent patients was determined using Dixon and Massey up-and-down sequential method, where the volume of local anaesthetic administered to each patient depended on the response of the previous one. If a patient received an inadequate block, the next treated patient’s dose was increased by 1.0 mL. If a patient had a successful block, the next patient was treated with a dose that was decreased by 1.0 mL. We estimated that 14 (more than 10) independent negative–positive up-and-down deflections were required for this study. Patient enrollment in the study was continued until the completion of seven successful consecutive blocks with the minimal volume of local anaesthetic were observed.

For sciatic nerve block, the lateral prominence of great trochanter and ischial tuberosity were identified and a line was drawn between these two landmarks using a skin-marking pen. After local infiltration of 1ml 1% lidocaine, the ultrasound probe was positioned perpendicular to the skin on the line and the 22-gauge nerve block needle was inserted in plane of the ultrasound beam. When the sciatic nerve was clearly seen in the ultrasound image, the probe was fixed and the needle was advanced toward the nerve with the stimulator delivering a current of 1mA. A positive motor response (dorsiflexion or plantar flexion) of the foot using a stimulus between 0.5 and 0.3 mA indicated appropriate proximity to the nerve.

After a test dose of LA to double exclude intraneural injection, 50% of the intended volume of ropivacaine 0.5% was injected. If the LA spread circumferentially under the US image, the remainder of the ropivacaine 0.5% dose was added and administered without adjusting the needle’s position. To ensure circumferential spread of the LA, if the LA spread unilaterally to either side of the sciatic nerve in ultrasound image, the needle was withdrawn to the subcutaneous level and then advanced toward the other side of the sciatic nerve. Once the appropriate proximity to the nerve was identified, the remaining LA was administered.

After the LA injection for sciatic nerve block, sensory and motor function of the tibial and common peroneal nerve were assessed by a blinded observer. The first motor/sensory evaluation was conducted at 10 minutes after delivery of anaesthesia and evaluations were repeated every 5 minutes for the following 25 minutes. Sensory blockade was evaluated after application of ice to the plantar and dorsolateral aspects of the foot. Sensation was graded using the following 3-point scale: 0 = no block (patient can feel touch and cold), 1 = analgesia (patient can feel touch, not cold), 2 = anaesthesia (patient cannot feel touch or cold). Motor blockade was assessed on a 3-point scale using plantar and dorsal flexion of foot, respectively. Grades were defined as follows: 0 = no block (full strength movement in both directions), 1 = paresis (weakened movement in at least one direction), 2 = paralysis (unable to move foot in either direction). A successful block was defined as grade 2 sensory and grade 1 motor function within 35 minutes of administration of analgesic and visual analog scale (VAS) pain of less than 1 in the lower extremity with no opioid administration during the operation.

Before starting arthroscopy, blockade effects of femoral nerve, lateral cutaneous nerve and obturator nerve were confirmed and the block was applied with combined 1% lidocaine and 0.5% ropivacaine when needed. IV dexmedetomidine 1μg/kg was administered to all patients for anxiety attenuation. No other sedative or analgesic was used intraoperatively in adequately blocked cases. If the effect of multiple nerve blocks was inadequate for the operation, general anaesthesia with laryngeal mask airway was used for the patient and the case was recorded. For postoperative analgesia, IV Sodium Parecoxib 40mg was administered approximately 30 minutes before the end of the operation, followed by 40 mg every 12 hours in the first 48 hours after surgery.
Patients were followed in the hospital for 48 hours, and clinical follow up was continued for one month. After surgery, numbness and motion of the lower limb that did not undergo a procedure was evaluated to identify intrathecal injection of LA. VAS pain scores at rest and at movement were recorded postoperatively at 24 and 48 hours. One month after the operation, at the time of clinical follow-up, VAS for skin numbness and paresthesia were evaluated.

Continuous variables are presented as means (standard deviation) with 95% confidence intervals (CI); categorical and nominal variables as presented as a percent of the total population. Database management and analyses were performed using the Statistical Package for the Social Sciences (IBM SPSS Statistics 17.0, Chicago, IL). Effective volume of ropivacaine 0.5% for sciatic nerve block was calculated using the probit analysis with Dixon’s up-and-down method.

**RESULTS**

Twenty-six patients between the ages of 18 and 48 years old were treated as part of the study. Patient demographics are reported in Table 1. Fifteen patients (58%) had successful sciatic nerve blocks while 11 failed (Table 1).

| Table 1. Patient demographics. Values are mean (SD) or number (proportion) |
|---------------------------|------------------|
| Age; years                | 32 (10.6)        |
| Body mass Index; kg.m⁻²   | 22.1 (5.6)       |
| ASA status I              | 19 (73%)         |
| Male                      | 21 (81%)         |
| Operation                 |                  |
| Arthroscopic meniscus repair | 10 (38%)     |
| Arthroscopic cruciate ligaments repair with or without meniscus repair | 16 (62%) |

The EV90 of ropivacaine (0.5%) was 13.0 ml (95% CI 12.6–15.0) The EV50 of ropivacaine 0.5% was 12.3ml (95% CI 11.8–12.8)(Figure 1).Grade 2 sensory block and grade 2 motor block after surgery was achieved in all patients (100%). No contralateral lower limb numbness was observed in any patients after surgery. For all patients, VAS at rest was no higher than 2 and VAS at movement was no higher than 4 within the first 48 hours after surgery. At one month follow up, no neurologic complications were noted.
DISCUSSION

Nerve blocks can provide adequate anaesthesia and postoperative analgesia for lower limb operations with minimal physical disturbances, particularly on hemodynamics and respiration. The use of femoral and sciatic nerve blocking for total knee arthroplasty is reported to reduce the length of hospital stay [3]. However, since multiple nerve blocks are frequently needed for lower limb surgery, a near-maximum dose of local anaesthetic is often used, which can increase the risk of local anaesthetic toxicity due to overdose injection [4,5]. Identification of the minimal effective dose for each single nerve such as femoral, sciatic or obturator may significantly reduce neurologic complications in lower extremity procedures.

Prior studies have been conducted to evaluate the minimum effective concentration or minimum effective volume of different LA such as lidocaine, ropivacaine, mepivacaine and bupivacaine or their combinations [1,6,7,8]. Ropivacaine is a widely used local anaesthetic with median duration and minimal neurotoxicity. Compared to bupivacaine, ropivacaine has reduced motor blocking. It is used in peripheral nerve block for both intraoperative anaesthesia and postoperative analgesia. The minimum effective volume and minimum effective concentration of ropivacaine to block femoral nerve has been widely reported. Ropivacaine 0.5% or above is usually used for anaesthesia, whereas lower concentrations are used for postoperative analgesia. Subgluteal injection of ropivacaine 0.5% for sciatic nerve block used in this study with lumbar plexus block has provided both adequate anaesthesia during the procedure as well as analgesia following the procedure.

The ED95 volumes necessary to achieve sciatic nerve blockade using a nerve stimulator were previously reported to be 17 ml and 30 ml with mepivacaine 1.5%, for subgluteal and popliteal sciatic nerve block, respectively [9]. Recently the ED95 of 0.5% ropivacaine for US-guided popliteal sciatic nerve block was reported to be 16 ml [10]. In the current study, both nerve stimulator and ultrasound guidance were used to accelerate detection of the nerve and prevent intraneural injection. Meanwhile ultrasound guidance may help to visualize the nerve thus reduce the LA consumption [9,11]. Ultrasound-guided circumferential injection of local anaesthetic around the sciatic nerve at the popliteal fossa can improve the rate of sensory block without an increase in block time or block-related complications, compared with either nerve stimulation or paraesthesia technique. On the other hand, using nerve
stimulation may also help to prevent intraneural injection and keep a reasonable distance from the nerve by adjusting the current. Lower minimal evoked currents (<0.5mA) have been reported to be associated with faster onset in sensory and motor block and longer block duration together with a more successful block\textsuperscript{[12]}. The current volume was calculated using the probit analysis with Dixon and Massey up-and-down sequential method. If the block failed, the next patient’s volume was increased by 1 ml (less than 10% of the initial volume) and if the block was successful, the volume was decreased by 1 ml. Furthermore, our study had 7 (more than 5) up-down swings, which would result in smaller standard error to calculate the MEAV. We acknowledge that the study has a number of limitations. The small sample size (n=26) may limit the external validity of the data. However, the primary benefit of the up-and-down procedure is that it substantially reduces the number of sample size required to determine ED50 \textsuperscript{[13]}. Another limitation of this study is that the rate of injection was not fixed. All blocks were performed by just two anesthesiologist. We cannot exclude the possibility that a rapid injection due to the proficiency of the individual is more pressurized would lead to more extensive spread of sciatic nerve.

CONCLUSION

In this study, both ultrasound and nerve stimulation were used and the minimal evoke current was set between 0.3mA and 0.5mA. Under these circumstances, the MEAV90 and MEAV50 of 0.5% ropivacaine to block sciatic nerve via subgluteal route has been titrated as 13.0ml and 12.3ml, respectively.

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DECLARATION OF CONFLICTING INTEREST

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